# METROPOLITAN COAL LONGWALLS 301-303

# WATER MANAGEMENT PLAN

Peabody

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**Revision Status Register**

| Section/Page/ Annexure | Revision Number | Amendment/Addition | Distribution | DP&E Approval Date |
|---|---|---|---|---|
| All | WMP-R01-A | Original – Draft for Consultation | DP&E, DPI-Water, OEH, WaterNSW | - |
| All | WMP-R01-B | Minor amendments to reflect revised Longwalls 302 and 303 | DP&E, DPI-Water, OEH, WaterNSW | - |
| Sections 4.1, 4.2, 7 and 8.5.3, and Figure 3 | WMP-R01-C | Minor amendments, including those to address DPI-Water comments | DP&E, DPI-Water, OEH, WaterNSW | 11 May 2017* |
| All | WMP-R01-D | Revised TARP and associated amendments to management plan | DP&E, DPI-Water, OEH, WaterNSW | - |
| Preface, Sections 4.2, 8.5.2 and 12; Tables 6, 11, 15, 19, 21 and 22 | WMP-R01-E | Minor amendments, including those to address WaterNSW and OEH comments | DP&E, CLWD, OEH, WaterNSW | - |
| All | WMP-R01-F | Revised Longwalls 301-303 Extraction Plan | DP&E, Department of Industry – Water, OEH, WaterNSW | - |

* The approval allows for the extraction of Longwalls 301 and 302 only.

**September 2018**

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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 Metropolitan Coal (Figure 1). Longwalls 301, 302 and 303 (herein referred to as Longwalls 301-303) are situated to the north of completed Longwalls 20-27 and define the next mining sub-domain within the Project underground mining area (Figures 1 and 2). Longwalls 304 on will be subject to future Extraction Plans.

## 1.1 PURPOSE AND SCOPE

In accordance with Condition 6, Schedule 3 of the Project Approval, this Water Management Plan (WMP) has been prepared as a component of the Metropolitan Coal Longwalls 301-303 Extraction Plan to manage the potential environmental consequences of the Extraction Plan on watercourses (including the Woronora Reservoir), aquifers and catchment yield.

The relationship of this WMP to the Metropolitan Coal Environmental Management Structure and to the Metropolitan Coal Longwalls 301-303 Extraction Plan is shown on Figure 3.

This WMP includes post-mining monitoring and management of water resources and watercourses, subject to the two previously approved Metropolitan Coal Water Management Plans for Longwalls 20-22 and Longwalls 23-27. That is, the Metropolitan Coal Longwalls 20-22 and Longwalls 23-27 Water Management Plans will be superseded by this document following the completion of Longwall 27 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*.

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

## 1.2 STRUCTURE OF THE WATER MANAGEMENT PLAN

The remainder of the WMP is structured as follows:

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

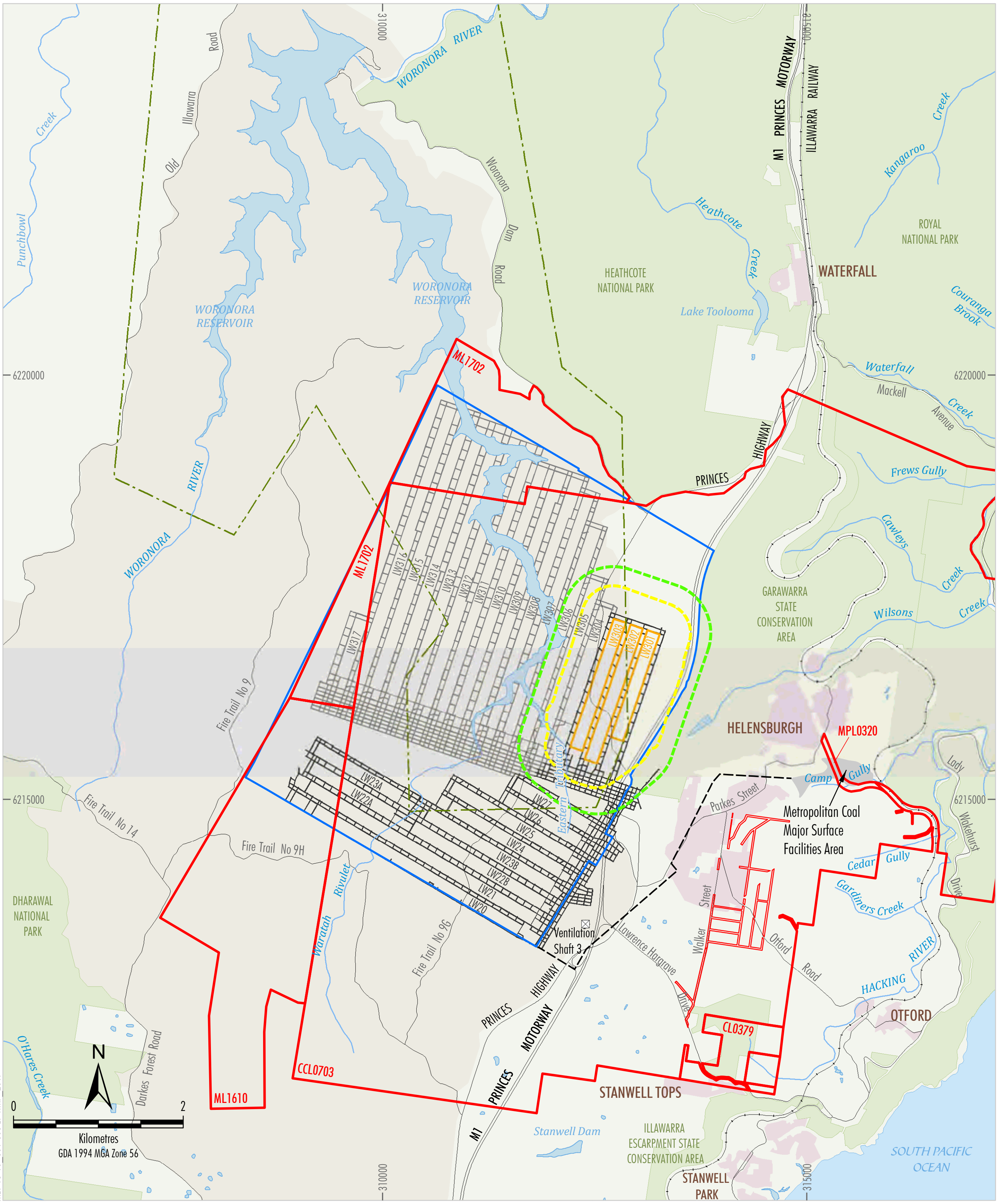
Section 3: Outlines the statutory requirements applicable to the WMP.

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

Section 5: Provides a revised assessment of the potential subsidence impacts and environmental consequences for Longwalls 301-303.

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 301-303 Secondary Extraction
- 35° Angle of Draw and/or Predicted 20 mm Subsidence Contour
- 600 m from Secondary Extraction of Longwalls 301-303
- Woronora Notification Area
- Existing Underground Access Drive (Main Drift)

*Source: Land and Property Information (2015); Department of Industry (2015); Metropolitan Coal (2018); MSEC (2018)*

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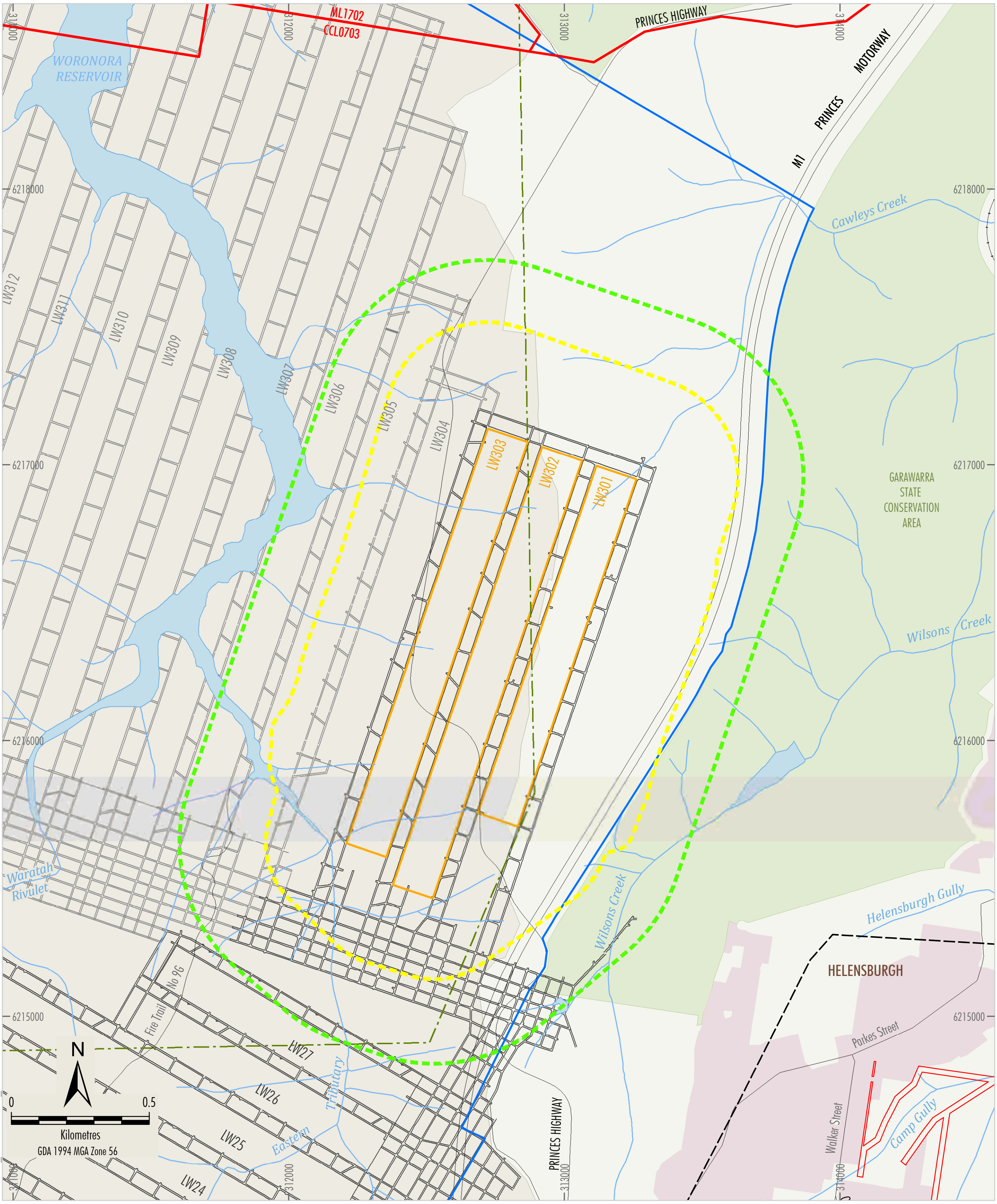
**Longwalls 301 - 303 and Project Underground Mining Area**

**Figure 1**

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*Source: Land and Property Information (2015); Department of Industry (2015); Metropolitan Coal (2018); MSEC (2018)*

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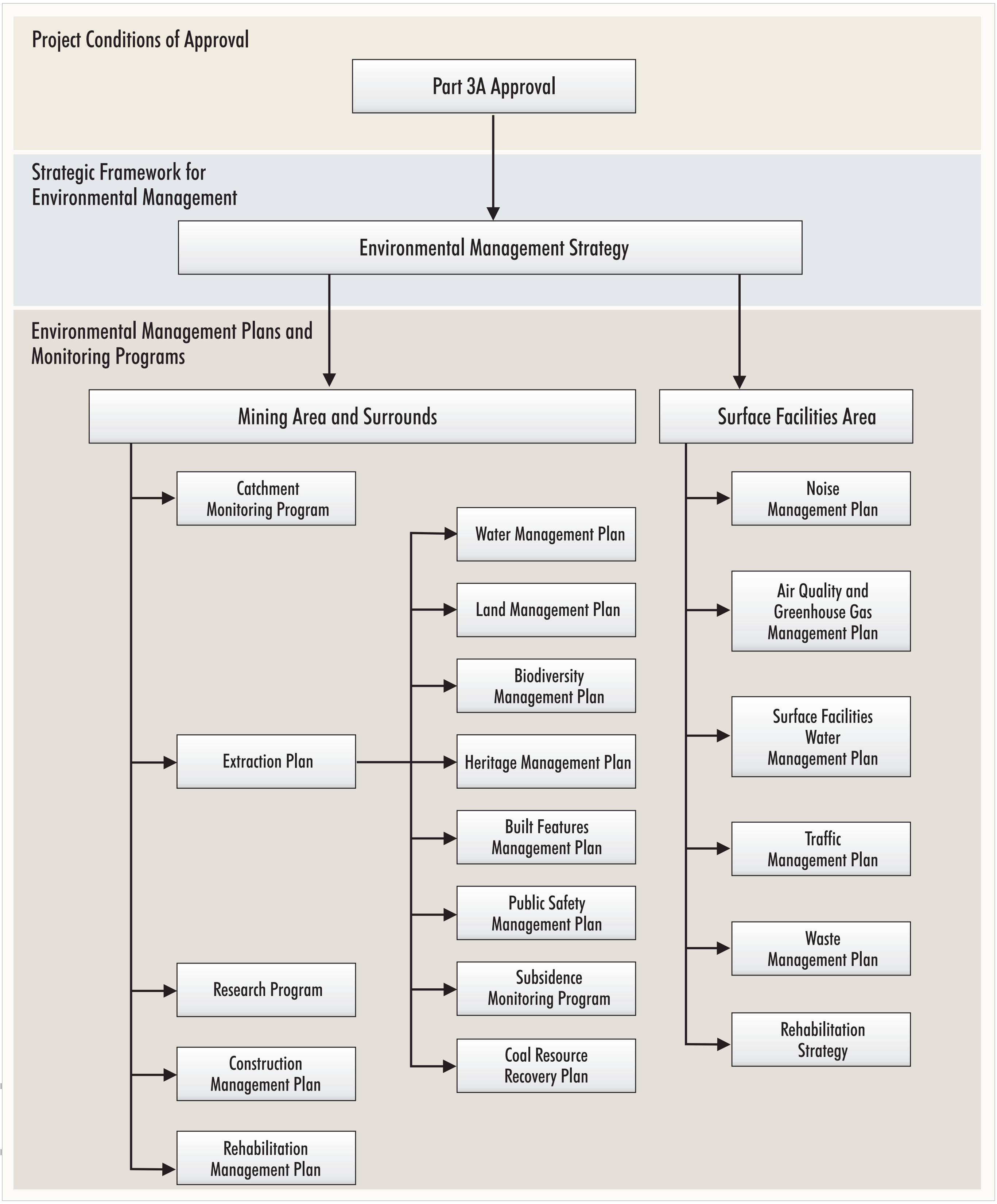
**Longwalls 301 - 303 Layout**

**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 WMP. |

# 2 WATER MANAGEMENT PLAN REVIEW AND UPDATE

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

- an audit under Condition 8, Schedule 7;
- an incident report under Condition 6, Schedule 7;
- an annual review under Condition 3, Schedule 7; and

if necessary, revised to the satisfaction of the Director-General (now Secretary) of the DP&E, to ensure the WMP is updated on a regular basis and to incorporate any recommended measures to improve environmental performance.

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

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

## 2.1 DISTRIBUTION REGISTER

In accordance with Condition 10, Schedule 7 of the Project Approval 'Access to Information', Metropolitan Coal will make the WMP publicly available on the Peabody website. A hard copy of the WMP will also be maintained at the Metropolitan Coal site.

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

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

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

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

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

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

# 3 STATUTORY REQUIREMENTS

Metropolitan Coal's statutory obligations are contained in:

(i) the conditions of the Project Approval;

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

(iii) other relevant legislation.

These are described below.

## 3.1 EP&A ACT APPROVAL

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

> ***SECOND WORKINGS***
>
> ***Extraction Plan***
>
> *6. The Proponent shall prepare and implement an Extraction Plan for all second workings in the mining area to the satisfaction of the Director-General. This plan must:*
>
> *…*
>
> *(f) include a:*
>
> *…*
>
> - *Water Management Plan, which has been prepared in consultation with OEH, SCA*[1] *and NOW*[2]*, to manage the environmental consequences of the Extraction Plan on watercourses (including the Woronora Reservoir), aquifers and catchment yield;*

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

[2] The NSW Office of Water (NOW) changed to the Department of Primary Industries – Water (DPI-Water), then to the Department of Industry, Crown Lands and Water Division (CLWD) and now to the Department of Industry - Water.

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

**Table 1**
**Management Plan Requirements**

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

## 3.2 LICENCES, PERMITS AND LEASES

In addition to the Project Approval, all activities at or in association with Metropolitan Coal 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 DRG (Division of Resources and Geoscience, previously Division of Resources and Energy [DRE]), under the NSW *Mining Act, 1992* (e.g. Consolidated Coal Lease [CCL] 703, Mining Lease [ML] 1610, ML 1702, Coal Lease [CL] 379 and Mining Purpose Lease [MPL] 320).
- The *Metropolitan Coal Mining Operations Plan 1 October 2012 to 30 September 2019* approved by the DRG.
- The conditions of Environment Protection Licence (EPL) No. 767 issued by the NSW Environment Protection Authority (EPA) under the NSW *Protection of the Environment Operations Act, 1997*. Revision of the EPL will be required prior to the commencement of Metropolitan Coal activities that differ from those currently licensed.
- The prescribed conditions of specific surface access leases within CCL 703 for the installation of surface facilities as required.
- Water Access Licences (WALs) issued by the NSW Department of Primary Industries – Water (DPI-Water) (now the Department of Industry – 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 (previously the Sydney Catchment Authority [SCA]) 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):

- *Contaminated Land Management Act, 1997;*
- *Crown Lands Act, 1989;*
- *Dams Safety Act, 1978;*
- *Dangerous Goods (Road and Rail Transport) Act, 2008;*
- *Energy and Utilities Administration Act, 1987;*
- *Fisheries Management Act, 1994;*
- *Mining Act, 1992;*
- *Noxious Weeds Act, 1993;*
- *Protection of the Environment Operations Act, 1997;*

- *Rail Safety (Adoption of National Law) Act, 2012;*
- *Roads Act, 1993;*
- *Biodiversity Conservation Act, 2016;*
- *Water NSW Act, 2014;*
- *Water Act, 1912;*
- *Water Management Act, 2000;*
- *Work Health and Safety Act, 2011;* and
- *Work Health and Safety (Mines and Petroleum Sites) Act, 2013*.

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

# 4 RELEVANT WATER MANAGEMENT INFORMATION OBTAINED SINCE PROJECT APPROVAL

## 4.1 SURFACE WATER

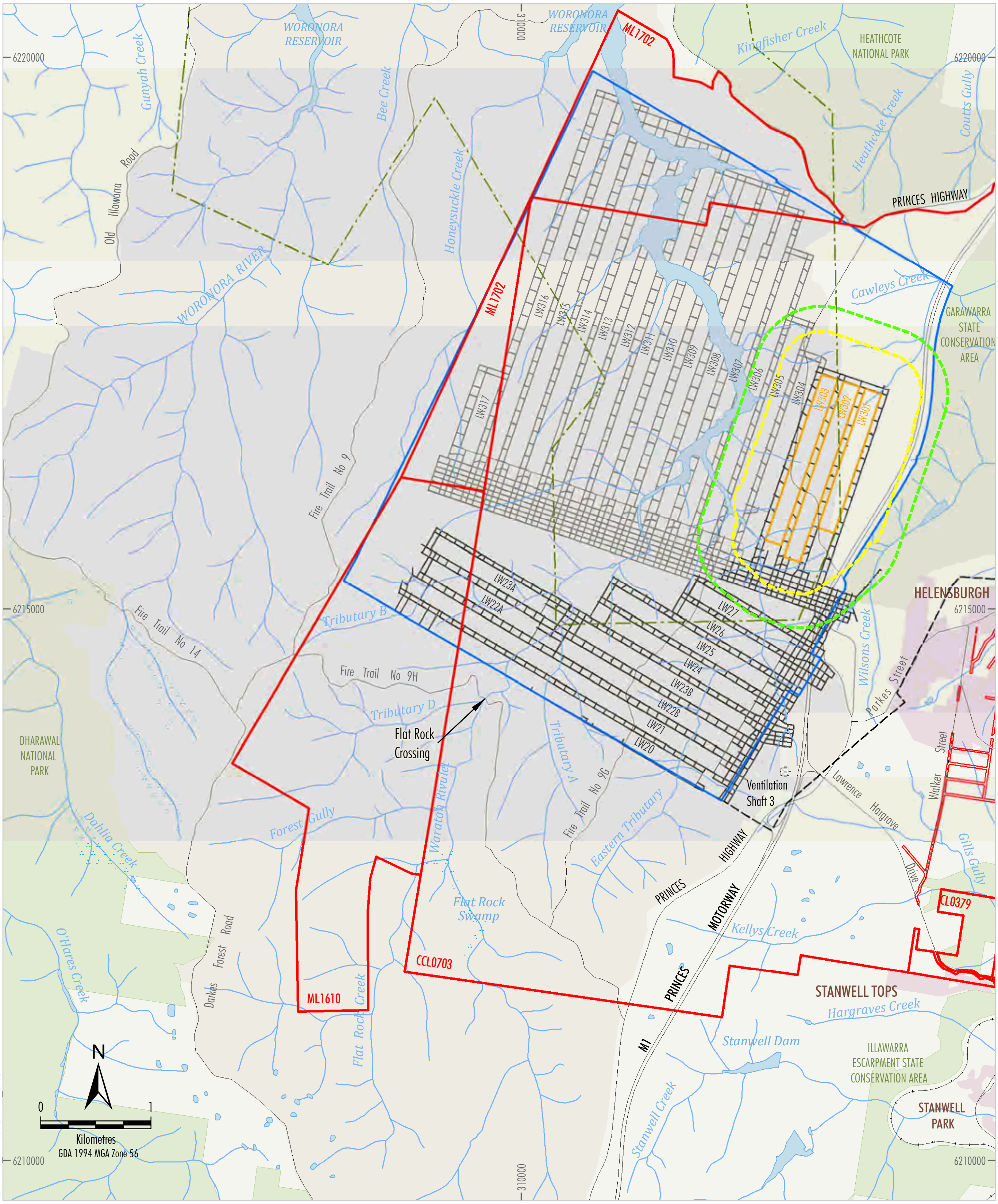
Streams occurring within 600 m of Longwalls 20-22, Longwalls 23-27 and Longwalls 301-303 secondary extraction include the Waratah Rivulet and its tributaries (such as Tributary A and B) and the Eastern Tributary and its tributaries (Figure 4). The locations of pools on the Waratah Rivulet and the Eastern Tributary are shown on Figure 5.

The Preferred Project Report (HCPL, 2009), and Metropolitan Coal Longwalls 20-22 and Longwalls 23-27 Water Management Plans indicated that valley closure values of greater than 200 millimetres (mm) were predicted at pools/rock bars on the Waratah Rivulet upstream of the maingate of Longwall 23 (Figure 5). Pools P to W on the Waratah Rivulet (Figure 5) were predicted to be subject to valley closure values of less than 200 mm.

The Preferred Project Report, and Metropolitan Coal Longwalls 20-22 and Longwalls 23-27 Water Management Plans indicated that valley closure values of greater than 200 mm were predicted at pools/rock bars along the Eastern Tributary (from Pool ETF over Longwall 20 extending to Pool ETAC over Longwall 26 and from Pool ETAH over Longwall 27 extending to Pool ETAL downstream of Longwall 27) (Figure 5). Approximately 244 metres (m) of the Eastern Tributary between the maingate of Longwall 26 and the full supply level of the Woronora Reservoir (i.e. from Pool ETAH to Pool ETAL) was predicted to be subject to valley closure values of greater than 200 mm as a result of Longwalls 23-27.

The Preferred Project Report, and Metropolitan Coal Longwalls 20-22 and Longwalls 23-27 Water Management Plans indicated that valley closure values of greater than 200 mm would also occur on Tributary B (maximum predicted total closure of 718 mm at the completion of Longwall 27).

The NSW Planning Assessment Commission's Report for the Metropolitan Coal Project (NSW Planning Assessment Commission, 2009) indicates the Panel considered 'negligible consequence' for a watercourse to mean, *'no diversion of flows, no change in the natural drainage behaviour of pools, minimal iron staining, and minimal gas releases'*, and is assumed to be achieved in circumstances where predicted valley closure is less than 200 mm.




LEGEND

- Mining Lease Boundary
- Woronora Special Area
- Railway
- Project Underground Mining Area Longwalls 20-27 and 301-317
- Longwalls 301-303 Secondary Extraction
- 35° Angle of Draw and/or Predicted 20 mm Subsidence Contour
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- Existing Underground Access Drive (Main Drift)
- Woronora Notification Area

*Source: Land and Property Information (2015); Department of Industry (2015); Metropolitan Coal (2018); MSEC (2018)*

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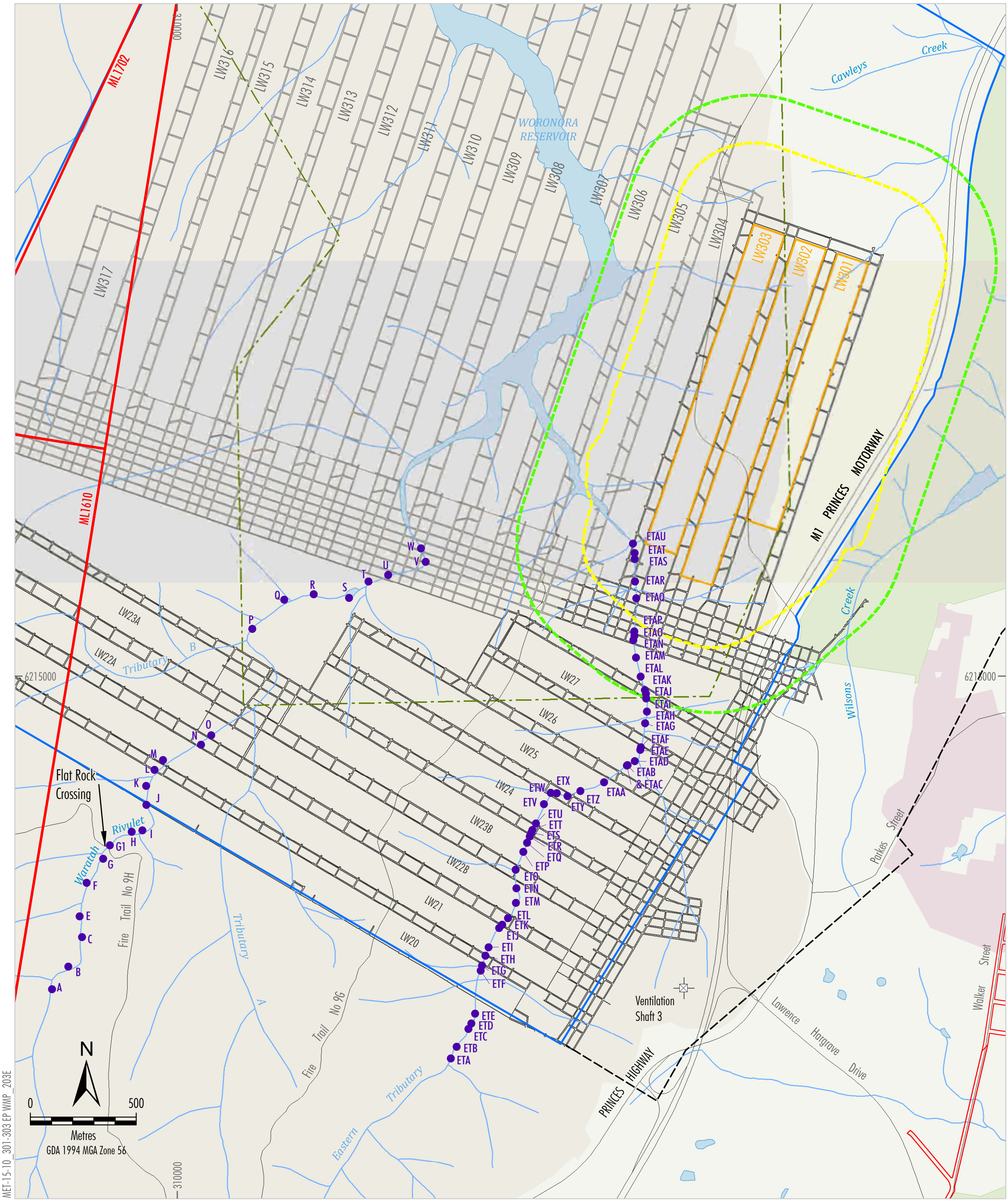
Streams Within the Project Underground Mining Area and Surrounds

**Figure 4**




Source: Land and Property Information (2015); Department of Industry (2015); Metropolitan Coal (2018); MSEC (2018)

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

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Waratah Rivulet and Eastern Tributary Pools

**Figure 5**

***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) and a number of pools on the Eastern Tributary (Pools ETG, ETJ, ETM, ETU, ETW, ETAF, ETAG, ETAH, ETAI, ETAQ, ETAT[3] and ETAU) and Tributary B (Pools RTP1 and RTP2) have also either been manually monitored on a daily basis or monitored using a continuous water level sensor and logger (Figure 6).

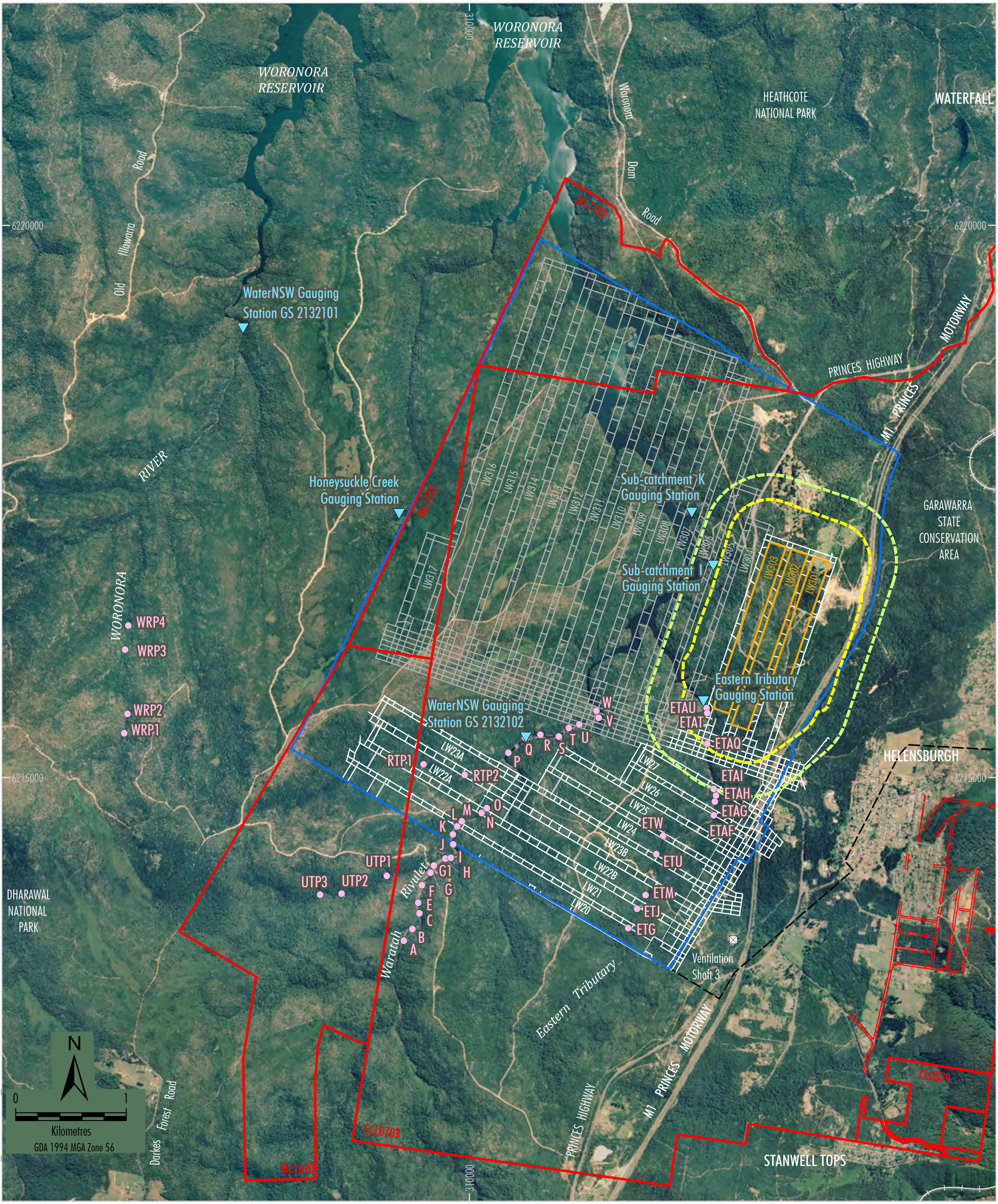
The stream inspections, pool water level monitoring and surface water flow monitoring have identified subsidence impacts and environmental consequences consistent with those described in the Metropolitan Coal Project Environmental Assessment (Project EA) (HCPL, 2008), Preferred Project Report, and Metropolitan Coal 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.

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.

[3] A water level meter was installed in Pool ETAT in March 2018.

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- 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 (2018); MSEC (2008; 2018)*

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Surface Water Quantity Sites

**Figure 6**

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 as described in the Metropolitan Coal Rehabilitation Management Plan (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). Since the commencement of Longwall 20, stream remediation activities on the Waratah Rivulet have been conducted at Pools A, F and G. To date, mining has not resulted in the diversion of flows or change to the natural drainage behaviour of pools downstream of the maingate of Longwall 23 (i.e. Pools P to W) (Figure 5).

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

Sections of the Eastern Tributary were predicted to be subject to greater than 200 mm of valley closure, which has resulted in the cracking and dilation of bedrock and associated diversion of surface flow and leakage of water through rock bars at pools along the Eastern Tributary.

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

In December 2016 and January 2017, a number of pools 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. The combined data that is available to MSEC for the Southern Coalfield (including the Waratah Rivulet and Eastern Tributary results) indicated that less than 10% of all pools have experienced the diversion of flow at predicted closure values of less than 200 mm, consistent with previous assessments of potential pool impacts. Downstream of the Longwall 26 maingate, mine subsidence has resulted in the diversion of flows or change to the natural drainage behaviour of Pools ETAG to ETAR (Figure 5).

To date, mining has not resulted in the diversion of flows or change to the natural drainage behaviour of Pools ETAS, ETAT and ETAU (Figure 5).

***Woronora Reservoir Inflows***

For the Project EA a comprehensive analysis of stream flow data and data on the yield behaviour of Woronora Reservoir indicated that past mining at Metropolitan Coal had no discernible effect on the inflow to, or yield from, the reservoir. Surface water flow monitoring at the Waratah Rivulet, Woronora River (Figure 6) and O'Hares Creek gauging stations since the commencement of Longwall 20 in 2010 indicates there has been a negligible reduction in the quantity of water resources reaching the Woronora Reservoir.

As documented in the original model in the Project Environmental Assessment, the Waratah Rivulet catchment model is capable of reliably identifying a loss of 1 ML/day. One (1) ML/day meets the definition of 'negligible' (being small and unimportant, such as not to be worth considering) on the basis that it is a small component of overall inflows – it represents about 1.4% of annual average inflow to the reservoir; and is small compared to changes in inflows caused by changes in climate and catchment conditions. It is also noted that 1 ML/day is well above the reduction in catchment yield that is actually predicted.

The surface water flow monitoring data obtained from the Eastern Tributary gauging station has also been assessed. The results indicate that flow at the Eastern Tributary gauging station has been consistent with model predictions.

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

***Iron Staining***

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.

On 14 October 2016, Metropolitan Coal reported the exceedance of the *minimal iron staining* component of the Eastern Tributary performance measure to the Secretary of the DP&E and other relevant agencies in accordance with Condition 6, Schedule 7 of the Project Approval and the Metropolitan Coal Longwalls 23-27 Water Management Plan Contingency Plan. Subsequent incident reports were provided to the DP&E and other relevant agencies on 21 October 2016, 25 November 2016, 21 December 2016, 3 February 2017 and 21 February 2017 and provided a concise summary of information relevant to the performance of the mine relative to is Extraction Plans and Approval Conditions for the Eastern Tributary.

Inspections of iron staining/flocculent on the Eastern Tributary between the full supply level and the Longwall 26 maingate in August 2018 recorded residual iron staining (i.e. where previous fresh iron staining has receded and iron flocculent was not present) from boulderfield ETAF to rock bar ETAP (Metropolitan Coal, 2018). Fresh iron staining/flocculent was evident in the reach from Pool ETAQ to boulderfield ETAU (Metropolitan Coal, 2018).

***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, ETAI, ETAL and ETAM on the Eastern Tributary (Figure 5). 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; 2016; 2017; 2018).

***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 aluminium, which would likely occur following fresh cracking of the stream bed.

Surface water quality has been monitored at a number of sites on Waratah Rivulet, Tributary B, Tributary D, Eastern Tributary, Far Eastern Tributary, Honeysuckle Creek, Bee Creek and Woronora River. Trends in the monitoring data to date for key parameters (pH, electrical conductivity, dissolved iron, dissolved manganese and dissolved aluminium) at the sites listed in Table 2 have been summarised by Hydro Engineering & Consulting (2018). The water quality sites are shown on Figure 7.

The cracking and dilation of bedrock and associated diversion of surface flow and leakage of water through rock bars at pools which has occurred on the Eastern Tributary (including the reach associated with the exceedance of the Eastern Tributary watercourse performance measure) has resulted in impacts on water quality, in particular increases in dissolved manganese and iron. Assessment of the water quality monitoring results to date by Associate Professor Barry Noller (The University of Queensland) 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. Metropolitan Coal has shortened the length of Longwall 303 by 98 m to maintain the maximum predicted total closure on the lower reaches of the Eastern Tributary to less than 200 mm.

**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.<br>• Upstream sites on Waratah Rivulet show slightly acidic to near neutral pH values with higher (slightly alkaline) values being recorded at downstream sites.<br>• Electrical conductivity has been consistently low.<br>• Dissolved iron and dissolved manganese concentrations have typically been higher at the upper to middle reach sites.<br>• Dissolved aluminium has been consistent from upstream to downstream and low. |
| Woronora River (control sites WOWQ 1 and WOWQ 2) | • Sites on Woronora River typically show slightly acidic and high variability in pH.<br>• Electrical conductivity values have been consistently low and similar to values recorded on Waratah Rivulet.<br>• Dissolved iron has been generally low and similar to values recorded in Waratah Rivulet.<br>• Dissolved aluminium concentrations have been typically low and typically higher upstream.<br>• Dissolved manganese has been typically low with evidence of more elevated concentrations occurring in the summer months. |
| Eastern Tributary (sites ETWQ F, ETWQ J, ETWQ N, ETWQ U, ETWQ W, ETWQ AF, ETWQ AH, ETWQ AQ and ETWQ AU) | • Sampling sites on Eastern Tributary show variable but typically near neutral pH values.<br>• Electrical conductivity values have historically been low, however were more variable during 2017, with higher values recorded associated with low water levels.<br>• Dissolved aluminium concentrations are typically low, with some spikes occasionally recorded.<br>• 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. |

**Table 2 (Continued)**
**Stream Water Quality Monitoring Results**

| Stream | Monitoring Results to Date |
|---|---|
| Bee Creek, Honeysuckle Creek, Far Eastern Tributary, Tributary B and Tributary D (sites BCWQ 1, HCWQ 1, FEWQ 1, RTWQ 1, and UTWQ 1) | • 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.<br>• 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.<br>• Dissolved iron concentrations have been generally low at these sites with periodic small spikes in dissolved iron recorded mostly during summer months.<br>• Dissolved manganese concentrations have been generally low and consistent with historical values.<br>• 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 and this trend continued throughout 2017. |

Source: after Hydro Engineering & Consulting (2018)

***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.

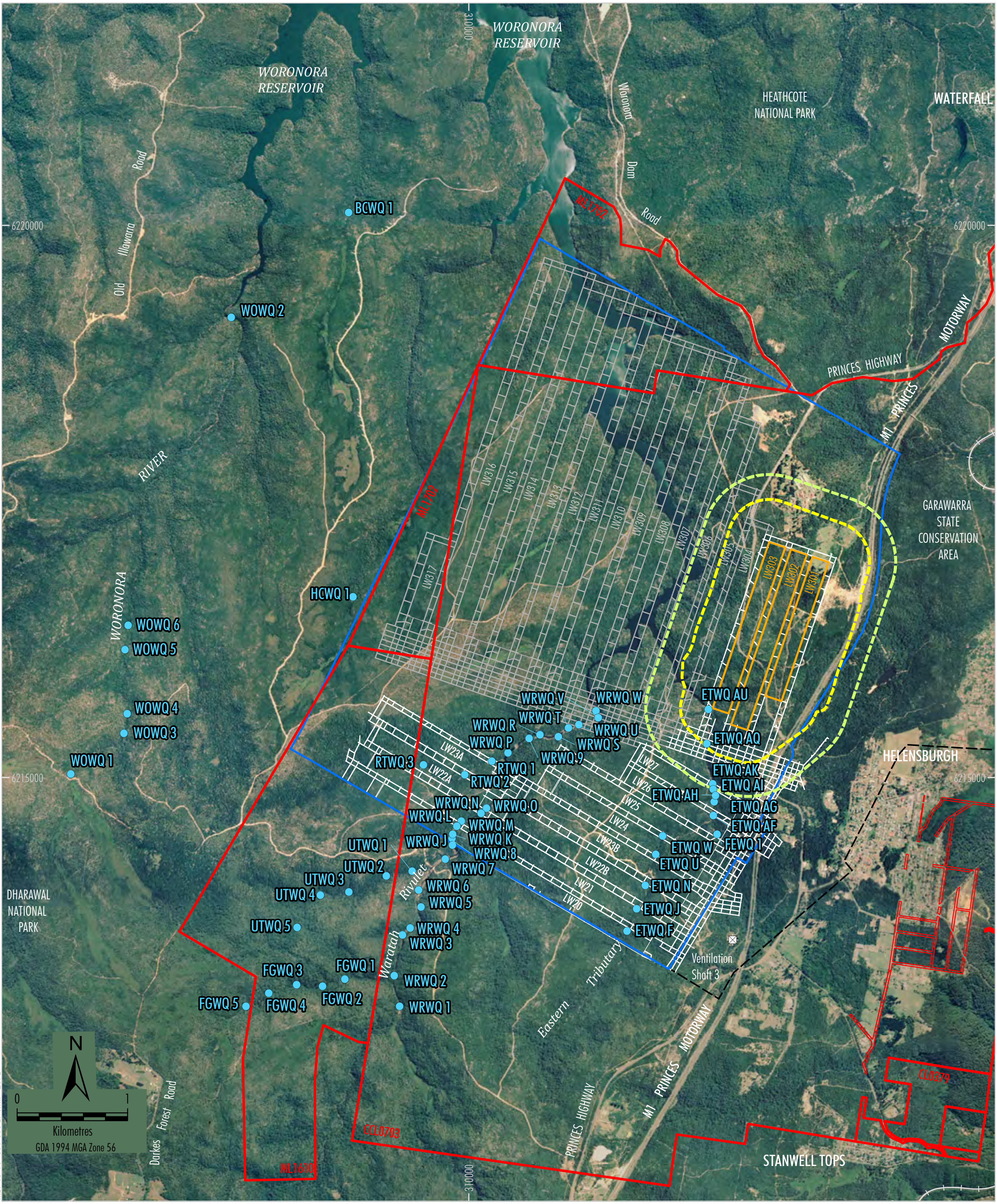
Metropolitan Coal sources water quality data for the Woronora Reservoir from WaterNSW in accordance with a data exchange agreement and analyses data for total iron, total aluminium and total manganese from 0 m to 9 m below the reservoir surface.

The data has been assessed consistent with the Trigger Action Response Plan in Section 8.8. The water quality monitoring results to date are consistent with the predictions and indicate there has been a negligible reduction in the water quality of Woronora Reservoir.

## 4.2 GROUNDWATER

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

- Perched groundwater system – generally above and independent of the regional groundwater table (typically less than 50 m below the ground surface). Excess rainfall produces a permanent perched water table within swamp sediments and outcropping sandstone that is independent of the regional water table in the Hawkesbury Sandstone. As the swamps are essentially rain-fed, water levels within upland swamps fluctuate seasonally with climatic conditions.
- Shallow groundwater system – the shallow groundwater system (extending typically to less than 100 m below the ground surface) is separate from the perched groundwater system and defines a regional water table.
- Deep groundwater system – although the shallow and deep groundwater systems are connected, low permeability of the Bald Hill Claystone provides a degree of isolation between the Hawkesbury Sandstone (Figure 8) that hosts shallow groundwater and the underlying Bulgo Sandstone and deeper formations that host deep groundwater. The deep groundwater system is typically more than 100 m below the ground surface.




LEGEND

- Mining Lease Boundary
- Railway
- Project Underground Mining Area Longwalls 20-27 and 301-317
- Longwalls 301-303 Secondary Extraction
- 35° Angle of Draw and/or Predicted 20 mm Subsidence Contour
- 600 m from Secondary Extraction of Longwalls 301-303
- 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 (2018); MSEC (2018)*

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Surface Water Quality Sites

**Figure 7**

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. There are seven registered bores[4] in the vicinity of Metropolitan Coal. The locations of the three nearest bores are shown on Figure 9.

***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. |

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 are 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 has been 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[5] has been prepared (HydroSimulations, 2018) and the model will be used for the assessment of future longwalls (i.e. for Longwalls 304 on).

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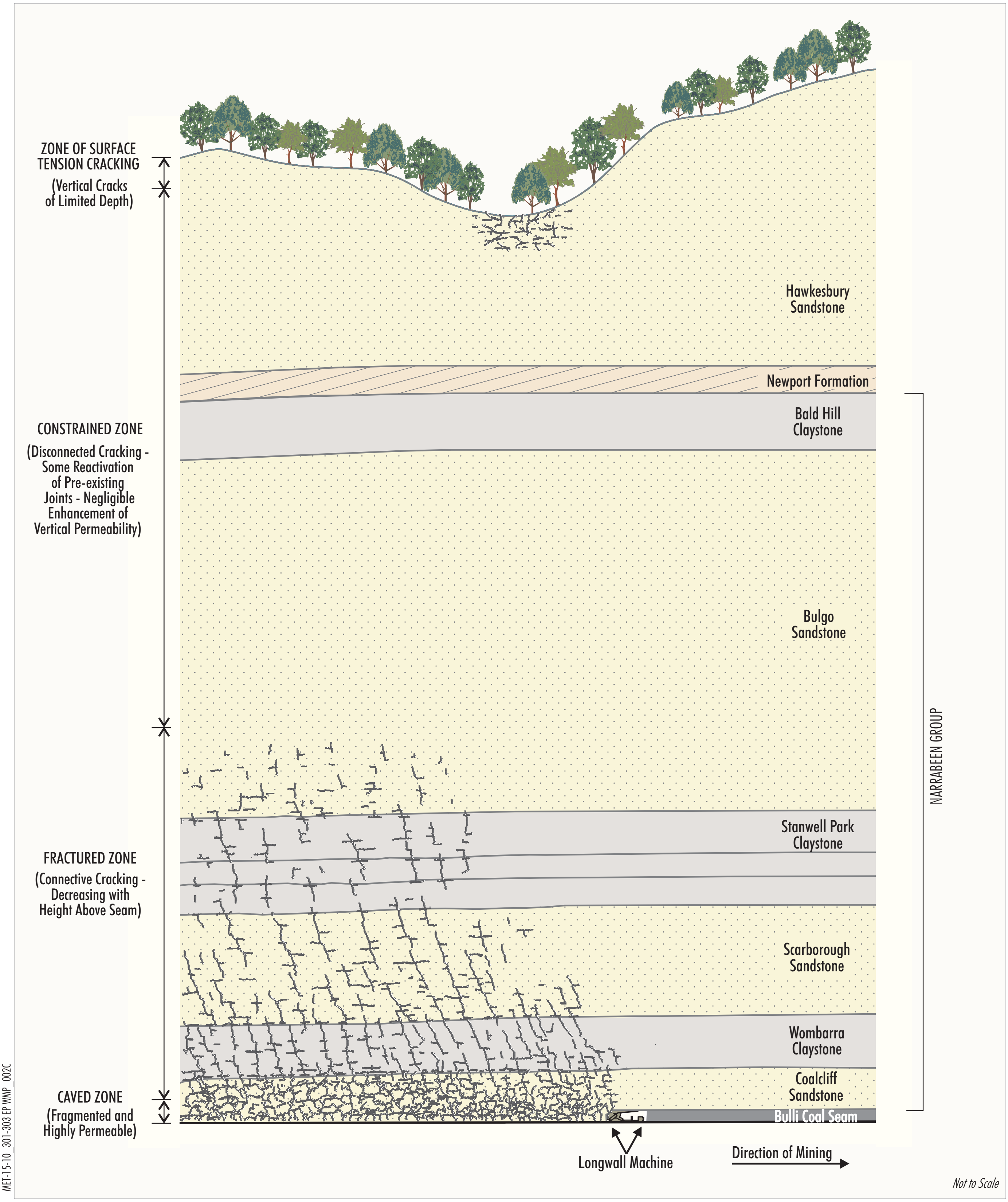
4 Details of the registered bores are included in Table 2 in Appendix B of the *Metropolitan Coal Project Environmental Assessmen*t (HCPL, 2008).

5 This updated groundwater model has not been used for any Longwalls 20-27 assessments, and has not been used for any of the predictions in the LW301-303 WMP.




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

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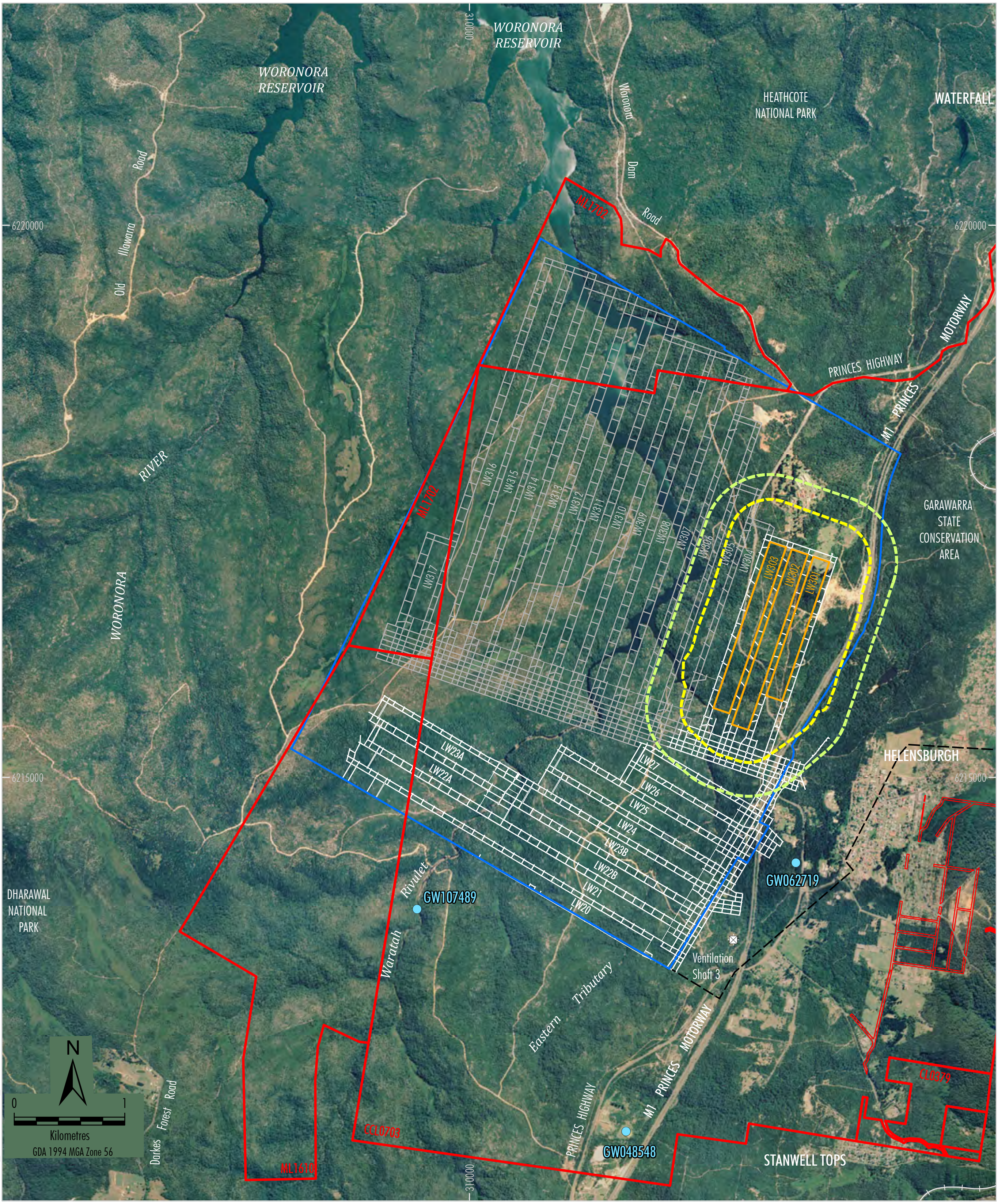
Schematic - Longwall Mining and Subsidence Profile

**Figure 8**




LEGEND

- Mining Lease Boundary
- Railway
- Project Underground Mining Area Longwalls 20-27 and 301-317
- Longwalls 301-303 Secondary Extraction
- 35° Angle of Draw and/or Predicted 20 mm Subsidence Contour
- 600 m from Secondary Extraction of Longwalls 301-303
- Existing Underground Access Drive (Main Drift)
- Registered Bore

Note: 1. Registered bore GW27422 is not shown. It is located approximately 5 km north-east of GW62719.
Registered bores GW018337, GW018338 and GW018339 are not shown. They are located approximately 3.7 km, 4.5 km and 4.5 km south-west of GW107489, respectively.

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

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Registered Bore Locations

**Figure 9**

***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 Biodiversity Management Plans, included:

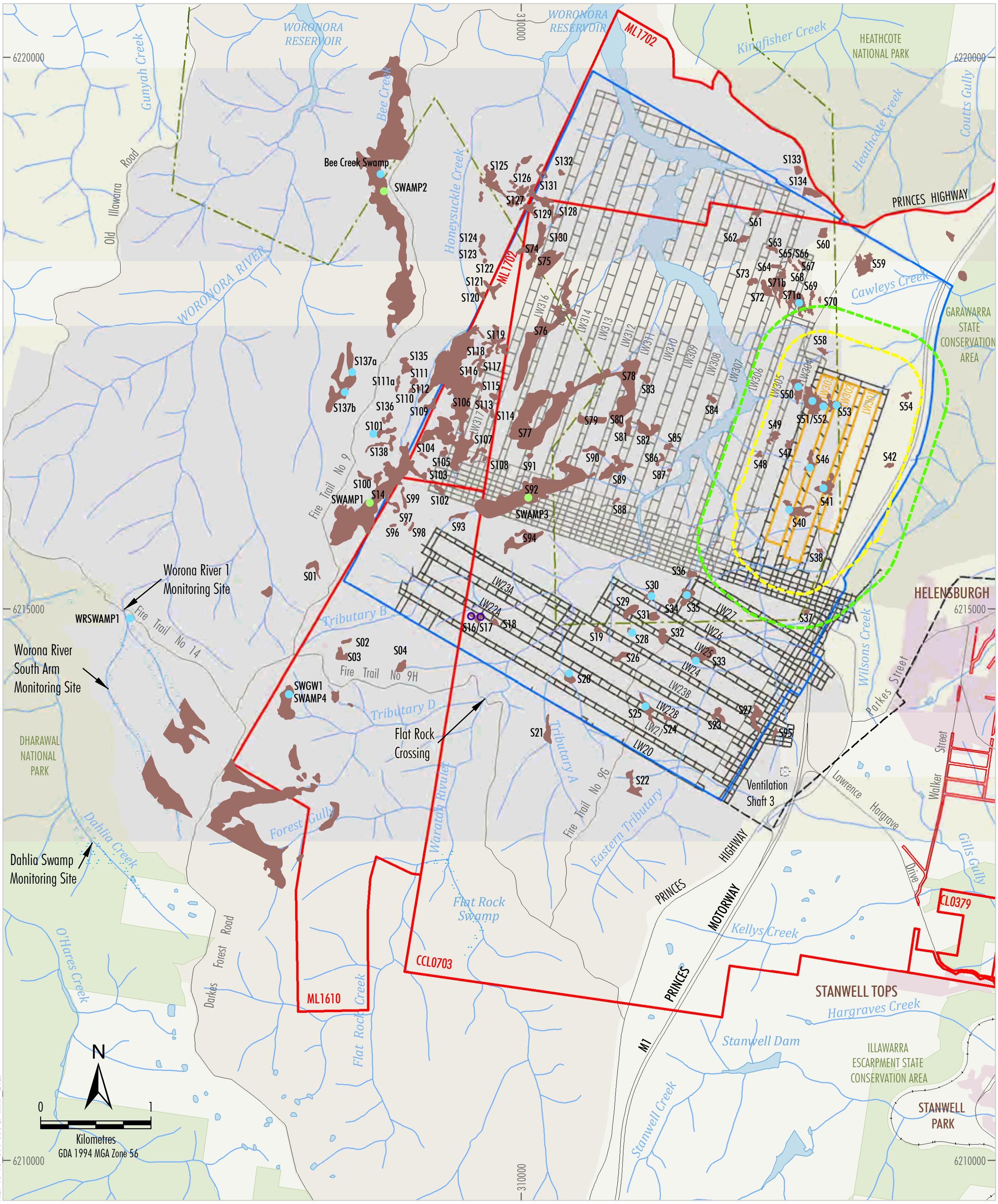
- Any cracking of the bedrock within upland swamps is expected to be isolated and of a minor nature, due to the relatively low magnitudes of the predicted strains and the relatively high depths of cover.
- Surface cracking resulting from mine subsidence within the upland swamps is not expected to result 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 is 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 are expected to be immeasurable when compared to the scale of seasonal and even individual rainfall event based changes in swamp groundwater levels.
- Whilst swamp grades vary naturally, the predicted maximum mining-induced tilts are 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 is 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 10). 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 10). 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 10).



LEGEND

- Mining Lease Boundary
- Woronora Special Area
- Railway
- Project Underground Mining Area Longwalls 20-27 and 301-317
- Longwalls 301-303 Secondary Extraction
- 35° Angle of Draw and/or Predicted 20 mm Subsidence Contour
- 600 m from Secondary Extraction of Longwalls 301-303
- Woronora Notification Area
- Existing Underground Access Drive (Main Drift)
- 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 (2018); MSEC (2018); after NPWS (2003), Bangalay Botanical Surveys (2008) and Eco Logical Australia (2015; 2016)*

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**Upland Swamp Groundwater Piezometer Locarions**

**Figure 10**

MET-15-10 301-303 EP WMP 212F

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.

Analyses to date indicate the swamp substrate water levels of all swamps have remained perched with the exception of Swamp 20 and Swamp 28 (HydroSimulations, 2018). 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 1a) (HydroSimulations, 2018). This trend has continued to be observed (HydroSimulations, 2018). It is considered that Longwall 21 caused a mining effect at Swamp 20, but the effects have not been exacerbated by Longwalls 22-27 or Longwall 301.

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 1b). 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.

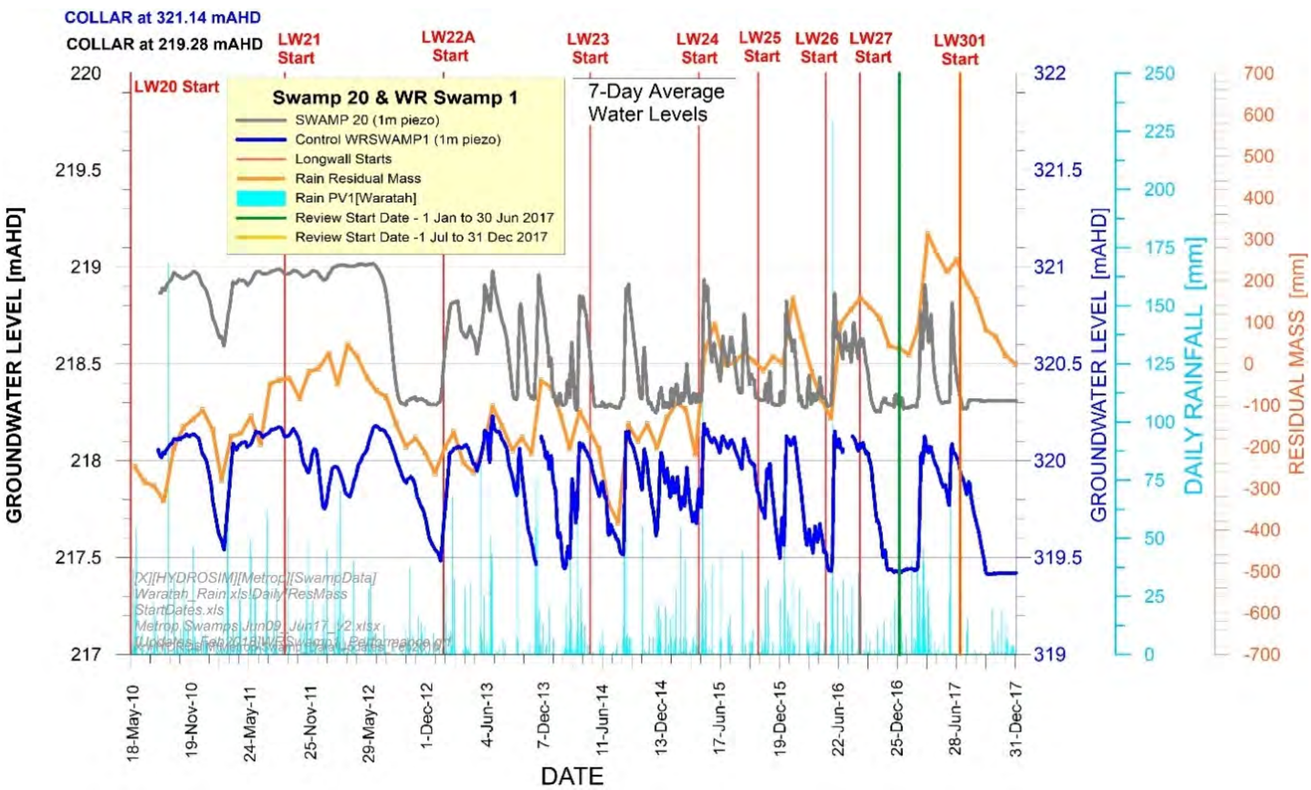



**Chart 1a: Comparison of Piezometer Responses at Swamp 20 and Woronora River 1 Control Swamp**

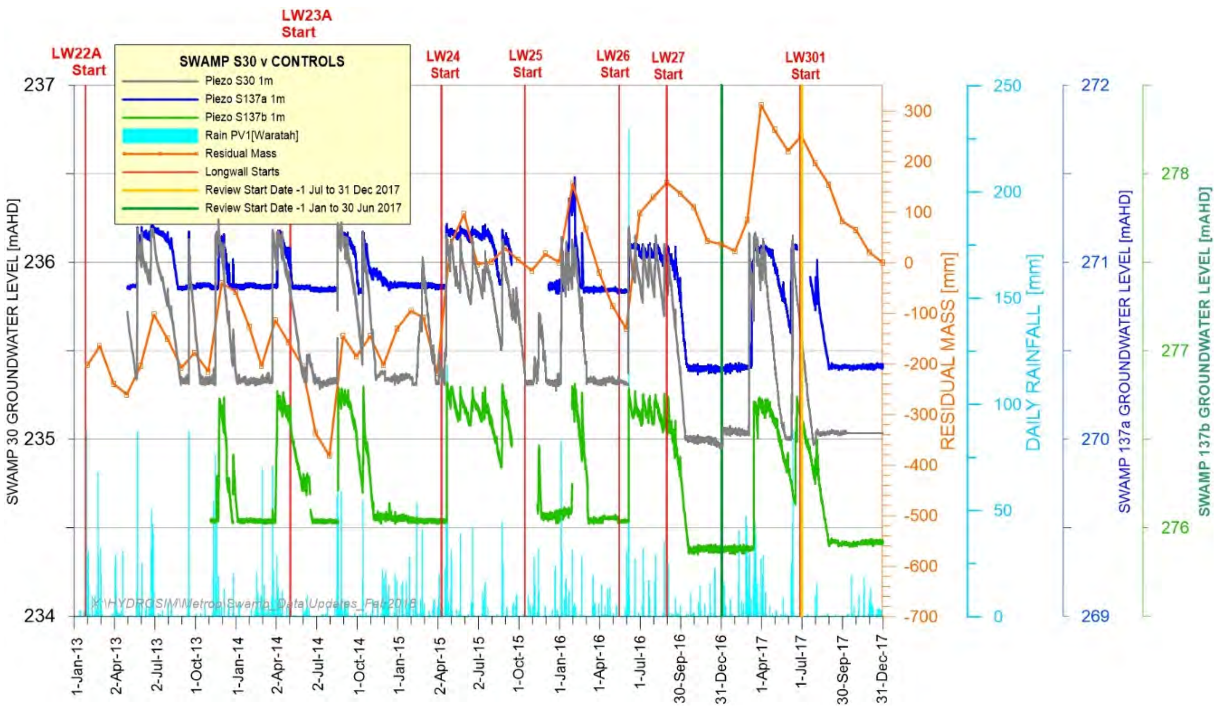



**Chart 1b: Groundwater Hydrographs at Swamp 28 and Two Control Swamps (137a and 137b)**

While the water lost from Swamp 20 and Swamp 28 was retained in the unsaturated sandstone above the regional water table, the changes in swamp water levels as a result of cracking are measurable when compared to seasonal individual rainfall event based changes in swamp groundwater levels. There is currently no sign that the vegetation in Swamp 20 is being impacted by the changed hydrological conditions. The autumn 2017 vegetation monitoring results suggest that 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] has not been 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 (Figure 9) 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 is reinforced by the groundwater modelling which indicates 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 as a result of enhanced groundwater – surface water interactions (as described for surface water quality above).

The locations of groundwater bores that have been sampled for groundwater levels/pressures and groundwater quality at Metropolitan Coal are shown on Figures 11 and 12, respectively.

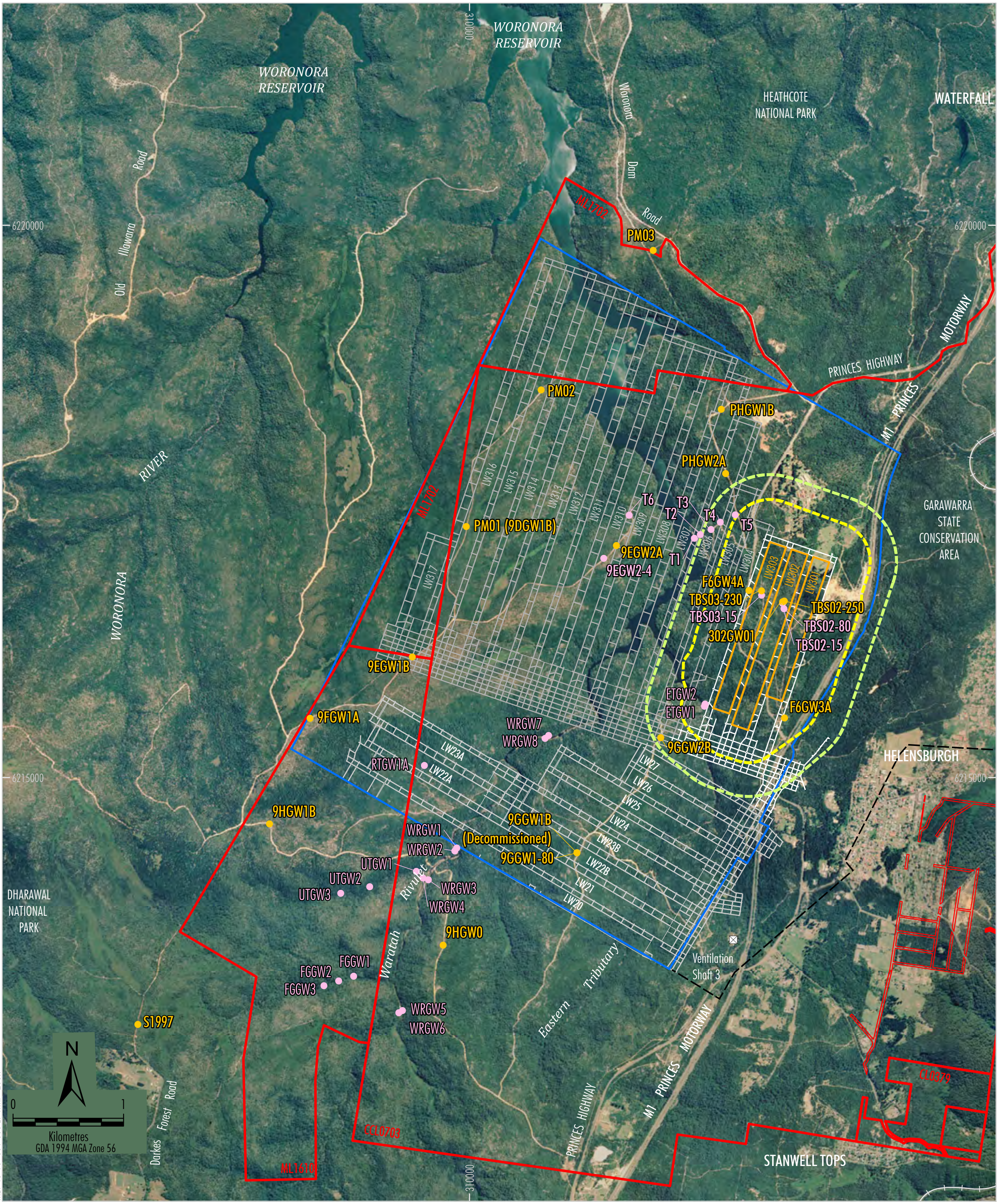
The groundwater monitoring results are considered to be consistent with the potential subsidence impacts and environmental consequences described in the Project EA, Preferred Project Report, and Metropolitan Coal Water Management Plans.

***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.

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 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 Narrabeen Group sandstones.
- Groundwater discharge to the mined seam would occur from above and below the seam in proportion to local permeabilities. The water make (i.e. groundwater inflow) is expected to be in the order of 0.1 megalitres per day (ML/day) for Longwalls 20-27 and from 0.045 to 0.6 ML/day for Longwalls 301-303. Modelling indicated that the inflow could be up to 0.5 ML/day from the deep groundwater system during mining of Longwall 24 and up to 0.6 ML/day during the mining of Longwall 302.
- 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.




LEGEND

- Mining Lease Boundary
- Railway
- Project Underground Mining Area Longwalls 20-27 and 301-317
- Longwalls 301-303 Secondary Extraction
- 35° Angle of Draw and/or Predicted 20 mm Subsidence Contour
- 600 m from Secondary Extraction of Longwalls 301-303
- Existing Underground Access Drive (Main Drift)
- Groundwater Level/Pressure Bore
- Groundwater Level Bore

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

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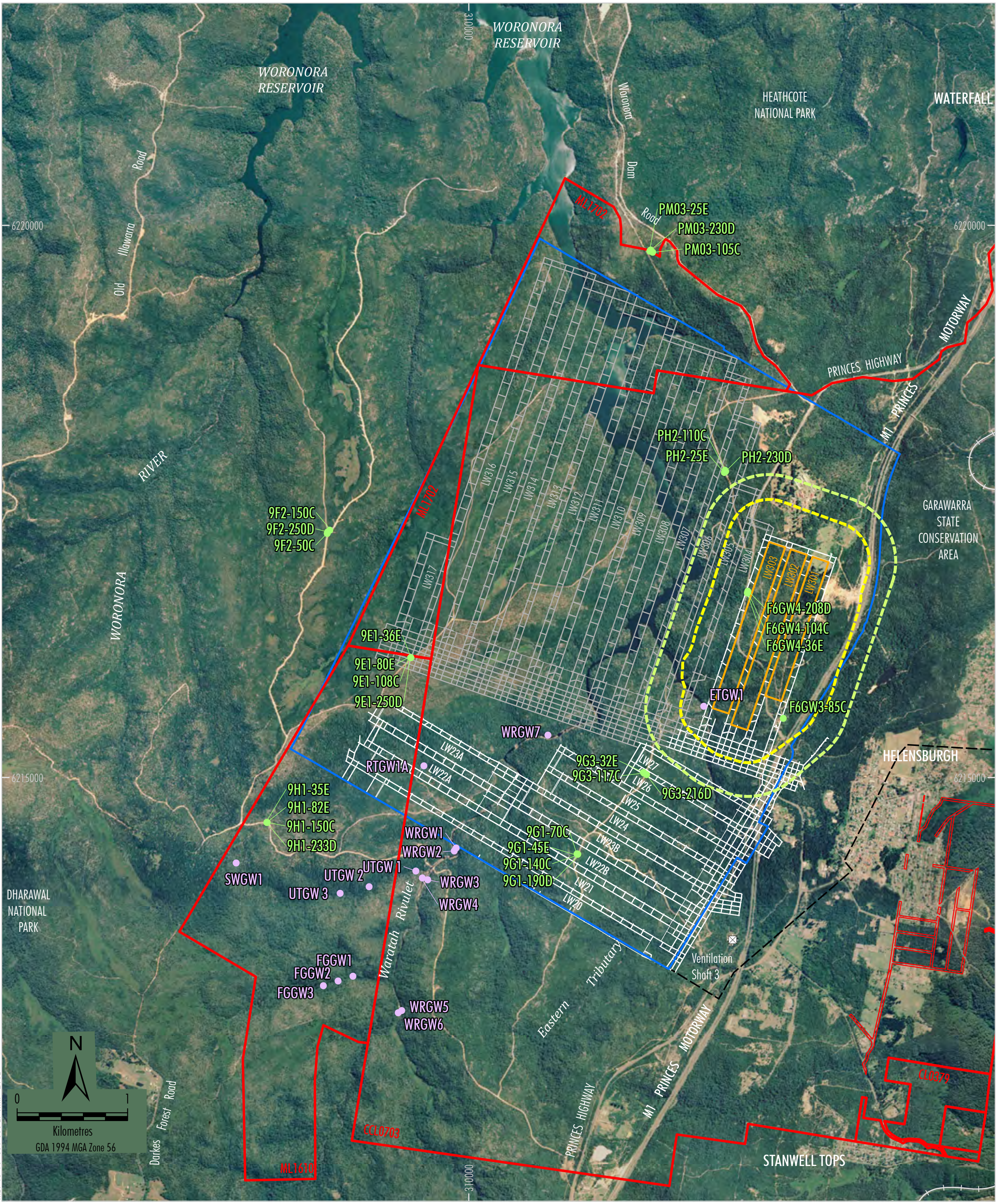
Groundwater Level and/or Pressure Bore Locations

**Figure 11**




LEGEND

- Mining Lease Boundary
- Railway
- Project Underground Mining Area Longwalls 20-27 and 301-317
- Longwalls 301-303 Secondary Extraction
- 35° Angle of Draw and/or Predicted 20 mm Subsidence Contour
- 600 m from Secondary Extraction of Longwalls 301-303
- Existing Underground Access Drive (Main Drift)
- Deep Groundwater Chemistry Site
- Shallow Groundwater Quality Site

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

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Groundwater Quality Sites

**Figure 12**

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 is a very high probability that a constrained zone will 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 have 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 both support 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, results in a constrained zone in the overburden that remains rigid and acts as a bridge which isolates shallow and deep aquifers.

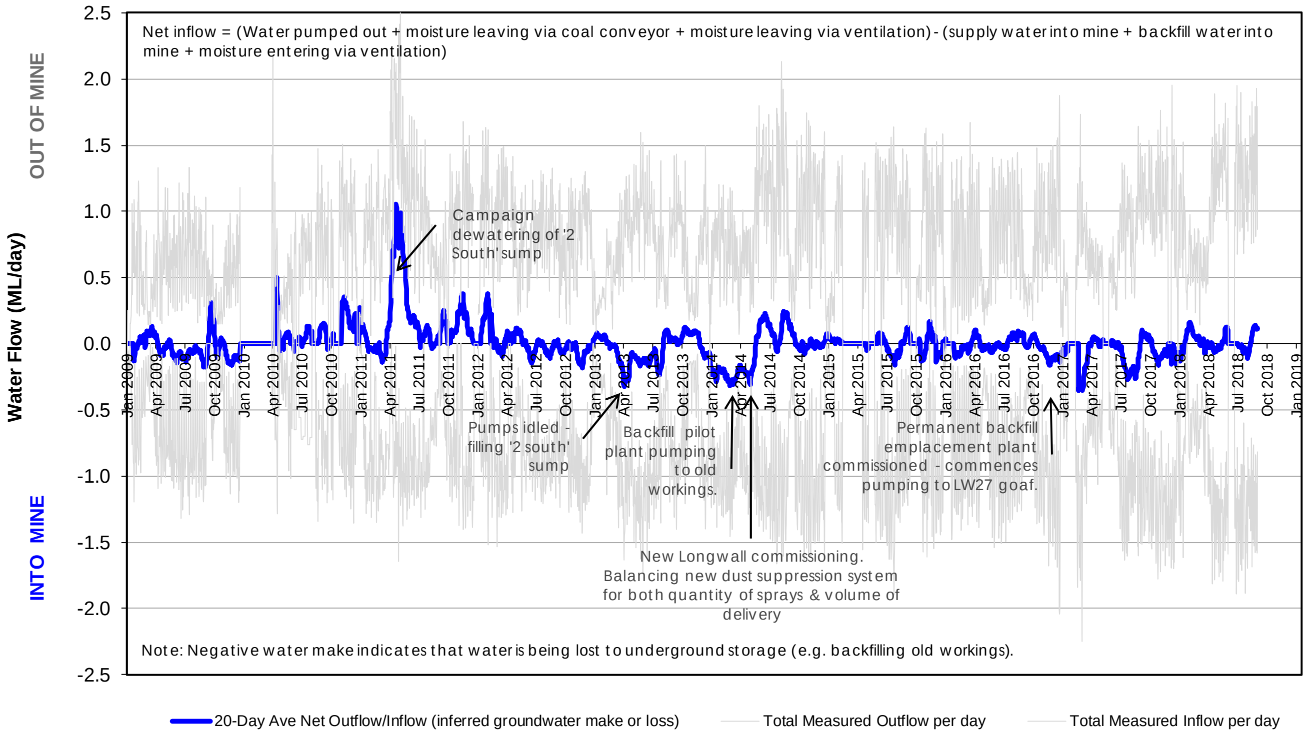
Metropolitan Coal conducts weekly inspections of development workings for water accumulation. The mine inspections have not identified any abnormal water flows from the goaf, geological structure, or strata generally either prior to, or since, the commencement of Longwall 20.

Monitoring of the mine water balance (mine water make) is calculated from the difference between total mine inflows and total mine outflows (refer Section 8.6 for details). The 20 day average daily mine water make has consistently been less than 0.5 ML/day since 2009 (Charts 2a and 2b). The increased water make during the period April 2011 to July 2011 (Chart 2a) was a result of dewatering of old workings in advance of the 200 Mains Panel (Metropolitan Coal, 2011). The monitoring results are consistent with the predictions for mine water make.

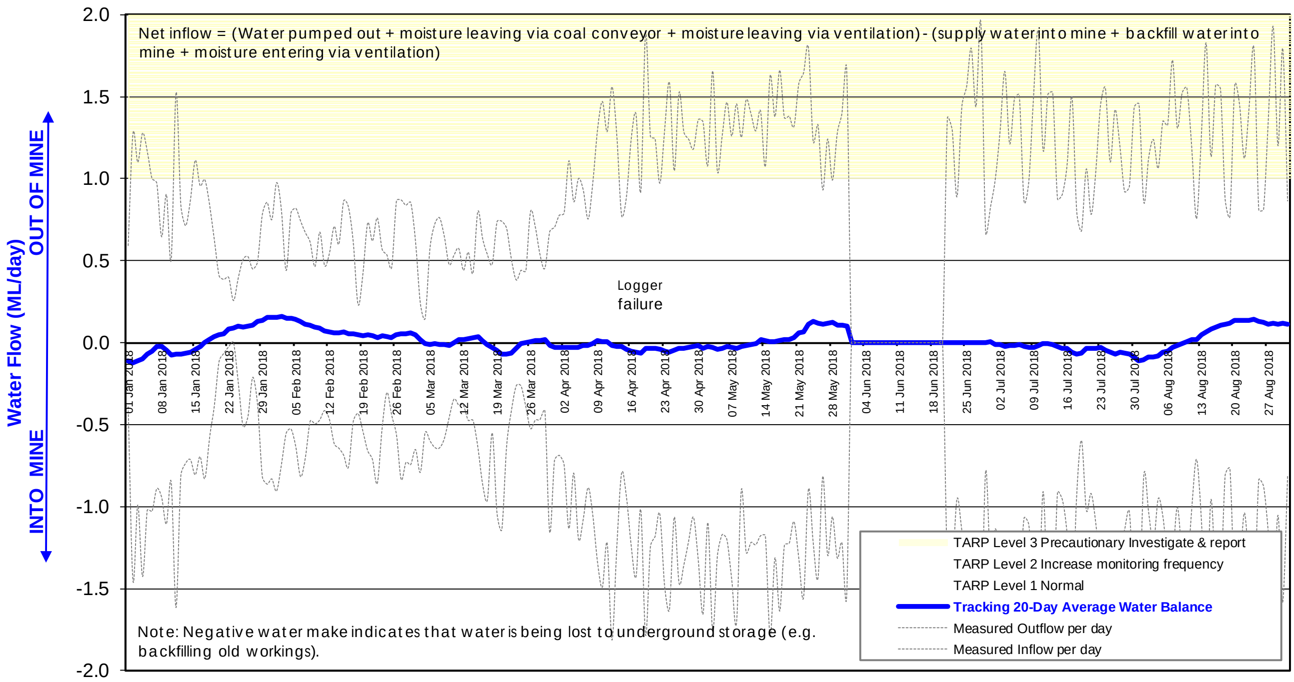
Further to a request from the Dams Safety Committee, a water balance for the 300 area (i.e. a localised water balance underground in and about the 300 series longwalls) has been established using a series of water meters installed underground. The results of the localised water balance are shown in Chart 2c. Metropolitan Coal will provide the results of the localised water balance, with the results of the overall mine water balance (Charts 2a and 2c) to the Dams Safety Committee monthly.

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, PM03, PHGW1B, PHGW2A, F6GW3A and F6GW4A (Figure 11) 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.

In accordance with the Dams Safety Committee Approval (26 April 2012), for mining within the Woronora Reservoir Notification Area, Metropolitan Coal has undertaken sampling programs to investigate the properties of groundwater above and below the Hawkesbury Sandstone and to establish chemical signatures that would indicate mining-induced fracturing through the Bald Hill Claystone, should it occur. The groundwater quality sites monitored in accordance with the Water Fingerprinting Monitoring Program are shown on Figure 12. The data are analysed through statistics, trend diagrams (Stiff, Schoeller and Piper), time-series plots, spatial maps, and ratio plots. Although a few sampling sites are grout-impacted, there is sufficient reliable data to show a clear distinction between groundwaters in the upper Hawkesbury Sandstone, lower Hawkesbury Sandstone and upper Bulgo Sandstone. To date, there is no evidence of mining-induced leakage across the Bald Hill Claystone.




## Chart 2a Estimated Daily Mine Water Make, 2009 to August 2018




## Chart 2b Estimated Daily Mine Water Make, January to August 2018

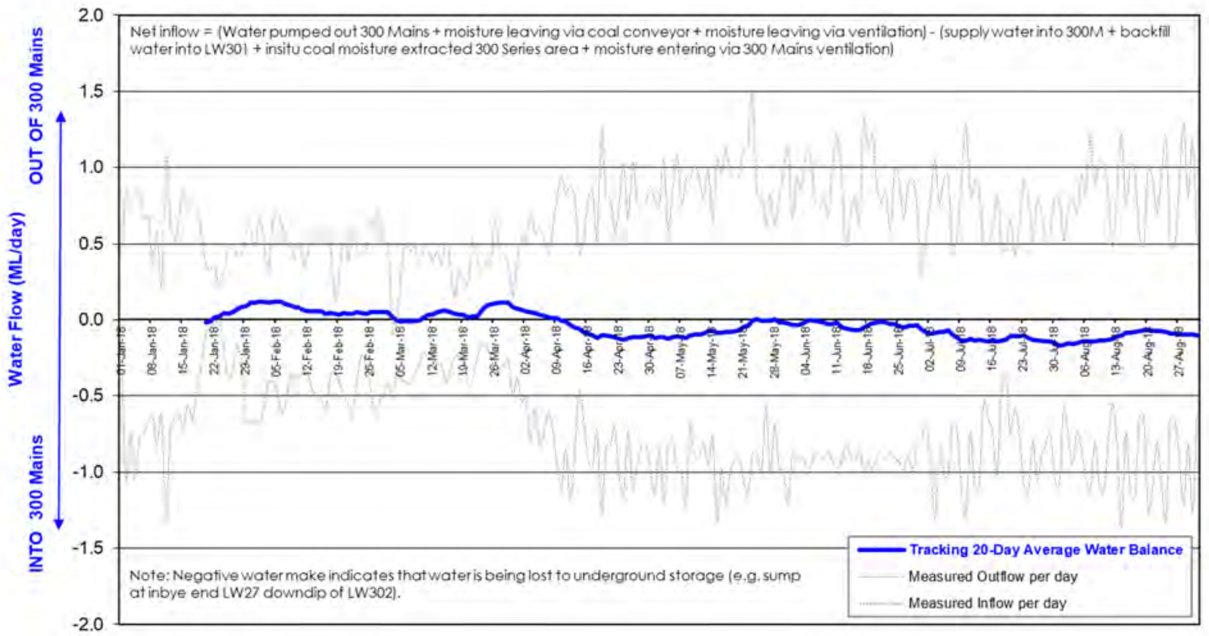



**Chart 2c 300 Mains Water Balance, January to August 2018**

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.

***Significance of Chain Pillars on Simulated Groundwater Pressures***

The Research Program, *Significance of Chain Pillars on Simulated Groundwater Pressures*, funded by Metropolitan Coal has been implemented and progressed by Dr. Noel Merrick. The research program is investigating the role played by chain pillars in isolating groundwater pressure reductions above mined longwall panels, and whether they might limit the outwards propagation of pressure reductions and environmental effects. The outcomes of this research will be an improved understanding of the significance of chain pillars with respect to alteration of the groundwater regime, a quantitative appreciation of critical pillar widths in absolute and relative terms and a rationale for considering geotechnical model outputs in terms of groundwater model inputs (permeability fields).

Investigation of potential fractured zone height algorithms has resulted in a paper with Mr Steven Ditton (Ditton Geotechnical Services) titled *A New Subsurface Fracture Height Prediction Model for Longwall Mines in the NSW Coalfields (*Ditton and Merrick, 2014). The paper describes the outcomes of the review of the 'state-of-the-art' subsurface fracture zone height prediction models and the development of a new model based on Buckingham's PI-Term theory and analytical models of strata behaviour during the caving process above longwalls. The model includes the key fracture height driving parameters of panel width (W), cover depth (H), mining height (T) and local geology factors to estimate the A and B zone horizons above a given longwall panel.

The research program is examining spatial scale effects, and differences in spatial scales that are routinely applied in the geotechnical and hydrogeological disciplines. A cross-section model is being built with a structured grid using traditional modelling software (MODFLOW-SURFACT), using a range of different scales. A report has been prepared and currently is under review.

## 4.3 WORONORA RESERVOIR IMPACT STRATEGY

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

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

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

The additional monitoring sites and environmental investigations included the installation of two streamflow monitoring stations in sub-catchments K and I and the installation of a pluviometer in the vicinity of the northern end of Longwall 307.

A number of groundwater monitoring bores have also been installed as a component of the Woronora Reservoir Impact Strategy including a goaf hole over Longwall 302 (302GW01). Metropolitan Coal installed five copper wire and four optical fibre piezometers in hole 302GW01 to monitor groundwater as longwall extraction progressed. Unfortunately, most of the sensor cables were severed by ground movement as Longwall 302 passed under the site. Follow-up piezometer installation to monitor post-mining groundwater pressures similar to the previous goaf hole sites with traditional copper cabling is scheduled for late 2018.

At the time the mining face crossed the position of bore 302GW01, the pressure head profile suggests that the top of the connected fracture zone would have been between the sensors at 340 m and 380 m depth. This would correspond to a fracture height range of 166-206 m. The Ditton calculation of fracture height (using the geology model and t' of 20 m) gives a range of 168-192 m (A to A95), whereas the Tammetta method gives 152-189 m (C to C95). Both algorithms are in good agreement with observation. Due to the observation of very low pressure heads to greater height than expected shortly after the day on which the mining face passed the bore, and uncertainty over whether the VWP sensors are recording valid data from that time, Metropolitan Coal will install a post-mining open bore hole to obtain a direct measurement of post-mining water pressures over time on the recommendation of the Woronora Reservoir Impact Strategy independent experts.

Metropolitan Coal also installed additional bores over Longwall 302 (TBS02-80, TBS02-250 and TBS02-15) and Longwall 303 (TBS03 – 230 and TBS03-15) (Figure 11). The two deep holes have vibrating wire piezometers installed 15 m above and below the Bald Hill Claystone. A summary of the groundwater monitoring results analysed to date is provided in Sections 4.3.1 and 4.3.2.

Two deep inclinometer monitoring points (TBS02-250 and TBS03-230) were established on the centreline axis of Longwall 302 and Longwall 303 (Figure 11) to establish trends of horizontal shearing as the extraction of the respective longwalls progress towards the instruments. The inclinometers monitor horizontal shearing locations, measure the magnitude and direction of shearing in the Hawkesbury Sandstone and record any basal shearing on the sandstone contact with the Bald Hill Claystone formation. A total of 10 inclinometer surveys have been completed at TBS02-250 between January and June 2018. The data suggests lateral movement associated with the extraction of Longwall 302 has resulted in a north-east trending displacement across multiple shear planes identifiable at depths 74 m, 105 m, 114 m, 162 m and 202 m. The follow up piezometer hole planned for 302GW01 in late 2018 will test for any permeability changes associated with the identified shear planes.

### 4.3.1 Groundwater Monitoring Results

Groundwater pressures were first recorded at bore 302GW01 in November 2017 when the mining face was approximately 450 m to the south in the adjacent Longwall 301, heading away from 302GW01. During the extraction of Longwall 302, the heads in 302GW01 commenced rising in all but the shallowest piezometer when the mining face was about 300 m from the bore, The rises of 10-60 m are expected to be due to dynamic compression of the rock matrix as the mining face approached the bore. About a week before the mining face passed beneath the bore on 25 May 2018, the groundwater heads declined substantially, except for the shallowest piezometer at 80 m depth. About a week after the crossing, eight of the nine sensors ceased to function. It is probable that the sensor cables sheared off at the shear planes identified by the TBS02 inclinometer surveys. However, the two corresponding sensors in bore TBS02, 20 m away, survived the crossing and have continued to record meaningful data. The observed drawdowns were about 80 m at the base of the Hawkesbury Sandstone and about 140 m at the top of the Bulgo Sandstone. Since then, the water levels have recovered by about 20 m and 10 m respectively (at September 2018), so that the pressure heads (the height of water above the sensor) are currently about 50 m and 25 m respectively. At bore TBS03 in the centre of Longwall 303, to the immediate west of TBS02, the corresponding pressure heads are currently about 90 m and 140 m respectively.

Further west, over the pillar between Longwalls 303 and 304, bore F6GW4 has been recording groundwater heads at eight depths since August 2013. The sensors at this bore responded to the passing of the mining face (450 m away) during Longwall 301 with mild rises in head at most depths followed by mild drawdown. During the extraction of Longwall 302 (250 m away), larger rises in head occurred prior to the date of crossing (25 May 2018) followed by substantial declines in the lowest three piezometers (from the lower Bulgo Sandstone to Bulli Coal). The heads at TBS03 are consistent with those measured at F6GW4, and the responses at F6GW4 are consistent with those at 302GW01.

The two shallow 15 m standpipes have recorded stable depths to water of about 7 m at TBS02-15 and about 9 m at TBS03-15 over the past six months since measurements commenced. The deeper standpipe at TBS02-80 has recorded heads consistent with those at the 80 m piezometer at 302GW01, with a difference of about 3m. While the 80 m piezometer at 302GW01 continues recording, with no evident sustained mining effect, the standpipe hole has become obstructed.

### 4.3.2 Pre-Mining Permeability Measurements

Pre-mining packer testing was conducted in bore 302GW01 for 15 12-metre sections from 238 m to 490 m depth below the Bald Hill Claystone. The interpreted hydraulic conductivities ranged from $8 \times 10^{-7}$ m/d in the Scarborough Sandstone to $5 \times 10^{-4}$ m/d in the lower Bulgo Sandstone, with a median of $8 \times 10^{-5}$ m/d. Across these lithologies, the groundwater model has a median horizontal value of $3 \times 10^{-3}$ m/d and a median vertical value of $1 \times 10^{-5}$ m/d. Laboratory measurements of horizontal and vertical permeability were made on core taken from the Hawkesbury Sandstone, Bald Hill Claystone and Bulgo Sandstone. Typical results for horizontal hydraulic conductivity were $4 \times 10^{-5}$, $4 \times 10^{-6}$ and $2 \times 10^{-6}$ m/d respectively. Corresponding typical values in the groundwater model are, respectively, $2 \times 10^{-3}$, $7 \times 10^{-5}$ and $6 \times 10^{-3}$ m/d. The higher values in the model are consistent with the upscaling required when measurements are made at different scales.

At bore TBS02, pre-mining packer testing was conducted from 99 m in Hawkesbury Sandstone to 243 m total depth, beneath the Bald Hill Claystone. The Hawkesbury Sandstone hydraulic conductivities ranged from $2 \times 10^{-6}$ m/d to $1 \times 10^{-3}$ m/d with a median of $6 \times 10^{-4}$ m/d. The Bald Hill Claystone measurements were $6 \times 10^{-5}$ and $3 \times 10^{-4}$ m/d (average $4 \times 10^{-4}$ m/d), and the upper Bulgo Sandstone had a single value of $1 \times 10^{-4}$ m/d. For these lithologies, the groundwater model has consistent horizontal hydraulic conductivities of $2 \times 10^{-3}$ (median), $7 \times 10^{-5}$ and $7 \times 10^{-4}$ m/d.

# 5 REVISED ASSESSMENT OF POTENTIAL ENVIRONMENTAL CONSEQUENCES

## 5.1 LONGWALLS 301-303 EXTRACTION LAYOUT

Longwalls 301-303 and the area of land within 600 m of Longwalls 301-303 secondary extraction are shown on Figures 1 and 2. Longwall extraction will occur from north to south. The longwall layout includes 163 m panel widths (void) with 45 m pillars (solid).

The provisional extraction schedule for Longwalls 301-303 is provided in Table 4.

**Table 4**
**Provisional Extraction Schedule**

| Longwall | Estimated Start Date | Estimated Duration | Estimated Completion Date |
|---|---|---|---|
| Longwall 301 | 28 June 2017 | 8 months | 4 February 2018 |
| Longwall 302 | 29 March 2018 | 8 months | October 2018 |
| Longwall 303 | November 2018 | 8 months | June 2019 |

Note 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 the 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 301-303 Extraction Plan[6] *viz.* Land Management Plan, Heritage Management Plan, Biodiversity Management Plan and this WMP to give appropriate consideration to risk assessment and risk management in accordance with the DP&E and DRE (2015) *Guidelines for the Preparation of Extraction Plans*.

The suitably qualified and experienced experts endorsed by the Secretary of the DP&E for the preparation of the Metropolitan Coal Longwalls 301-303 Extraction Plan participated in the ERA[7].

The ERA process involved the key steps described below.

***Review of Relevant Documentation***

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

- The *Environmental Risk Analysis* (SP Solutions, 2008) conducted for the Project EA (Appendix O of the Project EA).
- The Preferred Project Report. 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 revised subsidence predictions and assessments for the approved changes to the first workings layout for Longwalls 301-303 (Metropolitan Coal, 2016a).
  - Following further mine planning investigations, Metropolitan Coal identified that significant operational efficiencies and consequently a significant economic benefit would be achieved by rotating the first workings of Longwalls 301-317 to be square with the 300 Mains (a rotation of approximately six degrees). The Secretary of the DP&E approved the revised first workings in accordance with Condition 5, Schedule 3 of the Project Approval on 20 April 2015.
  - On 5 May 2016, Metropolitan Coal requested the approval of the Secretary of the DP&E to further amend the first workings layout for Longwalls 301-303. The proposed changes to the first workings layout for Longwalls 301-303 were as follows:
    - Longwall 301 – reduce the panel void length from 1,680 m to 1,428 m, with no change to the tailgate pillar dimensions.
    - Longwall 302 – reduce the panel void length from 2,637 m to 1,954 m, with a reduction in the tailgate pillar width by 25 m for approximately 608 m of the panel length.

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6 Individual risk assessments have been undertaken separately for the Metropolitan Coal Longwalls 301-303 Built Features Management Plan and the Metropolitan Coal Longwalls 301-303 Public Safety Management Plan, and are reported in their respective documents.

7 Participants included Mr Peter DeBono (Mine Subsidence Engineering Consultants, Subsidence), Dr Noel Merrick (HydroSimulations, Groundwater), Mr Lindsay Gilbert (Hydro Engineering & Consulting, Surface Water), Dr David Goldney (Cenwest Environmental Services, Fauna), Dr Colin Bower (FloraSearch, Flora), Mr Jamie Reeves (Niche Environment and Heritage, Heritage), Mr Joshua Hunt (Resource Strategies, Land), Mr Jon Degotardi (Metropolitan Coal) and Mr Ryan Pascoe (Metropolitan Coal).

- Longwall 303 – reduce the panel void length from 2,760 m to 2,122 m, with a reduction in the tailgate pillar width by 25 m for approximately 728 m of the panel length.

The changes to the first workings layout for Longwalls 301-303 described above were approved by the Secretary of the DP&E on 16 June 2016.[8]

***Risk Identification***

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

***ERA Workshop***

The ERA workshop for Longwalls 301-303 was conducted on 21 June 2016 via a teleconference. The ERA workshop was facilitated by an independent specialist, Operational Risk Mentoring.

While the general consensus of the workshop participants was the additional (specific) issues/risks were broadly assessed and ranked as part of the previous *Environmental Risk Analysis* (SP Solutions, 2008), it was considered necessary to assess some specific potential environmental issues (upland swamps and the Eastern Tributary) in further detail for Longwalls 301-303, considering experience to date from Longwalls 20-27 and other local mines. These were assessed using the same probability, consequence and risk rankings tables as used in the original *Environmental Risk Analysis* (SP Solutions, 2008). The re-assessed risk rankings for Longwalls 301-303 were within the "low" range and consequently the potential outcomes can still be integrated into the existing management systems for effective review and monitoring (Metropolitan Coal, 2016b).

***ERA Report Review***

All ERA participants were asked to review the draft report that was prepared to summarise the outcomes of the risk assessment workshop. Participants' comments were incorporated into the final Metropolitan Coal (2016c) report.

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

## 5.3 REVISED SUBSIDENCE PREDICTIONS

The subsidence predictions for Longwalls 301-303 in relation to streams and upland swamps have been prepared by MSEC (2018)[9]. The revised subsidence effects, subsidence impacts and potential environmental consequences to upland swamps are addressed in the Metropolitan Coal Longwalls 301-303 Biodiversity Management Plan (Figure 3).

***Waratah Rivulet***

The Waratah Rivulet is located approximately 1 km west of Longwall 303, at its closest point to Longwalls 301-303 secondary extraction (Figure 1). At this distance, the Waratah Rivulet is not predicted to experience any measurable subsidence or valley related movements resulting from the extraction of Longwalls 301-303 (MSEC,2018).

8 Note that subsequent to the completion of the Environmental Risk Assessment, Metropolitan Coal made further revisions to the lengths of Longwalls 301-303. The updated longwall layout is shown on the WMP figures.

9 The valley closure modelling has been updated to reflect the shortening of Longwall 301 by 346 m (not previously reflected in the closure modelling) as described in the Subsidence Report (Appendix I of the Longwalls 301-303 Extraction Plan).

***Eastern Tributary***

The Eastern Tributary flows in a northerly direction into the Woronora Reservoir. Within the Longwalls 301-303 35 degree (°) angle of draw and/or predicted 20 mm subsidence contour, the Eastern Tributary flows into the full supply level of the Woronora Reservoir (Figure 2). Longwalls 301-303 do not directly mine beneath the Eastern Tributary (Figure 2).

When the Woronora Reservoir is at full capacity water backs up and covers an area referred to as the inundation area. The inundation area includes parts of the Eastern Tributary in the 301 to 303 area. When the water level is below the full supply level, portions of the Eastern Tributary inundation area form temporary pools above exposed rock bars.

The maximum predicted values of total conventional subsidence, tilt, curvature, upsidence and closure for the Eastern Tributary, resulting from the extraction of Longwalls 301-303, is provided in Table 5 (MSEC,2018).

**Table 5**
**Maximum Predicted Subsidence, Tilt, Curvature, Upsidence and Closure for the Eastern Tributary Resulting from Extraction of Longwalls 301, 302 and 303**

| Longwall | Maximum Predicted | | | | | |
|---|---|---|---|---|---|---|
| | Subsidence[1] (mm) | Tilt[2] (mm/m) | Hogging Curvature[3] ($km^{-1}$) | Sagging Curvature[3] ($km^{-1}$) | Upsidence[4] (mm) | Closure[5] (mm/m) |
| LW 301 | <20 | <0.5 | <0.01 | <0.01 | 30 | 50 |
| LW 302 | <20 | <0.5 | 0.01 | <0.01 | 40 | 60 |
| LW 303 | 30 | <0.5 | 0.01 | <0.01 | 80 | 100 |

Source: after MSEC (2018).

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.

A comparison of the maximum predicted subsidence, upsidence and closure for the Eastern Tributary resulting from the Extraction Plan Layout of Longwalls 301-303, with those based on the Preferred Project Layout for Longwalls 301-303, are provided in Table 6. The revised maximum predicted subsidence, upsidence and closure for the Eastern Tributary, are less than the maxima for the Preferred Project Layout (MSEC,2018). The maximum predicted total closure on the Eastern Tributary within the Longwalls 301-303 35° angle of draw and/or predicted 20 mm subsidence contour is 100 mm (Table 5).

**Table 6**
**Comparison of Maximum Predicted Conventional Subsidence Parameters for the Eastern Tributary based on the Preferred Project Layout and the Extraction Plan Layout**

| Layout | Maximum Predicted Total Conventional | | |
|---|---|---|---|
| | Subsidence (mm) | Upsidence (mm) | Closure (mm) |
| Preferred Project Layout (LW301-303)[1] | 200 | 175 | 150 |
| Extraction Plan Layout[2] | 30 | 80 | 100 |

Source: after MSEC (2018).

mm = millimetres

1 Preferred Project Layout (LW301-303) – after completion of Longwall 303 of the Preferred Project Layout.

2 Extraction Plan Layout – after completion of Longwall 303 of the Extraction Plan Layout (i.e. Longwalls 301-303 subject of this WMP).

The predicted profiles of subsidence, upsidence and closure along the Eastern Tributary, resulting from the extraction of Longwalls 301-303, are shown on Figure 13 (MSEC, 2018).

Figure 13 indicates that the maximum predicted total closure along the lower reaches of the Eastern Tributary (i.e. outside of the 35° angle of draw and/or predicted 20 mm subsidence contour) is less than 200 mm.

***Other Drainage Lines/Streams***

Small first and second order streams are located within the Longwalls 301-303 35° angle of draw and/or predicted 20 mm subsidence contour (Figure 2). Many of the streams consist of shallow drainage lines from the topographical high point above Longwalls 301-303. Shallow drainage lines have small valley heights of generally less than 10 m and are predicted to experience small magnitudes of predicted upsidence and closure (MSEC,2018). Valley heights increase at the lower reaches of these streams.

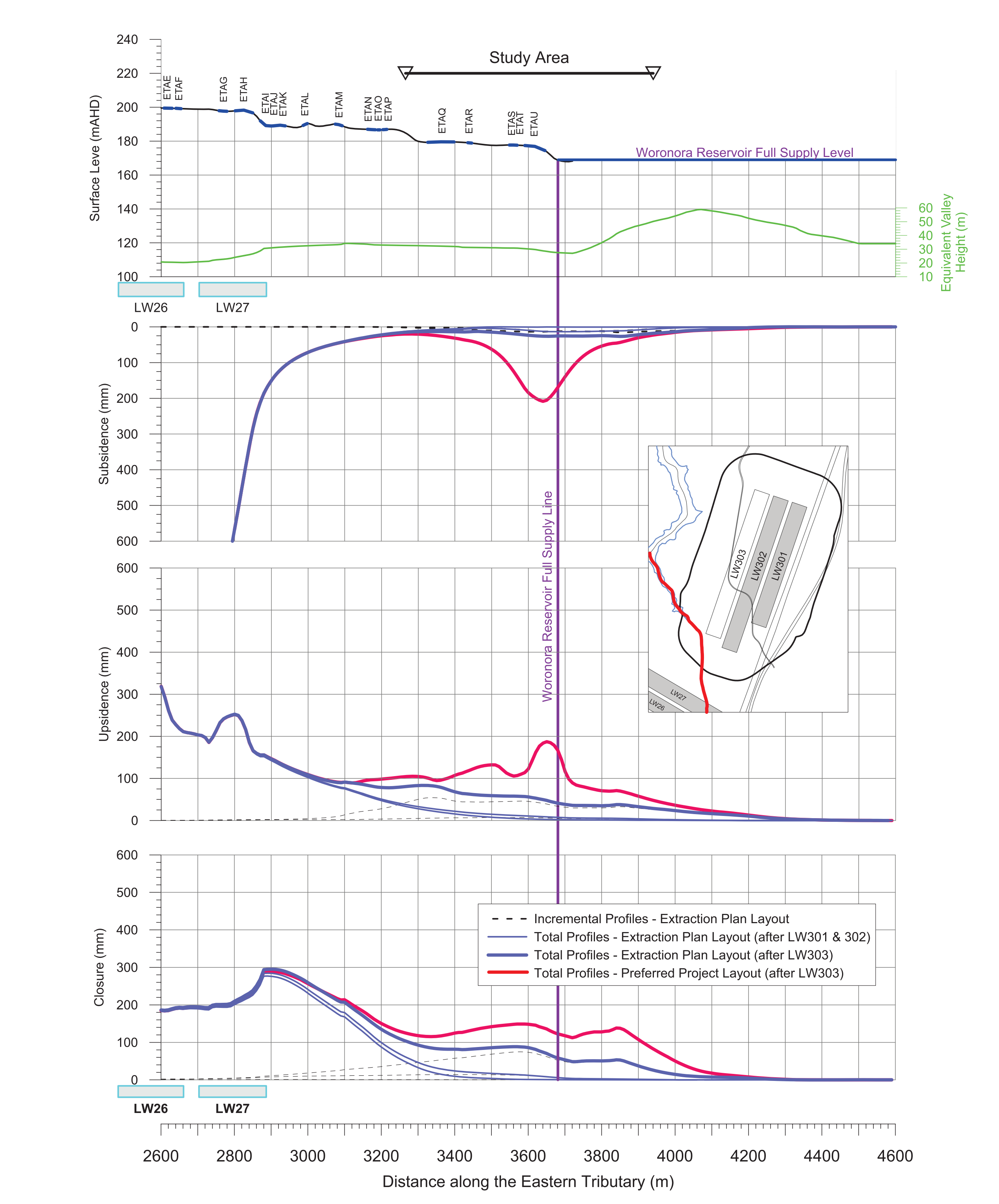
The stream with the largest valley height above Longwalls 301-303 is located near the southern end of Longwalls 302 and 303 (Figure 2). The stream has a maximum valley height of approximately 20 m and is predicted to experience maximum total closure of 120 mm. There are two streams with slightly greater valley heights to the west of Longwalls 301-303, however since they are outside the longwall layouts, the predicted closure is lower.

## 5.4 REVISED ASSESSMENT OF POTENTIAL SUBSIDENCE IMPACTS AND ENVIRONMENTAL CONSEQUENCES

### 5.4.1 Surface Water

The revised subsidence predictions for the Extraction Plan Layout do not change the subsidence impact assessment or assessment of environmental consequences provided in the Project EA and Preferred Project Report for streams.

Fracturing could develop in the bedrock along the section of the Eastern Tributary located closest to the proposed longwalls (MSEC, 2018). Minor and isolated fracturing could occur up to approximately 400 m from the longwalls, as has been observed along other streams in the Southern Coalfield (*ibid*.). The sizes and extents of fracturing are expected to be considerably less than those observed along other streams that were located directly above the previously extracted longwalls.




MET-15-10_301-303 EP WMP_004E

Source: MSEC (2018)

Peabody
METROPOLITAN COAL

Predicted Profiles of Subsidence, Upsidence and Closure along the Eastern Tributary and Woronora Reservoir due to Longwalls 301 - 303

**Figure 13**

The small first and second order streams located within the Longwalls 301-303 35° angle of draw and/or predicted 20 mm subsidence contour (Figure 2) could experience the full range of predicted subsidence movements.

The potential subsidence impacts and environmental consequences for these streams, based on the Extraction Plan Layout, are consistent with those assessed for the Preferred Project Layout that are described in Section 4.

The maximum predicted total closure on the Eastern Tributary within the Longwalls 301-303 35° angle of draw and/or predicted 20 mm subsidence contour is 100 mm. The maximum predicted total closure on the lower reaches of the Eastern Tributary (i.e. outside of the 35° angle of draw and/or predicted 20 mm subsidence contour) as a result of the Extraction Plan Layout is less than 200 mm.

### 5.4.2 Groundwater[10]

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

Potential environmental consequences of Longwalls 301-303 extraction on aquifers and baseflow to watercourses have been predicted using two groundwater model variants, termed the "high-inflow" model and the "low-inflow" model for the Extraction Plan Layout. The models compare favourably in their calibration performance against measured groundwater levels and vertical hydraulic gradient profiles, but they differ in the rate of predicted mine inflow. The two models (i.e. the "high-inflow" model and the "low-inflow" model) provide upper and lower bound predictions of impacts and mine inflow that can be used to assess the performance of the Project, as described in Section 8. As mining and data collection proceed, confidence levels in the model parameters will increase and should allow convergence to a single model in the future.[11]

Transient simulation is performed for 19 stress periods and 11 fracture zone time-slices (TS), with Longwalls 301-303 occupying TS6 to TS9. Two extra periods of six months each after the end of Longwall 303 allow for completion of fracturing and commencement of recovery if no further mining were to occur. At the commencement of each new longwall in the model, the fracture zone above the previous longwall is activated.

***Catchment Yield[12]***

Based on the period of record available for the Woronora Reservoir (1977 to 2008) at the time of the Project EA, the low-inflow and high-inflow model predictions (refer to the section above for a description of these two groundwater models) indicate a negligible reduction in catchment yield due to Longwalls 301-303 extraction (i.e. 0.0014% and 0.013% of the annual average yield to the reservoir, respectively)[13].

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[10] The groundwater model predictions described in this section and referred to elsewhere in this WMP were conducted for the Preferred Project Layout (i.e. the mine plan detailed in the Preferred Project Report), which included considerably longer longwall lengths for Longwalls 301-303. Accordingly, the groundwater predictions presented are more conservative than would be the case for the longwall layout presented in this WMP. The change in mine plan for the 300 series of longwalls (described in Section 5.2) has the effect of placing some bores closer to mining and some bores farther away. This will have an effect on the expected drawdowns at each monitoring point, but the vertical profile shapes would retain the same character.

[11] The high-inflow and low-inflow variants will collapse to a single model for the assessment of future longwalls.

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

[13] Gilbert & Associates (2008) prepared a water balance for Woronora Reservoir using SCA reservoir data and calculated a total yield to Woronora Reservoir over 31 years of approximately 800,000 ML, which equates to an annual average yield of 25,806 ML. The low-inflow and high-inflow groundwater models predict 0.001 ML/day and 0.009 ML/day reductions in catchment yield, respectively, for Longwalls 301-303 extraction.

***Mine Groundwater Inflows***

The simulated groundwater inflow to Longwalls 301-303 is presented on Chart 3 for both the low-inflow and high-inflow models, at the end of each mined panel, and six months after completion of Longwall 303 (assuming no new mining). The inflow is expected to lie in the range 45-600 kL/day. As these rates are consistent with the predictions made in the Project EA, the Project EA estimates of mine groundwater inflow at the end of mining remain valid.

***Vertical Head Profiles***

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

The predicted head profiles for multi-piezometer bores are presented on Charts 4 to 12 at the end of Longwalls 301 and 303. The locations of these bores are shown on Figure 11. As expected, Charts 4 to 12 show more extensive depressurisation for the high-inflow model, whereas the low-inflow model has a sudden drop in pressure around 400 to 450 m below ground surface.

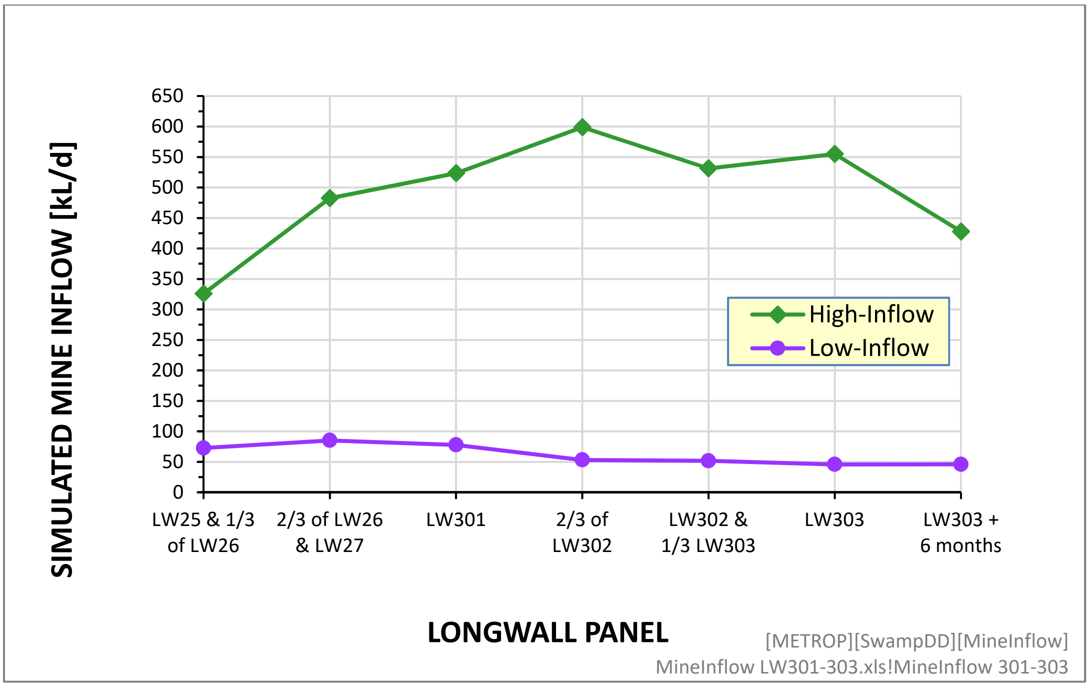



**Chart 3: Predicted Groundwater Inflows to Longwalls 301-303 as Mining Proceeds**

[Note: The rate of mine inflow reduces in the 303+6 months time slice due to the receding cumulative contribution of Longwalls 301 to 303 as piezometric heads are reduced and as a consequence of the model not including mining beyond Longwall 303 for this WMP.]

Every bore shows some mining effect. The least affected is PM02, which is the furthest from active mining. The order of total predicted mining effect is: 9GGW2B, F6GW3A, F6GW4A, 9EGW1B, PHGW2A, 9EGW2A, PHGW1B, PM01 (9DGW1B) and PM02 (Figure 11).

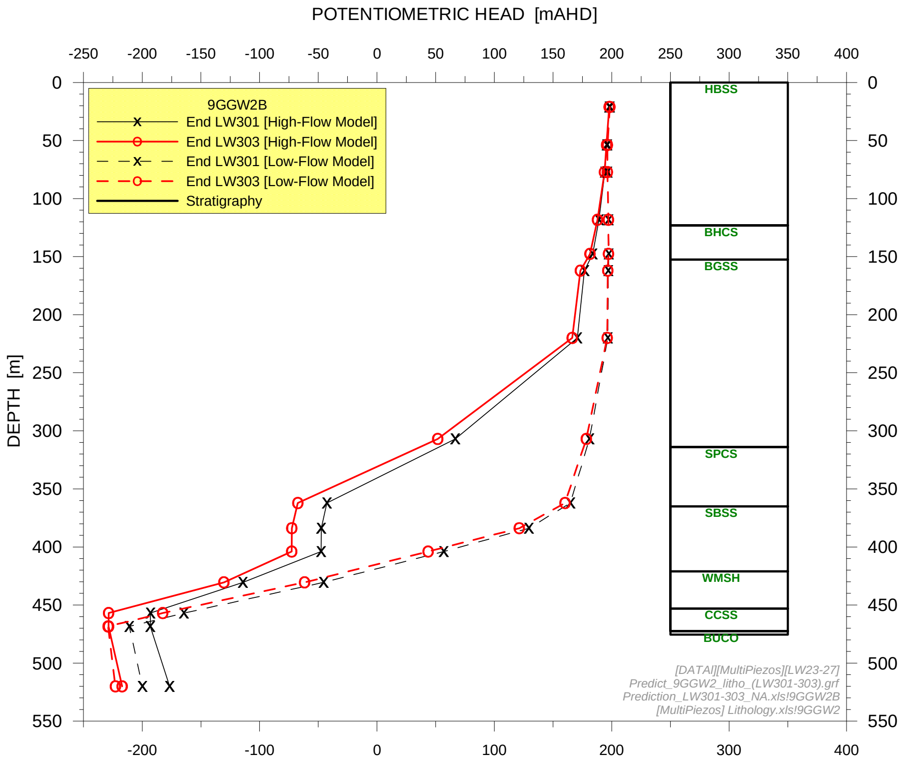



**Chart 4: Predicted Vertical Head Profiles at Bore 9GGW2B at the end of Longwalls 301 and 303** [refer to Figure 11 for bore location]

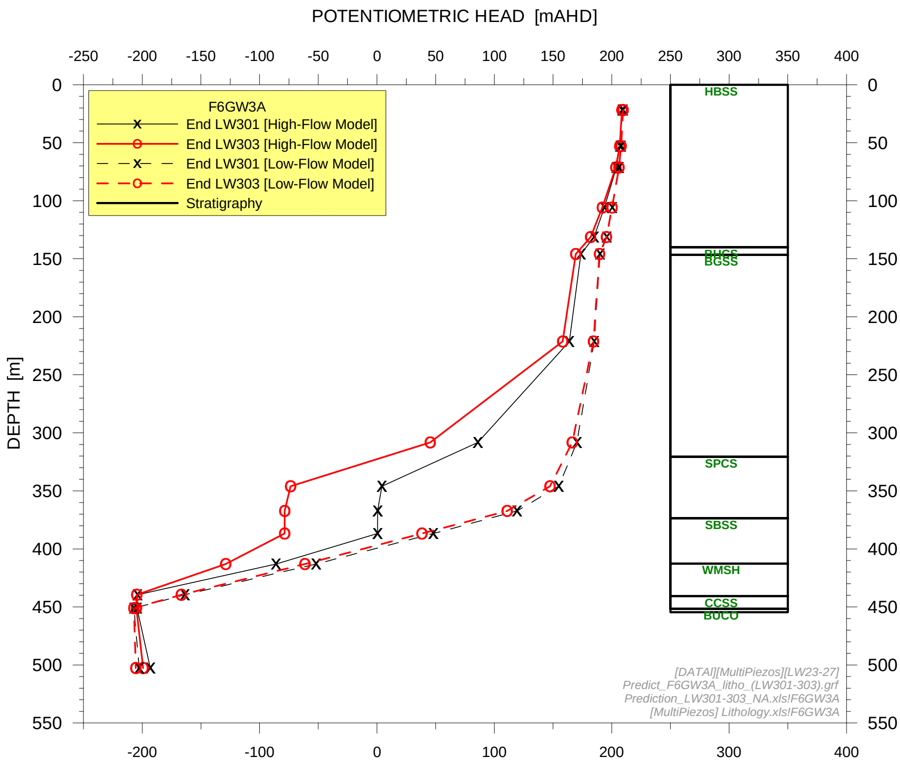



**Chart 5: Predicted Vertical Head Profiles at Bore F6GW3A at the end of Longwalls 301 and 303** [refer to Figure 11 for bore location]

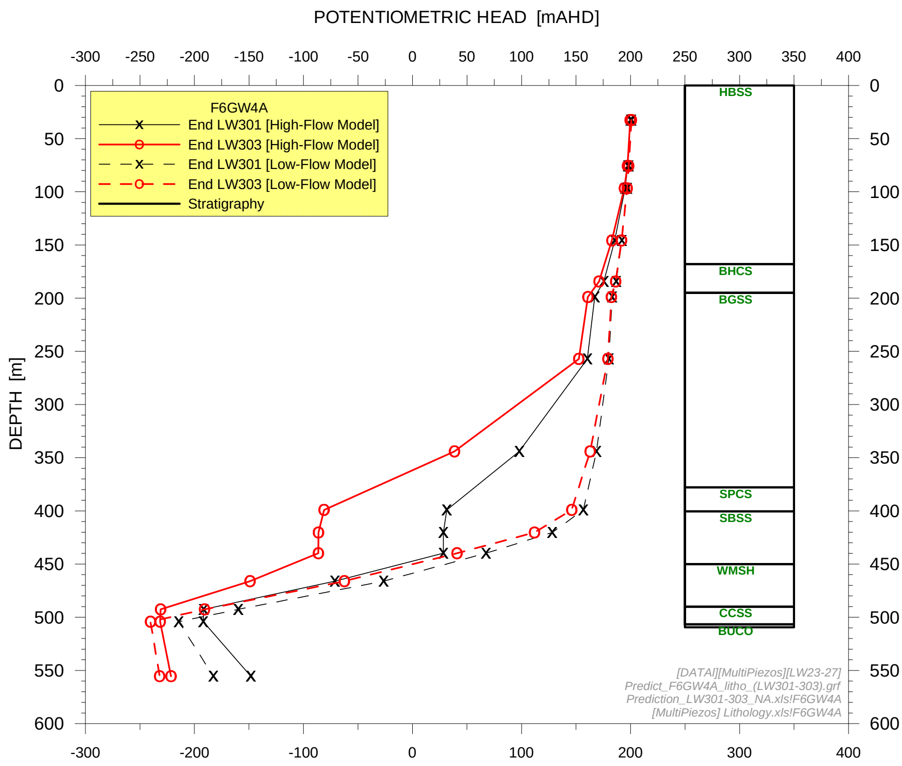



**Chart 6: Predicted Vertical Head Profiles at Bore F6GW4A at the end of Longwalls 301 and 303** [refer to Figure 11 for bore location]

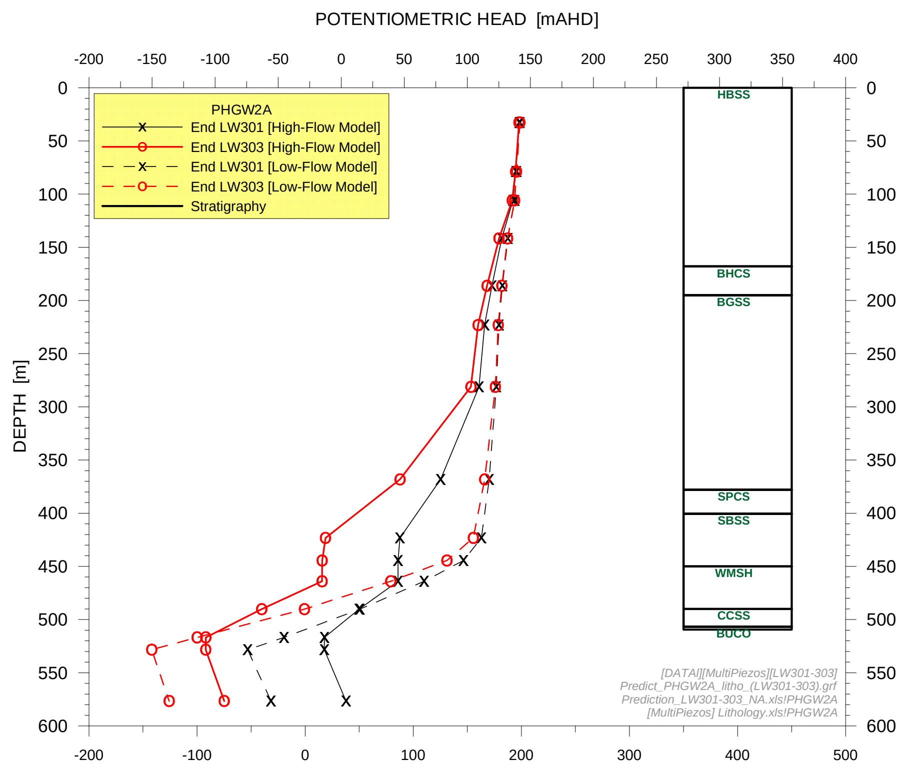



**Chart 7: Predicted Vertical Head Profiles at Bore PHGW2A at the end of Longwalls 301 and 303** [refer to Figure 11 for bore location]

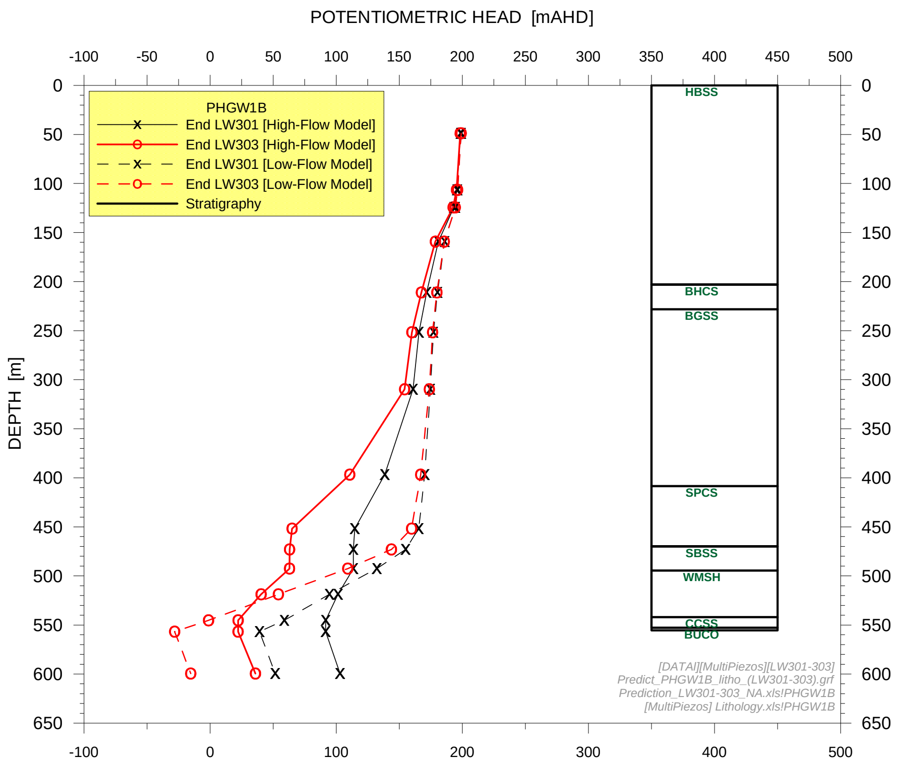



**Chart 8: Predicted Vertical Head Profiles at Bore PHGW1B at the end of Longwalls 301 and 303** [refer to Figure 11 for bore location]

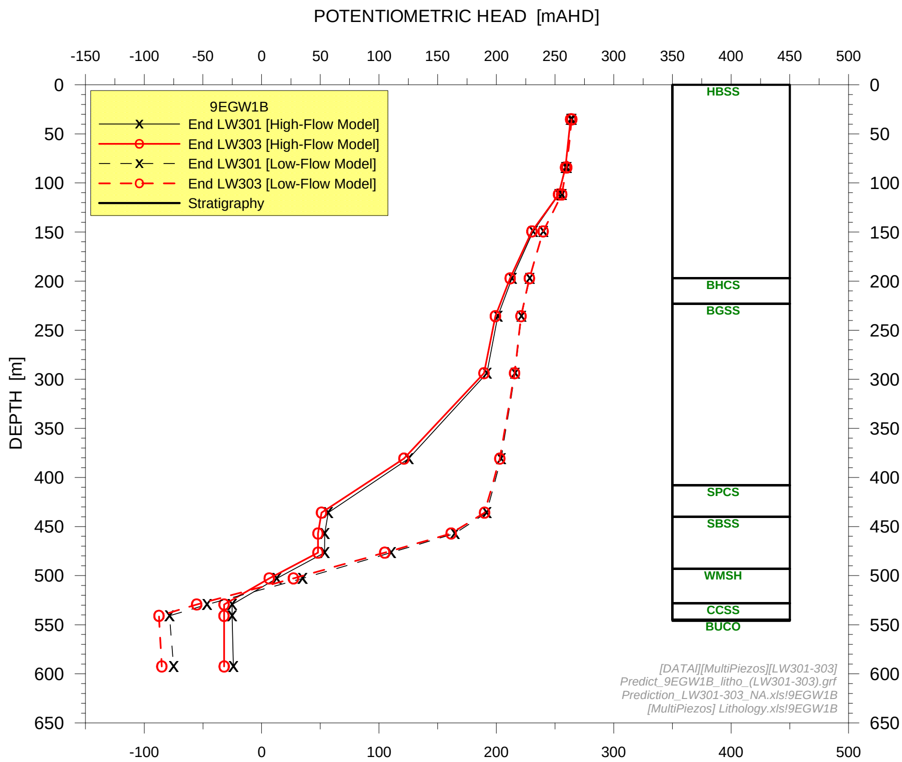



**Chart 9: Predicted Vertical Head Profiles at Bore 9EGW1B at the end of Longwalls 301 and 303** [refer to Figure 11 for bore location]

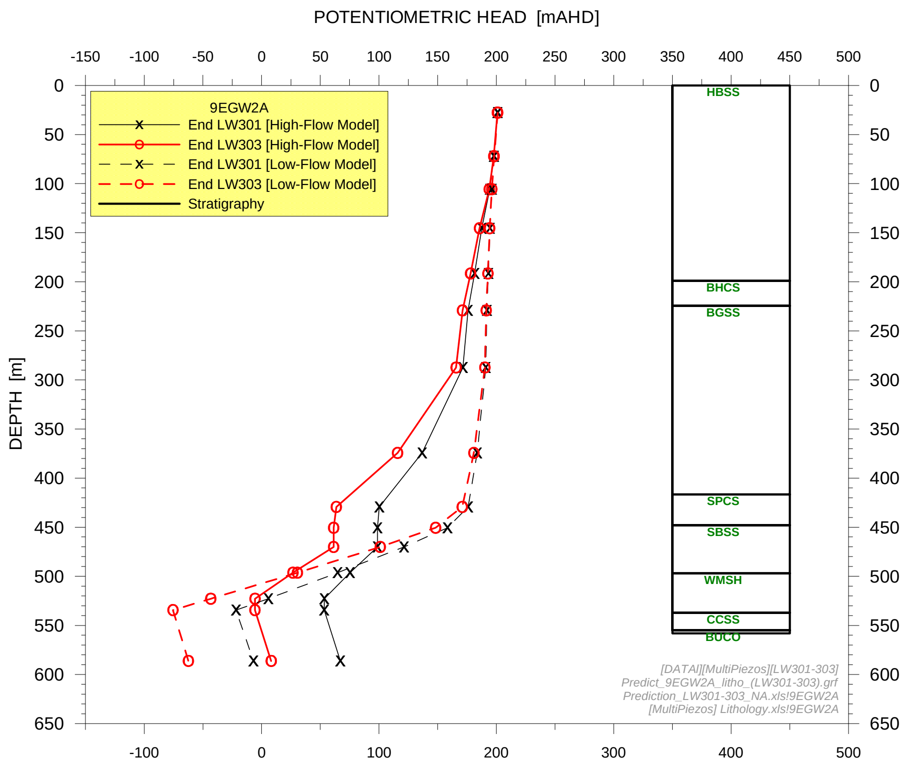



**Chart 10: Predicted Vertical Head Profiles at Bore 9EGW2A at the end of Longwalls 301 and 303** [refer to Figure 11 for bore location]

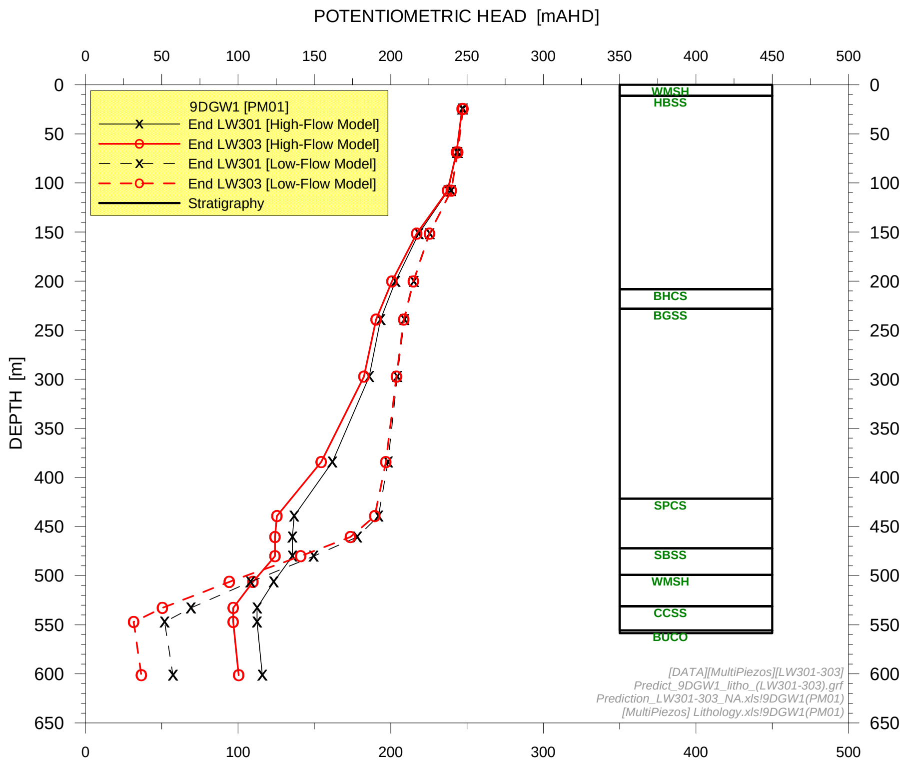



**Chart 11: Predicted Vertical Head Profiles at Bore PM01 (9DGW1B) at the end of Longwalls 301 and 303** [refer to Figure 11 for bore location]

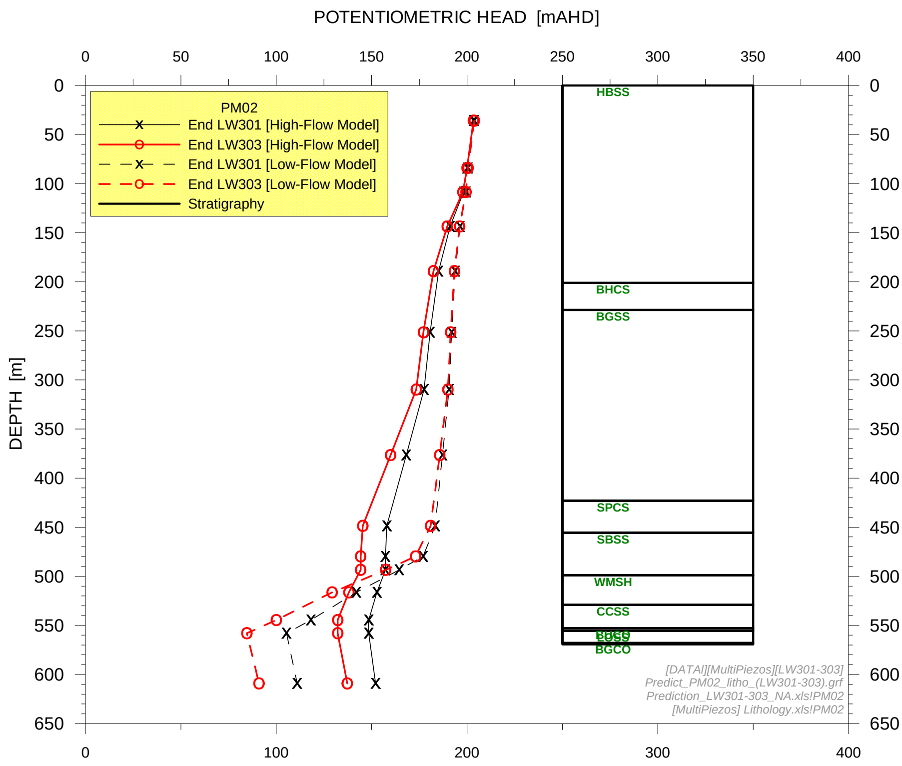



**Chart 12: Predicted Vertical Head Profiles at Bore PM02 at the end of Longwalls 301 and 303** [refer to Figure 11 for bore location]

The performance measures, *No connective cracking between the surface and the mine* and *Negligible leakage from the Woronora Reservoir* are not predicted to be exceeded by the mining of Longwalls 301-303.

# 6 PERFORMANCE MEASURES AND INDICATORS

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

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

*Table 1: Subsidence Impact Performance Measures*

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

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

Metropolitan Coal will also assess the Project against the water resource and watercourse performance indicators outlined in Table 7.

**Table 7**
**Summary of Water Resource and Watercourse Performance Indicators and Measures**

| Performance Measure | Performance Indicator(s) |
|---|---|
| Negligible reduction to the quantity of water resources reaching the Woronora Reservoir. | *Changes in the quantity of water entering Woronora Reservoir are not significantly different post-mining compared to pre-mining, that are not also occurring in the control catchment(s).* |
| Negligible reduction to the quality of water resources reaching the Woronora Reservoir. | *Changes in the quality of water entering Woronora Reservoir are not significantly different post-mining compared to pre-mining concentrations that are not also occurring at control site WOWQ2.* |
| No connective cracking between the surface and the mine. | *Visual inspection does not identify abnormal water flow from the goaf, geological structure, or the strata generally.* |
| | *The 20-day average mine water make does not exceed 1 ML/day.* |
| | *Significant departure from the predicted envelope of the vertical potentiometric head profile at Bore 9GGW2B does not occur.* |
| | *Significant departure from the predicted envelope of the vertical potentiometric head profile at Bore F6GW3A does not occur.* |
| No connective cracking between the surface and the mine.<br>Negligible leakage from the Woronora Reservoir. | *The hydraulic gradient to the Woronora Reservoir at full supply level from Bore F6GW4A is reduced by no more than 20% from that measured to 30 June 2017.* |
| | *The hydraulic gradient to the Woronora Reservoir at full supply level from Bore PHGW2A is reduced by no more than 20% from that measured to 30 June 2017.* |
| Negligible leakage from the Woronora Reservoir. | *The hydraulic gradient to the Woronora Reservoir at full supply level from Bore 9GGW2B is reduced by no more than 40% from that measured to 30 June 2017.* |
| | *The hydraulic gradient to the Woronora Reservoir at full supply level from Bore 9EGW2A is reduced by no more than 20% from that measured to 30 June 2017.* |
| | *The hydraulic gradient to the Woronora Reservoir at full supply level from Bore PM02 is reduced by no more than 20% from that measured to 30 June 2017.* |
| | *The water level at bore T2 is greater than 170. 0 m.* |
| | *The water level at bore T3 is greater than 171.8 m.* |
| | *The hydraulic gradient from transect bore T5 to bore T3 is reduced by no more than 10% from that measured on 30 June 2017.* |
| Negligible reduction in the water quality of Woronora Reservoir. | *Changes in the quality of water in the Woronora Reservoir are not significantly different post-mining compared to pre-mining concentrations.* |

**Table 7 (Continued)**
**Summary of Water Resource and Watercourse Performance Indicators and Measures**

| Performance Measure | Performance Indicator(s) |
|---|---|
| Negligible environmental consequences (that is, no diversion of flows, no change in the natural drainage behaviour of pools, minimal iron staining, and minimal gas releases) on the Waratah Rivulet between the full supply level of the Woronora Reservoir and the maingate of Longwall 23 (upstream of Pool P). | *No change to the natural drainage behaviour of Pools P, Q, R, S, T, U, V and W.* |
| | *Analysis of water level data for Pools P, T, U, V and W indicates the water level is at or above the pool's previous minimum.* |
| | *Analysis of water level data for Pools Q, R and S indicates the water levels are above that required to maintain water over the downstream rock bar.* |
| | *Visual inspection of the Waratah Rivulet from Pool P to the full supply level of the Woronora Reservoir does not show significant changes in the extent or nature of iron staining that isn't also occurring in the Woronora River (control site).* |
| | *Gas releases in Waratah Rivulet from Pool P to the full supply level of the Woronora Reservoir have not increased beyond those observed up to the commencement of Longwall 301 extraction.* |
| Negligible environmental consequences over at least 70% of the stream length (that is no diversion of flows, no change in the natural drainage behaviour of pools, minimal iron staining and minimal gas releases) of the Eastern Tributary between the full supply level of the Woronora Reservoir and the maingate of Longwall 26. | *No change to the natural drainage behaviour of Pools ETAS, ETAT and ETAU.* |
| | *Analysis of water level data for Pool ETAU indicates the water levels are above that required to maintain water over the downstream rock bar.* |
| | *Gas releases in Eastern Tributary between the full supply level of the Woronora Reservoir and the maingate of Longwall 26 have not increased beyond those observed up to the commencement of Longwall 301 extraction.* |

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

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

Section 8.8 provides detailed TARPs to assess the water resource and watercourse subsidence impact performance indicators and measures.

# 7 BASELINE DATA

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

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

## 7.1 METEOROLOGY

Regional and local meteorological data is available from the Bureau of Meteorology (BoM) weather stations at Lucas Heights (Station Number 66078), Helensburgh (Station Number 68028), Darkes Forest (Station Number 68024), and 'Reverces' (Station Number 568069) (Table 8). Rainfall data is also available from Metropolitan Coal pluviometers situated in the Waratah Rivulet catchment (site PV1), Woronora River catchment (site PV2), Honeysuckle Creek catchment (site PV5), Waratah Rivulet catchment (site PV6) and Eastern Tributary catchment (site PV7) and Woronora Reservoir catchment (site PV8) (Figure 14).

Evaporation data is available from Lucas Heights (Station Number 66078) (Table 8), the discontinued WaterNSW station at the Woronora Dam (Table 8) and the Metropolitan Coal evaporimeter within the Waratah Rivulet catchment, at site PV1 (Table 8 and Figure 14).

**Table 8**
**Meteorological Monitoring Station Locations and Recording Periods**

| Station Number | Data Type | Period of Record |
|---|---|---|
| Lucas Heights (BoM Station Number 66078) | Evaporation, ground minimum temperature, air maximum temperature, air temperature, dew point, mean sea level pressure, total cloud amount, wind speed, maximum wind gust speed, rainfall and rainfall intensity | 1958 to present |
| Darkes Forest (BoM Station Number 68024) | Rainfall (BoM daily read converted to pluviometer) | 1894 to present |
| Helensburgh (BoM Station Number 68028) | Rainfall (BoM daily read converted to pluviometer) | 1889 to 2005 |
| 'Reverces' (BoM Station Number 568069) | Rainfall (pluviometer) | 2000 to present |
| Waratah Rivulet (site PV1) | Rainfall (Metropolitan Coal pluviometer)<br>Evaporation data (Metropolitan Coal evaporimeter) | 2006 to present<br>2010 to present |
| Woronora River (site PV2) | Rainfall (Metropolitan Coal pluviometer) | 2007 to present |
| Woronora Reservoir (566052) | Evaporation data (WaterNSW station) | From 1976 (discontinued) |
| Honeysuckle Creek (site PV5) | Rainfall (Metropolitan Coal pluviometer) | 2010 to present |
| Waratah Rivulet (site PV6) | Rainfall (Metropolitan Coal pluviometer) | 2010 to present |
| Eastern Tributary (site PV7) | Rainfall (Metropolitan Coal pluviometer) | 2010 to present |
| Woronora Reservoir catchment (site PV8) | Rainfall (Metropolitan Coal pluviometer) | January 2018 to present |

## 7.2 SURFACE WATER

### 7.2.1 Stream Features

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

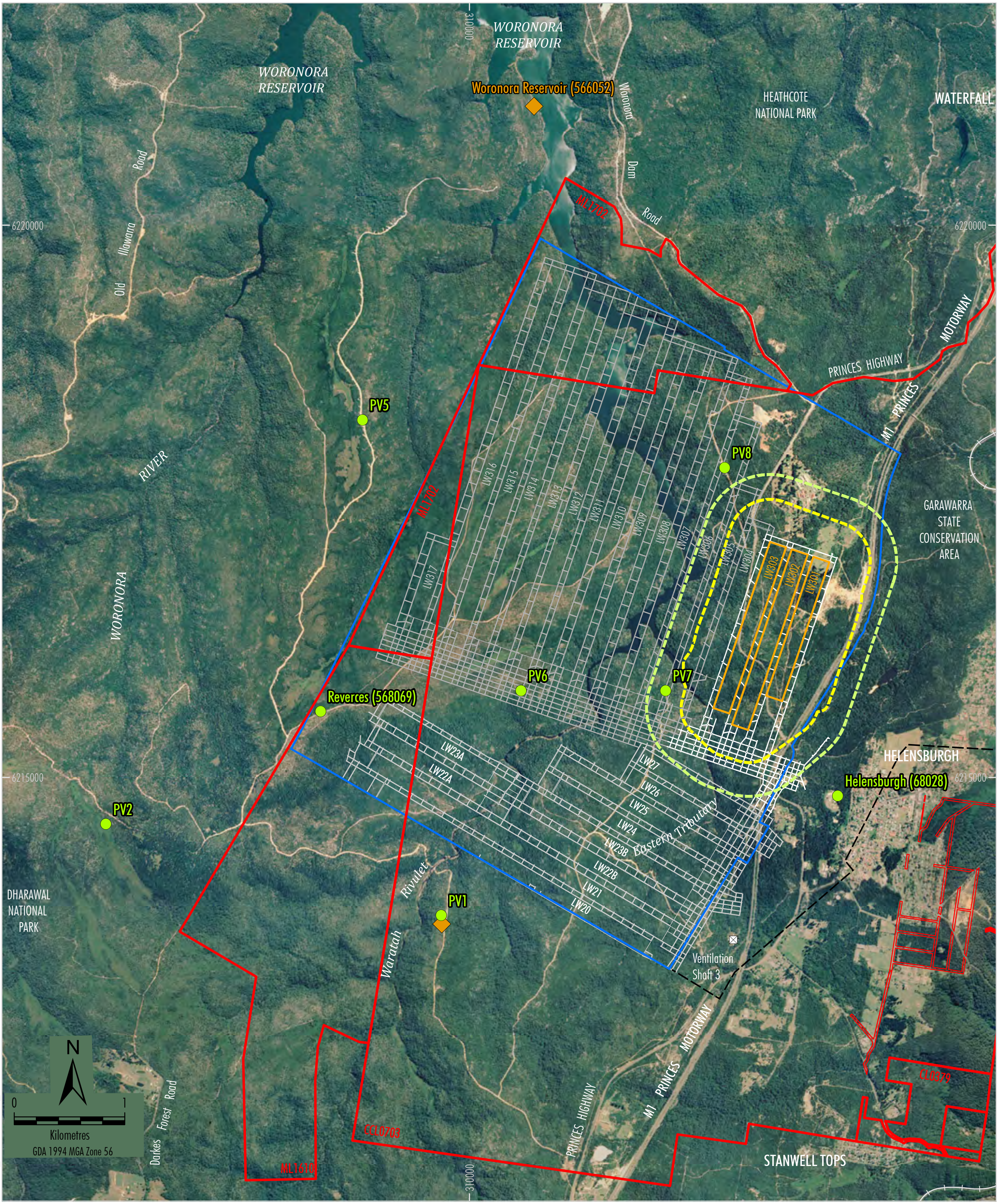
Visual and photographic surveys conducted in accordance with the Metropolitan Coal Water Management Plans have recorded:

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

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

Gilbert & Associates (now Hydro Engineering & Consulting) conducted a visual inspection and photographic survey of streams in the vicinity of Longwalls 301-303 in July 2015. Hydro Engineering & Consulting's (2016) report is provided in Appendix 5[14].

[14] Note, subsequent to the completion of the Hydro Engineering & Consulting (2016) report, Metropolitan Coal revised the layout of Longwalls 301-303. The updated longwall layout is shown on the WMP Figures.




LEGEND

- Mining Lease Boundary
- Railway
- Project Underground Mining Area Longwalls 20-27 and 301-317
- Longwalls 301-303 Secondary Extraction
- 35° Angle of Draw and/or Predicted 20 mm Subsidence Contour
- 600 m from Secondary Extraction of Longwalls 301-303
- Existing Underground Access Drive (Main Drift)
- Evaporimeter
- Pluviometer

Note: 1 The Bureau of Meteorology pluviometer at Darkes Forest (68024) is not shown. It is located approximately 3.75 km south of the Metropolitan Coal pluviometer (PV2).

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

Peabody

METROPOLITAN COAL

Meteorological Sites

**Figure 14**

### 7.2.2 Surface Water Flow

Surface water flow data is available for the gauging stations listed in Table 9. The locations of the Waratah Rivulet (GS 2132102), Woronora River (GS 2132101), Eastern Tributary (GS 300078), Honeysuckle Creek (GS 300077), Sub-catchment I (GS 300092) and Sub-catchment K (GS 300093) gauging stations are shown on Figure 6. Surface water flow data is available from the Department of Industry – Water gauging stations on O'Hares Creek: an upstream gauging station at Darkes Forest (GS 212002) and a downstream gauging station near the town of Wedderburn (GS 213200). The O'Hares Creek catchment is located immediately south and west of the Woronora Dam catchment. Longwall mining occurred in the catchment of the Wedderburn gauging station (GS 213200) in 1986 to 1987 and 1990 to 1999.

**Table 9**
**Gauging Station Locations and Recording Periods**

| Station Number | Watercourse | Catchment Area ($km^2$) | Period of Record |
|---|---|---|---|
| WaterNSW (GS 2132102) | Waratah Rivulet, upstream of the Woronora Reservoir full supply level | 20.2 | February 2007 to present |
| WaterNSW (GS 2132101)[1] | Woronora River, upstream of the Woronora Reservoir full supply level | 12.4 | February 2007 to present |
| Department of Industry - Water (GS 213002) | O'Hares Creek at Darkes Forest | 16 | 1924 to 1930 |
| Department of Industry - Water (GS 213200) | O'Hares Creek at Wedderburn | 73 | 1978 to present |
| Metropolitan Coal (GS 300078) | Eastern Tributary, upstream of the Woronora Reservoir full supply level | 6.7 | January 2013 to present |
| Metropolitan Coal (GS 300077) | Honeysuckle Creek (control site) | 4.6 | January 2013 to present |
| Sub-catchment I (GS 300092) | A tributary of the Woronora Reservoir | 0.22 | May 2018 to present |
| Sub-catchment K (GS 300093) | A tributary of the Woronora Reservoir | 0.21 | May 2018 to present |

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

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

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

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

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

Catchment models will be developed for the gauging stations established on the tributaries of the Woronora Reservoir as a component of the Catchment Monitoring Program to inform future Extraction Plans.

#### 7.2.3 Pool Water Levels

Pool water level data is available for a number of sites on the Waratah Rivulet, Eastern Tributary, Tributary B, Tributary D and the Woronora River (Table 10).

The locations of the pools are shown on Figure 5. Pools and rock bars along the Waratah Rivulet, Eastern Tributary, Tributary A and Tributary B are shown on the detailed mapping and photographs provided in Appendices 1 to 4, respectively.

**Table 10**
**Pool Water Level Sites**
**(Manual and/or Continuous Water Level Data)**

| Site Number | Watercourse | Commencement Date |
|---|---|---|
| Pool A | Waratah Rivulet | 29/9/2005 |
| Pool B | Waratah Rivulet | 29/9/2005 |
| Pool C | Waratah Rivulet | 29/9/2005 |
| Pool E | Waratah Rivulet | 29/9/2005 |
| Pool F | Waratah Rivulet | 29/9/2005 |
| Pool G | Waratah Rivulet | 29/9/2005 |
| Pool G1 | Waratah Rivulet | 13/10/2005 |
| Pool H | Waratah Rivulet | 12/10/2005 |
| Pool I | Waratah Rivulet | 12/10/2005 |
| Pool J | Waratah Rivulet | 1/7/2010 |

**Table 10 (Continued)**
**Pool Water Level Sites**
**(Manual and/or Continuous Water Level Data)**

| Site Number | Watercourse | Commencement Date |
|---|---|---|
| Pool K | Waratah Rivulet | 1/7/2010 |
| Pool L | Waratah Rivulet | 11/12/2008 |
| Pool M | Waratah Rivulet | 11/12/2008 |
| Pool N | Waratah Rivulet | 11/12/2008 |
| Pool O | Waratah Rivulet | 11/12/2008 |
| Pool P | Waratah Rivulet | 11/12/2008 |
| Pool Q | Waratah Rivulet | 20/1/2010 |
| Pool R | Waratah Rivulet | 11/12/2008 |
| Pool S | Waratah Rivulet | 11/12/2008 |
| Pool T | Waratah Rivulet | 20/1/2010 |
| Pool U | Waratah Rivulet | 20/1/2010 |
| Pool V | Waratah Rivulet | 20/1/2010 |
| Pool W | Waratah Rivulet | 20/1/2010 |
| Pool ETG | Eastern Tributary | 16/2/2011 |
| Pool ETJ | Eastern Tributary | 29/3/2011 |
| Pool ETM | Eastern Tributary | 11/12/2008 |
| Pool ETU | Eastern Tributary | 18/5/2010 |
| Pool ETW | Eastern Tributary | 18/5/2010 |
| Pool ETAF | Eastern Tributary | 12/11/2010 |
| Pool ETAG | Eastern Tributary | 12/11/2010 |
| Pool ETAH | Eastern Tributary | 19/1/2011 |
| Pool ETAI | Eastern Tributary | 19/1/2011 |
| Pool ETAQ | Eastern Tributary | 17/1/2011 |
| Pool ETAT | Eastern Tributary | 23/03/2018 |
| Pool ETAU | Eastern Tributary | 18/5/2010 |
| Pool RTP1 | Tributary B | 7/3/2007 |
| Pool RTP2 | Tributary B | 7/3/2007 |
| Pool UTP1 | Tributary D | 7/3/2007 |
| Pool UTP2 | Tributary D | 7/3/2007 |
| Pool UTP3 | Tributary D | 7/3/2007 |
| Pool WRP1 | Woronora River (Control Site) | 11/12/2008 |
| Pool WRP2 | Woronora River (Control Site) | 1/7/2010 |
| Pool WRP3 | Woronora River (Control Site) | 1/7/2010 |
| Pool WRP4 | Woronora River (Control Site) | 1/7/2010 |

### 7.2.4 Stream Water Quality

Water quality data has been collected at a large number of sites including sites on the Waratah Rivulet, Eastern Tributary, Far Eastern Tributary, Woronora River, Bee Creek, Honeysuckle Creek, Tributary B, Tributary D and Forest Gully. The water quality sites are summarised in Table 11 and shown on Figure 7.

**Table 11**
**Stream Water Quality Sites**

| Site Number | Watercourse | Commencement Date |
|---|---|---|
| WRWQ 1 | Waratah Rivulet | 27/9/2006 |
| WRWQ 2 | Waratah Rivulet | 27/9/2006 |
| WRWQ 3 | Waratah Rivulet | 27/9/2006 |
| WRWQ 4 (Pool B) | Waratah Rivulet | 27/9/2006 |
| WRWQ 5 | Waratah Rivulet | 27/9/2006 |
| WRWQ 6 (Pool F) | Waratah Rivulet | 27/9/2006 |
| WRWQ 7 (Pool H) | Waratah Rivulet | 27/9/2006 |
| WRWQ 8 | Waratah Rivulet | 27/9/2006 |
| WRWQ 9 (Pool Q) | Waratah Rivulet | 27/9/2006 |
| WRWQ J | Waratah Rivulet | 27/1/2010 |
| WRWQ K | Waratah Rivulet | 27/1/2010 |
| WRWQ L | Waratah Rivulet | 11/12/2008 |
| WRWQ M | Waratah Rivulet | 11/12/2008 |
| WRWQ N | Waratah Rivulet | 11/12/2008 |
| WRWQ O | Waratah Rivulet | 11/12/2008 |
| WRWQ P | Waratah Rivulet | 11/12/2008 |
| WRWQ R | Waratah Rivulet | 11/12/2008 |
| WRWQ S | Waratah Rivulet | 11/12/2008 |
| WRWQ T | Waratah Rivulet | 10/2/2010 |
| WRWQ U | Waratah Rivulet | 10/2/2010 |
| WRWQ V | Waratah Rivulet | 10/2/2010 |
| WRWQ W | Waratah Rivulet | 10/2/2010 |
| UTWQ 1 | Waratah Rivulet | 3/8/2006 |
| UTWQ 2 | Tributary D | 3/8/2006 |
| UTWQ 3 | Tributary D | 3/8/2006 |
| UTWQ 4 | Tributary D | 3/8/2006 |
| UTWQ 5 | Tributary D | 3/8/2006 |
| FGWQ 1 | Forest Gully | 1/8/2006 |
| FGWQ 2 | Forest Gully | 1/8/2006 |
| FGWQ 3 | Forest Gully | 1/8/2006 |
| FGWQ 4 | Forest Gully | 1/8/2006 |
| FGWQ 5 | Forest Gully | 1/8/2006 |
| RTWQ 1 | Tributary B | 3/8/2006 |
| RTWQ 2 | Tributary B | 3/8/2006 |
| RTWQ 3 | Tributary B | 3/8/2006 |
| ETWQ F | Eastern Tributary | 17/2/2010 |
| ETWQ J | Eastern Tributary | 17/2/2010 |
| ETWQ N | Eastern Tributary | 7/9/2007 |
| ETWQ U | Eastern Tributary | 28/1/2010 |
| ETWQ W | Eastern Tributary | 28/1/2010 |
| ETWQ AF | Eastern Tributary | 28/1/2010 |
| ETWQ AG | Eastern Tributary | 28/1/2010 |

**Table 11 (Continued)**
**Stream Water Quality Sites**

| Site Number | Watercourse | Commencement Date |
|---|---|---|
| ETWQ AH | Eastern Tributary | 28/1/2010 |
| ETWQ AI | Eastern Tributary | 28/1/2010 |
| ETWQ AK | Eastern Tributary | 28/1/2010 |
| ETWQ AQ | Eastern Tributary | 28/1/2010 |
| ETWQ AU | Eastern Tributary | 28/1/2010 |
| FEWQ 1 | Far Eastern Tributary | 7/9/2007 |
| BCWQ 1 | Bee Creek | 7/9/2007 |
| HCWQ 1 | Honeysuckle Creek | 7/9/2007 |
| WOWQ 1 | Woronora River (Control Site) | 7/9/2007 |
| WOWQ 2 | Woronora River (Control Site) | 17/1/2008 |
| WOWQ 3 | Woronora River (Control Site) | 11/12/2008 |
| WOWQ 4 | Woronora River (Control Site) | 28/1/2010 |
| WOWQ 5 | Woronora River (Control Site) | 28/1/2010 |
| WOWQ 6 | Woronora River (Control Site) | 28/1/2010 |

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

### 7.2.5 Woronora, Nepean and Cataract Reservoir Water Quality

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

## 7.3 GROUNDWATER

### 7.3.1 Swamp Groundwater Levels

Groundwater level data is available for a number of upland swamps including from piezometers in the swamp substrate and/or piezometers in the shallow sandstone, as summarised in Table 12. The piezometer locations are shown on Figure 10.

**Table 12**
**Swamp Substrate and Shallow Groundwater Level Sites**

| Site Number | Swamp | Easting | Northing | RL (m AHD) | Depth (m) | Lithology | Commencement Date |
|---|---|---|---|---|---|---|---|
| SWAMP1 | S14 | 308625 | 6215963 | 295.6 | 3.1 | Hawkesbury Sandstone | 7 February 2007 |
| SWAMP2 | Bee Creek Swamp | 308755 | 6218787 | 245.3 | 1.5 | Hawkesbury Sandstone | 4 April 2007 |
| SWAMP3 | S92 | 310063 | 6216007 | 294.7 | 4.3 | Hawkesbury Sandstone | 7 February 2007 |

**Table 12 (Continued)**
**Swamp Substrate and Shallow Groundwater Level Sites**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| SWAMP4 | S06 | 307891 | 6214219 | 344.1 | 1.0 | Hawkesbury Sandstone | 12 March 2009 |
| SWGW1 | S06 | 307893 | 6214226 | 343.7 | ~20 | Hawkesbury Sandstone | 12 March 2009 |
| S25 | S25 | 311125 | 6214115 | 273.1 | ~0.9 | Hawkesbury Sandstone | 31 August 2010 |
| | | 311126 | 6214117 | 272.9 | ~10 | | |
| S101 (control) | S101 | 308658 | 6216585 | 293.4 | ~0.9 | Hawkesbury Sandstone | 31 August 2010 |
| | | 308659 | 6216585 | 293.4 | ~10 | | |
| S16[1] | S16 | 309702 | 6214791 | 251.2 | ~10 | Hawkesbury Sandstone | 30 August 2010 |
| S17 | S17 | 309599 | 6214931 | 240.6 | ~10 | Hawkesbury Sandstone | 1 September 2010 |
| S20 | S20 | 310431 | 6214413 | 219.3 | ~0.9 | Hawkesbury Sandstone | 1 September 2010 |
| | | 310429 | 6214403 | 219.1 | ~4 | | |
| | | 310428 | 6214401 | 219.1 | ~10 | | |
| WRSWAMP1 (control) | Woronora River 1 | 306454 | 6214914 | 321.1 | ~0.9 | Hawkesbury Sandstone | 2 September 2010 |
| | | 306452 | 6214913 | 321.1 | ~4 | | |
| | | 306451 | 6214912 | 321.0 | ~10 | | |
| S28 | S28 | 311003 | 6214783 | 247.9 | ~1 | Hawkesbury Sandstone | 8 March 2013 |
| | | 311002 | 6214782 | 247.8 | ~10 | | |
| S30 | S30 | 311180 | 6215115 | 236.2 | ~1 | Hawkesbury Sandstone | 8 March 2013 |
| | | 311176 | 6215115 | 236.0 | ~10 | | |
| S33 | S33 | 311582 | 6214529 | 241.3 | ~1 | Hawkesbury Sandstone | 8 March 2013 |
| | | 311585 | 6214528 | 241.2 | ~10 | | |
| S35 | S35 | 311501 | 6215126 | 256.0 | ~1 | Hawkesbury Sandstone | 8 March 2013 |
| | | 311500 | 6215156 | 256.1 | ~10 | | |
| S137a (control) | S137a | 308466 | 6217145 | 271.3 | ~1 | Hawkesbury Sandstone | 8 March 2013 |
| | | 308463 | 6217148 | 271.1 | ~10 | | |
| S137b (control) | S137b | 308399 | 6216962 | 276.6 | ~1 | Hawkesbury Sandstone | 8 March 2013 |
| | | 308396 | 6216961 | 276.7 | ~10 | | |
| Bee Creek Swamp (control) | Bee Creek Swamp | 308724 | 6218941 | 241.1 | ~1 | Hawkesbury Sandstone | 8 March 2013 |
| | | 308723 | 6218939 | 241.3 | ~10 | | |
| S40 | S40 | 312428 | 6215898 | 231.9 | 1.0 | Hawkesbury Sandstone | 28 June 2016 |
| | | 312429 | 6215897 | 232.1 | 9.9 | | |
| S41 | S41 | 312740 | 6216093 | 279.6 | 0.8 | Hawkesbury Sandstone | 28 June 2016 |
| | | 312739 | 6216093 | 279.4 | 9.9 | | |
| S46 | S46 | 312615 | 6216277 | 282.6 | 0.7 | Hawkesbury Sandstone | 28 June 2016 |
| | | 312616 | 6216278 | 282.8 | 10.1 | | |
| S50 | S50 | 312510 | 6217013 | 266.8 | 0.4 | Hawkesbury Sandstone | 27 June 2016 |
| | | 312509 | 6217012 | 266.9 | 9.9 | | |

**Table 12 (Continued)**
**Swamp Substrate and Shallow Groundwater Level Sites**

| Site Number | Swamp | Easting | Northing | RL (m AHD) | Depth (m) | Lithology | Commencement Date |
|---|---|---|---|---|---|---|---|
| S51 | S51 | 312639 | 6216883 | 274.9 | 0.6 | Hawkesbury Sandstone | 28 June 2016 |
| | | 312638 | 6216884 | 274.9 | 9.9 | | |
| S52 | S52 | 312739 | 6216836 | 283.8 | 1.1 | Hawkesbury Sandstone | 30 June 2016 |
| | | 312738 | 6216835 | 283.7 | 9.8 | | |
| S53 | S53 | 312859 | 6216845 | 295.6 | 1.7 | Hawkesbury Sandstone | 28 June 2016 |
| | | 312858 | 6216845 | 295.5 | 9.9 | | |
| S71a | S71a | 312519 | 6217774 | 276.6 | 0.3 | Hawkesbury Sandstone | 27 June 2016 |
| | | 312519 | 6217772 | 276.6 | 9.9 | | |

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

The NSW Government's *Draft Policy Framework for Biodiversity Offsets for Upland Swamps and Associated Threatened Species* (May 2015) (Draft Upland Swamp Offsets Policy) and the Independent Expert Scientific Committee's (IESC's) *Advice to decision maker on coal mining – Further advice on impacts to swamps* (24 July 2015) (IESC advice) were reviewed and considered in detail in developing the Longwalls 301-303 groundwater monitoring program for the Metropolitan Coal Longwalls 301-303 Biodiversity Management Plan.

The Draft Upland Swamp Offsets Policy proposes shallow groundwater monitoring in every swamp within 400 m of longwall mining. The IESC's advice recommends that each swamp potentially impacted by mining have two transects of piezometers, installed perpendicular to each other, with a minimum of five piezometers along the two transects. Within the transects, the IESC advice also recommends a piezometer be installed at the deepest point in the swamp's sediments and not be placed such such that they are all overlying pillars between longwalls. The IESC's advice also recommends at least three control swamps be matched with each potentially impacted swamp (individual sites may serve as controls for multiple potentially impacted swamps). To reduce baseline variance between control and impact locations, control sites need to be as similar as practicable to the impact sites in terms of vegetation, geomorphology and hydrology, and size.

Field inspections were conducted by Metropolitan Coal[15] to determine suitable locations for the installation of groundwater piezometers in upland swamps overlying and in the vicinity of Longwalls 301-303. The objective of the field inspections was to select piezometer locations consistent with the Draft Upland Swamp Offsets Policy and the IESC's advice.

Consistent with the Draft Upland Swamp Offsets Policy Metropolitan Coal proposed monitoring of each swamp within 400 m of Longwalls 301-303 with the exception of Swamps 42 and 54 on the basis of predicted subsidence (Figure 10).

Given the majority of the swamps are small in size and the vegetation disturbance that would be required for piezometer installation, the IESC recommendation of two transects was not considered necessary or appropriate to assess the impacts on swamp groundwater. That is, the majority of swamps were not considered large enough to support or warrant a transect of three plus bores within each individual swamp.

15 The field inspection team included a hydrogeologist (HydroSimulations) and a botanist (Eco Logical Australia) to inform the positioning of the swamp piezometers.

Based on the results of the field inspections, a monitoring design was proposed which retained the same general principle of the Longwalls 20-27 monitoring design: that is, a piezometer in the swamp substrate be installed (to refusal) and one in the shallow groundwater (at a depth of 10 m). In consideration of the IESC's advice regarding the use of transects, monitoring locations that create larger transects which span multiple swamps, across multiple longwalls (from upgradient to downgradient) were proposed. The piezometers, where practicable, were also proposed to be positioned to avoid chain pillars. Where a terminal step occurs within a swamp (and where cracking of the terminal step has the potential to result in impacts to swamp substrate water levels), the paired piezometers are located close to the terminal step. Other factors which guided the proposed piezometer locations included the depth to sediment and proximity to existing access (where possible) in order to minimise disturbance.

In accordance with the Metropolitan Coal Construction Management Plan, 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, 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 on the basis of vegetation characteristics, landform features, swamp sediment profile and predicted subsidence. Piezometer sites 50, 51, 52 and 53 provide an extended transect which allows for monitoring of the Swamp 50 to 53 complex along the gradient and over consecutive longwalls. The locations of the groundwater piezometers are shown on Figure 10.

The continuation of upland swamp groundwater monitoring for Longwalls 20-27 and the upland swamp groundwater monitoring program for Longwalls 301-303 is described in Section 8.5.1.

### 7.3.2 Shallow Groundwater Levels Near Streams

Shallow groundwater level data is available for a number of sites near streams, as summarised in Table 13. The piezometer locations are shown on Figure 11.

**Table 13**
**Shallow Groundwater Level Sites Near Streams**

| Site Number | Location | Easting | Northing | RL (m AHD) | Depth (m) | Lithology | Commencement Date |
|---|---|---|---|---|---|---|---|
| WRGW1 | Waratah Rivulet | 309886 | 6214360 | 207.8 | ~20 | Hawkesbury Sandstone | 16 February 2007 |
| WRGW2 | Waratah Rivulet | 309868 | 6214335 | 207.9 | ~20 | Hawkesbury Sandstone | 16 February 2007 |
| WRGW3 | Waratah Rivulet | 309629 | 6214072 | 215.0 | ~20 | Hawkesbury Sandstone | 16 February 2007 |
| WRGW4 | Waratah Rivulet | 309579 | 6214090 | 217.8 | ~20 | Hawkesbury Sandstone | 16 February 2007 |
| WRGW5 | Waratah Rivulet | 309393 | 6212890 | 225.4 | ~20 | Hawkesbury Sandstone | 4 April 2007 |
| WRGW6 | Waratah Rivulet | 309361 | 6212871 | 226.1 | ~20 | Hawkesbury Sandstone | 4 April 2007 |
| WRGW7 | Waratah Rivulet | 310717 | 6215382 | 184.2 | ~20 | Hawkesbury Sandstone | September 2010 |
| WRGW8[1] | Waratah Rivulet | 310685 | 6215353 | 184.3 | ~20 | Hawkesbury Sandstone | September 2010 |

**Table 13 (Continued)**
**Shallow Groundwater Level Sites Near Streams**

| Site Number | Location | Easting | Northing | RL (m AHD) | Depth (m) | Lithology | Commencement Date |
|---|---|---|---|---|---|---|---|
| RTGW1A[2] | Tributary B | 309593 | 6215109 | 222.0 | ~19.5 | Hawkesbury Sandstone | 23 August 2007 |
| FGGW1 | Forest Gully | 308951 | 6213200 | 232.4 | ~20 | Hawkesbury Sandstone | 8 March 2007 |
| FGGW2 | Forest Gully | 308816 | 6213158 | 240.5 | ~20 | Hawkesbury Sandstone | 4 April 2007 |
| FGGW3 | Forest Gully | 308682 | 6213113 | 250.4 | ~20 | Hawkesbury Sandstone | 4 April 2007 |
| UTGW1 | Tributary D | 309520 | 6214151 | 218.2 | ~20 | Hawkesbury Sandstone | 16 February 2007 |
| UTGW2 | Tributary D | 309097 | 6214012 | 237.6 | ~20 | Hawkesbury Sandstone | 7 March 2007 |
| UTGW3 | Tributary D | 308833 | 6213951 | 247.2 | ~20 | Hawkesbury Sandstone | 7 March 2007 |
| ETGW1 | Eastern Tributary | 312129 | 6215644 | 172.6 | ~20 | Hawkesbury Sandstone | September 2010 |
| ETGW2 | Eastern Tributary | 312134 | 6215664 | 172.1 | ~20 | Hawkesbury Sandstone | September 2010 |

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

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

### 7.3.3 Groundwater Levels/Pressures

In June 2015, WaterNSW requested Metropolitan Coal consider the installation of a transect of groundwater bores between the Woronora Reservoir and the ridge to the east of the reservoir for the 300 series longwalls. Metropolitan Coal installed groundwater transect bores T1 to T5 at the sites shown on Figure 11 and detailed in Table 14 in June 2016 (data loggers installed in September 2016). Further to a request from WaterNSW, Metropolitan Coal installed an additional groundwater bore (T6) to the west of the Woronora Reservoir (Table 14).

**Table 14**
**Groundwater Transect**

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

Metropolitan Coal groundwater level and/or pressure data is also available from the multi-level piezometers and single-level piezometers listed in Table 15 and shown on Figure 11. Groundwater level/pressure data is also available at site S1997, courtesy of BHP Billiton Illawarra Coal (Table 15 and Figure 11).

**Table 15**
**Groundwater Level and Groundwater Level/Pressure Sites**

| Site Number | Location | Easting | Northing | Collar (m AHD) | Depth (m) | Elevation (m AHD) | Lithology | Commencement Date |
|---|---|---|---|---|---|---|---|---|
| 9HGW0 | Longwall 10 Goaf Hole on Fire Trail 9H | 309762 | 6213480 | 274.5 | 35.0 | 239.5 | Hawkesbury Sandstone | 12-Apr-07 |
| | | | | | 70.0 | 204.5 | Hawkesbury Sandstone | |
| | | | | | 110.0 | 164.5 | Hawkesbury Sandstone | |
| | | | | | 135.0 | 139.5 | Bald Hill Claystone | |
| | | | | | 165.0 | 109.5 | Bulgo Sandstone | |
| | | | | | 205.0 | 69.5 | Bulgo Sandstone | |
| | | | | | 250.0 | 24.5 | Bulgo Sandstone | |
| | | | | | 300.0 | -25.5 | Bulgo Sandstone | |
| 9HGW1B | Fire Trail 9H west of Longwall 18 | 308189 | 6214580 | 351.2 | 52.0 | 299.2 | Hawkesbury Sandstone | 12-Nov-08 |
| | | | | | 81.5 | 269.7 | Hawkesbury Sandstone | |
| | | | | | 158.0 | 193.2 | Hawkesbury Sandstone | |
| | | | | | 174.6 | 176.6 | Newport Formation | |
| | | | | | 205.4 | 145.8 | Bald Hill Claystone | |
| | | | | | 225.4 | 125.8 | Bulgo Sandstone | |
| | | | | | 303.0 | 48.2 | Bulgo Sandstone | |
| | | | | | 385.6 | -34.4 | Bulgo Sandstone | |

**Table 15 (Continued)**
**Groundwater Level and Groundwater Level/Pressure Sites**

| Site Number | Location | Easting | Northing | Collar (m AHD) | Depth (m) | Elevation (m AHD) | Lithology | Commencement Date |
|---|---|---|---|---|---|---|---|---|
| 9GGW1B[1] | Fire Trail 9G | 310974 | 6214317 | 287.9 | 45.0 | 242.9 | Hawkesbury Sandstone | 14-Mar-09 |
| | | | | | 59.5 | 228.4 | Hawkesbury Sandstone | |
| | | | | | 124.0 | 163.9 | Hawkesbury Sandstone | |
| | | | | | 159.0 | 128.9 | Bald Hill Claystone | |
| | | | | | 179.0 | 108.9 | Bulgo Sandstone | |
| | | | | | 345.1 | -57.2 | Bulgo Sandstone | |
| | | | | | 385.1 | -97.2 | Bulgo Sandstone | |
| | | | | | 404.1 | -116.2 | Stanwell Park Claystone | |
| | | | | | 416.0 | -128.2 | Scarborough Sandstone | |
| | | | | | 476.7 | -188.8 | Coal Cliff Sandstone | |
| 9GGW1-80[1] | Fire Trail 9G | 310974 | 6214317 | 287.0 | ~80.0 | 206.9 | Hawkesbury Sandstone | 21-Nov-13 |
| 9GGW2B | Fire Trail 9G at western end of Longwall 27 | 311734 | 6215359 | 240.8 | 55.0 | 185.8 | Hawkesbury Sandstone | 20-Apr-10 |
| | | | | | 80.3 | 160.5 | Hawkesbury Sandstone | |
| | | | | | 105.5 | 135.3 | Hawkesbury Sandstone | |
| | | | | | 137.8 | 103.0 | Bald Hill Claystone | |
| | | | | | 162.5 | 78.3 | Bulgo Sandstone | |
| | | | | | 304.0 | -63.2 | Bulgo Sandstone | |
| | | | | | 339.5 | -98.7 | Stanwell Park Claystone | |
| | | | | | 393.0 | -152.2 | Scarborough Sandstone | |
| | | | | | 437.0 | -196.2 | Wombarra Claystone | |
| | | | | | 474.1 | -233.3 | Bulli Coal Seam | |

**Table 15 (Continued)**
**Groundwater Level and Groundwater Level/Pressure Sites**

| Site Number | Location | Easting | Northing | Collar (m AHD) | Depth (m) | Elevation (m AHD) | Lithology | Commencement Date |
|---|---|---|---|---|---|---|---|---|
| 9FGW1A | Fire Trail 9F west of Longwall 22A | 308556 | 6215537 | 310.2 | 55.0 | 255.2 | Hawkesbury Sandstone | 19-Feb-10 |
| | | | | | 73.5 | 236.7 | Hawkesbury Sandstone | |
| | | | | | 137.0 | 173.2 | Hawkesbury Sandstone | |
| | | | | | 184.5 | 125.7 | Bald Hill Claystone | |
| | | | | | 209.5 | 100.7 | Bulgo Sandstone | |
| | | | | | 369.0 | -58.8 | Bulgo Sandstone | |
| | | | | | 404.5 | -94.3 | Stanwell Park Claystone | |
| | | | | | 455.0 | -144.8 | Scarborough Sandstone | |
| | | | | | 490.5 | -180.3 | Wombarra Claystone | |
| | | | | | 513.3 | -203.1 | Bulli Coal Seam | |
| 9EGW1B | Fire Trail 9E | 309483 | 6216091 | 309.0 | 52.0 | 257.0 | Hawkesbury Sandstone | 1-Nov-09 |
| | | | | | 91.0 | 218.0 | Hawkesbury Sandstone | |
| | | | | | 170.0 | 139.0 | Hawkesbury Sandstone | |
| | | | | | 213.0 | 96.0 | Bald Hill Claystone | |
| | | | | | 233.0 | 76.0 | Bulgo Sandstone | |
| | | | | | 403.0 | -94.0 | Bulgo Sandstone | |
| | | | | | 424.0 | -115.0 | Stanwell Park Claystone | |
| | | | | | 450.0 | -141.0 | Scarborough Sandstone | |
| | | | | | 488.0 | -179.0 | Scarborough Sandstone | |
| | | | | | 541.5 | -232.5 | Coal Cliff Sandstone | |

**Table 15 (Continued)**
**Groundwater Level and Groundwater Level/Pressure Sites**

| Site Number | Location | Easting | Northing | Collar (m AHD) | Depth (m) | Elevation (m AHD) | Lithology | Commencement Date |
|---|---|---|---|---|---|---|---|---|
| 9EGW2A | Fire Trail 9E | 311331 | 6217099 | 276.9 | 60.0 | 216.9 | Hawkesbury Sandstone | 28-May-11 |
| | | | | | 107.5 | 169.4 | Hawkesbury Sandstone | |
| | | | | | 155.0 | 121.9 | Hawkesbury Sandstone | |
| | | | | | 211.8 | 65.1 | Bald Hill Claystone | |
| | | | | | 234.5 | 42.4 | Bulgo Sandstone | |
| | | | | | 406.5 | -129.6 | Bulgo Sandstone | |
| | | | | | 432.5 | -155.6 | Stanwell Park Claystone | |
| | | | | | 454.0 | -177.1 | Scarborough Sandstone | |
| | | | | | 483.5 | -206.6 | Scarborough Sandstone | |
| | | | | | 517.0 | -240.1 | Wombarra Claystone | |
| | | | | | 556.5 | -279.6 | Bulli Coal Seam | |
| 9EGW2-4[2] | Fire Trail 9E | 311216 | 6216986 | 276.3 | 407.0 | -131 | Bulgo Sandstone | 18-Dec-17 |
| | | | | | 454.0 | -178 | Scarborough Sandstone | |
| | | | | | 484.0 | -208 | Scarborough Sandstone | |
| | | | | | 517.0 | -241 | Wombarra Shale | |
| | | | | | 557.0 | -281 | Bulli Coal Seam | |
| F6GW3A | Old Princes Hwy east of LW 301 | 312855 | 6215539 | 242.6 | 50.0 | 192.6 | Hawkesbury Sandstone | 17-Jun-13 |
| | | | | | 70.0 | 172.6 | Hawkesbury Sandstone | |
| | | | | | 100.0 | 142.6 | Hawkesbury Sandstone | |
| | | | | | 135.0 | 107.6 | Newport Formation | |
| | | | | | 220.0 | 22.6 | Bulgo Sandstone | |
| | | | | | 308.0 | -65.4 | Bulgo Sandstone | |
| | | | | | 380.0 | -137.4 | Bulgo Sandstone | |
| | | | | | 450.0 | -207.4 | Bulli Seam | |

**Table 15 (Continued)**
**Groundwater Level and Groundwater Level/Pressure Sites**

| Site Number | Location | Easting | Northing | Collar (m AHD) | Depth (m) | Elevation (m AHD) | Lithology | Commencement Date |
|---|---|---|---|---|---|---|---|---|
| F6GW4A | Old Princes Hwy between LW303 and LW304 | 312531 | 6216694 | 265.0 | 50.0 | 215.0 | Hawkesbury Sandstone | 17-Jun-13 |
| | | | | | 90.0 | 175.0 | Hawkesbury Sandstone | |
| | | | | | 139.0 | 126.0 | Hawkesbury Sandstone | |
| | | | | | 201.0 | 64.0 | Bulgo Sandstone | |
| | | | | | 278.0 | -13.0 | Bulgo Sandstone | |
| | | | | | 362.0 | -97.0 | Bulgo Sandstone | |
| | | | | | 440.0 | -175.0 | Scarborough Sandstone | |
| | | | | | 512.0 | -247.0 | Bulli Seam | |
| PHGW2A | Fire Trail west of Princes Highway | 312322 | 6217752 | 263.0 | 60.0 | 203.0 | Hawkesbury Sandstone | 16-Mar-11 |
| | | | | | 97.5 | 165.5 | Hawkesbury Sandstone | |
| | | | | | 135.0 | 128.0 | Hawkesbury Sandstone | |
| | | | | | 181.5 | 81.5 | Bald Hill Claystone | |
| | | | | | 201.0 | 62.0 | Bulgo Sandstone | |
| | | | | | 365.0 | -102.0 | Bulgo Sandstone | |
| | | | | | 389.0 | -126.0 | Stanwell Park Claystone | |
| | | | | | 411.0 | -148.0 | Scarborough Sandstone | |
| | | | | | 437.0 | -174.0 | Scarborough Sandstone | |
| | | | | | 470.0 | -207.0 | Wombarra Claystone | |
| | | | | | 508.0 | -245.0 | Bulli Coal Seam | |

**Table 15 (Continued)**
**Groundwater Level and Groundwater Level/Pressure Sites**

| Site Number | Location | Easting | Northing | Collar (m AHD) | Depth (m) | Elevation (m AHD) | Lithology | Commencement Date |
|---|---|---|---|---|---|---|---|---|
| PHGW1B | Fire Trail west of Princes Highway | 312281 | 6218335 | 289.8 | 65.0 | 224.8 | Hawkesbury Sandstone | 28-Jun-10 |
| | | | | | 115.5 | 174.3 | Hawkesbury Sandstone | |
| | | | | | 166.0 | 123.8 | Hawkesbury Sandstone | |
| | | | | | 215.5 | 74.3 | Bald Hill Claystone | |
| | | | | | 238.0 | 51.8 | Bulgo Sandstone | |
| | | | | | 396.0 | -106.3 | Bulgo Sandstone | |
| | | | | | 432.0 | -142.3 | Stanwell Park Claystone | |
| | | | | | 482.3 | -192.6 | Scarborough Sandstone | |
| | | | | | 518.3 | -228.6 | Wombarra Claystone | |
| | | | | | 554.1 | -264.4 | Bulli Coal Seam | |
| PM01 (9DGW1B) | Fire Trail 9D | 309971 | 6217271 | 283.6 | 52.0 | 231.7 | Hawkesbury Sandstone | 5-Feb-10 |
| | | | | | 90.0 | 193.7 | Hawkesbury Sandstone | |
| | | | | | 170.0 | 113.7 | Hawkesbury Sandstone | |
| | | | | | 218.0 | 65.7 | Bald Hill Claystone | |
| | | | | | 238.0 | 45.7 | Bulgo Sandstone | |
| | | | | | 415.0 | -131.3 | Bulgo Sandstone | |
| | | | | | 440.0 | -156.3 | Stanwell Park Claystone | |
| | | | | | 482.0 | -198.3 | Scarborough Sandstone | |
| | | | | | 494.0 | -210.3 | Scarborough Sandstone | |
| | | | | | 547.5 | -263.8 | Coal Cliff Sandstone | |

**Table 15 (Continued)**
**Groundwater Level and Groundwater Level/Pressure Sites**

| Site Number | Location | Easting | Northing | Collar (m AHD) | Depth (m) | Elevation (m AHD) | Lithology | Commencement Date |
|---|---|---|---|---|---|---|---|---|
| PM02 | Fire Trail 9D | 310650 | 6218509 | 267.4 | 35.0 | 232.4 | Hawkesbury Sandstone | 23-Dec-07 |
| | | | | | 100.0 | 167.4 | Hawkesbury Sandstone | |
| | | | | | 220.0 | 47.4 | Bald Hill Claystone | |
| | | | | | 250.0 | 17.4 | Bulgo Sandstone | |
| | | | | | 400.0 | -132.7 | Bulgo Sandstone | |
| | | | | | 435.0 | -167.7 | Stanwell Park Claystone | |
| | | | | | 475.0 | -207.7 | Scarborough Sandstone | |
| | | | | | 495.0 | -227.7 | Scarborough Sandstone | |
| PM03 | Woronora Dam Road | 311664 | 6219773 | 265.0 | 64.0 | 201.0 | Hawkesbury Sandstone | 14-Feb-11 |
| | | | | | 106.5 | 158.5 | Hawkesbury Sandstone | |
| | | | | | 149.0 | 116.0 | Hawkesbury Sandstone | |
| | | | | | 189.3 | 75.7 | Bald Hill Claystone | |
| | | | | | 214.0 | 51.0 | Bulgo Sandstone | |
| | | | | | 385.0 | -120.0 | Bulgo Sandstone | |
| | | | | | 408.0 | -143.0 | Stanwell Park Claystone | |
| | | | | | 430.2 | -165.2 | Scarborough Sandstone | |
| | | | | | 462.0 | -197.0 | Scarborough Sandstone | |
| | | | | | 492.0 | -227.0 | Wombarra Claystone | |
| | | | | | 526.0 | -261.0 | Coal Cliff Sandstone | |

**Table 15 (Continued)**
**Groundwater Level and Groundwater Level/Pressure Sites**

| Site Number | Location | Easting | Northing | Collar (m AHD) | Depth (m) | Elevation (m AHD) | Lithology | Commencement Date |
|---|---|---|---|---|---|---|---|---|
| S1997* | North Cliff | 306997 | 6212765 | 370.2 | 24.0 | 346.2 | Hawkesbury Sandstone | 10-Jun-09 |
| | | | | | 68.5 | 301.7 | Hawkesbury Sandstone | |
| | | | | | 132.0 | 238.2 | Hawkesbury Sandstone | |
| | | | | | 218.0 | 152.2 | Bulgo Sandstone | |
| | | | | | 292.5 | 77.7 | Bulgo Sandstone | |
| | | | | | 372.0 | -1.8 | Bulgo Sandstone | |
| | | | | | 429.0 | -58.8 | Scarborough Sandstone | |
| | | | | | 441.5 | -71.3 | Scarborough Sandstone | |
| | | | | | 454.0 | -83.3 | Scarborough Sandstone | |
| | | | | | 504.5 | -134.3 | Coal Cliff Sandstone | |
| | | | | | 511.6 | -141.4 | Bulli Coal Seam | |
| 302GW01[3] | Overlying Longwall 302 | 312952 | 6216553 | 305.1 | 80.0 | 225.1 | Hawkesbury Sandstone | Commenced 23-Nov-17<br><br>End Date 25-May-18 |
| | | | | | 150.0 | 155.1 | Hawkesbury Sandstone | |
| | | | | | 200.0 | 105.1 | Newport Formation | |
| | | | | | 245.0 | 60.1 | Interbedded Shale and Sandstone | |
| | | | | | 340.0 | -34.9 | Bulgo Sandstone | |
| | | | | | 380.0 | -74.9 | Bulgo Sandstone | |
| | | | | | 400.0 | -94.9 | Bulgo Sandstone | |
| | | | | | 410.0 | -104.9 | Bulgo Sandstone | |
| | | | | | 440.0 | -134.9 | Scarborough Sandstone | |
| TBS02-80 | Overlying Longwall 302 | 312849 | 6216579 | 305.1 | 82.5 | 222.6 | Hawkesbury Sandstone | 1-Oct-17 |
| TBS02-250 | Overlying Longwall 302 | 312852 | 6216598 | 306.1 | 192.0 | 114.1 | Newport Formation | 27-Oct-17 |
| | | | | | 243.0 | 63.1 | Shale/ Sandstone | |
| TBS02-15 | Overlying Longwall 302 | 312837 | 6216577 | 304.2 | 15.5 | 288.7 | Hawkesbury Sandstone | 31-Oct-17 |

**Table 15 (Continued)**
**Groundwater Level and Groundwater Level/Pressure Sites**

| Site Number | Location | Easting | Northing | Collar (m AHD) | Depth (m) | Elevation (m AHD) | Lithology | Commencement Date |
|---|---|---|---|---|---|---|---|---|
| TBS03-230 Pre-Mining | Overlying Longwall 303 | 312647 | 6216691 | 281.9 | 162.0 | 119.9 | Newport Formation | 22-Feb-18 |
| | | | | | 213.0 | 68.9 | Shale/ Sandstone | |
| TBS03-15 | Overlying Longwall 303 | 312647 | 6216691 | 281.9 | 15.5 | 266.4 | Hawkesbury Sandstone | 23-Feb-18 |

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

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

3 302GW01 piezometer site intended to be first site to safely monitor throughout the longwall extraction process with new optical fibre piezometers. Optical fibres unfortunately were severed by ground movement as Longwall 302 passed under the site. Follow-up piezometer installation is scheduled for late 2018 to monitor post mining groundwater pressures similar to previous goaf hole sites with traditional copper cabling.

* Data courtesy of BHP Billiton Illawarra Coal.

***Measured Vertical Head Profiles***

The measured vertical hydraulic head profiles for all installed multi-piezometer bores (Table 15) will be monitored as a component of this WMP. The measured vertical hydraulic head profiles for multi-piezometer bores 9GGW2B, F6GW3A, F6GW4A, PHGW2A, PHGW1B, 9EGW1B, 9EGW2A, PM01 (9DGW1B) and PM02 will be compared against their predicted vertical head profiles as described in Section 8.5.3. Their measured vertical hydraulic head profiles are illustrated on Charts 13 to 21 on stratigraphic sections with piezometer offtakes, average potentiometric head levels and pressure heads. It should be noted that the heads at these bores have potentially been affected to some degree by previous mining at Metropolitan Coal and/or other nearby mines (e.g. North Cliff and Darkes Forest).

***Bore 9GGW2B***

Bore 9GGW2B is located at the western end of Longwall 27, approximately 1.5 km on the northern side of previously extracted Longwalls 6 and 7 which were mined in 2000-2001, and about 500 m south-west of Longwall 303. Significant depressurisation appears to have occurred at that time (Chart 13). No definite additional depressurisation resulted from mining. since 2011. The head profile (at 31 May 2017) after the mining of Longwall 27 exhibited considerable drawdowns in the three Hawkesbury Sandstone piezometers. The most significant depressurisation occurred at Stanwell Park Claystone (piezometer P339) due to the mining of Longwall 26 and Longwall 27. Piezometer P339 maintained about 160 m pressure head. P138, P162, P304, P393 and P474 deep vibrating wire piezometers have unreliable data up to 31 May 2017. The second lowest piezometer (P437) in the Wombarra Claystone maintained a pressure head of about 215 m.

For comparison with other bores, the head in the Lower Hawkesbury Sandstone is about 175 m AHD and the head in the Lower Bulgo Sandstone is about 90 m AHD. The recent two head profiles in Chart 13 show that the heads are varying with time as mining proceeds.

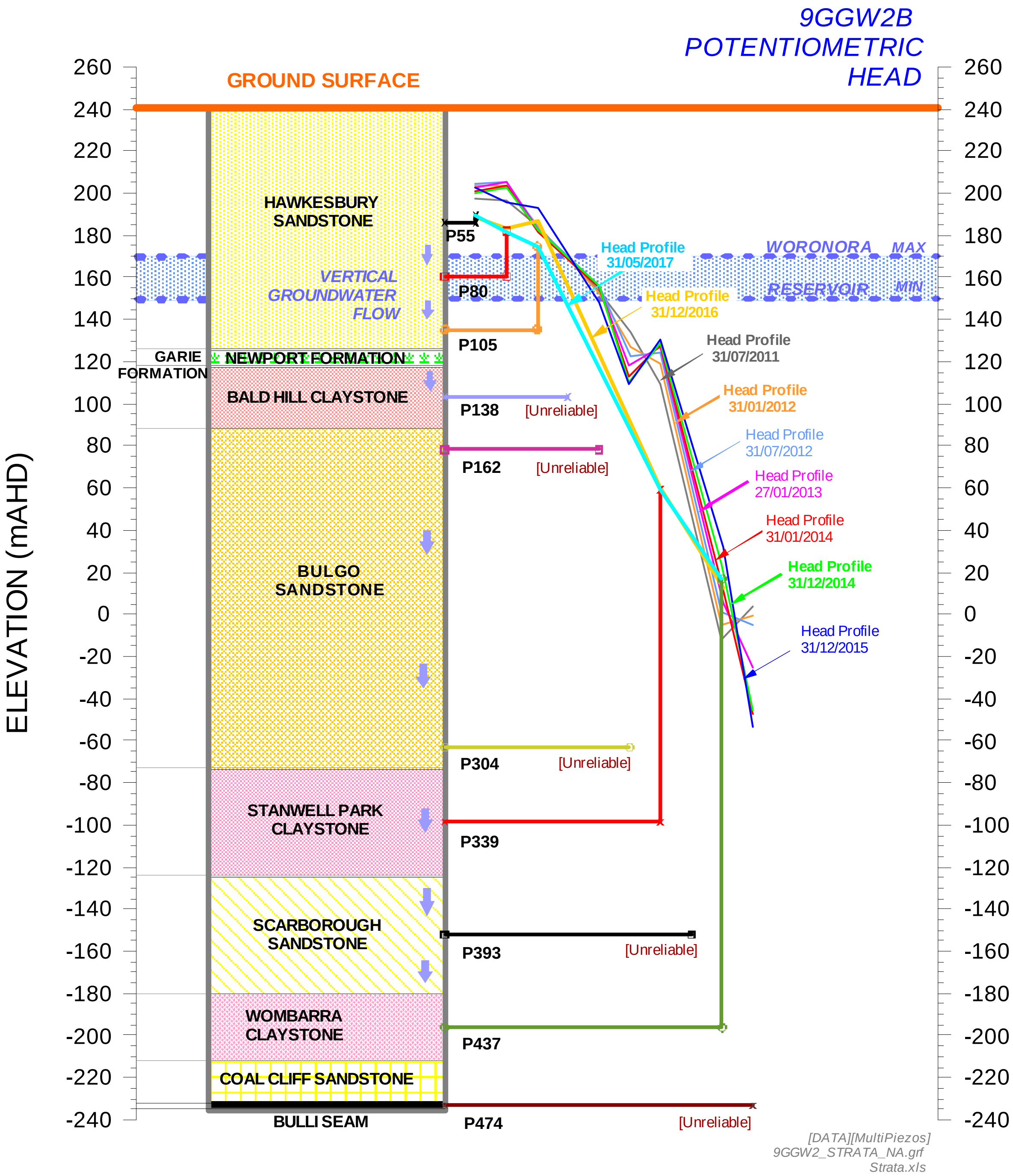



**Chart 13: Vertical Groundwater Flow Directions, Relative Piezometer Elevations and Potentiometric Heads at Bore 9GGW2B**

***Bore F6GW3A***

Bore F6GW3A is located adjacent to Longwall 301 at its southern end, and at about 800 m from Longwall 27. Significant depressurisation has occurred from historical workings to the east about 500 m distant.

For comparison with other bores, the head in the Lower Hawkesbury Sandstone is about 185 m AHD and the head in the Lower Bulgo Sandstone is about 60 m AHD. The profiles at various times in Chart 14 show that the heads are not varying significantly with time as mining proceeds.

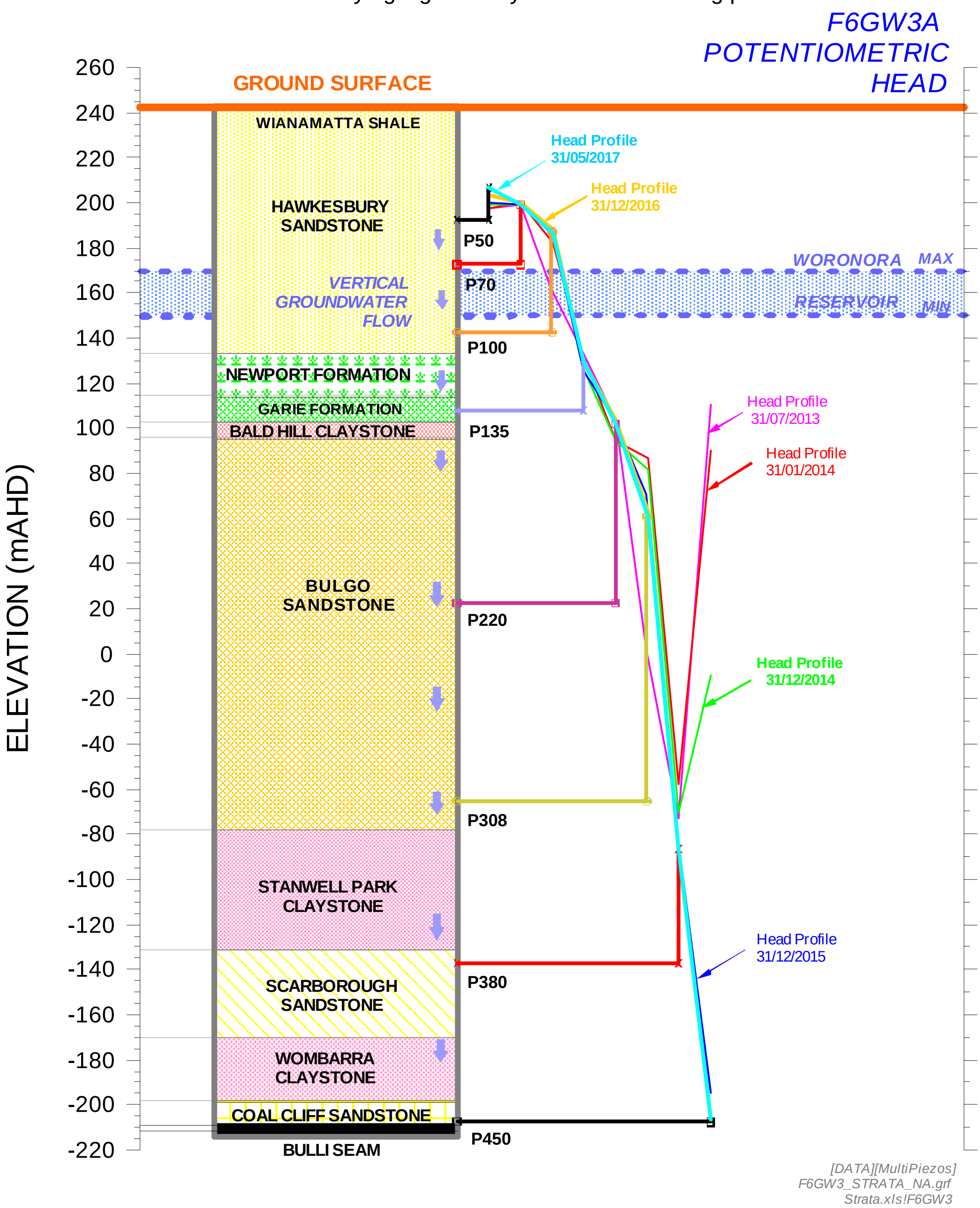



**Chart 14: Vertical Groundwater Flow Directions, Relative Piezometer Elevations and Potentiometric Heads at Bore F6GW3A**

### *Bore F6GW4A*

Bore F6GW4A lies above the coal pillar on the western side of Longwall 303. Very little depressurisation has occurred to date (Chart 15). For comparison with other bores, the head in the Lower Hawkesbury Sandstone is about 180 m AHD and the head in the Lower Bulgo Sandstone is about 130 m AHD. The profiles at various times in Chart 15 show that the heads are not varying significantly with time as mining proceeds.

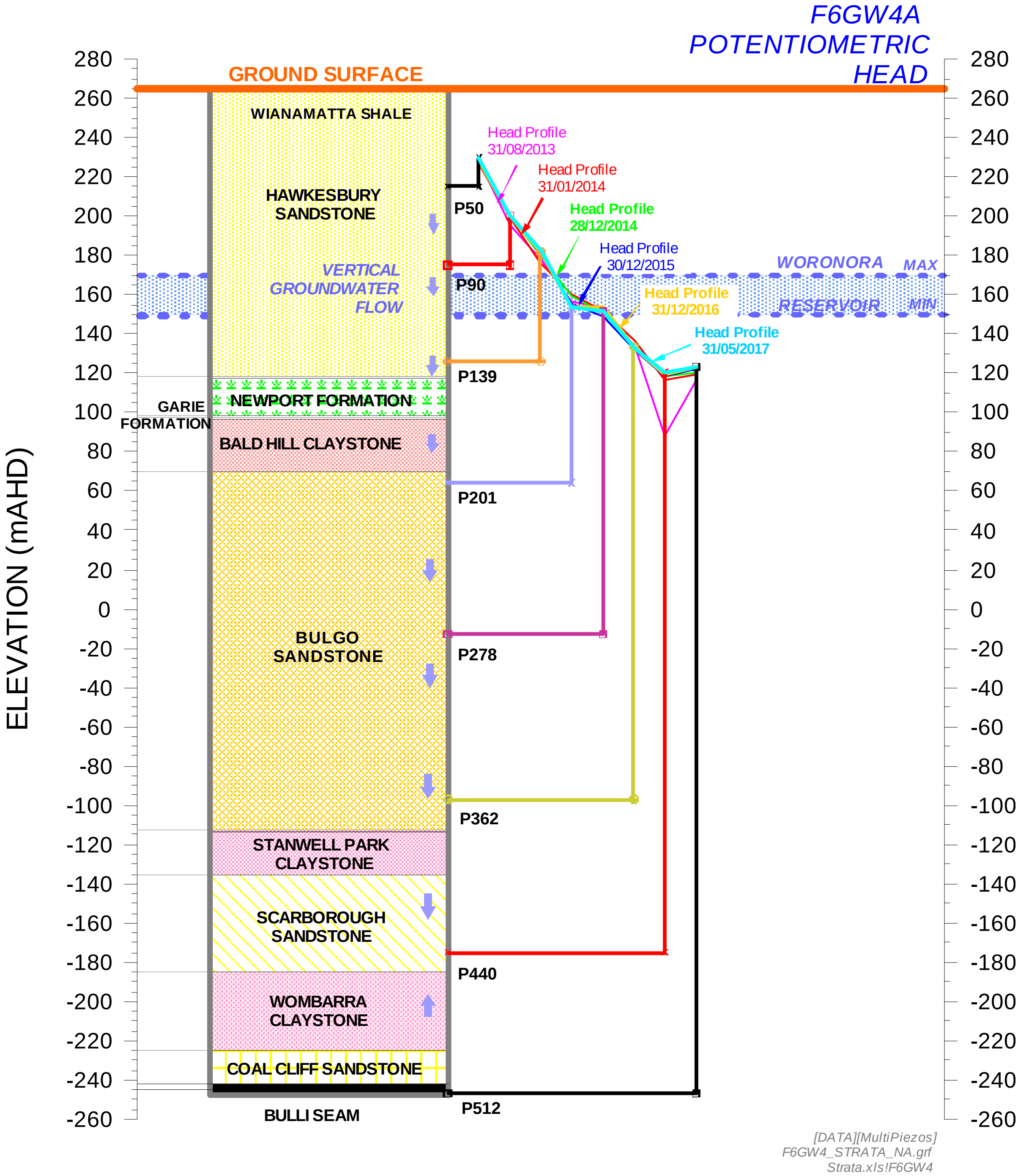



**Chart 15: Vertical Groundwater Flow Directions, Relative Piezometer Elevations and Potentiometric Heads at Bore F6GW4A**

***Bore PHGW2A***

As bore PHGW2A is located approximately 2.5 km north of Longwall 27 and the same distance from the historical workings to the east, no recent mining effect is evident (Chart 16). There is a mild downwards hydraulic gradient. This bore is about 700 m north-west of Longwall 303.

For comparison with other bores, the head in the Lower Hawkesbury Sandstone is about 180 m AHD and the head in the Lower Bulgo Sandstone is about 125 m AHD. The profiles at various times in Chart 16 show that the heads are not varying with time as mining proceeds.

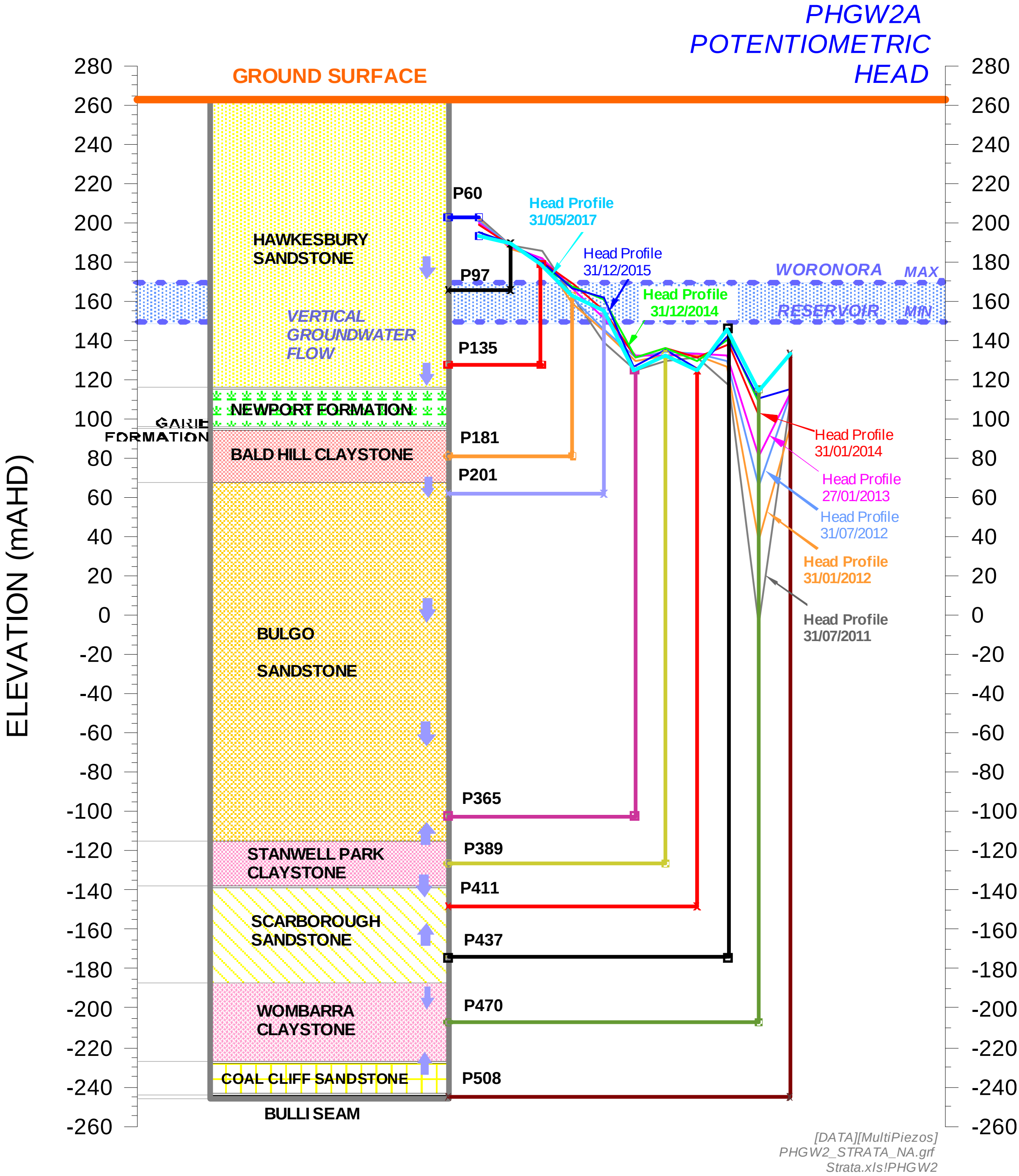



**Chart 16: Vertical Groundwater Flow Directions, Relative Piezometer Elevations and Potentiometric Heads at Bore PHGW2A**

***Bore PHGW1B***

Bore PHGW1B is about 500 m due north of PHGW2B and about 1,200 m north-west of Longwall 303. It would be expected to have a similar vertical hydraulic profile to PHGW2A, but in fact it has a stronger gradient (Chart 17). This seems to be due to the naturally higher lateral hydraulic gradient towards the north-east in deeper strata.

For comparison with other bores, the head in the Lower Hawkesbury Sandstone is about 190 m AHD and the head in the Lower Bulgo Sandstone is about 110 m AHD. The profiles at various times in Chart 17 show that the heads are not varying with time as mining proceeds. The observed variations are stabilisation effects.

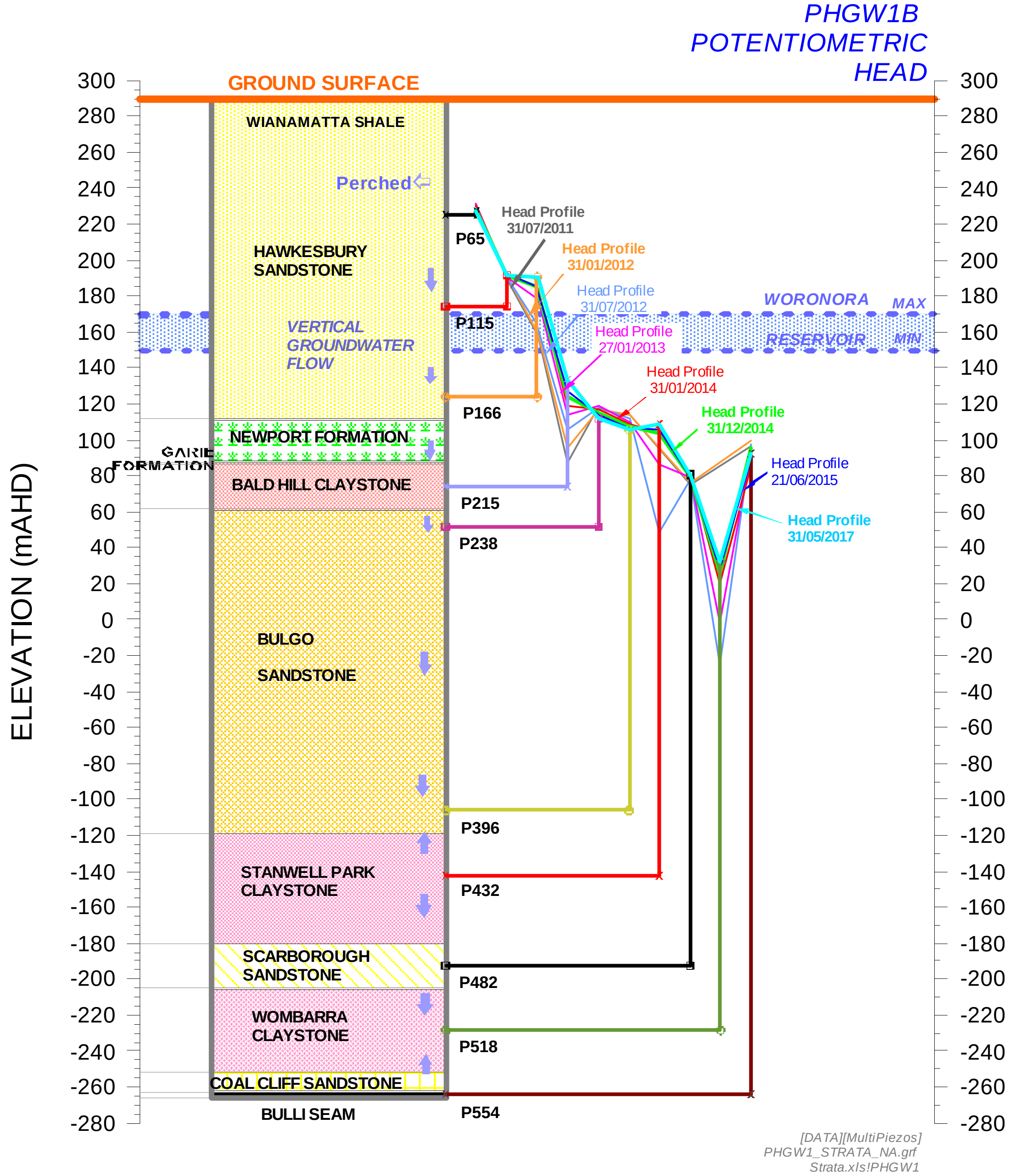



**Chart 17: Vertical Groundwater Flow Directions, Relative Piezometer Elevations and Potentiometric Heads at Bore PHGW1B**

***Bore 9EGW1B***

Bore 9EGW1B is located approximately 500 m north of the western end of Longwall 23A and 3 km west of Longwall 303. Some depressurisation appears to have occurred in the Lower Bulgo Sandstone and lower formations due to mining to the south (Chart 18).

For comparison with other bores, the head in the Lower Hawkesbury Sandstone is about 240 m AHD and the head in the Lower Bulgo Sandstone is about 175 m AHD. The profiles at various times in Chart 18 show that the heads are not varying significantly with time as mining proceeds, but several piezometers have taken time to stabilise.

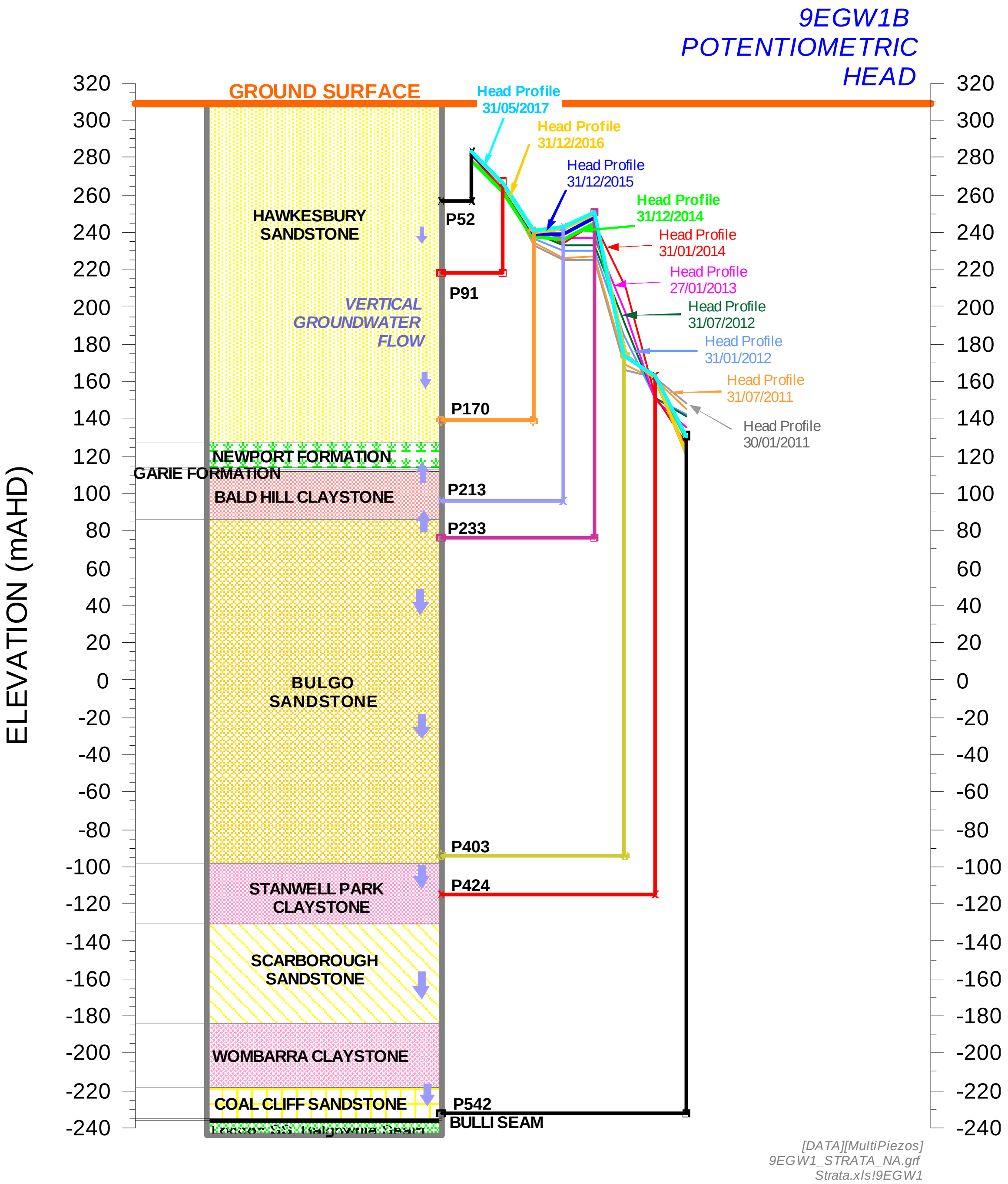



**Chart 18: Vertical Groundwater Flow Directions, Relative Piezometer Elevations and Potentiometric Heads at Bore 9EGW1B**

***Bore 9EGW2A***

Bore 9EGW2A is located approximately 1.3 km due west of Longwall 303. The vibrating wire piezometers indicate substantial depressurisation at depth, but the records are erratic and not internally consistent (Chart 19). Hence, the vibrating wire piezometers at the lower Bulgo Sandstone and from the Scarborough Sandstone to downwards have unreliable data up to 31 May 2017.

For comparison with other bores, the head in the Lower Hawkesbury Sandstone is about 170 m AHD and the head in the Lower Bulgo Sandstone is possibly about 145 m AHD. The profiles at various times in Chart 19 show that there is no definitive reduction in heads with time as mining proceeds, but several piezometers have taken time to stabilise.

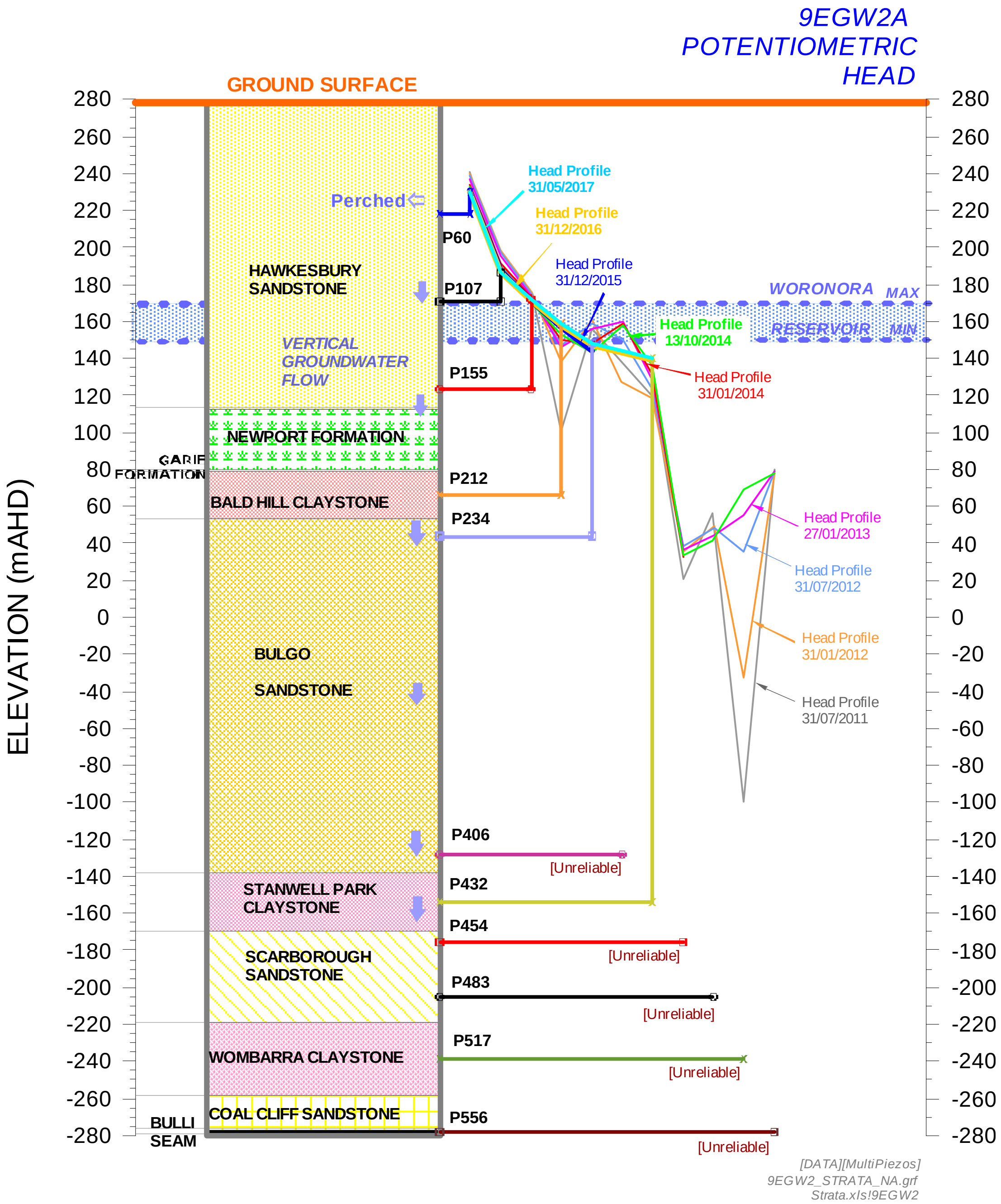



**Chart 19: Vertical Groundwater Flow Directions, Relative Piezometer Elevations and Potentiometric Heads at Bore 9EGW2A**

***Bore PM01 (9DGW1B)***

Bore PM01 (9DGW1B) is located approximately 2.7 km west of Longwall 303. This site has a similar vertical head gradient to that observed at PHGW1B, apparently due to the naturally higher lateral hydraulic gradient towards the north-east in deeper strata.

For comparison with other bores, the head in the Lower Hawkesbury Sandstone is about 240 m AHD and the head in the Lower Bulgo Sandstone is about 145 m AHD. The profiles at various times in Chart 20 show that the heads are not varying significantly with time as mining proceeds, but the Scarborough Sandstone piezometer (P482) has been unstable.

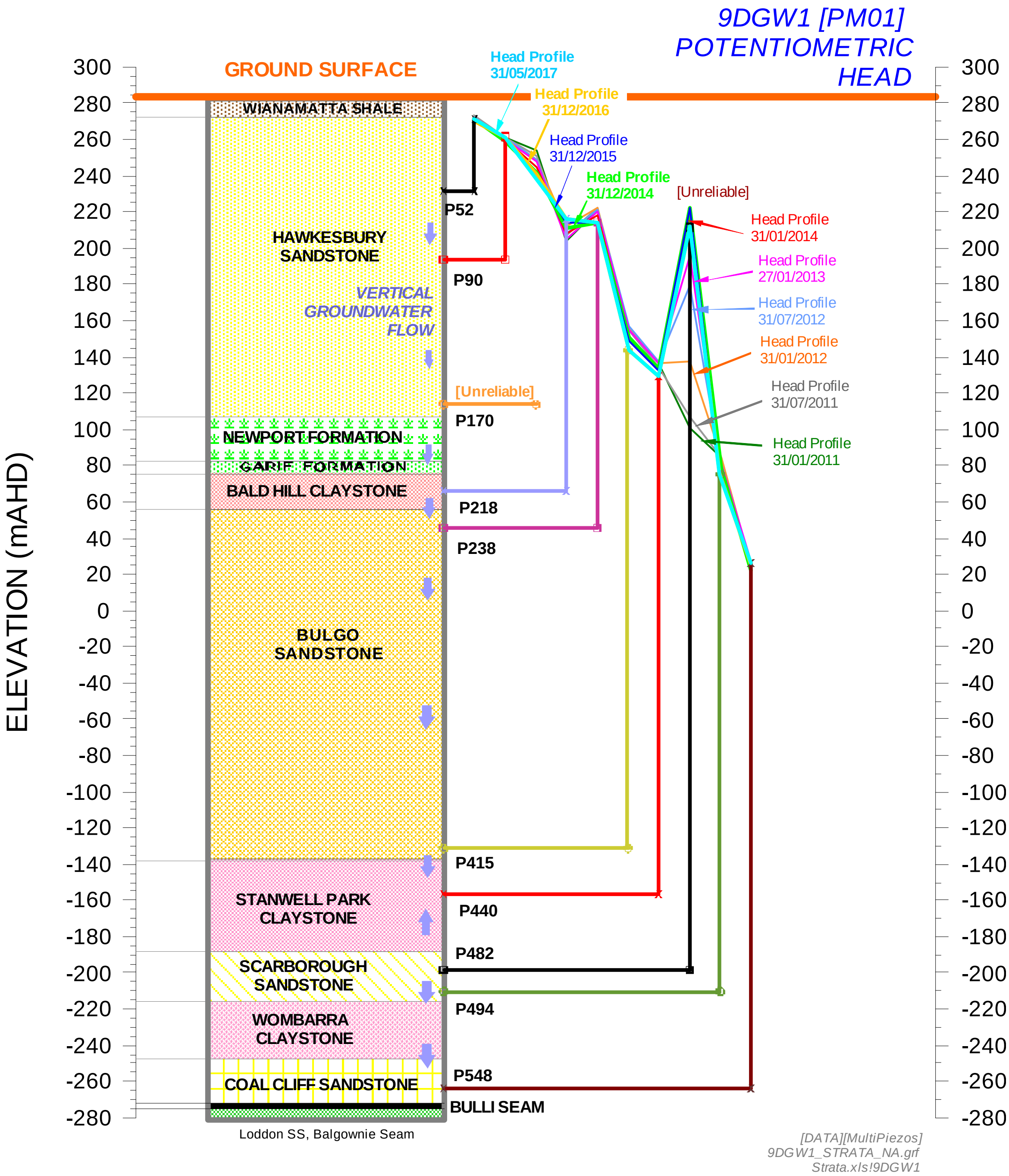



**Chart 20: Vertical Groundwater Flow Directions, Relative Piezometer Elevations and Potentiometric Heads at Bore PM01 (9DGW1B)**

***Bore PM02***

Bore PM02 is located approximately 2.5 km north-west of Longwall 303. Being far from historical and recent mining, it would not be expected to show any dramatic response to mining but could show a slight slow decline in heads as the groundwater "cone of depression" extends radially away from the area of mining. Chart 21 indicates that all potentiometric heads are high and within 40 m of the maximum level of the Woronora Reservoir. As there is no difference in head between the Lower Bulgo Sandstone and the Lower Scarborough Sandstone, it is inferred that there is no substantial change in vertical hydraulic gradient (at depth) due to mining.

For comparison with other bores, the head in the Lower Hawkesbury Sandstone is about 185 m AHD and the head in the Lower Bulgo Sandstone is about 125 m AHD. The profiles at various times in Chart 21 show that the heads are not varying significantly with time as mining proceeds.

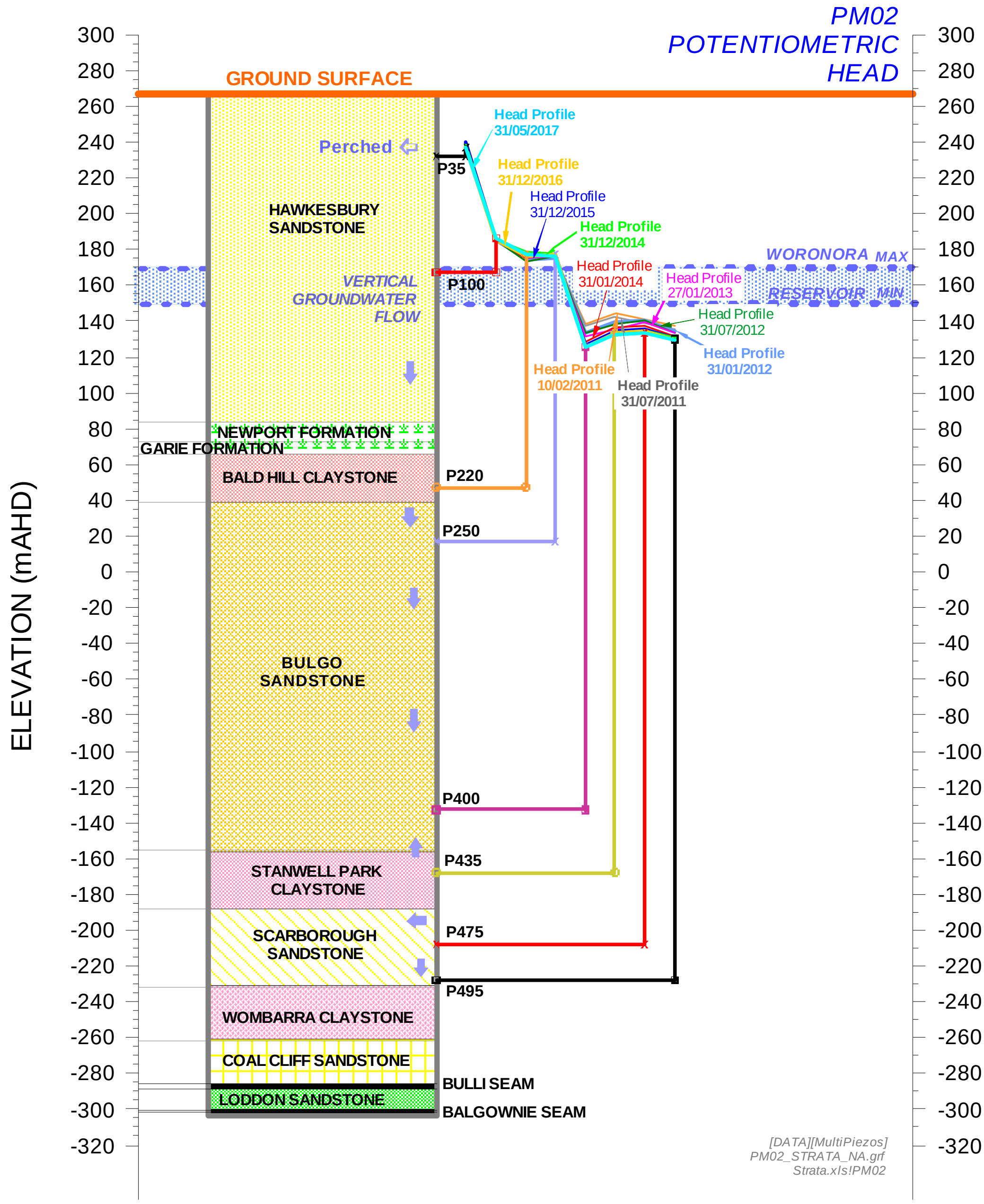



**Chart 21: Vertical Groundwater Flow Directions, Relative Piezometer Elevations and Potentiometric Heads at Bore PM02**

### 7.3.4 Mine Water Make

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

Charts 2a and 2b in Section 5.4.2 shows the mine water make results to August 2018. The 20 day average daily mine water make has consistently been less than 0.5 ML/day (Chart 2a). The monitoring results are consistent with the predictions for mine water make.

### 7.3.5 Groundwater Quality

Groundwater quality data is available from a number of sites with installed piezometers, as summarised in Table 16. The locations of the groundwater quality sites are shown on Figure 12.

**Table 16**
**Shallow Groundwater Quality Sites**

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

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

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

Groundwater quality is also sampled by Metropolitan Coal to meet its Dams Safety Committee Approval requirements. The groundwater quality sampling sites are detailed in Table 17 and shown on Figure 12.

**Table 17**
**Deep Groundwater Chemistry Sites**

| EES (2014) Bore Name | Metropolitan Coal Site Number | Easting | Northing | Collar (m AHD) | Depth (m) | Elevation (m AHD) | Lithology | Sampling Type | Status |
|---|---|---|---|---|---|---|---|---|---|
| 9F2-50C | 9FGW2 | 308717.4 | 6217210.3 | 289.8 | 50 | 239.8 | Upper Hawkesbury Sandstone | Chemical and Static Water Level | Operational |
| 9F2-150C | | 308740.7 | 6217240.7 | 289.8 | 150 | 139.8 | Lower Hawkesbury Sandstone | Chemical and Static Water Level | Operational (grout impacted) |
| 9F2-250D | | 308720.5 | 6217223.8 | 289.8 | 250 | 39.8 | Bulgo Sandstone | Chemical and Static Water Level | Operational (grout impacted) |
| PH2-25E | PHGW2 | 312316.1 | 6217761.1 | 263.0 | 25 | 238 | Upper Hawkesbury Sandstone | Chemical and Static Water Level | Operational |
| PH2-110C | | 312322.3 | 6217782.3 | 263.1 | 110 | 153 | Lower Hawkesbury Sandstone | Chemical and Static Water Level | Operational (potentially grout impacted) |
| PH2-230D | | 312327.1 | 6217772.3 | 262.2 | 230 | 33 | Bulgo Sandstone | Chemical and Static Water Level | Operational |
| PM03-25E | PM03 | 311640.8 | 6219766.2 | 265.7 | 25 | 242.7 | Upper Hawkesbury Sandstone | Chemical and Static Water Level | Operational |
| PM03-105C | | 311665.2 | 6219754.9 | 265.7 | 105 | 160.7 | Lower Hawkesbury Sandstone | Chemical and Static Water Level | Operational |
| PM03-230D | | 311647.6 | 6219776.1 | 265.7 | 230 | 35.7 | Bulgo Sandstone | Chemical and Static Water Level | Operational (potentially grout impacted) |

**Table 17 (Continued)**
**Deep Groundwater Chemistry Sites**

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

**Table 17 (Continued)**
**Deep Groundwater Chemistry Sites**

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

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

# 8 MONITORING PROGRAM

Subsidence parameters will be measured in accordance with the Metropolitan Coal Longwalls 301-303 Subsidence Monitoring Program (Figure 3). In summary, surveys will be conducted to measure subsidence movements in three dimensions using a total station survey instrument. Subsidence movements will be measured along subsidence lines that have been positioned across the general landscape.

A monitoring program will be implemented to monitor the impacts and environmental performance of the Project on water resources and watercourses during the mining of Longwalls 301-303. The monitoring program is described in Sections 8.1 to 8.7.

Section 8.8 provides detailed TARPs to assess the water resource and watercourse subsidence impact performance indicators and measures.

## 8.1 METEOROLOGY

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

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

A pan evaporimeter at site PV1 (Figure 9) will monitor evaporation in the Waratah Rivulet catchment.

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

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

## 8.2 STREAM FEATURES

As described in Section 5.3, the Waratah Rivulet is located approximately 1 km west of Longwall 303, at its closest point to Longwalls 301-303 secondary extraction (Figures 1 and 4). At this distance, the Waratah Rivulet is not predicted to experience any measurable subsidence or valley related movements resulting from the extraction of Longwalls 301-303 (MSEC, 2018). Notwithstanding, visual inspections and photographic surveys will be conducted along the Waratah Rivulet from Pool P to the full supply level of the Woronora Reservoir within three months of the completion of each longwall to provide a record of the Waratah Rivulet stream features post the mining of Longwall 27.

Visual and photographic surveys of the Eastern Tributary from the full supply level of the Woronora Reservoir to the maingate of Longwall 26 will be conducted monthly when mining is within 400 m of the stream and within three months of the completion of each longwall.

The visual and photographic surveys will record:

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

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

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

Any gas releases identified as occurring on the Waratah Rivulet and Eastern Tributary to the full supply level by the visual inspections during the mining of Longwalls 301-303 (either during the visual and photographic surveys or other catchment monitoring) will be monitored weekly to determine the nature of the gas releases, gas concentration (samples taken for the analysis for carbon dioxide and methane content) and any observable environmental effects (e.g. impacts to riparian vegetation or fish kills). Weekly monitoring will be conducted at pools observed with gas releases, until no gas releases have been observed at the pool for three consecutive weeks.

## 8.3 SURFACE WATER QUANTITY

### 8.3.1 Surface Water Flow

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

- the WaterNSW owned gauging station on the Waratah Rivulet, close to the inundation limits of the Woronora Reservoir (GS 2132102);
- the Metropolitan Coal owned gauging station on the Eastern Tributary, close to the inundation limits of the Woronora Reservoir (GS 300078);
- the WaterNSW owned gauging station on the Woronora River, close to the inundation limits of the Woronora Reservoir (GS 2132101) (control site);
- the Metropolitan Coal owned gauging station on Honeysuckle Creek (GS 300077) (control site);

- the Department of Industry – Water gauging station on O'Hares Creek at Wedderburn (GS 213200) (control site);
- the Metropolitan Coal owned gauging station on a tributary of the Woronora Reservoir (Sub-catchment I [GS 300092]); and
- the Metropolitan Coal owned gauging station on a tributary of the Woronora Reservoir (Sub-catchment K [GS 300093]).

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

Metropolitan Coal will continue to source flow data for the O'Hares Creek gauging station at Wedderburn from the Department of Industry – Water.

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

### 8.3.2 Pool Water Levels and Drainage Behaviour

The water level in Pools B, C, E, G, G1, H and I on Waratah Rivulet will be manually monitored daily (Figure 6) until such time that continuous water level sensors are installed and operating.

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

- Pools A, F, J, K, L, M, N, O, P, Q, R, S, T, U, V and W on Waratah Rivulet;
- Pools ETG, ETJ, ETM, ETU, ETW, ETAF, ETAG, ETAH, ETAI, ETAQ, ETAT and ETAU on the Eastern Tributary; and
- control Pools WRP1, WRP2, WRP3 and WRP4 on the Woronora River.

Data from these devices will be downloaded monthly.

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

Pools ETAS, ETAT and ETAU situated downstream of the maingate of Longwall 26 on the Eastern Tributary will be visually inspected weekly when mining of Longwalls 301-303 is within 400 m of the Eastern Tributary. Pool ETAS is a rockbar controlled pool. Water enters the pool as surface flow from boulderfield ETAR. The downstream rockbar is permeable (allowing both underflow and surface flow), and appears to be mainly detached blocks and boulders. Due to the nature of rockbar ETAS, Pool ETAS and Pool ETAT typically sit at the same level. Pool ETAT is a rockbar controlled pool. Water enters the pool as surface flow or underflow through rockbar ETAS. The downstream rockbar is effectively impermeable. Pool ETAU flows through Eastern Tributary gauging station, over a rock bar/waterfall, into ETAU boulderfield.

Observations will include:

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

## 8.4 SURFACE WATER QUALITY

### 8.4.1 Stream Water Quality

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

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

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

Unfiltered water quality samples will also be collected monthly at the following sites and analysed for total iron:

- sites WRWQ 2, WRWQ 6, WRWQ 8, WRWQ 9, WRWQ M, WRWQ N and WRWQ P on the Waratah Rivulet;
- sites ETWQ F, ETWQ J, ETWQ N, ETWQ AF and ETWQ AQ on the Eastern Tributary; and
- control site WOWQ 2 on the Woronora River.

Monitoring of water quality in areas subject to mining indicates that the effects of subsidence on water quality have been most noticeable in iron, manganese, and to a lesser extent, aluminium (Gilbert & Associates, 2008). These parameters will be used to trigger further assessment of subsidence impacts on water quality as outlined in the TARPs provided in Section 8.8.

### 8.4.2 Woronora, Nepean and Cataract Reservoir Water Quality

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

Consistent with the monitoring of water reaching the Woronora Reservoir (Section 8.4.1), the water quality data will be analysed for key water quality parameters of relevance to water supply and effects of subsidence, namely: total iron; total manganese; and total aluminium. These parameters will be used to trigger further assessment of subsidence impacts on reservoir water quality as outlined in the TARPs provided in Section 8.8.

## 8.5 GROUNDWATER LEVELS

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

### 8.5.1 Swamp Groundwater Levels

Monitoring of upland swamp groundwater levels will be conducted in accordance with the Metropolitan Coal Longwalls 301-303 Biodiversity Management Plan.

In summary, groundwater monitoring of upland swamps will include the monitoring of paired piezometers (i.e. one swamp substrate piezometer to a depth of approximately 1 m and one sandstone piezometer to a depth of approximately 10 m) in Swamps 40, 41, 46, 51, 52 and 53 overlying Longwalls 301-303 (Figure 10). Each piezometer has been equipped with a data logger for continuous water level monitoring.

Swamp substrate 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 and in control Swamps 101, 137a, 137b, Bee Creek Swamp and Woronora River 1 (WRSWAMP 1) (Figure 10) for Longwalls 20-27. None of these swamp groundwater monitoring sites are located within 600 m of Longwalls 301-303 secondary extraction. As described in Section 2, this WMP 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 DP&E.

### 8.5.2 Shallow Groundwater Levels Near Streams

Continuous water level monitoring of shallow groundwater will be conducted along streams at (Figure 11):

- sites WRGW1, WRGW2 and WRGW7 along Waratah Rivulet; and
- site ETGW1 along the Eastern Tributary.

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

### 8.5.3 Groundwater Levels/Pressures

Continuous groundwater level monitoring will also be conducted at an approximately east-west transect of bores (sites T1, T2, T3, T4, T5 and T6) located to the west of Longwalls 301-303. Data from the divers in the standpipes will be downloaded monthly and the measured water levels at these bores will be compared against the water table at the Woronora Reservoir. A survey bench mark (survey pin in solid rock away from the Woronora Reservoir's waters edge) has been installed. A portable Digital Automatic Level will be used to measure water level each month from this station.

Additional groundwater standpipes have been installed as a component of the Woronora Reservoir Impact Strategy, namely bores TBS02-80, TBS02-15 and bore TBS03-15 (Figure 11).

Continuous groundwater level/pressure monitoring will be conducted at (Figure 11):

- site 9HGW0 (Longwall 10 Goaf Hole);
- site 9EGW1B;
- site 9FGW1A;
- site 9GGW2B;
- site 9HGW1B;
- site PM02;
- site 9GGW1-80;
- site PM01 (9DGW1B);
- site 9EGW2A;
- site PM03;
- site PHGW1B;
- site PHGW2A;
- site F6GW3A;
- site F6GW4A;
- site 9EGW2-4;
- site 302GW01;
- site TBS02-250; and
- site TBS03-230.

Data from the piezometers will be downloaded monthly.

Vertical profiles of potentiometric head are effective monitors of the capacity of an aquifer system to maintain pressure during the formation of deformation zones caused by caving and subsidence. Head profiles show a characteristic reduction in head with depth due to mining. That is, as mining moves closer, groundwater pressures can fall. Vertical groundwater head profiles will be used to assess the potential for connective cracking between the surface and the mine. The measured vertical hydraulic head profiles for nine bores (those most relevant to Longwalls 301-303, as listed in Section 7.3.3 and shown in Charts 13 to 21) will be compared against the predicted vertical hydraulic head profiles for each bore as outlined in the TARPs provided in Section 8.8.

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

### 8.5.4 Woronora Reservoir Leakage

Continuous groundwater level/pressure monitoring will be conducted at bores PM02, 9GGW2B, PHGW2A, 9EGW2A and F6GW4A and data from the piezometers will be downloaded monthly. The water tables measured at Bores PM02, 9GGW2B, PHGW2A, 9EGW2A and F6GW4A will be compared against the full supply level of Woronora Reservoir to assess reductions in hydraulic gradient from the bores to the Woronora Reservoir as detailed in the TARPs in Section 8.8.

As described in Section 8.5.2, continuous groundwater level monitoring will also be conducted at an approximately east-west transect of bores (sites T1, T2, T3, T4, T5 and T6) located to the west of Longwalls 301-303. Data from the divers in the standpipes will be downloaded monthly and the measured water levels at select bores will be compared against the water table at the Woronora Reservoir as detailed in the TARPs in Section 8.8.

## 8.6 MINE WATER MAKE

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

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

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

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

Monitoring of the mine water balance will comprise:

- Metered water reticulated into the mine (recorded continuously and downloaded monthly).
- Backfill water used to assist pumping into the mine (recorded continuously and downloaded monthly).
- Metered water reticulated out of the mine (recorded continuously and downloaded monthly).

- Manual measurement of moisture content into and out of the mine through the mine ventilation system using a digital psychrometer. The frequency of readings will be as follows:
  - every hour over a 9 hour period on two occasions during a 12 month period;
  - daily (week day) except public holidays or other circumstances (access, fan maintenance, etc.) that prevent readings to be taken; and
  - once per week as a minimum.
- Measurement of the in-situ moisture content of the coal during channel sampling for coal quality.
- Measurement of the moisture content of run-of-mine (ROM) coal conveyed out of the mine at the drift portal using an automated moisture scanner. A fully automated data acquisition system records and stores the data.

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

Metropolitan Coal will also monitor the water balance for the 300 area (i.e. a localised water balance underground in and about the 300 series longwalls) using a series of underground water meters. Metropolitan Coal will provide the results of the localised water balance, with the results of the overall mine water balance to the Dams Safety Committee monthly.

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

## 8.7 GROUNDWATER QUALITY

Shallow groundwater quality sampling will be conducted monthly at the following sites (Figure 12):

- sites WRGW1, WRGW2 and WRGW7 along the Waratah Rivulet; and
- site ETGW2[16] along the Eastern Tributary.

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

## 8.8 TRIGGER ACTION RESPONSE PLANS AND ASSESSMENT OF PERFORMANCE INDICATORS AND MEASURES

The monitoring results will be used to assess the Project against the performance indicators and performance measures using the TARPs detailed in Tables 18 to 23.

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

**Table 18**
**Trigger Action Response Plan – Negligible Reduction to the Quantity of Water Resources Reaching the Woronora Reservoir**

| Performance Measure | Performance Indicator | Monitoring Site(s) | Parameters | Frequency/ Sample Size | Analysis Methodology | Error Types | Baseline | Significance Levels/ Triggers | | Action/Response |
|---|---|---|---|---|---|---|---|---|---|---|
| **Negligible reduction to the quantity of water resources reaching the Woronora Reservoir** | *Changes in the quantity of water entering Woronora Reservoir are not significantly different post-mining compared to pre-mining, that are not also occurring in the control catchment(s).* | WaterNSW gauging station on Waratah Rivulet (GS 2132102)<br>Department of Industry - Watergauging station on O'Hares Creek at Wedderburn (GS 213200) (control site)<br>WaterNSW owned gauging station on Woronora River (GS 2132101) (control site) | Surface water flow. | Monthly download of continuous data-logger. | Analysis of measured flow versus modelled flows in Waratah Rivulet using catchment model, specifically:<br>- Monitored flows will be filtered in order to assess low flows (i.e. flows of 1 mm/day or less)[1].<br>- The filtered monitored flows on Waratah Rivulet will be integrated over successive 14 day periods to produce a smoothed set of data for comparison with the corresponding integrated flows (14 day totals) predicted by the modified AWBM model for the Waratah Rivulet[2].<br>- The ratio of filtered monitored flows divided by the modified AWBM predicted flows will be calculated at 14 day intervals commencing at the beginning of the baseline period and advancing beyond the commencement of Longwall 20 secondary extraction. The median of the ratios will be analysed over a sliding window of 1 year.<br>Analysis of measured flow versus modelled flows in Waratah Rivulet, six monthly, within one month of download. | Accuracy of flow measurements which depend on measuring water level and conversion of water level (stage) to flow using a flow versus stage (rating curve).<br>Accuracy of catchment flow modelling. | Baseline data (prior to commencement of longwall 20) is available from the gauging station on Waratah Rivulet from March 2007 to May 2010. Estimated minimum daily flow recorded during baseline period was 0.048 ML/day<br>Baseline data for O'Hares Creek is available over the same period. Estimated minimum daily flow during adopted baseline period was 0.0063 ML/day.<br>Baseline data is available from the gauging station on Woronora River from January 2008. The Woronora River ceased flowing several times at the gauging stations during the baseline period. | Level 1 | The median of the ratios does not fall below the 35th percentile of the baseline data | Continue monitoring.<br>Six monthly reporting. |
| | | | | | | | | Level 2 | The median of the ratios falls below the $35^{th}$ percentile but does not fall below the 20th percentile of the baseline data | Increase the frequency of data analysis to quarterly (until such time that data analysis indicates a return to Level 1).<br>Six monthly reporting. |
| | | | | | | | | Level 3 | The median of the ratios falls below the 20th percentile of the baseline data | Conduct the same analysis of measured flow versus modelled flows for the control catchments, specifically:<br>- The filtered monitored flow rates on O'Hares Creek and Woronora River will be integrated over successive 14 day periods to produce a smoothed set of data for comparison with the corresponding integrated flows (14 day totals) predicted by the modified AWBM models of the same catchments.<br>- The ratio of the filtered monitored flow divided by the modified AWBM predicted flow will be calculated at 14 day intervals commencing at the beginning of the baseline period and advancing beyond the commencement of Longwall 20 secondary extraction. The median of the ratios will be analysed over a sliding window of 1 year.<br>If the same has occurred in a control catchment, continue monitoring and six monthly reporting.<br>If the same has not occurred in a control catchment:<br>• Increase the frequency of data analysis to quarterly (until such time that data analysis indicates a return to Level 1).<br>• Undertake investigation and assess against the performance measure. Report to DP&E, WaterNSW, Department of Industry – Water and OEH within one month of assessment completion.<br>• Consider the need for management measures, in accordance with Sections 8 and 9. |

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

[2] Note, this analysis approach is the same as that conducted for the Longwalls 20-22 and Longwalls 23-27 Water Management Plans. The analysis methodology has been improved by focussing the assessment on changes to low flows.

**Table 19-A**
**Trigger Action Response Plan – Negligible Reduction to the Quality of Water Resources Reaching the Woronora Reservoir**

| Performance Measure | Performance Indicator | Monitoring Site(s) | Parameters | Frequency/ Sample Size | Analysis Methodology | Error Types | Baseline | Significance Levels/Triggers | | Action/Response |
|---|---|---|---|---|---|---|---|---|---|---|
| **Negligible reduction to the quality of water resources reaching the Woronora Reservoir.** | *Changes in the quality of water entering Woronora Reservoir are not significantly different post-mining compared to pre-mining concentrations that are not also occurring at control site WOWQ2.* | Site WRWQ9 on the Waratah Rivulet.<br>Site ETWQ AU on the Eastern Tributary.<br>Control site WOWQ2 on the Woronora River. | Iron (Fe).<br>Manganese (Mn).<br>Aluminium (Al).<br>[Field filtered]. | Monthly. | Water quality data analysed quarterly, following the receipt of laboratory data[1]:<br>• Adjusted baseline mean plus two standard deviations[2, 3] have been calculated for each water quality parameter and are provided in Table 19-B.<br>• Adjusted baseline mean plus one standard deviation[4, 5] has been calculated for each water quality parameter and are provided in Table 19-B.<br>The six month mean metal concentration will also be calculated at the end of each six month review period. | Potential for sampling, laboratory and data management errors. | <u>WRWQ9</u><br>• Fe (0.03 to 0.39 mg/L).<br>• Mn (0.01[6] to 0.069 mg/L).<br>• Al (0.001[6] to 0.15 mg/L).<br><u>ETWQ AU</u><br>• Fe (0.1 to 0.5 mg/L).<br>• Mn (0.005[6] to 0.033 mg/L).<br>• Al (0.03 to 0.11 mg/L).<br><u>WOWQ2</u><br>• Fe (0.05[6] to 1.3 mg/L).<br>• Mn (0.01[6] to 0.1 mg/L).<br>• Al (0.0005[6] to 0.11 mg/L). | Level 1 | Data analysis indicates no water quality parameter exceeds the adjusted baseline mean plus two standard deviations. | Continue monitoring.<br>Six monthly reporting. |
| | | | | | | | | Level 2 | Data analysis indicates any water quality parameter exceeds the adjusted baseline mean plus two standard deviations for one month. | Increase the frequency of data analysis to monthly (until such time that data analysis indicates a return to Level 1).<br>Six monthly reporting. |
| | | | | | | | | Level 3 | Data analysis indicates:<br>• any water quality parameter exceeds the adjusted baseline mean plus two standard deviations for two consecutive months; or<br>• over a three month period the water quality parameter exceeds the adjusted mean plus two standard deviations in the first month, the adjusted mean plus one standard deviation in the next month and the adjusted mean plus two standard deviations in the third month; or<br>• the six month mean exceeds the adjusted baseline mean plus one standard deviation for two consecutive assessment periods (i.e. over two six monthly reports); and<br>• there was not a similar exceedance of the trigger at the control site. | Increase the frequency of data analysis to monthly (until such time that data analysis indicates a return to Level 1).<br>Undertake investigation and assess against the performance measure. Report to DP&E, WaterNSW, Department of Industry – Water and OEH within one month of assessment completion.<br>Consider the need for management measures, in accordance with Sections 8 and 9. |

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

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

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

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

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

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

**Table 19-B**
**Adjusted Baseline Mean plus Standard Deviations for Sites WRWQ9, ETWQ AU and WOWQ2**

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

**Table 20**
**Trigger Action Response Plan – No Connective Cracking Between the Surface and the Mine and Negligible Leakage from Woronora Reservoir**

| Performance Measure | Performance Indicator | Monitoring Site(s) | Parameters | Frequency/ Sample Size | Analysis Methodology | Error Types | Baseline | Significance Levels/ Triggers | | Action/Response |
|---|---|---|---|---|---|---|---|---|---|---|
| **No connective cracking between the surface and the mine** | *Visual inspection does not identify abnormal water flow from the goaf, geological structure, or the strata generally.* | Underground. | Inspections of development workings for water accumulation. | Weekly. | Identification of abnormal water flow from the goaf, geological structure, or the strata generally. | N/A | No abnormal water flow from the goaf, geological structure, or the strata generally | Level 1 | Normal water flow identified from the goaf, geological structure, or the strata generally. | Continue monitoring.<br>Six monthly reporting. |
| | | | | | | | | Level 2 | Abnormal water flow identified from the goaf, geological structure, or the strata generally, however consistent with expected operational conditions. | Increase the frequency of data analysis to daily (until such time that data analysis indicates a return to Level 1).<br>Six monthly reporting. |
| | | | | | | | | Level 3 | Abnormal water flow identified from the goaf, geological structure, or the strata generally, inconsistent with expected operational conditions. | Increase the frequency of data analysis to daily (until such time that data analysis indicates a return to Level 1).<br>Undertake investigation and assess against the performance measure. Report to DP&E, WaterNSW, Department of Industry – Water and OEH within one month of assessment completion.<br>Consider the need for management measures, in accordance with Sections 8 and 9. |
| **No connective cracking between the surface and the mine** | *The 20-day average mine water make does not exceed 1 ML/day.* | Underground | • Metered water reticulated into the mine (mine inflow).<br>• Metered water reticulated out of the mine (mine outflow).<br>• Moisture content into and out of the mine through the mine ventilation system (mine inflow and outflow).<br>• *In-situ* moisture content of the coal (mine inflow).<br>• Moisture content of ROM coal conveyed out of the mine at the drift portal (mine outflow). | • Continuous monitoring, downloaded monthly.<br>• Continuous monitoring, downloaded monthly.<br>• Moisture content will be monitored:<br>- every hour over a 9 hour period on two occasions during a 12 month period;<br>- daily (week day) when possible;<br>- minimum once per week.<br>• Measured during routine channel sampling for coal quality.<br>• Continuous monitoring using an automated moisture scanner, downloaded monthly. | Water make[1] calculated from the difference between total mine inflows and total mine outflows, within one month of download. | Instrumentation precision. | The modelled daily mine inflow to Longwalls 301-303 is predicted to lie in the range from 0.06 ML/day (low-inflow) to 0.6 ML/day (high-inflow), on average[2]. | Level 1 | 20-day average mine water make is less than or equal to 0.5 ML/day. | Continue monitoring.<br>Six monthly reporting. |
| | | | | | | | | Level 2 | 20-day average mine water make is between 0.5 ML/day and 1 ML/day. | Increase the frequency of data analysis to fortnightly (until such time that data analysis indicates a return to Level 1).<br>Six monthly reporting. |
| | | | | | | | | Level 3 | 20-day average mine water make is greater than or equal to 1 ML/day. | Increase the frequency of data analysis to fortnightly (until such time that data analysis indicates a return to Level 1).<br>Undertake investigation and assess against the performance measure. Report to DP&E, WaterNSW, Department of Industry – Water and OEH within one month of assessment completion.<br>Consider the need for management measures, in accordance with Sections 8 and 9. |

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

2 HydroSimulations (2016) *Groundwater Review of Revised Longwalls 301-303 Layout*.

## Table 20 (Continued)
## Trigger Action Response Plan – No Connective Cracking Between the Surface and the Mine and Negligible Leakage from Woronora Reservoir

| Performance Measure | Performance Indicator | Monitoring Site(s) | Parameters | Frequency/ Sample Size | Analysis Methodology | Error Types | Baseline | Significance Levels/ Triggers | | Action/Response |
|---|---|---|---|---|---|---|---|---|---|---|
| **No connective cracking between the surface and the mine** | *Significant departure from the predicted envelope of the vertical potentiometric head profile at Bore 9GGW2B does not occur.* | Bore 9GGW2B | Groundwater pressures/levels | Monthly download of continuous datalogging. | Analysis of vertical head profiles, quarterly, within one month of download | Datalogger instrumentation precision to 1mm; error is +/- 0.5 mm | Predicted profile for longwall panel relevant to longwall status | Level 1 | 9GGW2B Head Profile is consistent with the shape and magnitude of the predicted High Inflow Model Curve[3, 4] | Continue monitoring.<br>Six monthly reporting. |
| | | | | | | | | Level 2 | 9GGW2B Head Profile is consistent with the shape of, and does not lie significantly to the left of the predicted High Inflow Model Curve [3, 4] | Increase the frequency of data analysis to monthly (until such time that data analysis indicates a return to Level 1).<br>Six monthly reporting. |
| | | | | | | | | Level 3 | 9GGW2B Head Profile is inconsistent with the shape of, or lies significantly to the left of the predicted High Inflow Model Curve [3, 4] | Increase the frequency of data analysis to monthly (until such time that data analysis indicates a return to Level 1).<br>Undertake investigation and assess against the performance measure. Report to DP&E, WaterNSW, Department of Industry – Water and OEH within one month of assessment completion.<br>Consider the need for management measures, in accordance with Sections 8 and 9. |
| **No connective cracking between the surface and the mine** | *Significant departure from the predicted envelope of the vertical potentiometric head profile at Bore F6GW3A does not occur.* | Bore F6GW3A | Groundwater pressures/levels | Monthly download of continuous datalogging. | Analysis of vertical head profiles, quarterly, within one month of download | Datalogger instrumentation precision to 1mm; error is +/- 0.5 mm | Predicted profile for longwall panel relevant to longwall status | Level 1 | F6GW3A Head Profile is consistent with the shape and magnitude of the predicted High Inflow Model Curve [3, 4] | Continue monitoring.<br>Six monthly reporting. |
| | | | | | | | | Level 2 | F6GW3A Head Profile is consistent with the shape of, and does not lie significantly to the left of the predicted High Inflow Model Curve [3, 4] | Increase the frequency of data analysis to monthly (until such time that data analysis indicates a return to Level 1).<br>Six monthly reporting. |
| | | | | | | | | Level 3 | F6GW3A Head Profile is inconsistent with the shape of, or lies significantly to the left of the predicted High Inflow Model Curve [3, 4] | Increase the frequency of data analysis to monthly (until such time that data analysis indicates a return to Level 1).<br>Undertake investigation and assess against the performance measure. Report to DP&E, WaterNSW, Department of Industry – Water and OEH within one month of assessment completion.<br>Consider the need for management measures, in accordance with Sections 8 and 9. |
| **No connective cracking between the surface and the mine.**<br>**Negligible leakage from the Woronora Reservoir.** | *The hydraulic gradient to the Woronora Reservoir at full supply level from Bore F6GW4A s reduced by no more than 20% from that measured to 30 June 2017.* | Bore F6GW4A (90.0 m) | Groundwater pressures/levels. | Monthly download of continuous datalogging. | Analysis of water tables, quarterly, within one month of download. | Datalogger instrumentation precision to 1mm; error is +/- 0.5 mm. | F6GW4A > 199.92 m AHD[5] | Level 1 | F6GW4A[6] >= 199.92 m AHD | Continue monitoring.<br>Six monthly reporting. |
| | | | | | | | | Level 2 | F6GW4A[6] < 199.92 m AHD and > 193.71 m AHD | Increase the frequency of data analysis to monthly (until such time that data analysis indicates a return to Level 1).<br>Six monthly reporting. |
| | | | | | | | | Level 3 | F6GW4A[6] =< 193.71 m AHD | Increase the frequency of data analysis to monthly (until such time that data analysis indicates a return to Level 1).<br>Undertake investigation and assess against the performance measures. Report to DP&E, WaterNSW, Department of Industry – Water and OEH within one month of assessment completion.<br>Consider the need for management measures, in accordance with Sections 8 and 9. |

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

4 Note that this trigger would require review and revision for the use of any updated groundwater model.

5 Minimum measurement to 30 June 2017.

6 7-Day Average Potentiometric Head at the mid Hawkesbury Sandstone Piezometer

**Table 20 (Continued)**
**Trigger Action Response Plan – No Connective Cracking Between the Surface and the Mine and Negligible Leakage from Woronora Reservoir**

| Performance Measure | Performance Indicator | Monitoring Site(s) | Parameters | Frequency/ Sample Size | Analysis Methodology | Error Types | Baseline | Significance Levels/ Triggers | | Action/Response |
|---|---|---|---|---|---|---|---|---|---|---|
| **No connective cracking between the surface and the mine.** **Negligible leakage from the Woronora Reservoir.** | *The hydraulic gradient to the Woronora Reservoir at full supply level from Bore PHGW2A is reduced by no more than 20% from that measured to 30 June 2017.* | Bore PHGW2A (97.5 m) | Groundwater pressures/levels. | Monthly download of continuous datalogging. | Analysis of water tables quarterly, within one month of download. | Datalogger instrumentation precision to 1mm; error is +/- 0.5 mm. | PHGW2A > 186.92 m AHD[5] | Level 1 | PHGW2A[6] >= 186.92 m AHD | Continue monitoring. Six monthly reporting. |
| | | | | | | | | Level 2 | PHGW2A[6] < 186.92 m AHD and > 183.31 m AHD | Increase the frequency of data analysis to monthly (until such time that data analysis indicates a return to Level 1). Six monthly reporting. |
| | | | | | | | | Level 3 | PHGW2A[6] =< 183.31 m AHD | Increase the frequency of data analysis to monthly (until such time that data analysis indicates a return to Level 1). Undertake investigation and assess against the performance measures. Report to DP&E, WaterNSW, Department of Industry – Water and OEH within one month of assessment completion. Consider the need for management measures, in accordance with Sections 8 and 9. |
| **Negligible leakage from the Woronora Reservoir.** | *The hydraulic gradient to the Woronora Reservoir at full supply level from Bore 9GGW2B is reduced by no more than 40% from that measured to 30 June 2017.* | Bore 9GGW2B (80.3 m) | Groundwater pressures/levels. | Monthly download of continuous datalogging. | Analysis of water tables, quarterly, within one month of download. | Datalogger instrumentation precision to 1mm; error is +/- 0.5 mm. | 9GGW2B > 181.38 m AHD[5] | Level 1 | 9GGW2B[6] >= 181.38 m AHD | Continue monitoring. Six monthly reporting. |
| | | | | | | | | Level 2 | 9GGW2B[6] < 181.38 m AHD and > 176.38 m AHD | Increase the frequency of data analysis to monthly (until such time that data analysis indicates a return to Level 1). Six monthly reporting. |
| | | | | | | | | Level 3 | 9GGW2B[6] =< 176.38 m AHD | Increase the frequency of data analysis to monthly (until such time that data analysis indicates a return to Level 1). Undertake investigation and assess against the performance measure. Report to DP&E, WaterNSW, Department of Industry – Water and OEH within one month of assessment completion. Consider the need for management measures, in accordance with Sections 8 and 9. |
| **Negligible leakage from the Woronora Reservoir.** | *The hydraulic gradient to the Woronora Reservoir at full supply level from Bore 9EGW2A is reduced by no more than 20% from that measured to 30 June 2017.* | Bore 9EGW2A[7] (107.5 m) | Groundwater pressures/levels. | Monthly download of continuous datalogging. | Analysis of water tables quarterly, within one month of download. | Datalogger instrumentation precision to 1mm; error is +/- 0.5 mm. | 9EGW2A > 186.32 m AHD[5] | Level 1 | 9EGW2A[6] >= 186.32 m AHD | Continue monitoring. Six monthly reporting. |
| | | | | | | | | Level 2 | 9EGW2A[6] < 186.32 m AHD and > 182.83 m AHD | Increase the frequency of data analysis to monthly (until such time that data analysis indicates a return to Level 1). Six monthly reporting. |
| | | | | | | | | Level 3 | 9EGW2A[6] =< 182.83 m AHD | Increase the frequency of data analysis to monthly (until such time that data analysis indicates a return to Level 1). Undertake investigation and assess against the performance measure. Report to DP&E, WaterNSW, Department of Industry – Water and OEH within one month of assessment completion. Consider the need for management measures, in accordance with Sections 8 and 9. |
| **Negligible leakage from the Woronora Reservoir.** | *The hydraulic gradient to the Woronora Reservoir at full supply level from Bore PM02 is reduced by no more than 20% from that measured to 30 June 2017.* | Bore PM02 (100 m) | Groundwater pressures/levels. | Monthly download of continuous datalogging. | Analysis of water tables, quarterly, within one month of download. | Datalogger instrumentation precision to 1mm; error is +/- 0.5 mm. | PM02 > 183.86 m AHD[5] | Level 1 | PM02[6] >= 183.86 m AHD | Continue monitoring. Six monthly reporting. |
| | | | | | | | | Level 2 | PM02[6] < 183.86 m AHD and > 180.86 m AHD | Increase the frequency of data analysis to monthly (until such time that data analysis indicates a return to Level 1). Six monthly reporting. |
| | | | | | | | | Level 3 | PM02[6] =< 180.86 m AHD | Increase the frequency of data analysis to monthly (until such time that data analysis indicates a return to Level 1). Undertake investigation and assess against the performance measure. Report to DP&E, WaterNSW, Department of Industry – Water and OEH within one month of assessment completion. Consider the need for management measures, in accordance with Sections 8 and 9. |

5 Minimum measurement to 30 June 2017.

6 7-Day Average Potentiometric Head at the mid Hawkesbury Sandstone Piezometer

7 Subject to change following installation of the new multi-level piezometer proximal to 9EGW2A and two shallow monitoring holes.

**Table 20 (Continued)**
**Trigger Action Response Plan – No Connective Cracking Between the Surface and the Mine and Negligible Leakage from Woronora Reservoir**

| Performance Measure | Performance Indicator | Monitoring Site(s) | Parameters | Frequency/ Sample Size | Analysis Methodology | Error Types | Baseline | Significance Levels/ Triggers | | Action/Response |
|---|---|---|---|---|---|---|---|---|---|---|
| **Negligible leakage from the Woronora Reservoir.** | *The water level at bore T2 is greater than 170. 0 m*[11] | Bore T2 | Groundwater levels | Monthly download of continuous datalogging. | Analysis of water tables quarterly, within one month of download. | Datalogger instrumentation precision to 1mm; error is +/- 0.5 mm | T2 = 171.09 m AHD[8] | Level 1 | T2 >= 171.0 m AHD | Continue monitoring.<br>Six monthly reporting. |
| | | | | | | | | Level 2 | T2 < 171.0 m AHD and > 170. 0 m AHD[9] | Increase the frequency of data analysis to monthly (until such time that data analysis indicates a return to Level 1).<br>Six monthly reporting. |
| | | | | | | | | Level 3 | T2 =< 170. 0 m AHD[9] | Increase the frequency of data analysis to monthly (until such time that data analysis indicates a return to Level 1).<br>Undertake investigation and assess against the performance measure. Report to DP&E, WaterNSW, Department of Industry – Water and OEH within one month of assessment completion.<br>Consider the need for management measures, in accordance with Sections 8 and 9. |
| **Negligible leakage from the Woronora Reservoir.** | *The water level at bore T3 is greater than 171.8 m*[11] | Bore T3 | Groundwater levels | Monthly download of continuous datalogging. | Analysis of water tables quarterly, within one month of download. | Datalogger instrumentation precision to 1mm; error is +/- 0.5 mm | T3 = 172.83 m AHD[8] | Level 1 | T3 >= 172.8 m AHD | Continue monitoring.<br>Six monthly reporting. |
| | | | | | | | | Level 2 | T3 < 172.8 m AHD and > 171.8 m AHD[9] | Increase the frequency of data analysis to monthly (until such time that data analysis indicates a return to Level 1).<br>Six monthly reporting. |
| | | | | | | | | Level 3 | T3 =< 171.8 m AHD[9] | Increase the frequency of data analysis to monthly (until such time that data analysis indicates a return to Level 1).<br>Undertake investigation and assess against the performance measure. Report to DP&E, WaterNSW, Department of Industry – Water and OEH within one month of assessment completion.<br>Consider the need for management measures, in accordance with Sections 8 and 9. |
| **Negligible leakage from the Woronora Reservoir.** | *The hydraulic gradient from transect bore T5 to bore T3 is reduced by no more than 10% from that measured on 30 June 2017.* | Bores T3 and T5 | Groundwater levels | Monthly download of continuous datalogging. | Analysis of water tables quarterly, within one month of download. | Datalogger instrumentation precision to 1mm; error is +/- 0.5 mm | T5-T3 = 17.92 m[10] | Level 1 | T5-T3 >= 17.92 m | Continue monitoring.<br>Six monthly reporting. |
| | | | | | | | | Level 2 | T5-T3 < 17.92 m and > 16.13 m | Increase the frequency of data analysis to monthly (until such time that data analysis indicates a return to Level 1).<br>Six monthly reporting. |
| | | | | | | | | Level 3 | T5-T3 =< 16.13 m | Increase the frequency of data analysis to monthly (until such time that data analysis indicates a return to Level 1).<br>Undertake investigation and assess against the performance measure. Report to DP&E, WaterNSW, Department of Industry – Water and OEH within one month of assessment completion.<br>Consider the need for management measures, in accordance with Sections 8 and 9. |

8 Minimum measurement to 30 June 2017.

9 Minimum measurement to 30 June 2017 less 1 m.

10 30 June 2017 measurement.

11 The performance indicators and TARPs for bores T2 and T3 will be revised in future revisions of the Water Management Plan as the current performance indicators and TARPs do not take into consideration climatic changes in the water level of the Woronora Reservoir. The connective cracking and negligible leakage performance indicators and TARPs will also be reviewed in this regard.

**Table 21**
**Trigger Action Response Plan – Negligible Reduction to the Quality of Water Resources in the Woronora Reservoir**

| Performance Measure | Performance Indicator | Monitoring Site(s) | Parameters | Frequency/ Sample Size | Analysis Methodology | Error Types | Baseline | Significance Levels/ Triggers | | Action/Response |
|---|---|---|---|---|---|---|---|---|---|---|
| **Negligible reduction in the water quality of Woronora Reservoir.** | *Changes in the quality of water in the Woronora Reservoir are not significantly different post-mining compared to pre-mining concentrations.* | Woronora Reservoir (site DW01) (subject to data availability from WaterNSW)<br>Nepean Reservoir (subject to data availability from WaterNSW)<br>Cataract Reservoir (subject to data availability from WaterNSW) | Total Iron (Fe).<br>Total Manganese (Mn).<br>Total Aluminium (Al). | Sampling frequency is variable. | Water quality data analysed annually, following the receipt of data from WaterNSW.<br>Water quality parameters, measured in the same location on the same day will be geometrically averaged.<br>The parameter records will be interpolated to provide daily records.<br>Concentration exceedance duration curves will be calculated for each parameter by determining the concentration exceeded at each location by percentages of days of the year covering the full range from 0% to 100%, at 5% intervals.<br>Baseline data[1] will be analysed in an annual format to determine concentration exceeded with an estimated average recurrence interval (ARI[2]) curve of 20 years by percentages of days in the year from 0% to 100%. For each percentage of time selected from this range, an ARI curve will be calculated by fitting a log Generalised Extreme Value distribution to the concentration exceeded each year of the baseline record by that percentage of days.<br>For each water quality parameter, the concentration exceedance curve for the current year of monitoring and the 20 year ARI exceedance curve calculated from the baseline records will be plotted on a graph. | Potential for sampling, laboratory and data management errors. | Baseline 10 and 20 year ARI exceedance curve | Level 1 | The current year's duration exceedance curve for a water quality parameter in Woronora Reservoir (total iron, total manganese and total aluminium) is below the baseline 10 year ARI exceedance curve for any range of the duration percentages from 0% to 75%. | Continue monitoring.<br>Annual reporting. |
| | | | | | | | | Level 2 | The current year's duration exceedance curve for a water quality parameter in Woronora Reservoir (total iron, total manganese and total aluminium) is above the baseline 10 year ARI but below the baseline 20 year ARI exceedance curve for any range of the duration percentages from 0% to 75%. | Plot and qualitatively assess the Woronora Reservoir, Nepean Reservoir and Cataract Reservoir water quality data every six months (until such time that data analysis indicates a return to Level 1).<br>Annual reporting. |
| | | | | | | | | Level 3 | The current year's duration exceedance curve for a water quality parameter in Woronora Reservoir (total iron, total manganese and total aluminium) is above the baseline 20 year ARI exceedance curve for any range of the duration percentages from 0% to 75%. | Plot and qualitatively assess the data from the Nepean Reservoir and Cataract Reservoir.<br>Undertake investigation and assess against the performance measure. Report to DP&E, WaterNSW, Department of Industry – Water and OEH within one month of assessment completion.<br>Consider the need for management measures, in accordance with Sections 8 and 9. |

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

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

## Table 22
## Trigger Action Response Plan – Negligible Environmental Consequences on Waratah Rivulet

| Performance Measure | Performance Indicator | Monitoring Site(s) | Parameters | Frequency/ Sample Size | Analysis Methodology | Error Types | Baseline | Significance Levels/ Triggers | | Action/Response |
|---|---|---|---|---|---|---|---|---|---|---|
| **No Diversion of Flows, No Change in the Natural Drainage Behaviour** | | | | | | | | | | |
| **Negligible environmental consequences (that is, no diversion of flows, no change in the natural drainage behaviour of pools, minimal iron staining, and minimal gas releases) on the Waratah Rivulet between the full supply level of the Woronora Reservoir and the maingate of Longwall 23 (upstream of Pool P).** | *No change to the natural drainage behaviour of Pools P, Q, R, S, T, U, V and W.* | Pools P to W on Waratah Rivulet.<br>Control pools on the Woronora River. | Streambed cracking and drainage behaviour. | Monthly, during download of pool water level data. | Visual inspections of Pools P to W for streambed cracking and changes to the natural drainage behaviour. | Limitations of visual observations. | No mine-induced surface cracking present at Pools P, Q, R, S, T, U, V or W within the stream bed or rock bar.<br>Pools P and T flow through and below rock bars. Pools Q, R and S terminate at rock bars.<br>Pools U and W terminate in a boulder field (i.e. no flow over a rock bar).<br>Pool V terminates in a rock bar characterised by partial flow over the rock bar and partial flow through and below the rock bar. | Level 1 | No mine-induced surface cracking or impacts to natural drainage behaviour observed | Continue monitoring.<br>Six monthly reporting. |
| | | | | | | | | Level 2 | Mine-induced surface cracking observed.<br>No impacts to natural drainage behaviour observed. | Initiate survey of the relevant subsidence cross line.<br>Assess pool water level data.<br>Six monthly reporting. |
| | | | | | | | | Level 3 | There appear to be impacts to natural drainage behaviour such that:<br>- a pool does not continue to flow over, through and/or below the rock bars (where relevant); or<br>- surface flow is not evident along the length of Pools P or T prior to flowing through/below the rock bars;<br>- surface flow is not evident along the length of Pools Q, R or S prior to flowing over the rock bars;<br>- surface flow is not evident along the length of Pool V prior to flowing over/through/below the rock bar; and<br>- surface flow is not evident along the length of Pools U or W prior to flowing through the downstream boulder field. | Initiate survey of the relevant subsidence cross line.<br>Assess pool water level data.<br>Undertake investigation and assess against the performance measure. Report to DP&E, WaterNSW, Department of Industry – Water and OEH within one month of assessment completion.<br>Consider the need for management measures, in accordance with Sections 8 and 9. |
| **Negligible environmental consequences (that is, no diversion of flows, no change in the natural drainage behaviour of pools, minimal iron staining, and minimal gas releases) on the Waratah Rivulet between the full supply level of the Woronora Reservoir and the maingate of Longwall 23 (upstream of Pool P).** | *Analysis of water level data for Pools P, T, U, V and W indicates the water level is at or above the pool's previous minimum.* | Pools P, T, U, V and W on Waratah Rivulet.<br>Control pools on the Woronora River. | Pool water level. | Monitored continuously, with a data logger and downloaded monthly. | Analysis of Pools P, T, U, V and W water level data against the pool's previous minimum, quarterly, within one month of download. | Water level sensor precision, data logger malfunction and download error. | Pool water level hydrographs to 30 June 2017[1] | Level 1 | The water level in Pools P, T, U, V or W has not been below the pool's previous minimum. | Continue monitoring.<br>Six monthly reporting. |
| | | | | | | | | Level 2 | The water level in Pools P, T, U, V or W has been below the pool's previous minimum, however, is considered to be due to an error type. | Increase the frequency of data analysis to monthly (until such time that data analysis indicates a return to Level 1).<br>Six monthly reporting. |
| | | | | | | | | Level 3 | The water level in Pools P, T, U, V or W has been below the pool's previous minimum and does not appear to be due to an error type; and the same is not occurring in control pool(s). | Increase the frequency of data analysis to monthly (until such time that data analysis indicates a return to Level 1).<br>Initiate survey of the relevant subsidence cross line.<br>Undertake investigation (including assessment of control pools) and assess against the performance measure. Report to DP&E, WaterNSW, Department of Industry – Water and OEH within one month of assessment completion.<br>Consider the need for management measures, in accordance with Sections 8 and 9. |

1 Hydro Engineering & Consulting (2017) Metropolitan Coal Surface Water Review 1 January to 30 June 2017.

**Table 22 (Continued)**
**Trigger Action Response Plan – Negligible Environmental Consequences on Waratah Rivulet**

| Performance Measure | Performance Indicator | Monitoring Site(s) | Parameters | Frequency/ Sample Size | Analysis Methodology | Error Types | Baseline | Significance Levels/ Triggers | | Action/Response |
|---|---|---|---|---|---|---|---|---|---|---|
| **No Diversion of Flows, No Change in the Natural Drainage Behaviour (Continued)** | | | | | | | | | | |
| **Negligible environmental consequences (that is, no diversion of flows, no change in the natural drainage behaviour of pools, minimal iron staining, and minimal gas releases) on the Waratah Rivulet between the full supply level of the Woronora Reservoir and the maingate of Longwall 23 (upstream of Pool P)** | *Analysis of water level data for Pools Q, R and S indicates the water levels are above that required to maintain water over the downstream rock bar.* | Pools Q, R and S on Waratah Rivulet.<br>Control pools on the Woronora River. | Pool water level. | Monitored continuously, with a data logger and downloaded monthly. | Analysis of Pools Q, R and S water level data against the level required to maintain water over the downstream rock bar, quarterly, within one month of download. | Water level sensor precision, data logger malfunction and download error. | Pool water level hydrographs to 30 June 2017[1] | Level 1 | The water level in Pools Q, R or S has been above that required to maintain water over the downstream rock bar. | Continue monitoring.<br>Six monthly reporting. |
| | | | | | | | | Level 2 | The water level in Pools Q, R or S has been below that required to maintain water over the downstream rock bar, however, appears to be due to an error type. | Increase the frequency of data analysis to monthly (until such time that data analysis indicates a return to Level 1).<br>Six monthly reporting. |
| | | | | | | | | Level 3 | The water level in Pools Q, R or S has been below that required to maintain water over the downstream rock bar and does not appear to be due to an error type and the same is not occurring in control pool(s). | Increase the frequency of data analysis to monthly (until such time that data analysis indicates a return to Level 1).<br>Initiate survey of the relevant subsidence cross line.<br>Undertake investigation (including assessment of control pools) and assess against the performance measure. Report to DP&E, WaterNSW, Department of Industry – Water and OEH within one month of assessment completion.<br>Consider the need for management measures, in accordance with Sections 8 and 9. |
| **Minimal Iron Staining** | | | | | | | | | | |
| **Negligible environmental consequences (that is, no diversion of flows, no change in the natural drainage behaviour of pools, minimal iron staining, and minimal gas releases) on the Waratah Rivulet between the full supply level of the Woronora Reservoir and the maingate of Longwall 23 (upstream of Pool P)** | *Visual inspection of the Waratah Rivulet from Pool P to the full supply level of the Woronora Reservoir does not show significant changes in the extent or nature of iron staining that isn't also occurring in the Woronora River (control site).* | Waratah Rivulet, from Pool P to the full supply level of the Woronora Reservoir. | Nature and extent of iron staining | Monthly | Visual inspections of Waratah Rivulet | Subjective nature of visual observations. | Iron staining present (dark in colour [crystalline goethite]), apparent in the baseline stream mapping photographs.<br>Natural seeps and associated iron staining also occur (as recorded by baseline mapping). | Level 1 | The extent or nature of iron staining in the Waratah Rivulet from Pool P to the full supply level of the Woronora Reservoir has not changed. | Continue monitoring.<br>Six monthly reporting. |
| | | | | | | | | Level 2 | The extent or nature of iron staining in the Waratah Rivulet from Pool P to the full supply level of the Woronora Reservoir has changed significantly, as a result of climatic conditions. | Record the nature and extent of the changes in the Waratah Rivulet.<br>Inspect the nature and extent of iron staining on the Woronora River (control site).<br>Increase the frequency of visual inspections on the Waratah Rivulet and Woronora River to weekly (until such time that data analysis indicates a return to Level 1).<br>Six monthly reporting. |
| | | | | | | | | Level 3 | The extent or nature of iron staining in the Waratah Rivulet from Pool P to the full supply level of the Woronora Reservoir has changed significantly, not as a result of climatic conditions (i.e. a similar change has not occurred in the Woronora River [control site]). | Record the nature and extent of the changes in the Waratah Rivulet.<br>Inspect the nature and extent of iron staining on the Woronora River (control site).<br>Increase the frequency of visual inspections on the Waratah Rivulet and Woronora River to weekly (until such time that data analysis indicates a return to Level 1).<br>Undertake investigation and assess against the performance measure. Report to DP&E, WaterNSW, Department of Industry – Water and OEH within one month of assessment completion.<br>Consider the need for management measures, in accordance with Sections 8 and 9. |

[1] Hydro Engineering & Consulting (2017) Metropolitan Coal Surface Water Review 1 January to 30 June 2017.

**Table 22 (Continued)**
**Trigger Action Response Plan – Negligible Environmental Consequences on Waratah Rivulet**

| Performance Measure | Performance Indicator | Monitoring Site(s) | Parameters | Frequency/ Sample Size | Analysis Methodology | Error Types | Baseline | Significance Levels/ Triggers | | Action/Response |
|---|---|---|---|---|---|---|---|---|---|---|
| **Minimal Gas Releases** | | | | | | | | | | |
| **Negligible environmental consequences (that is, no diversion of flows, no change in the natural drainage behaviour of pools, minimal iron staining, and minimal gas releases) on the Waratah Rivulet between the full supply level of the Woronora Reservoir and the maingate of Longwall 23 (upstream of Pool P)** | *Gas releases in Waratah Rivulet from Pool P to the full supply level of the Woronora Reservoir have not increased beyond those observed up to the commencement of Longwall 301 extraction.* | Waratah Rivulet, from Pool P to the full supply level of the Woronora Reservoir. | Free Carbon Dioxide as $CO_2$ (mg/L)<br>Methane (mg/L) | Visual inspections for gas releases monthly.<br>Weekly at pools that have been observed with gas releases, until no gas releases have been observed at the pool for three consecutive weeks. | Visual inspections, and where gas releases occur, water quality sampling.<br>Analysis of water quality results, quarterly, within one month of the receipt of laboratory results. | <u>Free Carbon Dioxide as $CO_2$ (mg/L)</u><br>ALS Method APHA 4500 $CO_2$-D Detection limit is 1 mg/L[3].<br><u>Methane (mg/L)</u><br>ALS Method EPO33: Methane Detection limit is 0.01 mg/L[4]. | No gas releases observed in Waratah Rivulet from Pool P to the full supply level of the Woronora Reservoir prior to the mining of Longwall 20.<br>Pool P - gas releases observed in February 2014; May 2014 to February 2015; May and June 2015; September 2015 to June 2017.<br>Pool U – gas releases observed in August 2016 to June 2017.<br>Pool W – gas releases observed in January to May 2016; October 2016.<br>Assessment of gas releases in pools to 30 June 2017 indicates the performance measure has been met. | Level 1 | Free carbon dioxide concentrations are equal to or less than 4 mg/L[1] in Waratah Rivulet pools from Pool P to the full supply level of the Woronora Reservoir.<br>Methane concentrations are equal to or less than 0.159 mg/L[1] in Waratah Rivulet pools from Pool P to the full supply level of the Woronora Reservoir. | Continue monitoring.<br>Six monthly reporting. |
| | | | | | | | | Level 2 | Free carbon dioxide concentrations are above 4 mg/L and equal to or less than 13 mg/L[2] in Waratah Rivulet pools from Pool P to the full supply level of the Woronora Reservoir.<br>Methane concentrations are above 0.159 mg/L and equal to or less than 0.478 mg/L[2] in Waratah Rivulet pools from Pool P to the full supply level of the Woronora Reservoir. | Increase the frequency of data analysis to monthly in pools subject to gas releases (until such time that data analysis indicates a return to Level 1).<br>Six monthly reporting. |
| | | | | | | | | Level 3 | Free carbon dioxide concentrations are above 13 mg/L in Waratah Rivulet pools from Pool P to the full supply level of the Woronora Reservoir.<br>Methane concentrations are above 0.478 mg/L in Waratah Rivulet pools from Pool P to the full supply level of the Woronora Reservoir. | Undertake investigation and assess against the performance measure. Report to DP&E, WaterNSW, Department of Industry – Water and OEH within one month of assessment completion.<br>Consider the need for management measures, in accordance with Sections 8 and 9. |

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

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

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

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

**Table 23**
**Trigger Action Response Plan – Negligible Environmental Consequences on Eastern Tributary**

| Performance Measure | Performance Indicator | Monitoring Site(s) | Parameters | Frequency/ Sample Size | Analysis Methodology | Error Types | Baseline | Significance Levels/ Triggers | | Action/Response |
|---|---|---|---|---|---|---|---|---|---|---|
| **No Diversion of Flows, No Change in the Natural Drainage Behaviour** | | | | | | | | | | |
| **Negligible environmental consequences over at least 70% of the stream length (that is, no diversion of flows, no change in the natural drainage behaviour of pools, minimal iron staining, and minimal gas releases) on the Eastern Tributary between the full supply level of the Woronora Reservoir and the maingate of Longwall 26**[1] | *No change to the natural drainage behaviour of Pools ETAS, ETAT and ETAU.* | Eastern Tributary between the full supply level of the Woronora Reservoir and the maingate of Longwall 26 | Stream cracking and drainage behaviour. | Monthly when Longwalls 301 -303 are not within 400 m of the Eastern Tributary.<br>Weekly when Longwalls 301 -303 are within 400 m of the Eastern Tributary. | Visual inspections of the Eastern Tributary between the full supply level of the Woronora Reservoir and the maingate of Longwall 26, for stream cracking and changes to natural drainage behaviour. | Limitations of visual observations | No mine-induced surface cracking observed to date at Pools ETAS or ETAT.<br>Two separate cracks at downstream end of rock bar ETAU. Crack 1; approximately 2m in length and 1-5mm wide, Crack 2; approximately 3m in length and 1-7mm wide (with a 150 mm x 80 mm section sheared).<br>Pool ETAS is a rock bar controlled pool. Water enters the pool as surface flow from boulderfield ETAR. The downstream rock bar is permeable (allowing both underflow and surface flow), and appears to be mainly detached blocks and boulders. Due to the nature of rock bar ETAS, Pool ETAS and Pool ETAT typically sit at the same level.<br>Pool ETAT is a rock bar controlled pool. Water enters the pool as surface flow or underflow through rock bar ETAS. The downstream rock bar is effectively impermeable.<br>Pool ETAU flows through Eastern Tributary gauging station, over a rock bar/waterfall | Level 1 | No mine-induced surface cracking at Pool ETAS or Pool ETAT; no increase in previous cracking at Pool ETAU.<br>No impacts to natural drainage behaviour observed. | Continue monitoring.<br>Six monthly reporting. |
| | | | | | | | | Level 2 | Mine-induced surface cracking observed at Pool ETAS or Pool ETAT, or increase observed in previous cracking at Pool ETAU.<br>No impacts to natural drainage behaviour observed. | Assess the monitoring results from the relevant subsidence cross lines (ETAT and ETAU).<br>Six monthly reporting. |
| | | | | | | | | Level 3 | There appear to be impacts to natural drainage behaviour such that there is not continual surface flow along the length of Pools ETAS, ETAT or ETAU. | Assess the monitoring results from the relevant subsidence cross lines.<br>Assess pool water level data for ETAU.<br>Undertake investigation and assess against the performance measure. Report to DP&E, WaterNSW, Department of Industry – Water and OEH within one month of assessment completion.<br>Consider the need for management measures, in accordance with Sections 8 and 9. |
| **Negligible environmental consequences over at least 70% of the stream length (that is, no diversion of flows, no change in the natural drainage behaviour of pools, minimal iron staining, and minimal gas releases) on the Eastern Tributary between the full supply level of the Woronora Reservoir and the maingate of Longwall 26**[1] | *Analysis of water level data for Pool ETAU indicates the water levels are above that required to maintain water over the downstream rock bar.* | Pool ETAU on the Eastern Tributary. | Pool water level. | Monitored continuously, with a data logger and downloaded monthly. | Analysis of Pool ETAU water level data against the level required to maintain water over the downstream rock bar, quarterly, within one month of download. | Water level sensor precision, Data logger malfunction and download error. | Pool water level hydrographs to 30 June 2017[2] | Level 1 | The water level in Pool ETAU have been above that required to maintain water over the downstream rock bar[3]. | Continue monitoring.<br>Six monthly reporting. |
| | | | | | | | | Level 2 | The water level in Pool ETAU has been below that required to maintain water over the downstream rock bar, however, appears to be due to an error type [3]. | Increase the frequency of data analysis to monthly (until such time that data analysis indicates a return to Level 1).<br>Six monthly reporting. |
| | | | | | | | | Level 3 | The water level in Pool ETAU has been below that required to maintain water over the downstream rock bar and does not appear to be due to an error type [3]. | Increase the frequency of data analysis to monthly (until such time that data analysis indicates a return to Level 1).<br>Assess the monitoring results from the Pool ETAU subsidence cross line.<br>Undertake investigation and assess against the performance measure. Report to DP&E, WaterNSW, Department of Industry – Water and OEH within one month of assessment completion.<br>Consider the need for management measures, in accordance with Sections 8 and 9. |

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

[2] Hydro Engineering & Consulting (2017) Metropolitan Coal Surface Water Review 1 January to 30 June 2017.

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

**Table 23 (Continued)**
**Trigger Action Response Plan – Negligible Environmental Consequences on Eastern Tributary**

| Performance Measure | Performance Indicator | Monitoring Site(s) | Parameters | Frequency/ Sample Size | Analysis Methodology | Error Types | Baseline | Significance Levels/ Triggers | | Action/Response |
|---|---|---|---|---|---|---|---|---|---|---|
| **No Diversion of Flows, No Change in the Natural Drainage Behaviour** | | | | | | | | | | |
| **Negligible environmental consequences over at least 70% of the stream length (that is, no diversion of flows, no change in the natural drainage behaviour of pools, minimal iron staining, and minimal gas releases) on the Eastern Tributary between the full supply level of the Woronora Reservoir and the maingate of Longwall 26**[1] | *Observed total closure at cross line ETAT and cross line ETAU is less than the predicted total closure.* | Cross lines ETAT and ETAU on the Eastern Tributary. | Observed total valley closure (mm)<br>Predicted total valley closure (mm) | Cross lines at Pools ETAT[1] and ETAU monitored at the following retreating face positions:<br>Longwall 302 – 1,000 m, 500 m, 300 m, 200 m, 100 m and end of panel; and<br>Longwall 303 - 1,000 m, 750 m, 500 m, 400 m, 300 m, 250 m, 200 m, 150 m, 100 m, 50 m and end of panel. | Comparison of observed total valley closure at cross lines ETAT and ETAU with predicted total valley closure at Pools ETAT and ETAU[2], within 21 days of receipt of subsidence monitoring data. | Survey accuracy of ±5 mm for relative horizontal movements.<br>Error types include operator errors (e.g. instrument/ reflector set up, logging and satellite lock times), satellite coverage (e.g. reduced in base of valleys), and instrumentation sensitivity | Pool ETAT and Pool ETAU predicted to have been subject to some valley closure as a result of Longwalls 20-27[3] and Longwall 301[4].<br>Pool ETAS is a rock bar controlled pool. Water enters the pool as surface flow from boulderfield ETAR. The downstream rock bar is permeable (allowing both underflow and surface flow), and appears to be mainly detached blocks and boulders. Due to the nature of rock bar ETAS, Pool ETAS and Pool ETAT typically sit at the same level.<br>Pool ETAT is a rock bar controlled pool. Water enters the pool as surface flow or underflow through rock bar ETAS. The downstream rock bar is effectively impermeable.<br>Pool ETAU flows through Eastern Tributary gauging station, over a rock bar/waterfall. | Level 1 | Observed total valley closure:<br>• at cross line ETAT is:<br>− less than or equal to 30 mm during LW302; and<br>− less than or equal to125 mm during LW303.<br>• at cross line ETAU is:<br>− less than or equal to 30 mm during LW302; and<br>− less than or equal to 120 mm during LW303. | Continue monitoring.<br>Six monthly reporting. |
| | | | | | | | | Level 2 | Observed total valley closure:<br>• at cross line ETAT is:<br>− greater than 30 mm during LW302; and/or<br>− greater than 25 mm during LW303.<br>• at cross line ETAU is:<br>− greater than 30 mm during LW302; and/or<br>− greater than 120 mm during LW303.<br>however, appears to be due to an error type. | Increase the frequency of data analysis to within 14 days of receipt of subsidence monitoring data (until such time that data analysis indicates a return to Level 1).<br>Six monthly reporting. |
| | | | | | | | | Level 3 | Observed total valley closure:<br>• at cross line ETAT is:<br>− greater than 30 mm during LW302; and/or<br>− greater than 25 mm during LW303.<br>• at cross line ETAU is:<br>− greater than 30 mm during LW302; and/or<br>− greater than 120 mm during LW303.<br>and does not appear to be due to an error type. | Increase the frequency of data analysis to within 14 days of receipt of subsidence monitoring data (until such time that data analysis indicates a return to Level 1).<br>Assess the results from the Pool ETAT and ETAU visual inspection and water level monitoring.<br>Undertake investigation[5] and report to DP&E, WaterNSW, Department of Industry – Water and OEH within one month of assessment completion. |

1 As Pools ETAS and ETAT are hydraulically connected (separated by a small area of detached block and boulders, with underflow) and Pool ETAS itself is situated immediately adjacent to a rock ledge approximately 8 m in height, Metropolitan Coal will not install a cross line at Pool ETAS. Rather, the cross line at the controlling rock bar ETAT will provide closure information relevant to both Pool ETAS and Pool ETAT.

2 Predicted total valley closure represents the full valley profile. Observed total closure represents a portion of the base of the valley.

3 Predicted total valley closure for Pools ETAT and ETAU as a result of Longwalls 20-27 is less than 10 mm, based on survey accuracy for relative horizontal movement of ±5 mm.

4 Predicted total valley closure for Pools ETAT and ETAU as a result of Longwall 301 is less than 10 mm, based on survey accuracy for relative horizontal movement of ±5 mm. It is noted that monitoring cross lines for Pools ETAT and ETAU were established after the completion of Longwall 27 and prior to the commencement of Longwall 301.

5 It should be noted that while data is available for subsidence impacts to rock bars/pool drainage behaviour associated with predicted total valley closure, data is not available for subsidence impacts to rock bars/pool drainage behaviour associated with observed total closure.

## Table 23 (Continued)
## Trigger Action Response Plan – Negligible Environmental Consequences on Eastern Tributary

| Performance Measure | Performance Indicator | Monitoring Site(s) | Parameters | Frequency/ Sample Size | Analysis Methodology | Error Types | Baseline | Significance Levels/ Triggers | | Action/Response |
|---|---|---|---|---|---|---|---|---|---|---|
| **Minimal Iron Staining** | | | | | | | | | | |
| **Negligible environmental consequences over at least 70% of the stream length (that is, no diversion of flows, no change in the natural drainage behaviour of pools, minimal iron staining, and minimal gas releases) on the Eastern Tributary between the full supply level of the Woronora Reservoir and the maingate of Longwall 26**[1] | N/A | Eastern Tributary between the full supply level of the Woronora Reservoir and the maingate of Longwall 26 | Nature and extent of iron staining | Monthly when Longwalls 301 -303 are not within 400 m of the Eastern Tributary.<br>Weekly when Longwalls 301 -303 are within 400 m of the Eastern Tributary. | Visual inspections of Eastern Tributary. | Subjective nature of visual observations. | On 14 October 2016, Metropolitan Coal reported the exceedance of the Eastern Tributary performance measure in relation to iron staining to the DP&E and other relevant agencies.<br>Iron staining/flocculent is present at a number of stream features between the maingate of Longwall 26 and the full supply level of the Woronora Reservoir. | N/A | N/A | Metropolitan Coal to monitor the nature and extent of iron staining on the Eastern Tributary during the mining of Longwalls 301- 303.<br>Metropolitan Coal to implement contingency measures (stream remediation measures) in accordance with the Project Approval and to the satisfaction of the Director General of the Division of Resources and Energy. |

1 The *minimal iron staining* component of this performance measure was exceeded during the mining of Longwalls 23-37, triggering contingency measures for the impacted pools. The nature and extent of iron staining on the Eastern Tributary will continue to be monitored during the mining of Longwalls 301-303.

**Table 23 (Continued)**
**Trigger Action Response Plan – Negligible Environmental Consequences on Eastern Tributary**

| Performance Measure | Performance Indicator | Monitoring Site(s) | Parameters | Frequency/ Sample Size | Analysis Methodology | Error Types | Baseline | Significance Levels/ Triggers | | Action/Response |
|---|---|---|---|---|---|---|---|---|---|---|
| **Minimal Gas Releases** | | | | | | | | | | |
| **Negligible environmental consequences over at least 70% of the stream length (that is, no diversion of flows, no change in the natural drainage behaviour of pools, minimal iron staining, and minimal gas releases) on the Eastern Tributary between the full supply level of the Woronora Reservoir and the maingate of Longwall 26** | *Gas releases in Eastern Tributary between the full supply level of the Woronora Reservoir and the maingate of Longwall 26 have not increased beyond those observed up to the commencement of Longwall 301 extraction.* | Eastern Tributary between the full supply level of the Woronora Reservoir and the maingate of Longwall 26 | Free Carbon Dioxide as $CO_2$ (mg/L)<br>Methane (mg/L) | Visual inspections for gas releases monthly.<br>Weekly at pools that have been observed with gas releases, until no gas releases have been observed at the pool for three consecutive weeks. | Visual inspections, and where gas releases occur, water quality sampling.<br>Analysis of water quality results, quarterly, within one month of the receipt of laboratory results. | Free Carbon Dioxide as $CO_2$ (mg/L)<br>ALS Method APHA 4500 $CO_2$-D Detection limit is 1 mg/L[3].<br>Methane (mg/L)<br>ALS Method EPO33: Methane Detection limit is 0.01 mg/L[4]. | No gas releases observed in Eastern Tributary prior to the mining of Longwall 20.<br>Pool ETAG – gas releases observed in February 2017.<br>Pool ETAI – gas releases observed in March 2017.<br>Pool ETAL – gas releases observed from January to March 2016.<br>Pool ETAM – gas releases observed from January to June 2016.<br>Assessment of gas releases in pools to 30 June 2017 indicates the performance measure has been met. | Level 1 | Free carbon dioxide concentrations are equal to or less than 4 mg/L[1] in Eastern Tributary pools between the full supply level of the Woronora Reservoir and the maingate of Longwall 26.<br>Methane concentrations are equal to or less than 0.159 mg/L[1] in Eastern Tributary pools between the full supply level of the Woronora Reservoir and the maingate of Longwall 26. | Continue monitoring.<br>Six monthly reporting. |
| | | | | | | | | Level 2 | Free carbon dioxide concentrations are above 4 mg/L and equal to or less than 13 mg/L[2] in Eastern Tributary pools between the full supply level of the Woronora Reservoir and the maingate of Longwall 26.<br>Methane concentrations are above 0.159 mg/L and equal to or less than 0.478 mg/L[2] in Eastern Tributary pools between the full supply level of the Woronora Reservoir and the maingate of Longwall 26. | Increase the frequency of data analysis to monthly in pools subject to gas releases (until such time that data analysis indicates a return to Level 1).<br>Six monthly reporting. |
| | | | | | | | | Level 3 | Free carbon dioxide concentrations are above 13 mg/L[2] in Eastern Tributary pools between the full supply level of the Woronora Reservoir and the maingate of Longwall 26.<br>Methane concentrations are above 0.478 mg/L[2] in Eastern Tributary pools between the full supply level of the Woronora Reservoir and the maingate of Longwall 26. | Undertake investigation and assess against the performance measure. Report to DP&E, WaterNSW, Department of Industry – Water and OEH within one month of assessment completion.<br>Consider the need for management measures, in accordance with Sections 8 and 9. |

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

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

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

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

# 9 MANAGEMENT MEASURES

This section describes the management measures that will be implemented to remediate impacts on water resources and watercourses. Management measures will be implemented, as appropriate, to comply with the relevant statutory requirements and the subsidence impact performance measure.

As described in Section 4.1, systematic and/or valley related movements are likely to result in the fracturing and dilation of the underlying strata of streams above and immediately adjacent to the longwalls. Cracking and dilation of bedrock may result in the localised diversion of a portion of the surface flow into subterranean flows or leakage from pools. Stream remediation measures will be implemented as described in Section 9.1.

Other potential subsidence impacts such as impacts on aesthetic values, stream bank erosion, cliff falls and swamps and the associated management measures are described in Section 9.2.

Management and rehabilitation measures for surface disturbance areas are described in Section 9.3.

Follow-up inspections will be conducted to assess the effectiveness of implemented management measures and the requirement for any additional management measures.

Management measures will be reported in the Annual Review (Section 12).

## 9.1 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:

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

Metropolitan Coal will conduct stream remediation works in accordance with the Metropolitan Coal Longwalls 301-303 Water Management Plan and Metropolitan Coal Rehabilitation Management Plan (Figure 3). An overview of stream remediation is provided in Sections 9.1.1 to 9.1.3 below.

### 9.1.1 Waratah Rivulet Stream Remediation

On the Waratah Rivulet, surface flow and pool holding capacity is required to be restored between the downstream edge of Flat Rock Swamp and the full supply level of the Woronora Reservoir.

***Downstream of Flat Rock Swamp to Longwall 20 Tailgate***

Pools A, B, C, E, F, G, G1, H and I on the Waratah Rivulet are situated in the completed mining area (i.e. overlying Longwalls 1 to 13) between Flat Rock Swamp and the tailgate of Longwall 20 (Figure 4). As described in Section 8.3.2, Pools B, C, E, G, G1, H and I will be manually monitored on a daily basis, while Pools A and F will be monitored continuously with a data logger.

As a result of previous mining, the water levels in pools upstream of Flat Rock Crossing (i.e. Pools A to G) and immediately downstream of Flat Rock Crossing (Pools G1) have been impacted by mine subsidence as described in the Metropolitan Coal Rehabilitation Management Plan (i.e. the pool water level has fallen below the cease to flow level).

Stream remediation activities have been undertaken at Pools A, F and G. The rock bars at Pools A and F are considered to largely control the pools located upstream of these rockbars. As a result, Metropolitan Coal anticipates that the restoration of surface flow and pool holding capacity at Pools A, and F will restore the surface flow and pool holding capacity of pools between Flat Rock Swamp and Pool F. Metropolitan Coal will assess whether stream remediation is required at any additional pools/rock bars between Flat Rock Swamp and Pool F once stream remediation activities at Pools A and F have been completed and a significant period of drier climatic conditions has been experienced.

In the event stream remediation activities are required at any additional pools/rock bars, Metropolitan Coal will prepare stream remediation plans in consultation with WaterNSW and DRG and include the plans in the Metropolitan Coal Rehabilitation Management Plan. Metropolitan Coal will also provide WaterNSW and the DRG with 14 days' notice of their intention to commence stream remediation activities at each pool/rock bar.

Stream remediation will be triggered at Pools H or I on the Waratah Rivulet if the water level in a pool falls below the water level required for continuous flow over the corresponding downstream rock bar (i.e. stops overflowing), except if as a result of climatic conditions. The control pools on Woronora River will be inspected (for a similar response). Note that since this reach of the Waratah Rivulet will experience subsidence, the absolute water RLs in m AHD will reduce with the RLs of the rock bars (notwithstanding any non-systematic subsidence effects). Surveys of the rock bars relative to the pool water levels have been conducted to assess the depth of water at which point the overflow of the downstream rock bar would cease. The water depth is directly measured by the water depth sensor and will be assessed against the relevant 'cease to overflow' value. If water monitoring sensors indicate that the depth of water has reached a level at which point water will cease to overflow the relevant rock bar, then visual inspection of the pool will be conducted.

Metropolitan Coal will advise WaterNSW, OEH, the Department of Industry - Water, Department of Primary Industries (Fishing), DP&E and DRG that the stream remediation process has been triggered. Stream remediation plans for rock bars G1, H and I are provided in the Metropolitan Coal Rehabilitation Management Plan. Metropolitan Coal will also provide WaterNSW and the DRG with 14 days' notice of their intention to commence stream remediation activities at each pool/rock bar.

Metropolitan Coal is committed to stream remediation at the earliest opportunity which will be influenced by a number of factors. These include the subsidence regime, stream flow conditions and status of current remediation works. These are described below.

*Subsidence Regime*

Stream remediation activities will not occur during periods when subsidence is more than 20 mm/month. More than one remedial effort may be required at an individual pool/rock bar given that additional impacts may be associated with successive longwalls. That is, additional stream remediation activities may need to be conducted following further subsidence following mining of the subsequent longwall.

*Stream Flow*

The specific timing of stream remediation activities will also be influenced by practical considerations, such as the amount of stream flow. Generally, the volume of stream flow is required to be such that surface flow over the respective rock bar is absent.

*Status of Current Remediation Works*

It is anticipated that remediation activities would generally follow mining in a downstream direction however as indicated previously, additional remediation measures may be required in some areas.

***Longwall 20 Tailgate to Longwall 23 Maingate***

Pools J, K, L, M, M1, N and O on the Waratah Rivulet are situated between the Longwall 20 tailgate and Longwall 23 maingate (Figure 4). Pools J to O will be monitored continuously with a data logger (Section 8.3.2).

Metropolitan Coal identified that the water level in Pool N fell below its cease to flow level in early September 2012. However, Pool N has overflowed its rock bar since December 2014 until the relatively short periods where it ceased to flow in January/February 2017 and in the latter half of December 2017 (Metropolitan Coal, 2018). The reference pools on Woronora River also ceased overflowing during the same period. Monitoring of Pool N water levels will continue to assess the requirement for stream remediation activities.

Stream remediation will be triggered at Pools J, K, L, M, M1 or O on the Waratah Rivulet if the water level in a pool falls below the water level required for continuous flow over the corresponding downstream rock bar (i.e. stops overflowing), except if as a result of climatic conditions. The control pools on Woronora River will be inspected (for a similar response). As described for the pools above, as this reach of the Waratah Rivulet will experience subsidence, the absolute water RLs in m AHD will reduce with the RLs of the rock bars (notwithstanding any non-systematic subsidence effects). Surveys of the rock bars relative to the pool water levels have been conducted to assess the depth of water at which point the overflow of the downstream rock bar would cease. The water level is directly measured by the water depth sensor and will be assessed against the relevant ‘cease to overflow’ value. If water monitoring sensors indicate that the depth of water has reached a level at which point water will cease to overflow the relevant rock bar, then visual inspection of the pool will be conducted.

Metropolitan Coal will advise WaterNSW, OEH, the Department of Industry - Water, Department of Primary Industries (Fishing), DP&E and DRG that the stream remediation process has been triggered. Stream remediation plans for rock bars J, L and N are provided in the Metropolitan Coal Rehabilitation Management Plan in the event stream remediation is required. Stream remediation plans for rock bars K, M, M1 and O are discussed in the Metropolitan Coal Rehabilitation Management Plan. Metropolitan Coal will also provide WaterNSW and the DRG with 14 days’ notice of their intention to commence stream remediation activities at each pool/rock bar. As described above, Metropolitan Coal is committed to stream remediation at the earliest opportunity, however the conduct of activities will be influenced by a number of factors.

The water level in Pool K is considered to be substantially controlled by the rock bar of Pool L. As a result, Metropolitan Coal anticipates that the restoration of surface flow and pool holding capacity at Pool L will restore the surface flow and pool holding capacity of Pool K. Metropolitan Coal will assess whether additional stream remediation works are required at Pool K once stream remediation activities at Pool L have been completed (if required). In the event stream remediation activities are required at Pool K once stream remediation activities at Pool L have been completed, Metropolitan Coal will prepare a stream remediation plan in consultation with WaterNSW and DRG and include the plan in Metropolitan Coal Rehabilitation Management Plan.

The water level in Pool O is considered to be substantially controlled by the water level in Pool P. As described in Section 6, the Project Approval requires Metropolitan Coal not to exceed the subsidence impact performance measure for the Waratah Rivulet watercourse outlined in Table 1 of Condition 1, Schedule 3 of the Project Approval (i.e. no diversion of flows or change in the natural drainage behaviour of Pool P). If stream remediation activities are required at Pool O, Metropolitan Coal will prepare a stream remediation plan.

***Downstream of the Maingate of Longwall 23***

Pools P, Q, R, S, T, U, V and W on the Waratah Rivulet are situated between the full supply level of the Woronora Reservoir and the maingate of Longwall 23 (upstream of Pool P) (Figure 4). Pools P to W will be monitored continuously with a data logger (Section 8.3.2).

Stream remediation will be triggered at Pools P, Q, R, S, T, U, V or W if the assessment of monitoring results indicates the performance measure:

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

has been exceeded.

### 9.1.2 Eastern Tributary Stream Remediation

In December 2016 and January 2017 a number of pools on the Eastern Tributary downstream of the Longwall 26 maingate 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 diversion of flows and drainage behaviour. As a result, stream remediation has been triggered for the Eastern Tributary. Pools ETAG to ETAU on the Eastern Tributary are situated downstream of the maingate of Longwall 26.

Stream remediation activities will be conducted in accordance with the Metropolitan Coal Water Management Plan and Metropolitan Coal Rehabilitation Management Plan.

### 9.1.3 Stream Remediation Activities

The Metropolitan Coal Rehabilitation Management Plan will describe the implementation and management of stream restoration works. Stream remediation activities typically include fracture characterisation, stream grouting, environmental management and monitoring, an overview of which is provided below.

***Fracture Characterisation***

Fracture characterisation activities will be conducted to measure the depth and lateral extent of the sub-surface fracture network at each rock bar requiring stream remediation, extending up to 20 m up the bank of the watercourse. Fracture characterisation activities will include the drilling of cored holes to a depth of approximately 20 m, or to 5 m below the deepest identified fracture, whichever is deeper, to:

- determine the depth of fracturing;
- measure the relative volume of fine versus large void spaces; and

- determine the horizontal connectivity between fractures.

A borehole calliper will be used to identify the location of individual fractures intersecting the drill holes.

***Stream Grouting Techniques***

The principal management measure that will be used to restore surface flow and pool holding capacity is the injection of polyurethane grouting products into the fracture network. A grout curtain will be constructed across a rock bar by drilling a line of holes at regular intervals (approximately 2 m) and progressively injecting polyurethane at a range of depths (approximately 20 m to surface). The injection of polyurethane grout reduces the permeability of the overall rock mass by filling voids and thereby reducing sub-surface flow pathways.

Other potential stream remediation techniques and their possible application to different situations include:

- Hand grouting – the sealing of cracks exposed on the surface using hand applicators.
- Shallow pattern grouting – drilling shallow holes using small hand held drilling equipment and low pressure injection of a grout using a portable pump.
- Deep pattern or curtain grouting – drilling deeper holes using traditional air and or reverse circulation drilling rigs. Higher pressure grouting techniques can also be used.
- Deep angle hole cement grouting – remote directional drilling techniques can be used to access otherwise inaccessible sites. The same grouting methods as deep pattern/curtain grouting outlined above can be used.

The full range of available techniques will be considered in the design of stream remediation programs for individual rock bars. The Metropolitan Coal Rehabilitation Management Plan will detail the proposed stream remediation design for specific pools/rock bars.

***Environmental Management Measures for Stream Remediation Works***

A range of environmental management measures will be implemented during the conduct of the stream remediation works in accordance with the Metropolitan Coal Rehabilitation Management Plan, including:

- management of any soil and vegetation disturbance;
- erosion and sediment controls to minimise the potential for any downstream effects;
- stream flow diversion and reduction of sub-surface flows during the application of polyurethane grouting products;
- drill cuttings containment and disposal;
- fuel management;
- management of grouting products and injection operations;
- waste management; and
- transport and handling of equipment and materials.

***Monitoring of Stream Remediation Works***

The performance of the stream remediation works will be monitored in accordance with the Metropolitan Coal Rehabilitation Management Plan. The Metropolitan Coal Rehabilitation Management Plan will describe the monitoring that will be conducted to assess the success of the remediation works against the Project rehabilitation objective. Examples of the type of monitoring parameters include:

- Pool water level monitoring.
- Monitoring of stream remediation methods.
- Effectiveness of environmental controls implemented during remediation works.
- Water quality monitoring.

## 9.2 OTHER SUBSIDENCE IMPACT MANAGEMENT MEASURES

### 9.2.1 Aesthetic Values

Potential aesthetic restoration measures include:

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

### 9.2.2 Stream Bank Erosion

Visual monitoring will be conducted to identify areas subject to excessive erosion and sedimentation. Where monitoring indicates the potential for excessive erosion or sediment migration, specific mitigation measures will be employed.

Potential management measures include:

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

### 9.2.3 Cliff Falls

Cliff and overhang site COH17 will be monitored to record evidence of potential subsidence impacts in accordance with the Metropolitan Coal Longwalls 301-303 Land Management Plan (Figure 3). The monitoring results will be used to assess the potential environmental consequences of the recorded subsidence impact and identify management measures, where appropriate.

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

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

The implementation of management measures will be considered with regard to the specific circumstances of the subsidence impact (e.g. the location, nature and extent of the impact) and the assessment of the environmental consequences in accordance with the Metropolitan Coal Longwalls 301-303 Land Management Plan (Figure 3).

### 9.2.4 Swamp Remediation Measures

In accordance with the Metropolitan Coal Longwalls 301-303 Biodiversity Management Plan (Figure 3), in the event remediation measures are proposed to be implemented in an upland swamp, Metropolitan Coal will prepare a swamp remediation plan for the swamp in consultation with the DP&E, OEH, WaterNSW, DPI - Fishing and DRG.

Potential remediation measures for impacts on upland swamps include:

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

The implementation of management measures will be considered with regard to the specific circumstances of the subsidence impact (e.g. the location, nature and extent of the impact) and the assessment of the environmental consequences in accordance with the Metropolitan Coal Longwalls 301-303 Biodiversity Management Plan (Figure 3).

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

The Metropolitan Coal Longwalls 301-303 Water Management Plan and Metropolitan Coal Rehabilitation Management Plan (Figure 3) will detail the rehabilitation of surface disturbance areas (including those associated with surface exploration activities, vehicular access tracks, environmental monitoring activities and other minor Project-related surface activities) and the remediation of stream pools and rock bars.

# 10 CONTINGENCY PLAN

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

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

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

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

## 10.1 POTENTIAL CONTINGENCY MEASURES

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

- The conduct of additional monitoring (e.g. increase in monitoring frequency or additional sampling) to inform the proposed contingency measures.

- The implementation of stream remediation measures to reduce the extent of fracturing consistent with the methods described in Section 9.1.
- The implementation of revegetation measures to remediate impacts of gas releases on riparian vegetation.
- The purchase of water from Sydney Water in accordance with a license agreement established to the satisfaction of WaterNSW and the DP&E.
- The provision of a suitable offset(s) to compensate for the reduction in the quantity of water resources reaching the Woronora Reservoir. Examples of potential offsets include improvement works in the Woronora Reservoir water supply catchment.
- The implementation of adaptive management measures. Examples of adaptive management measures include reducing the thickness of the coal seam extracted, narrowing of the longwall panels and/or increasing the setback of the longwalls from the affected area.

# 11 FUTURE EXTRACTION PLANS

In accordance with Condition 7, Schedule 3 of the Project Approval, Metropolitan Coal will collect baseline data for future Extraction Plans. The collection of baseline data for water resources and watercourses is described below.

## 11.1 SURFACE WATER

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

Streams relevant to the next Extraction Plan include the Waratah Rivulet, Eastern Tributary and the first and second order streams to the west of Longwalls 301-303 that flow into the Woronora Reservoir.

The visual and photographic survey of streams conducted for the Metropolitan Coal Longwalls 20-22 Water Management Plan (provided in Appendices 1 to 4 of this WMP) and the Metropolitan Coal Longwalls 301-303 Water Management Plan (provided in Appendix 5 of this WMP) will be applicable to the next Extraction Plan. Visual inspections and photographic surveys of streams has been conducted for Longwalls 304-306 and a report is currently being prepared for inclusion in the Longwall 304-306 Extraction Plan.

No additional pool water level or water quality monitoring sites are considered to be required for the next Extraction Plan. Visual inspection and photographic survey of the larger first and second order streams located to the west of the Woronora Reservoir (over Longwalls 307-310) has also been conducted and consideration is being given to pool water level and water quality monitoring in advance of the future longwalls.

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

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

## 11.2 GROUNDWATER

Paired swamp piezometers were installed in Swamps 50 and 71a in June 2016. Metropolitan Coal has confirmed the upland swamp vegetation communities present and checked the boundaries of upland swamps in the vicinity of Longwalls 304-306. The swamps have also been inspected to determine the appropriate locations for proposed additional swamp groundwater piezometers in consideration of the Draft Upland Swamps Policy and IESC advice.

Prior to the completion of Longwall 302, Metropolitan Coal investigated the potential use of swamp soil moisture meters/probes to trial the monitoring of soil moisture within a swamp. The majority of upland swamps to the immediate west of Longwall 303 are also small valley-side swamps. However, further in the 300 series mine plan, larger swamps occur.

A shallow groundwater transect located between the Woronora Reservoir and the ridge to the east of the reservoir (sites T1, T2, T3, T4 and T5) has been installed. Monitoring data obtained from the transect has been used to develop a performance indicator associated with leakage of water from the Woronora Reservoir as detailed in the TARPs in Section 8.8.

Metropolitan Coal has installed a new multi-level bore in the vicinity of 9EGW2A (i.e. bore 9EGW-4).

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

# 12 ANNUAL REVIEW AND IMPROVEMENT OF ENVIRONMENTAL PERFORMANCE

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

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

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

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

# 13 INCIDENTS

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

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

# 14 COMPLAINTS

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

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

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

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

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

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

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

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

# 15 NON-COMPLIANCES WITH STATUTORY REQUIREMENTS

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

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

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

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

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

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

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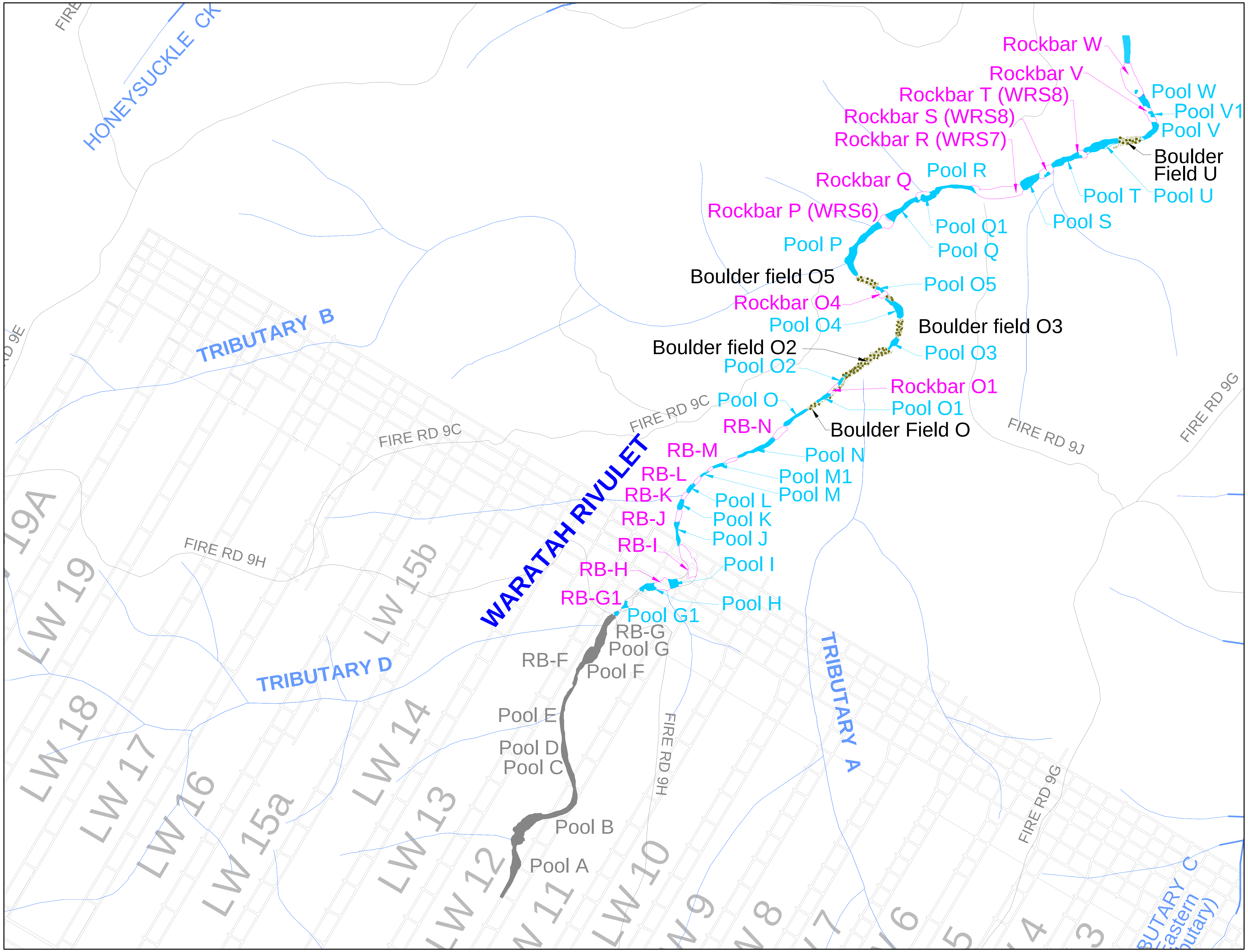
# APPENDIX 1

# WARATAH RIVULET STREAM MAPPING AND PHOTOGRAPHIC RECORD

# STREAM MAPPING SUMMARY – GENERAL LAYOUT



# POOL G1 - STREAM MAPPING SUMMARY

**G1-1** Upstream end of Pool G1 looking downstream

**G1-9** South East bank

**G1-11** North West bank

Pool G1 and Rockbar G1 notes (as at 16 Dec 2008)

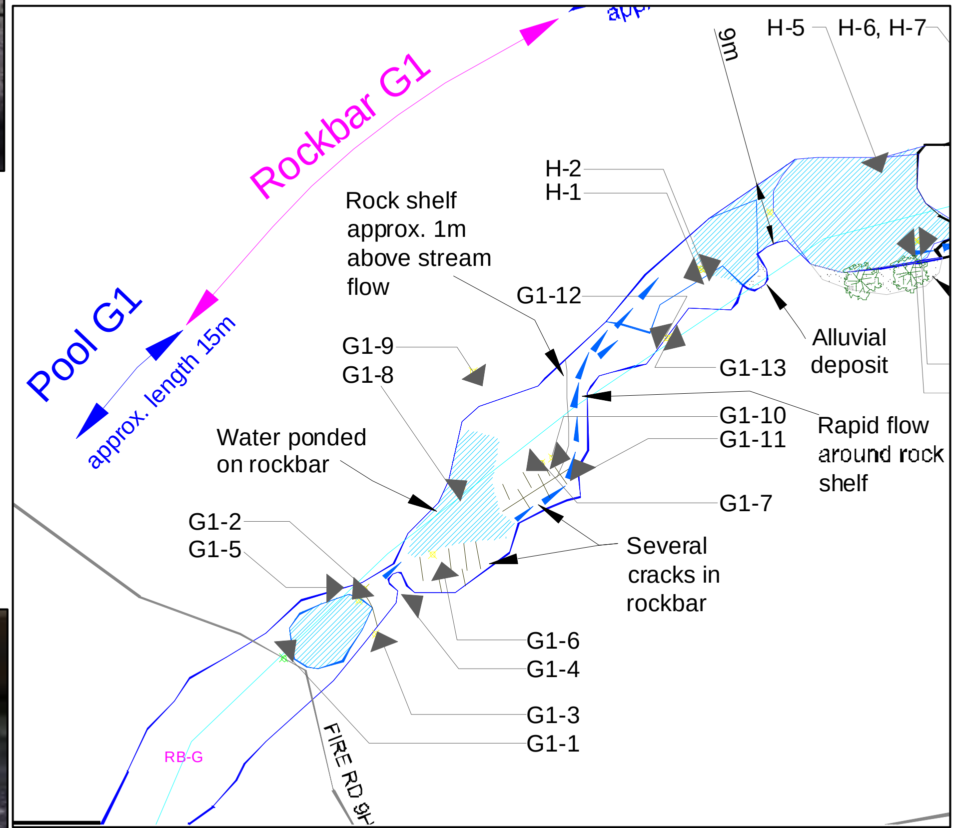
- Pool length is approximately 15m. Width varies from approximately 6m to 10m. Average depth is approximately 0.4m with a maximum of approximately 0.7m.
- Several cracks observed in the stream bed and in the rockbar downstream of the pool (see photos).
- Base of the pool is sandstone covered in stained sediment. Minor alluvial deposits on north side of pool.
- Pool flows out onto rockbar. Narrow turbulent flow over rockbar and some ponding. Rock shelf both sides of flow to approximately 1m maximum above water level.
- Cross bedding present.
- Rockbar approximately 24m wide u/s end and 32m wide at d/s end.

**G1-2** Downstream end of Pool G1 looking upstream

**G1-5** Cracking in rockbar

**G1-6** Cracking in rockbar

**G1-10** Iron Staining




**G1-7** On rockbar G1 looking upstream

**G1-14** Crack perpendicular to joint

**G1-15** Buckling

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| G1-1 | 309673 | 6214194 | 46 |
| G1-2 | 309686 | 6214204 | 226 |
| G1-3 | 309688 | 6214196 | 335 |
| G1-4 | 309695 | 6214202 | 46 |
| G1-5 | 309685 | 6214202 | 95 |
| G1-6 | 309698 | 6214210 | 348 |
| G1-7 | 309717 | 6214226 | 232 |
| G1-8 | 309703 | 6214222 | 52 |
| G1-9 | 309705 | 6214242 | 140 |
| G1-10 | 309719 | 6214227 | 104 |
| G1-11 | 309723 | 6214225 | 332 |
| G1-12 | 309739 | 6214248 | 350 |
| G1-13 | 309739 | 6214248 | 170 |
| G1-14 | 309739 | 6214248 | 290 |
| G1-15 | 309739 | 6214248 | 130 |

**G1-8** On rockbar G1 looking downstream

**G1-3** Cracking aross pool and deposits

**G1-4** Cracking in rockbar

**G1-12** Crack 20 to 50mm wide

**G1-13** Crack

# POOL H - STREAM MAPPING SUMMARY

**H-1** Upstream end of Pool H looking upstream

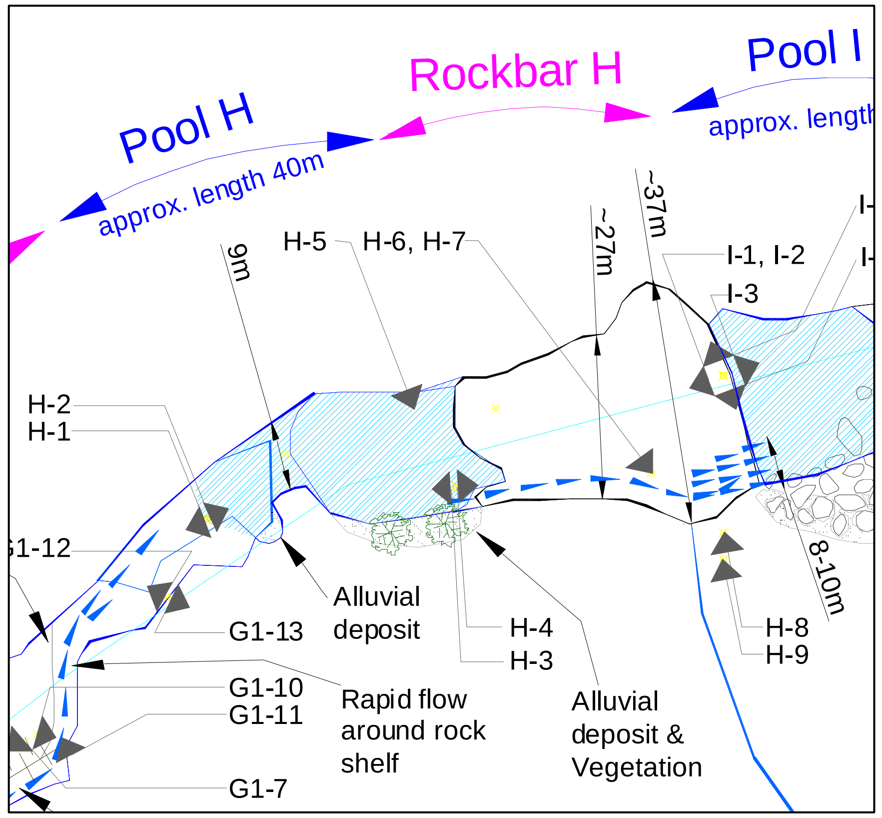
**H-5** South East bank

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

- Pool length is approximately 40m. Width is approximately 9m to 20m. Average depth is approximately 1m to 1.5m.
- Algae and alluvial deposits on the southern side of the pool bed.
- Alluvial deposits on southern bank.
- Rockbar H approximately 27 to 37m wide.
- Pool flows out onto rockbar. Narrow turbulent flow over rockbar and some ponding. Rock shelf both sides of flow approximately 1m above water level.
- Cross bedding present. Boulders present along northern side of pool.
- Minor cracking at downstream end of rockbar H.

**H-2** Upstream end of Pool H looking downstream

**H-8 and H-9** Cracks in rockbar, 5mm wide, 5m apart.




**H-3** Downstream end of Pool H looking upstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| H-1 | 309745 | 6214260 | 246 |
| H-2 | 309745 | 6214260 | 66 |
| H-3 | 309783 | 6214265 | 266 |
| H-4 | 309783 | 6214265 | 86 |
| H-5 | 309776 | 6214278 | 159 |
| H-7 | 309813 | 6214267 | 174 |
| H-8 | 309824 | 6214258 | 350 |
| H-9 | 309824 | 6214254 | 350 |

**H-4** Downstream end of Pool H looking downstream

**H-7** Flow at downstream end of pool H

# POOL I - STREAM MAPPING SUMMARY


**I-1 and I-2** Upstream end of Pool I looking upstream

<u>Pool I notes (as at 16 Dec 2008)</u>

- Pool length is approximately 20m. Width is approximately 21m. Average depth is approximately 1.4m.
- Pool bed is sandstone with sediment covering the rock surface.
- Sandstone cobbles to about 0.3m size at downstream end of pool. Boulders to about 1m size and vegetation along the southern bank.
- Cross bedding present in pool bed.
- Rockbar H rises approximately 1.5m above the u/s end of Pool I.
- Pool I flows out onto Rockbar I to form shallow flow and riffle across most of the width of the rockbar.

**I-3** Upstream end of Pool I looking downstream

**I-4** Northern bank at u/s end of pool

**I-7** Downstream end of Pool I looking upstream

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

**I-6** Downstream end of Pool I looking downstream

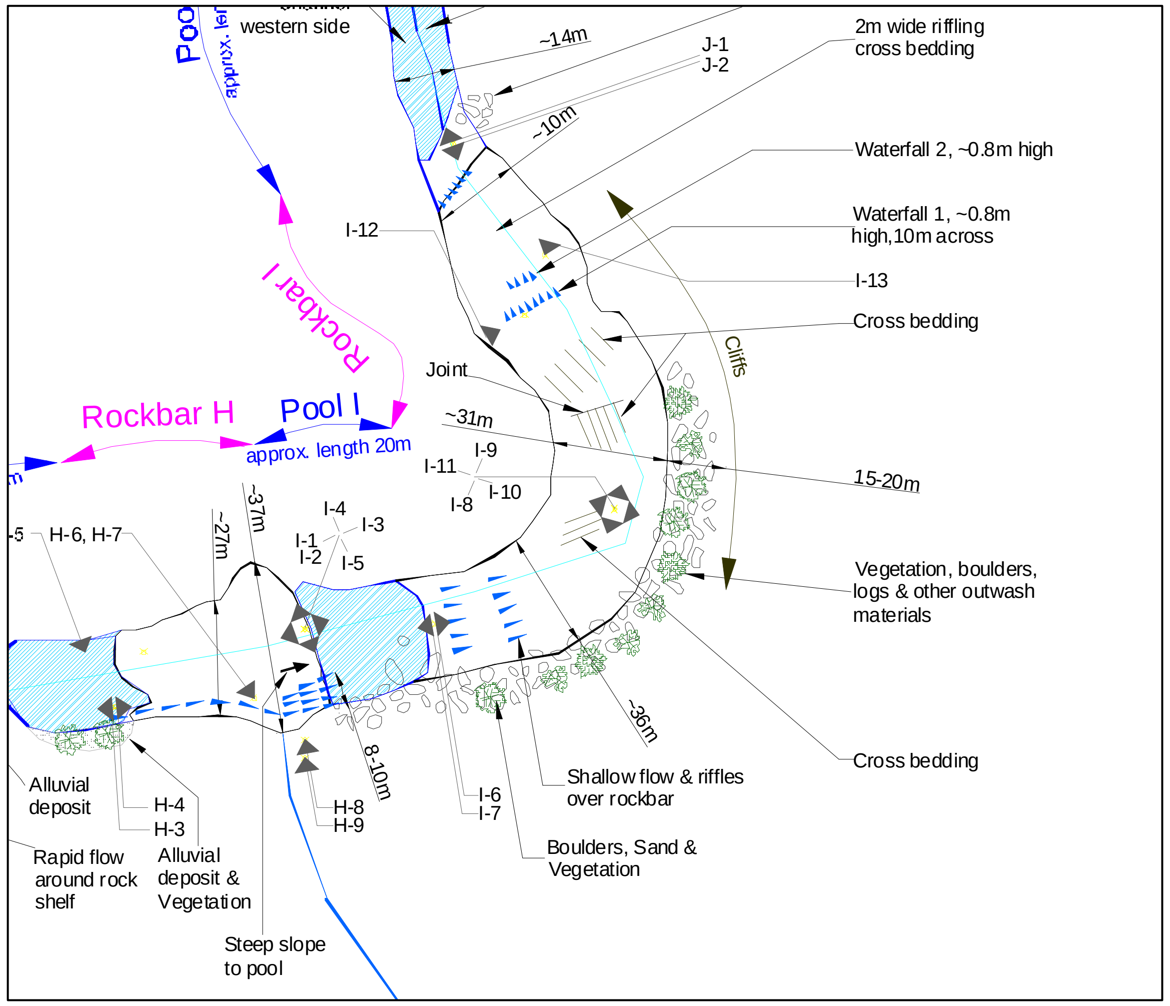



Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| I-1 | 309824 | 6214282 | 250 |
| I-2 | 309824 | 6214282 | 250 |
| I-3 | 309824 | 6214282 | 70 |
| I-4 | 309824 | 6214282 | 340 |
| I-5 | 309824 | 6214282 | 160 |
| I-6 | 309872 | 6214350 | 80 |
| I-7 | 309872 | 6214350 | 260 |

# ROCKBAR I - STREAM MAPPING SUMMARY

I-8 Rockbar I looking upstream

I-9 Rockbar I looking downstream

I-10 Eastern bank

I-12 Waterfall 1

I-11 Western bank

I-13 Waterfalls 1 and 2

Rockbar I notes (as at 16 Dec 2008)

- Width varies from approximately 31m to 36m. Length is approximately 150m.
- Water flows mainly over full width of rockbar as shallow flow and riffles.
- Cliffs located along the eastern edge of the rockbar.
- Two small waterfalls are located on the rockbar as shown on sketch.
- Cross bedding present.
- Approximately 3m vertical change in height from Pool H to Pool I.

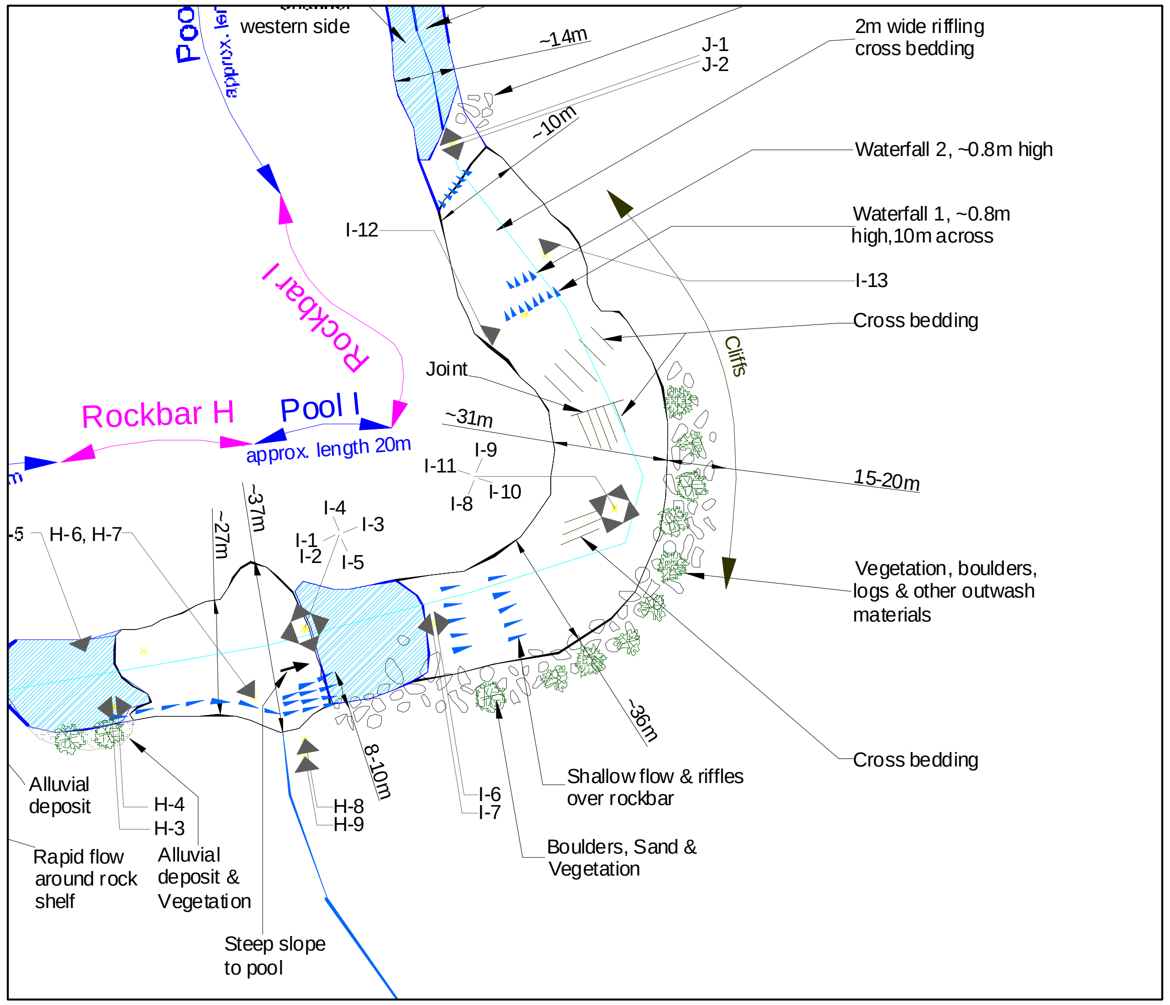



Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| I-8 | 309891 | 6214308 | 200 |
| I-9 | 309891 | 6214308 | 20 |
| I-10 | 309891 | 6214308 | 110 |
| I-11 | 309891 | 6214308 | 290 |
| I-12 | 309876 | 6214363 | 60 |
| I-13 | 309876 | 6214362 | 195 |

# POOL J - STREAM MAPPING SUMMARY

**J-1** Pool J upstream end looking downstream

**J-2** Pool J upstream end looking upstream

**J-3** Pool J downstream end looking upstream

**J-4** Pool J downstream end looking downstream

<u>Pool J and Rockbar J notes (as at 16 Dec 2008)</u>

- Width varies from approximately 12m to 14m. Length is approximately 60m.
- Water depth varies from approximately 0.8m to 1.0m along a deeper channel on the western side of the pool. Sandstone shelf about 0.3m below water surface along the eastern side of the pool.
- Rockbar J width varies from approximately 12m to 21m with an average width of approximately 20m.
- Water flows over most of the rockbar as shallow flow with minor riffles at the u/s and d/s ends of the rockbar.

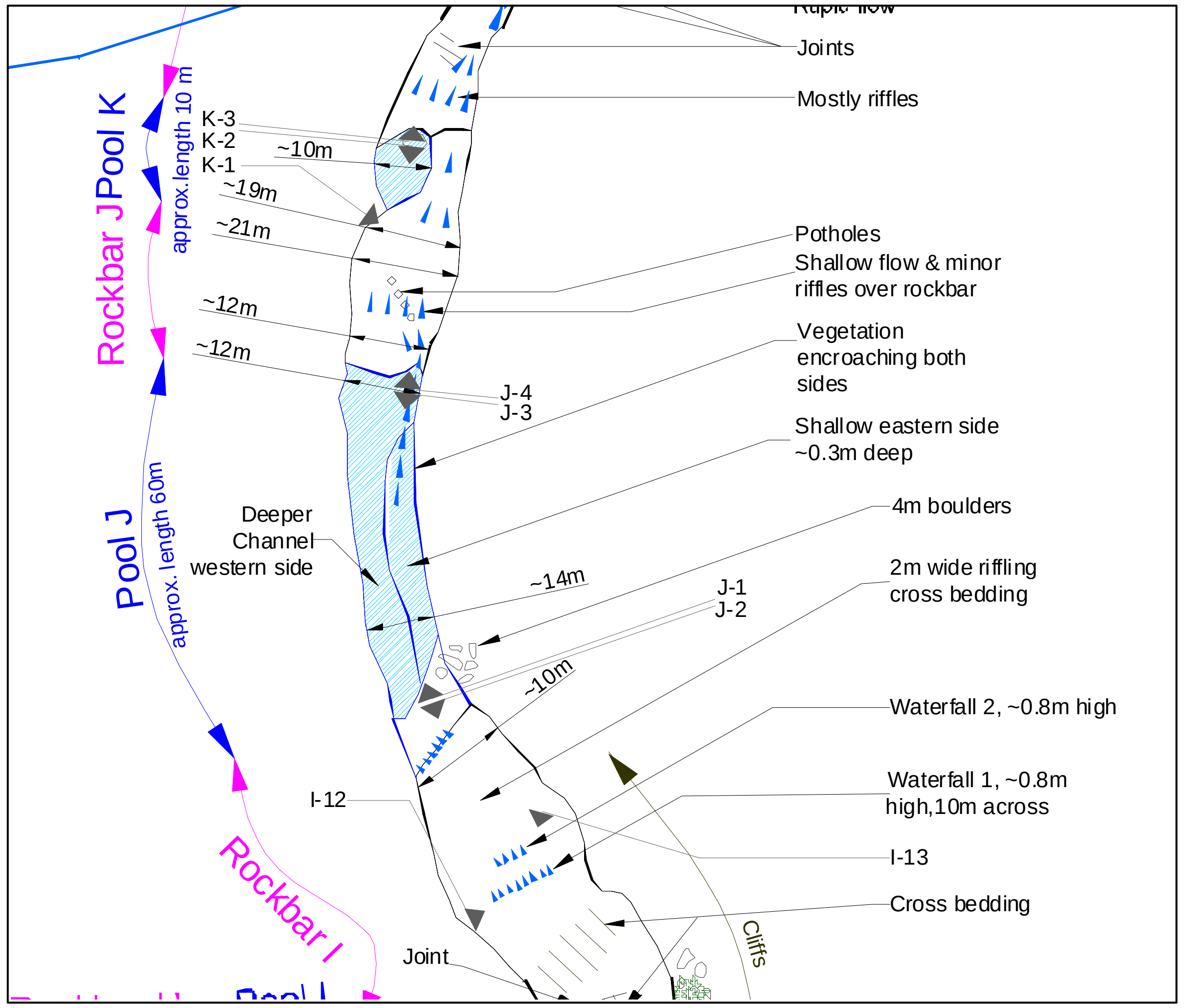



Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| J-1 | 309856 | 6214387 | 160 |
| J-2 | 309856 | 6214387 | 340 |
| J-3 | 309853 | 6214446 | 185 |
| J-4 | 309853 | 6214446 | 5 |

# POOL K - STREAM MAPPING SUMMARY

**K-1** Pool K upstream end looking towards west bank

**K-4** Joints across Rockbar K

**K-5** Joints across Rockbar K

**K-2** Pool K downstream end looking upstream

**L-4** Joints across Rockbar K

**K-3** Pool K downstream end looking downstream

**L-5** Joints across Rockbar K

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

- Dimensions are approximately 10m wide by 10m long.
- Water depth is approximately 0.9m
- Pool K is located on the west side of the downstream end of Rockbar J. Rockbar J forms an almost continuous rockbar with Rockbar K.
- Joints located across the middle of Rockbar K as shown in sketch.
- Water flows around Pool K and over most of the width of Rockbar K as shallow flow and riffles.

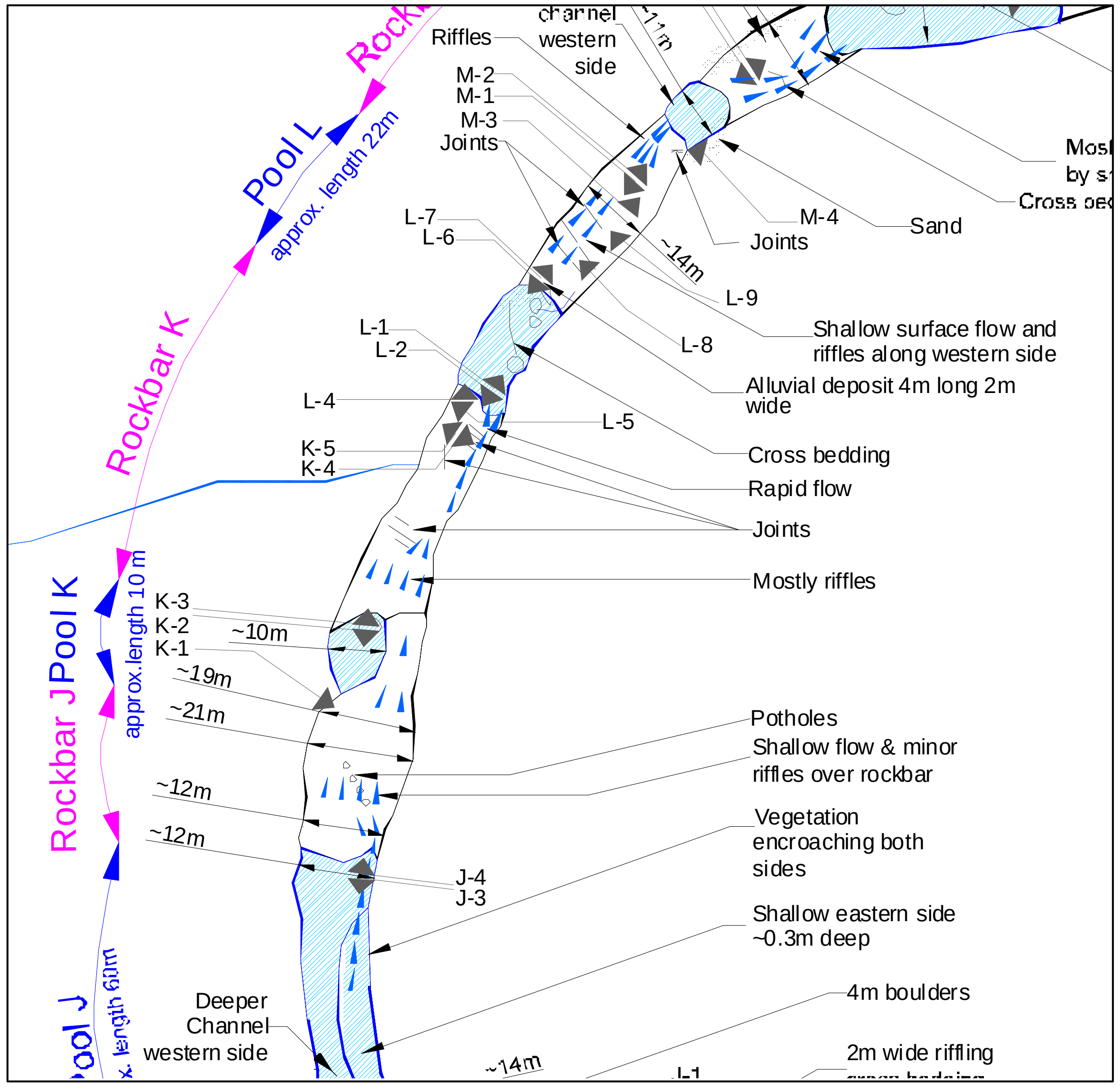



Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| K-1 | 309843 | 6214479 | 130 |
| K-2 | 309852 | 6214493 | 185 |
| K-3 | 309852 | 6214493 | 5 |
| K-4 | 309869 | 6214529 | 120 |
| K-5 | 309869 | 6214529 | 300 |
| L-4 | 309871 | 6214536 | 0 |
| L-5 | 309871 | 6214533 | 305 |

# POOL L - STREAM MAPPING SUMMARY

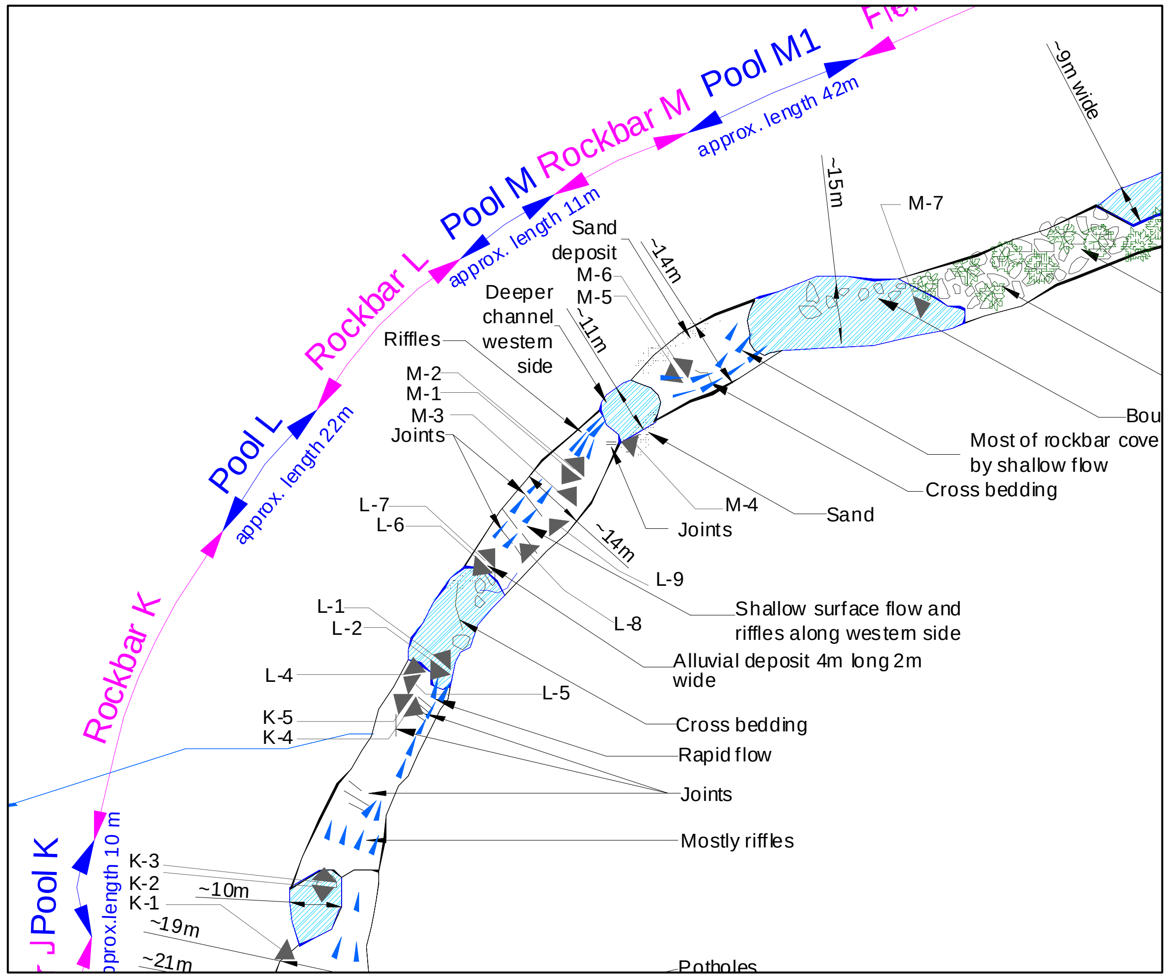
**L-1** Upstream end of Pool L looking downstream

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

- Pool length is approximately 22m. Width varies from approximately 10m to 12m. Water depth varies from approximately 0.6m to 0.9m.
- Pool bed is sandstone covered with sediment.
- Boulders to about 1m size located on eastern bank and downstream end.
- Alluvial deposit approximately 2m x 4m at downstream end of pool.
- Cross bedding present in pool bed.
- Water flows onto Rockbar L at the western bank then flows over approximately the western half of Rockbar L as shallow flow and riffles.
- Rockbar L width is approximately 13m.

**L-2** Upstream end of Pool L looking upstream

**L-8** Joints across u/s end of Rockbar L





**L-6** Downstream end of Pool L looking upstream

**L-9** Joint in Rockbar L

**L-7** Downstream end of Pool L looking downstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| L-1 | 309876 | 6214538 | 40 |
| L-2 | 309876 | 6214538 | 220 |
| L-6 | 309885 | 6214559 | 225 |
| L-7 | 309885 | 6214559 | 40 |
| L-8 | 309895 | 6214560 | 315 |
| L-9 | 309900 | 6214566 | 320 |

# POOL M and M1 - STREAM MAPPING SUMMARY

**M-1** Upstream end of Pool M looking upstream

**M-3** Riffling at u/s end of Pool M

<u>Pool M and Rockbar M notes (as at 16 Dec 2008)</u>

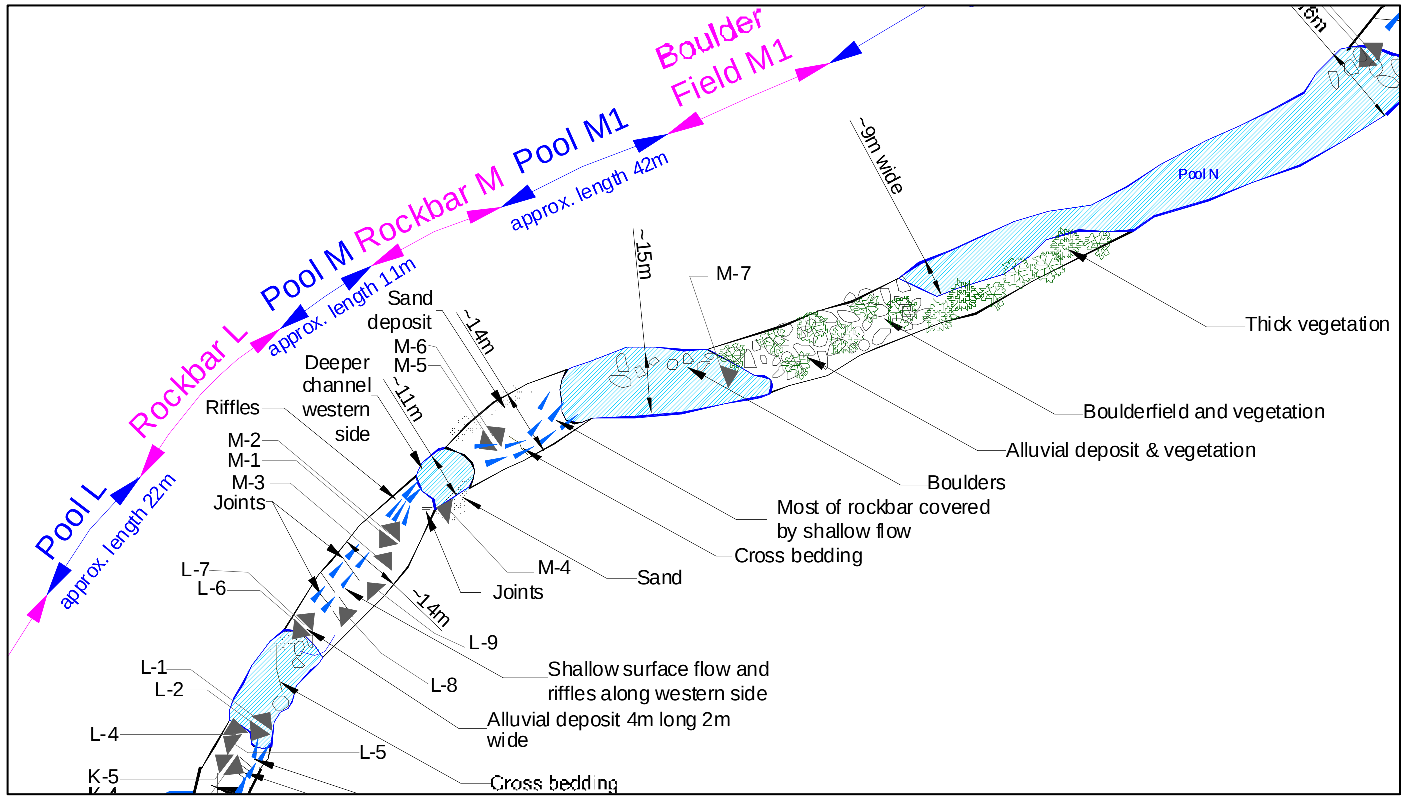
- Pool M is approximately 11m long and 11m wide. Water depth varies from approximately 0.3m to 0.9m with an average of approximately 0.6m. The deeper flow channel is on the western side of the pool.
- Pool bed is sandstone covered with sediment and sand deposits.
- Rockbar M is approximately 14m wide. Water flows over the rockbar from Pool M to Pool M1; width of flow is approximately 7m.
- Cross bedding present in pool bed and Rockbar M.

<u>Pool M1 notes (as at 16 Dec 2008)</u>

- Pool M1 is approximately 42m long and width varies from approximately 9m to 15m. Water depth varies from 0.3m to 1m with an average of approximately 1m.
- Base of Pool M1 is sandstone, covered with sediment.
- Boulders and detached blocks located along the north western side of the pool, approximately 1m to 6m in size.
- Pool M1 ends at boulder field consisting of boulders and blocks up to approximately 1m in size, and vegetation. Alluvial deposits and thick vegetation on the south western bank.

**M-2** Upstream end of Pool M looking downstream

**M-4** Joints in Rockbar M




**M-5** Downstream end of Pool M looking upstream

**M-6** Downstream end of Pool M looking downstream to Pool M1

**M-7** Downstream end of Pool M1 looking downstream to boulder field

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| M-1 | 309903 | 6214578 | 220 |
| M-2 | 309903 | 6214578 | 40 |
| M-3 | 309902 | 6214572 | 40 |
| M-4 | 309916 | 6214583 | 270 |
| M-5 | 309983 | 6214613 | 235 |
| M-6 | 309983 | 6214613 | 55 |
| M-7 | 309973 | 6214611 | 70 |

# POOL N (WRS5) - STREAM MAPPING SUMMARY

**N-1** Downstream end of Pool N looking upstream

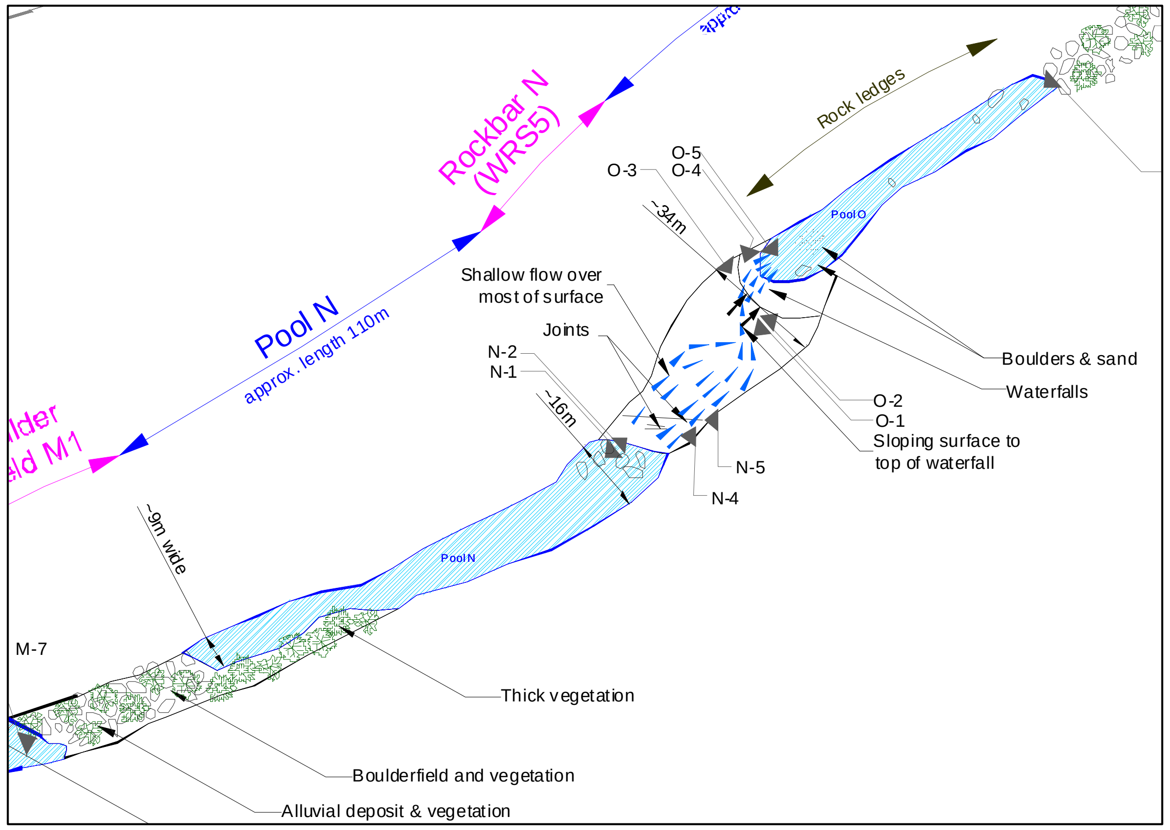
**N-4** Joints in rockbar N

<u>Pool N and Rockbar N (WRS5) notes (as at 16 Dec 2008)</u>

- Pool N is approximately 110m long and varies from 10m to 16m wide. Average water depth is approximately 1m.
- Pool bed is sandstone covered with sediment and sand deposits.
- Boulders to about 1m size present at the downstream end of the pool extending approximately 15m into the pool.
- Rockbar N (WRS5) varies from approximately 20m wide at the upstream end to approximately 34m wide at the downstream end.
- Water flows over most of the surface of the rockbar from Pool N and enters Pool O via riffles and 4 waterfalls. The slope of the riffles is generally along the sandstone bedding planes.
- The vertical drop in height from the top of Rockbar N to Pool O is approximately 5.5m to 6m.
- Cross bedding present.

**N-2** Downstream end of Pool N looking downstream

**N-5** Joints in Rockbar N




**O-1** Upstream end of Pool O looking upstream at Rockbar N (WRS5)

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| N-1 | 310109 | 6214679 | 230 |
| N-2 | 310109 | 6214679 | 50 |
| N-4 | 310127 | 6214681 | 270 |
| N-5 | 310132 | 6214685 | 270 |
| O-1 | 310143 | 6214707 | 50 |

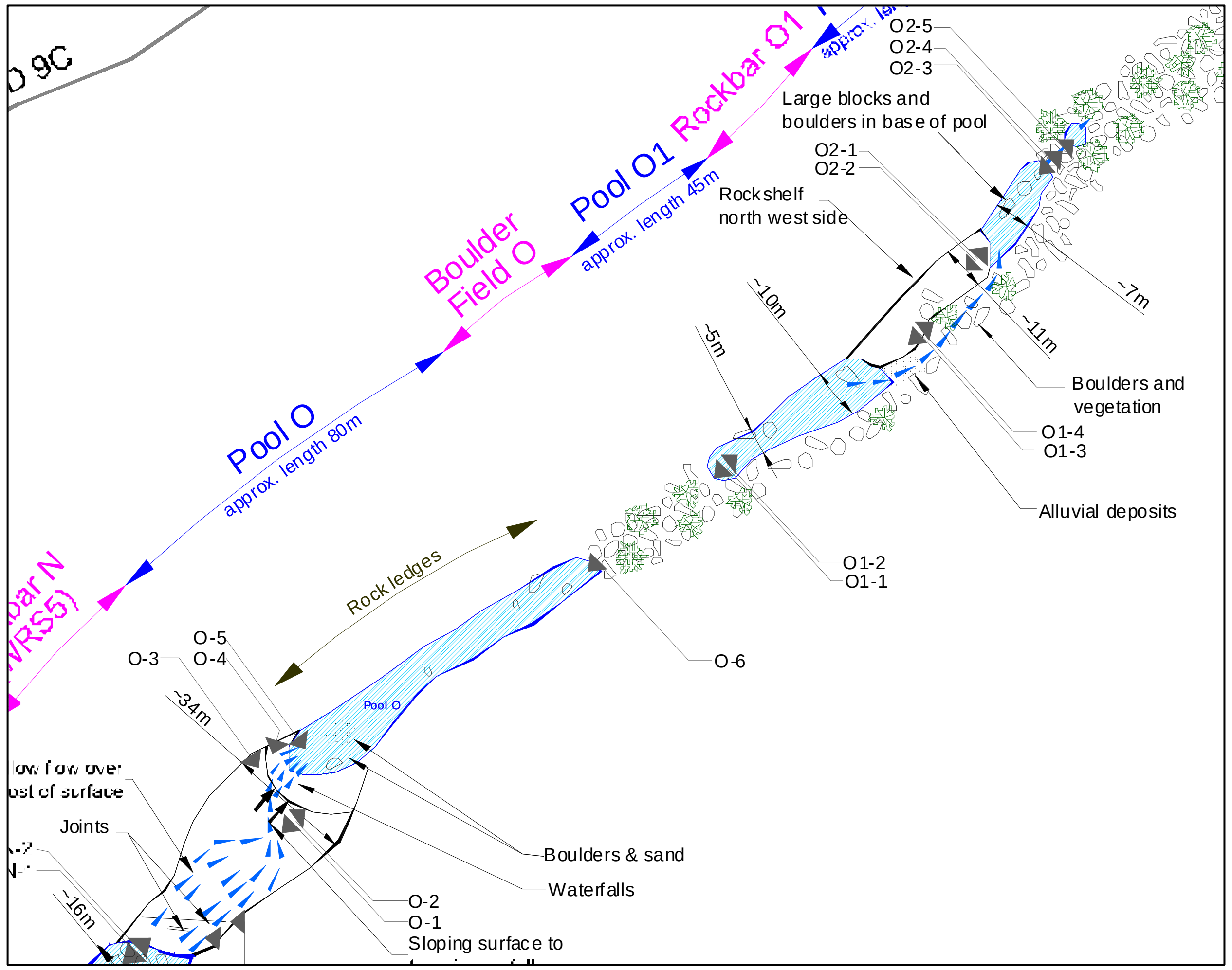
# POOL O - STREAM MAPPING SUMMARY

**O-1** Upstream end of Pool O looking upstream at Rockbar N (WRS5) and North Western Bank

Pool O notes (as at 16 Dec 2008)

- Pool O is approximately 80m long and varies in width from approximately 8m at the downstream end to 15m at the upstream end. Water depth varies from approximately 0.5m to 1m with an average of approximately 0.8m.
- Pool bed is sandstone covered with sediment and sand deposits.
- Boulders up to about 2m size scattterd through the pool. More boulders are located on the south east side of the pool and there are rock ledges along the north west side.
- The downstream end of the pool flows into a boulder field.
- The boulder field comprises boulders varying up to approximately 5m size, alluvial deposits and vegetation.
- Water flow is audible through the boulder field.

**O-2** Upstream end of Pool O looking downstream




**O-5** South Eastern Bank at waterfalls

**O-4** Looking upstream from base of waterfalls

**O-6** Downstream end of Pool O looking upstream

**O-3** South Eastern Bank at waterfalls

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| O-1 | 310143 | 6214707 | 230 |
| O-2 | 310143 | 6214707 | 50 |
| O-3 | 310134 | 6214721 | 145 |
| O-4 | 310140 | 6214724 | 200 |
| O-5 | 310144 | 6214724 | 145 |
| O-6 | 310209 | 6214763 | 230 |

# POOL O1 - STREAM MAPPING SUMMARY

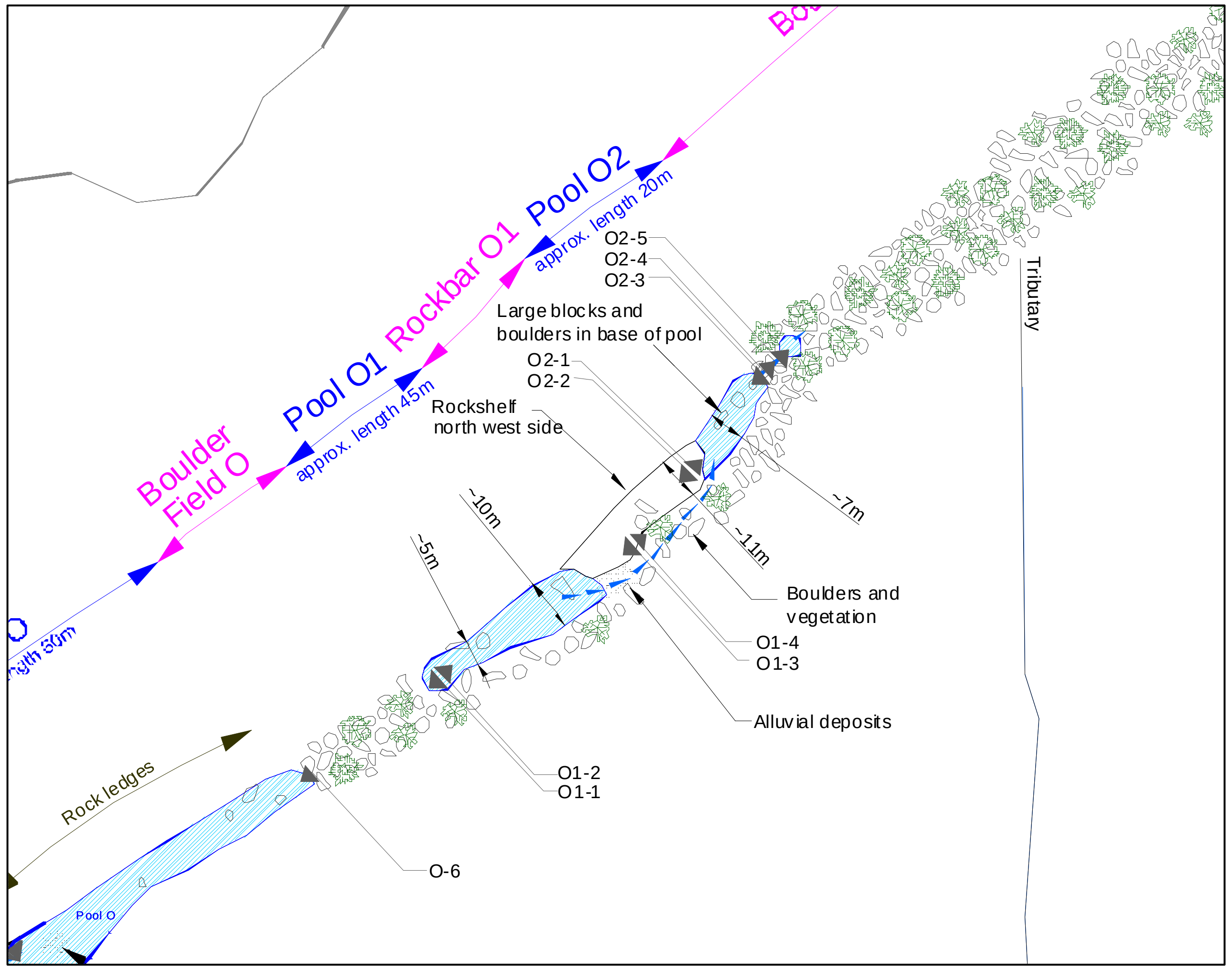
**O1-1** Upstream end of Pool O1 looking upstream

**O1-2** Upstream end of Pool O1 looking downstream

<u>Pool O1 notes (as at 17 Dec 2008)</u>

- Pool O1 is approximately 40m long and varies in width from approximately 5m to 11m. Water depth varies from approximately 0.3m to 1.2m.
- Pool bed is sandstone with potholes, and sand deposits and aquatic vegetation at the upstream end.
- The pool is surrounded by boulder field on all sides except the north west, which comprises rock ledge/rock shelf.
- The boulder field comprises boulders varying up to approximately 5m size, alluvial deposits and vegetation.
- The boulder field on the south east side of the pool is approximately 6m wide.
- Estimated distance between sandstone ledges on north east and south west banks is approximately 40m.
- Cross bedding present.
- Braided flow is audible through the boulder field.

**O1-3** Downstream end of Pool O1 looking upstream




**O1-4** Downstream end of Pool O1 looking downstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| O1-1 | 310237 | 6214784 | 230 |
| O1-2 | 310237 | 6214784 | 50 |
| O1-3 | 310279 | 6214813 | 230 |
| O1-4 | 310279 | 6214813 | 50 |

# POOL O2 - STREAM MAPPING SUMMARY

**O2-1** Upstream end of Pool O2 looking downstream

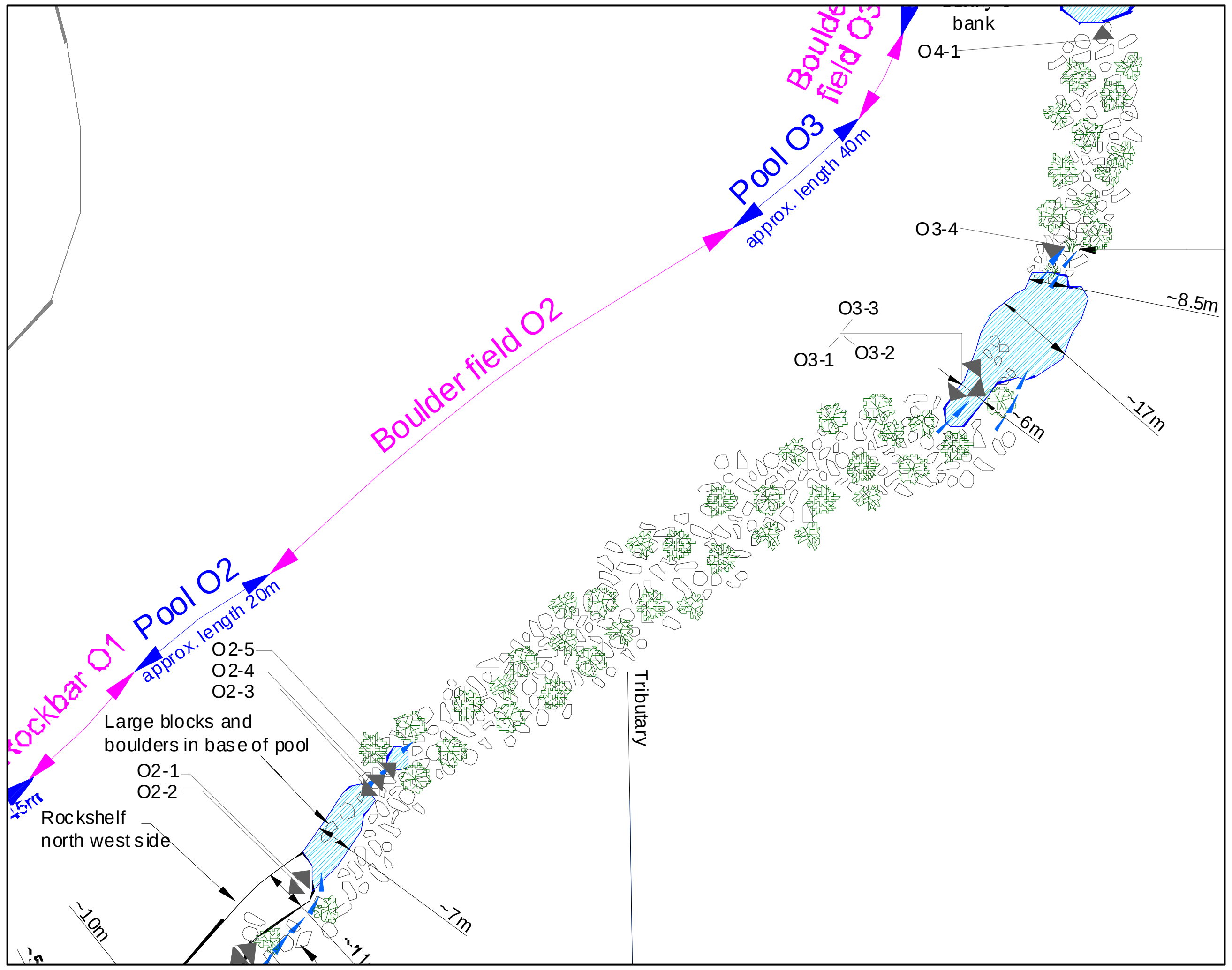
**O2-2** Upstream end of Pool O2 looking upstream

<u>Pool O2 notes (as at 17 Dec 2008)</u>

- Pool O2 is approximately 20m long and 7m wide. Water depth varies from approximately 0.3m to 0.5m.
- Pool bed is sandstone with alluvial deposits.
- The pool is located amongst a boulder field and has boulders and detached blocks up to approximately 5m in size in the base of the pool.
- There is a small pool immediately downstream of Pool 02. It is located amongst boulders and vegetation and is approximately 3m to 4m diameter.
- Braided flow is audible through the boulder field.

**O2-3** Downstream end of Pool O2 looking upstream

**O2-4** Downstream end of Pool O2 looking downstream





**O2-5** Small pool downstream of Pool O2

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| O2-1 | 310291 | 6214829 | 225 |
| O2-2 | 310291 | 6214829 | 45 |
| O2-3 | 310307 | 6214850 | 225 |
| O2-4 | 310307 | 6214850 | 45 |
| O2-5 | 310309 | 6214853 | 45 |

# POOL O3 - STREAM MAPPING SUMMARY

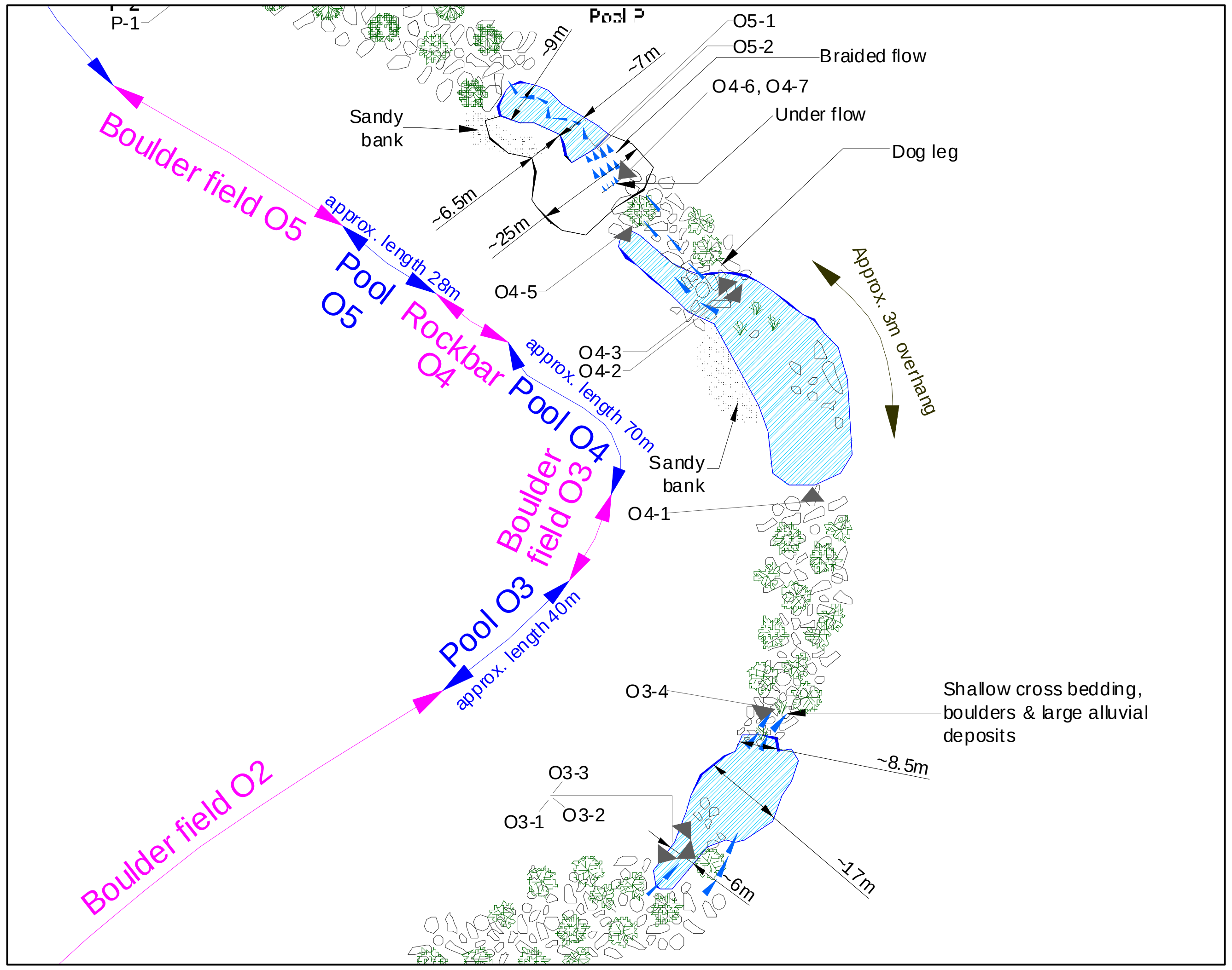
**O3-1** Upstream end of Pool O3 looking upstream

**O3-2** Upstream end of Pool O3 looking at east bank

<u>Pool O3 notes (as at 17 Dec 2008)</u>

- Pool O3 is approximately 40m long and varies in width from approximately 6m to 17m. Water depth varies from approximately 0.3m to 1.5m.
- Pool bed is sandstone with alluvial sand deposits and aquatic vegetation.
- Boulder field located upstream and downstream and comprises boulders varying up to approximately 5m size, alluvial deposits and vegetation.
- Braided flow is audible through the boulder field.

**O3-3** Upstream end of Pool O3 looking downstream




**O3-4** Downstream end of Pool O3 looking upstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| O3-1 | 310435 | 6214938 | 220 |
| O3-2 | 310435 | 6214938 | 130 |
| O3-3 | 310435 | 6214938 | 40 |
| O3-4 | 310454 | 6214966 | 190 |

# POOL O4 - STREAM MAPPING SUMMARY

**O4-1** Upstream end of Pool O4 looking downstream

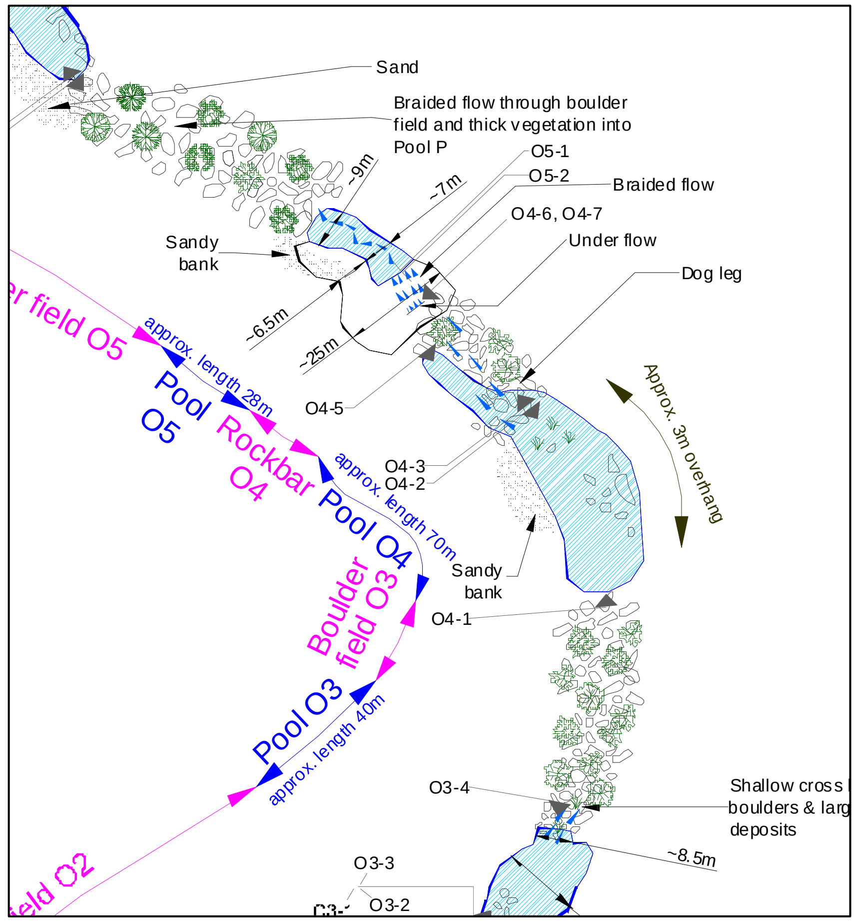
**O4-4** Sample of vegetation from base of pool

Pool O4 and Rockbar O4 notes (as at 17 Dec 2008)

- Pool O4 is approximately 70m long overall. The main section of the pool is approximately 55m long and 15m to 20m wide. A narrow section extends downstream of a dog leg, measuring approximately 15m long and 5m wide. Water depth varies from approximately 0.1m to 1m.
- Pool bed is sandstone with alluvial sand deposits, aquatic vegetation and boulders.
- The pool is located amongst a boulder field. The south western bank of the pool is sand.
- The boulder field comprises boulders varying up to approximately 5m size, alluvial deposits and vegetation.
- Rockbar O4 is approximately 25m wide. Underflow emerges onto the rockbar and flows into Pool O5.

**O4-2** At dog leg in Pool O4 looking upstream

**O4-5** Downstream end of Pool O4 looking upstream




**O4-3** At dog leg in Pool O4 looking downstream

**O4-6** Flow emerging at upstream end of Rockbar O4

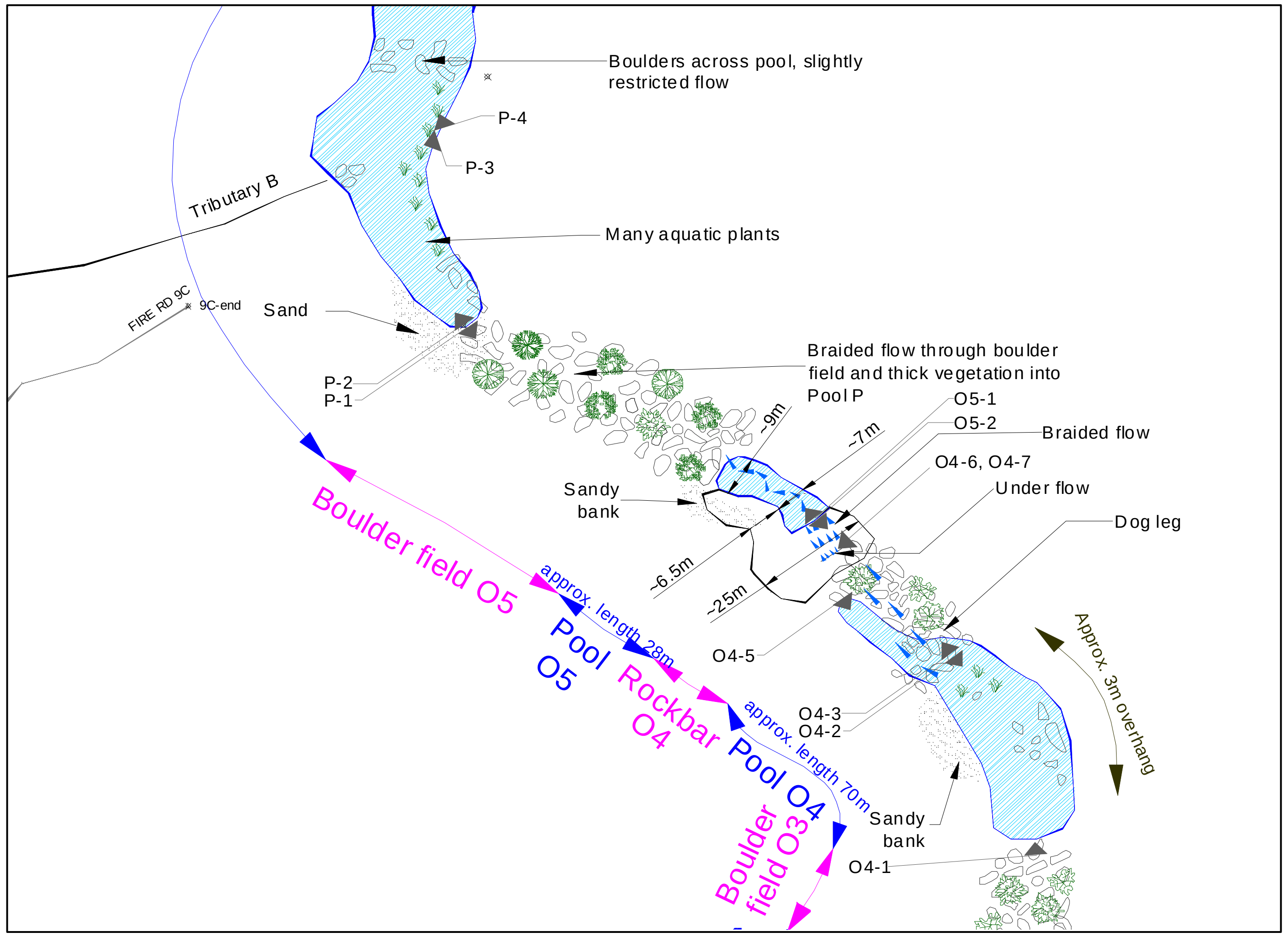
**O4-7** Flow emerging and alluvial deposit at upstream end of Rockbar O4

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| O4-1 | 310465 | 6215013 | 355 |
| O4-2 | 310447 | 6215058 | 145 |
| O4-3 | 310447 | 6215058 | 325 |
| O4-5 | 310424 | 6215070 | 145 |
| O4-6 | 310421 | 6215080 | 230 |
| O4-7 | 310421 | 6215080 | 230 |

# POOL O5 - STREAM MAPPING SUMMARY

**O5-1** Upstream end of Pool O5 looking upstream




**O5-2** Upstream end of Pool O5 looking downstream

Pool O5 notes (as at 17 Dec 2008)

- Pool O5 is approximately 28m long and varies in width from approximately 7m to 9m. Water depth varies from approximately 0.2m to 0.7m.
- Pool bed is sandstone with sand deposits and boulders and some aquatic vegetation.
- The pool is formed in the north east haf of Rockbar 04 at the downstream end of the rockbar. The exposed sandstone on the south west side of the pool slopes up from the pool to approximately 0.3m maximum height above the pool.

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| O5-1 | 310417 | 6215090 | 140 |
| O5-2 | 310417 | 6215090 | 320 |

# POOL P - STREAM MAPPING SUMMARY

**P-1** Upstream end of Pool P looking Upstream

**P-3** Looking south west to Tributary B

**P-2** Upstream end of Pool P looking Downstream

**P-4** Looking downstream to boulders and aquatic vegetation

**P-5** Downstream end of Pool P looking Upstream

**P-7** Underflow into rockbar

**P-6** Downstream end of Pool P looking Downstream

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

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

- Width varies from approximately 12m to 20m with an average of approximately 15m
- Water depth varies from approximately 2m (u/s end) to 0.2m with an average of approximately 0.6m
- Base of the pool is sandstone with several boulders and large detached blocks. Flow is restricted by boulders just downstream of Tributary B as shown in the sketch (Photo P-4).
- Minor alluvial deposits, mainly along the sides of the pool. Many aquatic plants near the u/s end on the eastern side of the pool.
- Water flows below the Rockbar P. Entry point is approximatlely 9m from the d/s end of Pool P at a 1.1m step up in the rockbar. Flow below the rockbar is audible .

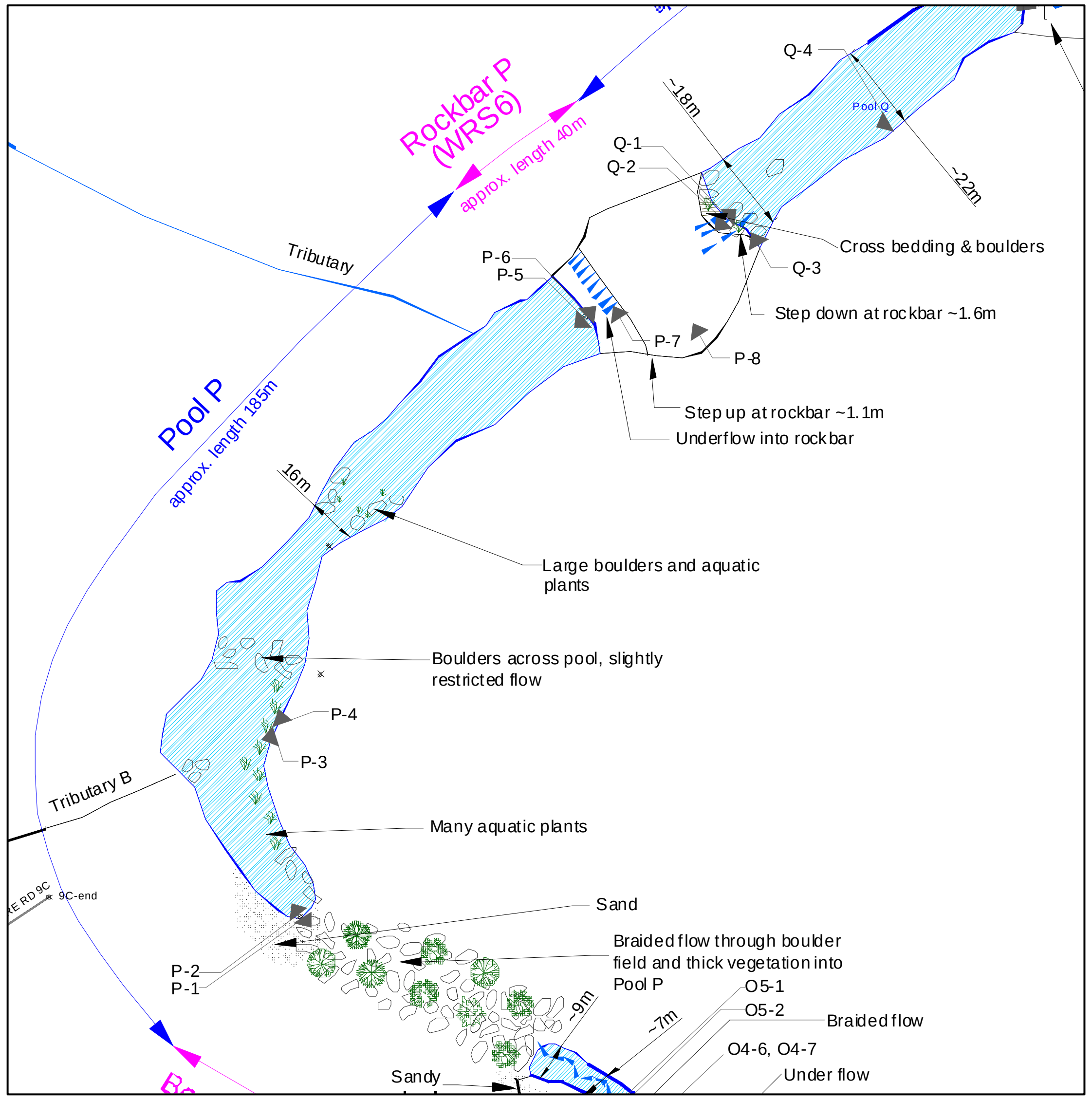
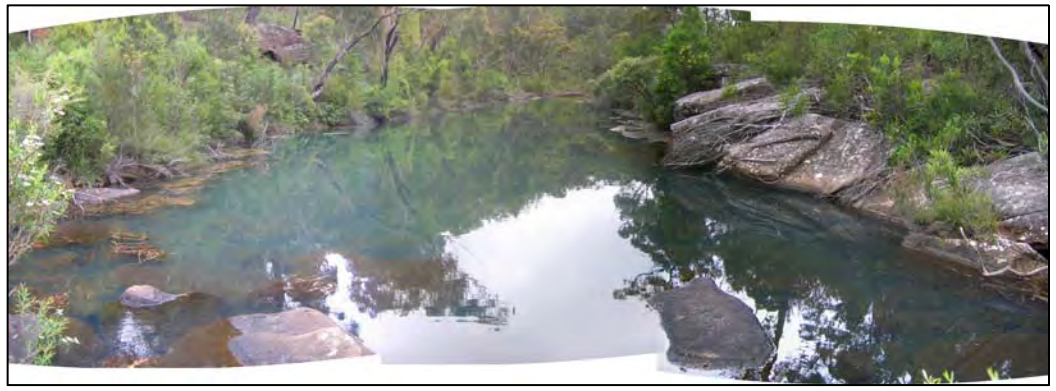



Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| P-1 | 310343 | 6215133 | 145 |
| P-2 | 310343 | 6215133 | 325 |
| P-3 | 310337 | 6215175 | 250 |
| P-4 | 310339 | 6215179 | 340 |
| P-5 | 310410 | 6215274 | 230 |
| P-6 | 310410 | 6215274 | 50 |
| P-7 | 310417 | 6215274 | 330 |
| P-8 | 310437 | 6215269 | 330 |

# POOL Q and Q1 - STREAM MAPPING SUMMARY



**Q-1** Upstream end of Pool Q looking Downstream

**Q-3** West bank at u/s end of Pool Q

**Q-2** Upstream end of Pool Q looking Upstream

**Q-4** Looking upstream at ~40m from the upstream end of Pool Q

**Q-5** Downstream end of Pool Q looking Upstream

**Q-6** Downstream end of Pool Q looking Downstream

Pool Q and Rockbar Q notes (as at 17 Dec 2008)

- Width varies from approximately 18m to 22m. Water depth varies from approximately 1m to 2m.
- Base of Pool Q is sandstone with some detached blocks.
- North west side of the rockbar is approximately 0.4m higher than the water level at the location of the flow between Pool Q and Q1.
- Rockbar Q is approximately 34m across at the widest point.

Pool Q1 notes (as at 17 Dec 2008)

- Water enters Pool Q1 via a small 0.4m waterfall.
- Pool Q1 is located within Rockbar Q.
- Width varies from approximately 9m to 21m. Length is approximately 30m. Water depth varies from approximately 0.3m to 1.1m.
- Base of the pool is sandstone with pot holes and some detached blocks.
- Elevation drops approximately 1m from Pool Q1 to Pool R.

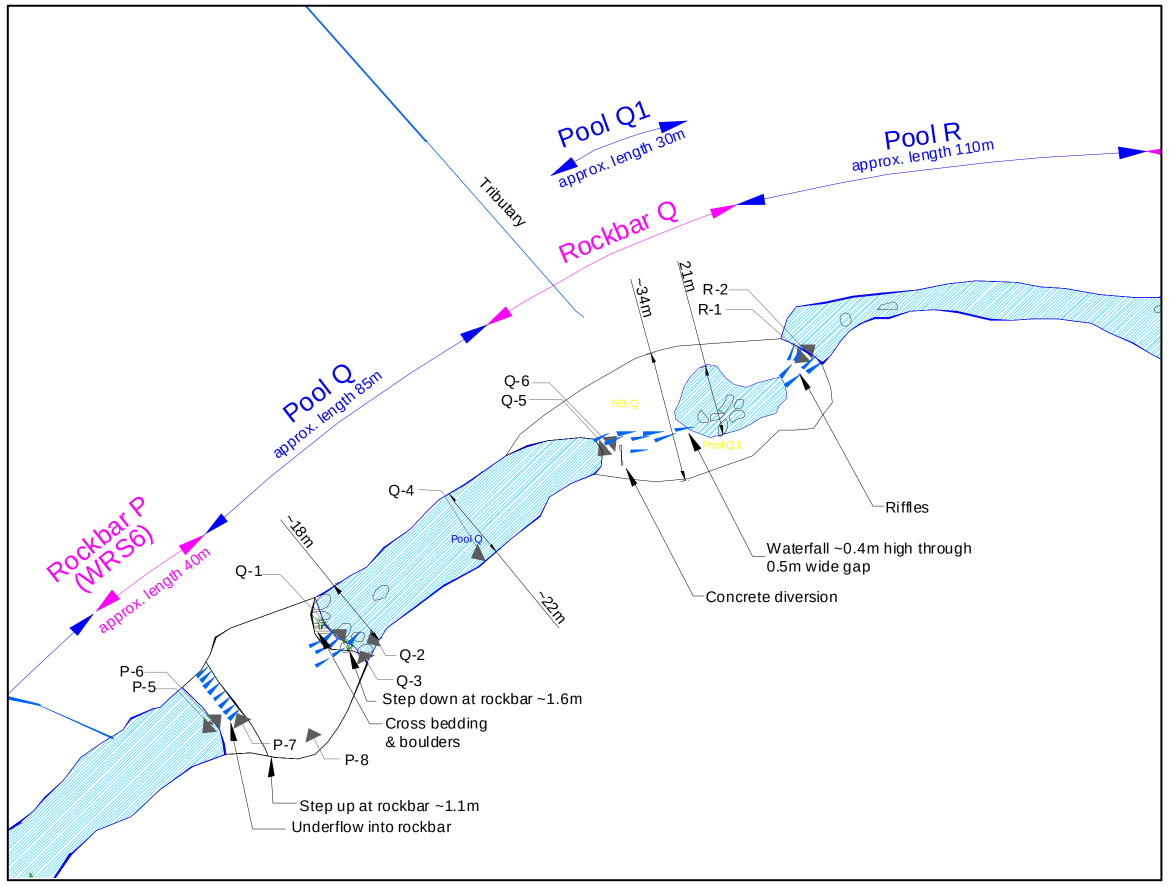



Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| Q-1 | 310443 | 6215297 | 50 |
| Q-2 | 310453 | 6215297 | 230 |
| Q-3 | 310451 | 6215291 | 330 |
| Q-4 | 310481 | 6215320 | 240 |
| Q-5 | 310514 | 6215349 | 230 |
| Q-6 | 310514 | 6215349 | 50 |

# POOL R - STREAM MAPPING SUMMARY

**R-1** Upstream end of Pool R looking Upstream

**R-2** Upstream end of Pool R looking Downstream

Pool R and Rockbar R (WRS7) notes (as at 17 Dec 2008)

- Width varies from approximately 12m (u/s end) to 22m (d/s end). Water depth varies from approximately 0.3m to 0.6m. Pool length is approximately 110m.
- Base of the pool is sandstone with detached blocks, and sediment. Boulders present up to approximately 5m size.
- Rockbar R width varies from approximately 18m to 27m. Rockbar R length is approximately 135m.
- Water flows over most of the width of the rockbar as shallow flow and riffles.
- Most of the rockbar surface has a shallow downstream slope with the last 20m becoming steeper.
- Vertical drop in height from Pool R to Pool S is approximately 7m.
- Four waterfalls located at d/s end of the rockbar from 0.4m to 1.2m height.

**R-3** Downstream end of Pool R looking Upstream

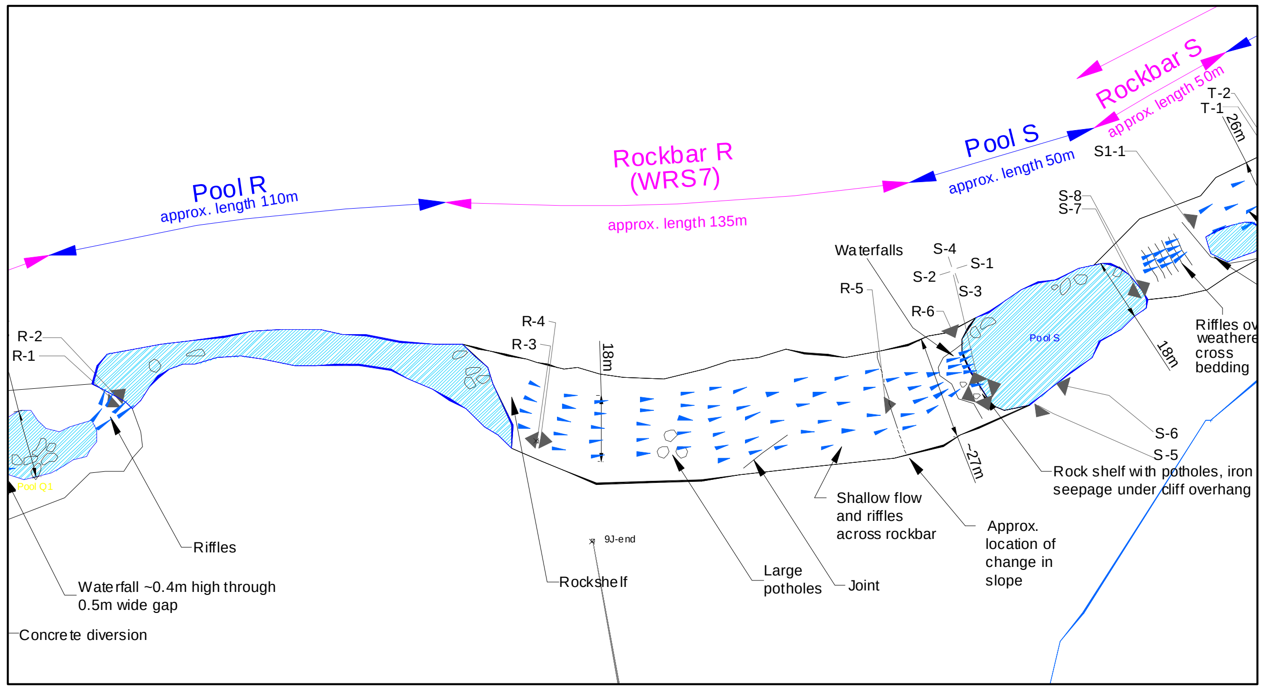



Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| R-1 | 310566 | 6215374 | 225 |
| R-2 | 310566 | 6215374 | 45 |
| R-3 | 310681 | 6215362 | 280 |
| R-4 | 310681 | 6215362 | 100 |
| R-5 | 310776 | 6215372 | 80 |
| R-6 | 310794 | 6215394 | 160 |

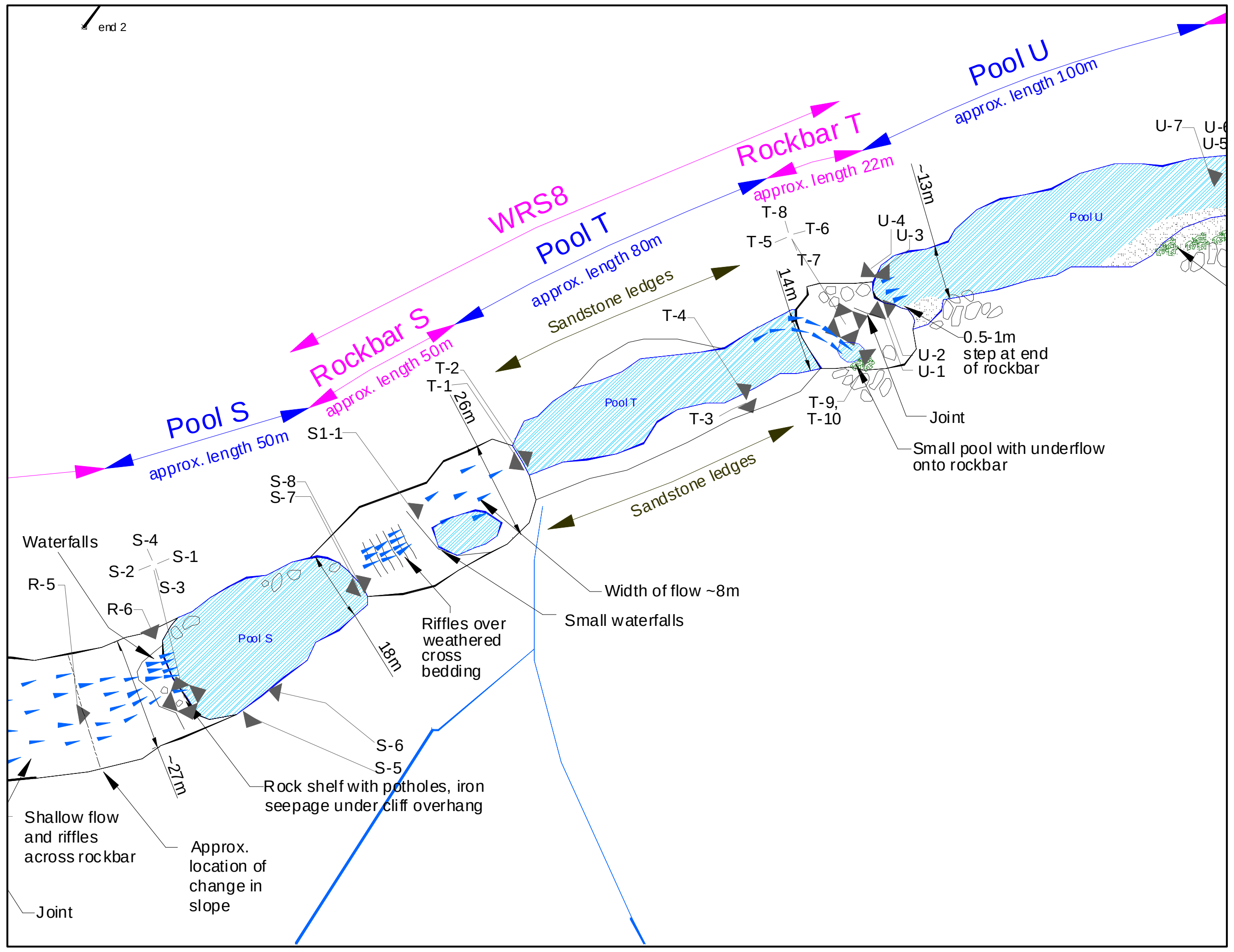
**R-4** Downstream end of Pool R looking Downstream

**R-5** Rockbar R change of slope looking Downstream

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

# POOL S1 - STREAM MAPPING SUMMARY

**S1-1** Pool S1 looking downstream and at south east bank




<u>Pool S1 notes (as at 17 Dec 2008)</u>

- Pool S1 is located at the approximate midpoint of Rockbar S.
- Pool S1 is approximately 14m long and 9m wide. Water depth is approximately 1.8m.
- Flow enters the pool by small waterfalls approximately 0.2m to 0.4m high.
- Base of the pool is sandstone.

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| S1-1 | 310858 | 6215423 | 65 |
| | | | |

# POOL S - STREAM MAPPING SUMMARY

**S-1** Upstream end of Pool S looking Downstream

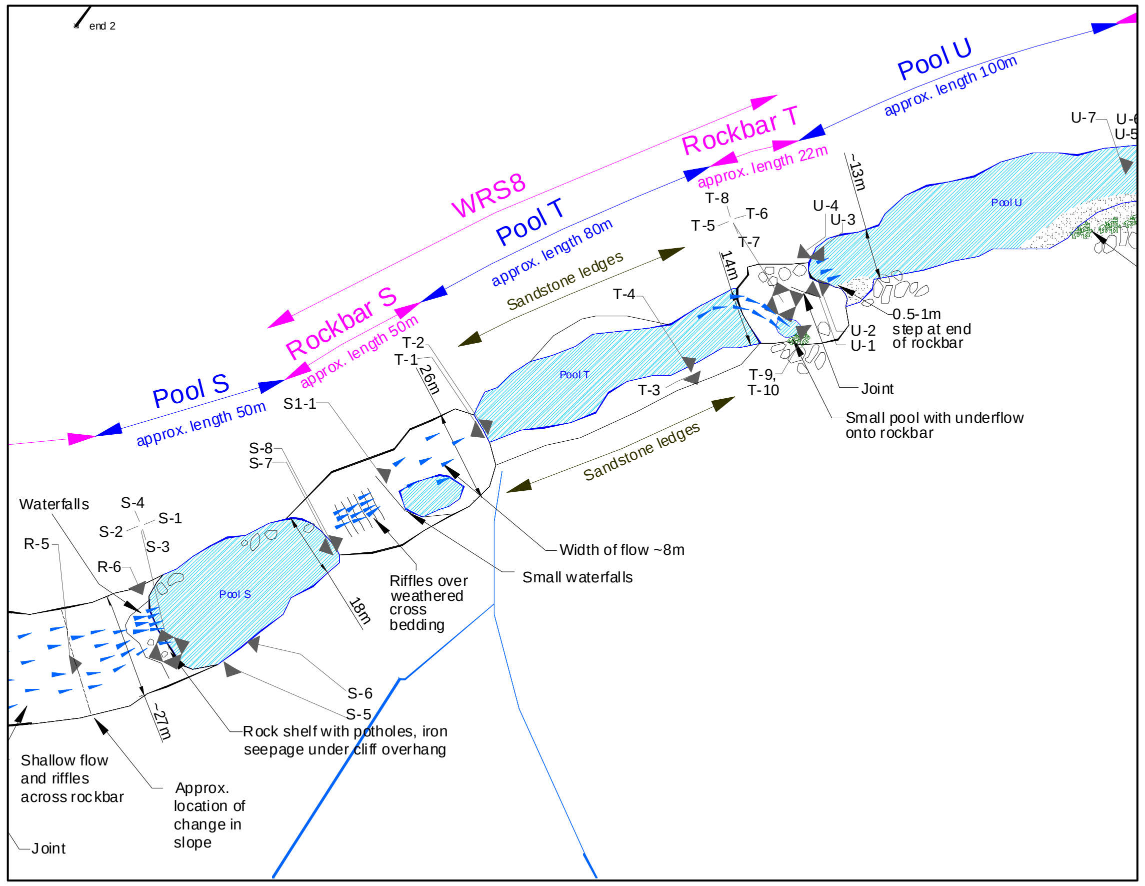
**S-3** South east bank and u/s end of Pool S

<u>Pool S and Rockbar S (WRS8) notes (as at 17 Dec 2008)</u>

- Width is approximately 18m. Water depth at the upstream end of Pool S is 4.7m. Averge depth appears to be approximately 1.5m. Length of Pool S is approximately 50m.
- Base of the pool is sandstone.
- Estimated total height of waterfalls at upstream end of Pool S is approximately 1.9m.
- Some boulders along north side to about 3m size.
- Rockbar S is approximately 50m long and 26m wide.
- Weathered cross bedding present in the upstream end of the rockbar.
- Water flows over most of the width of the rockbar with a small pool located at the approximate middle of the rockbar (See separate sheet for Pool S1).

**S-2** Upstream end of Pool S looking Upstream

**S-4** North west bank and u/s end of Pool S




**S-7** Downstream end of Pool S looking Upstream

**S-5** Iron staining at seepage

**S-8** Downstream end of Pool S looking Downstream

**S-6** Looking upstream to waterfalls from south east bank

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| S-1 | 310802 | 6215376 | 70 |
| S-2 | 310802 | 6215376 | 250 |
| S-3 | 310802 | 6215376 | 160 |
| S-4 | 310802 | 6215376 | 340 |
| S-5 | 310818 | 6215371 | 210 |
| S-6 | 310825 | 6215377 | 290 |
| S-7 | 310845 | 6215404 | 245 |
| S-8 | 310845 | 6215404 | 65 |

# POOL T - STREAM MAPPING SUMMARY

**T-1** Upstream end of Pool T looking Upstream

**T-3** Iron stain at seepage, south east bank

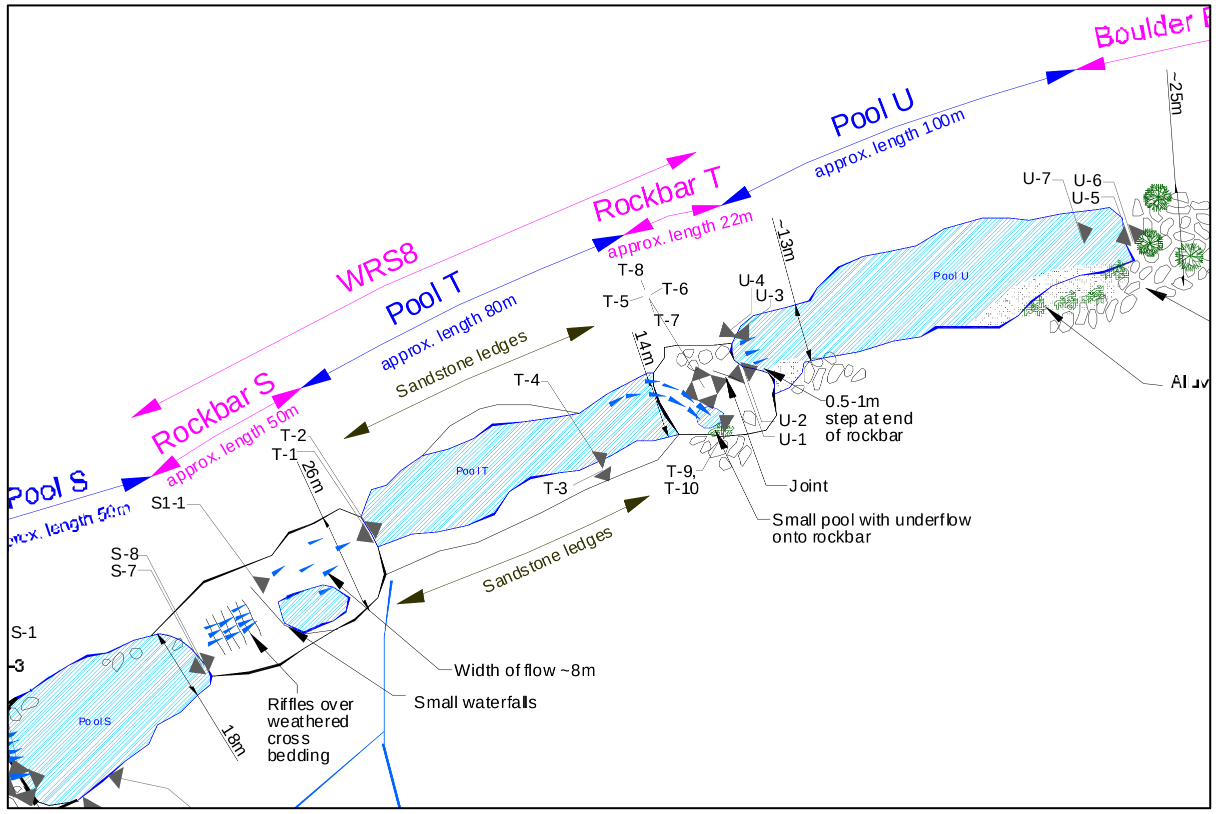
**T-4** Minor seepage at south east bank

<u>Pool T and Rockbar T (WRS8) notes (as at 24 Dec 2008)</u>

- Average width is approximately 14m. Depth varies from approximately 0.1m to 0.5m with an average of approximately 0.3m. The length of Pool T is approximately 80m.
- Base of the pool is sandstone with pot holes at about the middle of the pool and sediment at the upstream end.
- Sandstone ledges with cross bedding present both sides of the pool. Distance between ledges is approximately 30m.
- Minor seepage and iron staining observed at cross bedding in sandstone ledges.
- Rockbar T is approximately 22m long and 27m wide and has pot holes.
- Water from Pool T flows over the surface of Rockbar T to a small pool which is approximately 5m in diameter. Flow from the small pool enters the rockbar as underflow and emerges at Pool U.

**T-2** Upstream end of Pool T looking Downstream

**T-7** South east bank and downstream end of Pool T




**T-5** Downstream end of Pool T looking Upstream

**T-8** North west bank at downstream end of Pool T

**T-6** Downstream end of Pool T looking Downstream

**T-9** Small pool and underflow into rockbar

**T-10** Small pool on rockbar T

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| T-1 | 310885 | 6215436 | 240 |
| T-2 | 310885 | 6215436 | 60 |
| T-3 | 310935 | 6215464 | 150 |
| T-4 | 310935 | 6215464 | 70 |
| T-5 | 310965 | 6215471 | 250 |
| T-6 | 310965 | 6215471 | 70 |
| T-7 | 310965 | 6215471 | 160 |
| T-8 | 310965 | 6215471 | 340 |
| T-9 | 310971 | 6215462 | 330 |
| T-10 | 310971 | 6215462 | 300 |

# POOL U - STREAM MAPPING SUMMARY

**U-1** Upstream end of Pool U looking Upstream

**U-3** Potholes and flow emerging

**U-2** Upstream end of Pool U looking Downstream

**U-5** Downstream end of Pool U looking Upstream

**U-4** Potholes and flow emerging

**U-6** Downstream end of Pool U looking Downstream

**U-7** ~10m from Downstream end of Pool U looking Downstream

Pool U notes (as at 24 Dec 2008)

- Average width is approximately 13m. Water depth varies from approximately 0.3m to 1.3m. Pool length is approximately 100m.
- Base of the pool is sandstone with boulders and large detached blocks up to 4m size, and alluvial deposits mainly on the south east bank. Flow is restricted by boulders at about the middle of the pool.
- Aquatic vegetation observed at the upstream end and at the alluvial deposits.
- Pool U ends at a boulder field with boulders up to approximately 5m in size and vegetation. The width of the boulder field at the downstream end of the pool is approximately 25m.
- The vertical drop in height from Pool T to Pool U is approximately 4m.

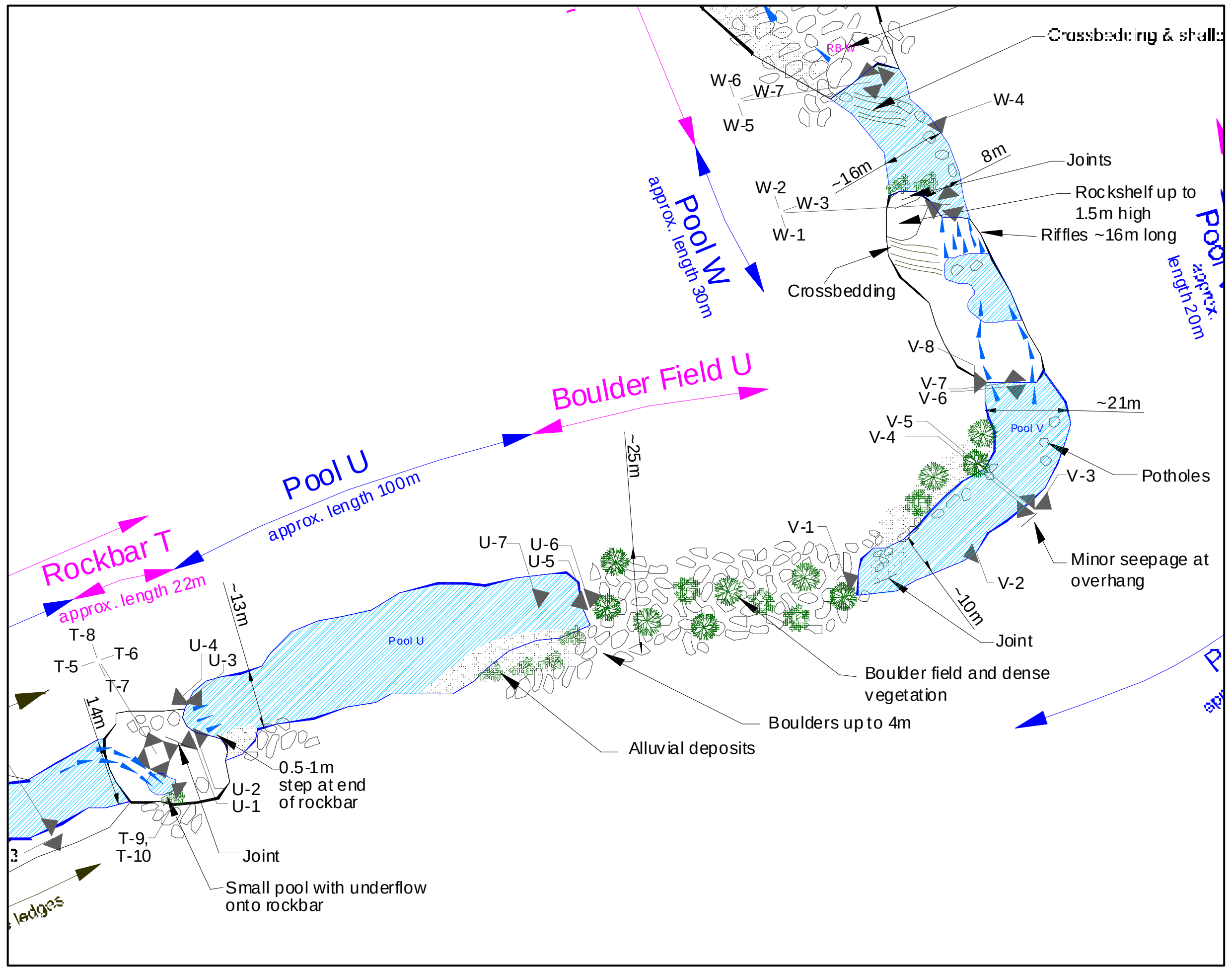



Photo Details

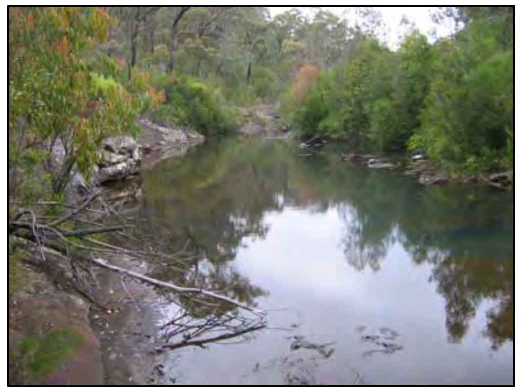
| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| U-1 | 310974 | 6215474 | 250 |
| U-2 | 310974 | 6215474 | 70 |
| U-3 | 310974 | 6215484 | 140 |
| U-4 | 310971 | 6215485 | 230 |
| U-5 | 311067 | 6215507 | 250 |
| U-6 | 311067 | 6215507 | 70 |
| U-7 | 311055 | 6215508 | 70 |

# POOL V - STREAM MAPPING SUMMARY


**V-1** Upstream end of Pool V looking Downstream


**V-3** Overhang at east bank


**V-2** Upstream end of Pool V looking Upstream


**V-4** Mid pool looking Upstream from east bank


**V-6** Downstream end of Pool V looking Upstream


**V-5** Mid pool looking Downstream from east bank


**V-7** Downstream end of Pool V looking Downstream


**V-8** Looking at east bank at Downstream end of Pool V

<u>Pool V and Rockbar V notes (as at 24 Dec 2008)</u>

- Width varies from approximately 10m to 21m. Water depth varies from approximately 0.1m (u/s end) to 1.2m (d/s end)
- Base of the pool is sandstone with scattered boulders, minor alluvial deposits at the upstream end and aquatic vegetation at the upstream end.
- Minor seepage observed from sandstone ledges on south east side.
- Rockbar V varies from approximately 13m to 21m width and is approximately 55m long.
- Cross bedding is present at the downstream end.
- Pool V1 is located on the east side of Rockbar V. Pool V1 is approximately 11m wide, 20m long and 1m deep.
- Water flows from Pool V1 to Pool W via riffles over an approximate 1m vertical drop in elevation. A rock shelf that rises approximately 1.5m above Pool W is located on the west side of the riffles.

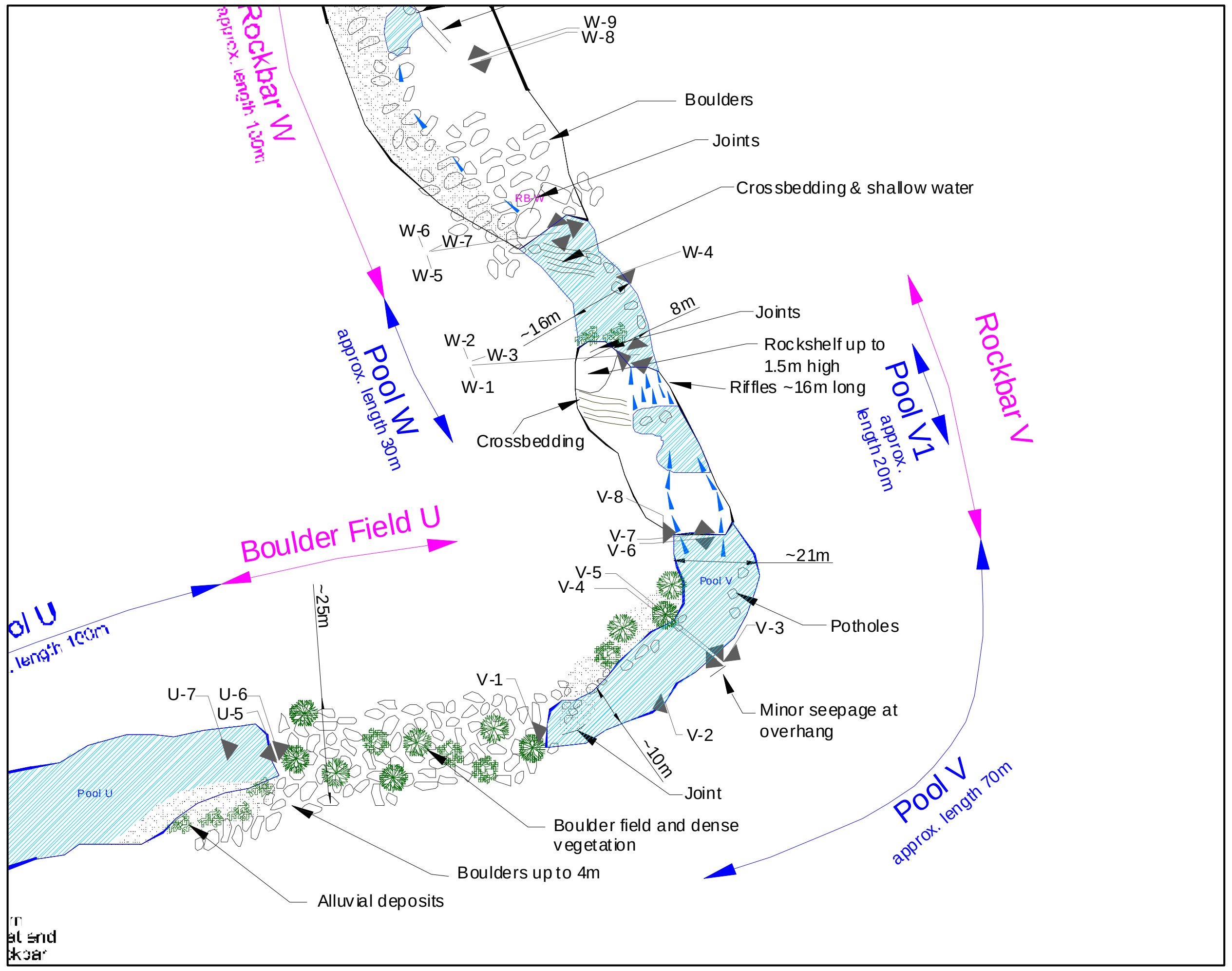



Photo Details

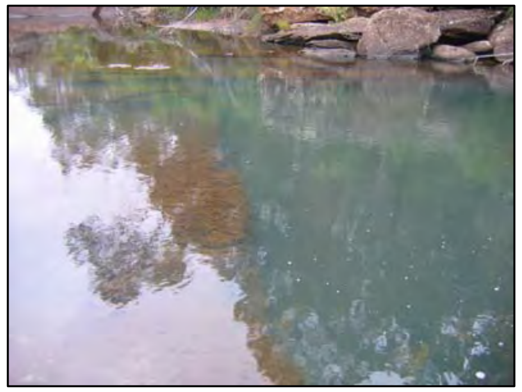
| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| V-1 | 311127 | 6215511 | 70 |
| V-2 | 311159 | 6215519 | 250 |
| V-3 | 311174 | 6215531 | 120 |
| V-4 | 311170 | 6215529 | 220 |
| V-5 | 311170 | 6215529 | 40 |
| V-6 | 311167 | 6215558 | 175 |
| V-7 | 311167 | 6215558 | 355 |
| V-8 | 311158 | 6215558 | 90 |

# POOL W - STREAM MAPPING SUMMARY

**W-1** Upstream end of Pool W looking Upstream

**W-3** East bank at Upstream end of Pool W

**W-2** Upstream end of Pool W looking Downstream



**W-4** Mid pool looking Upstream from east bank

**W-5** Downstream end of Pool W looking Upstream

**W-7** Looking at east bank at Downstream end of Pool W

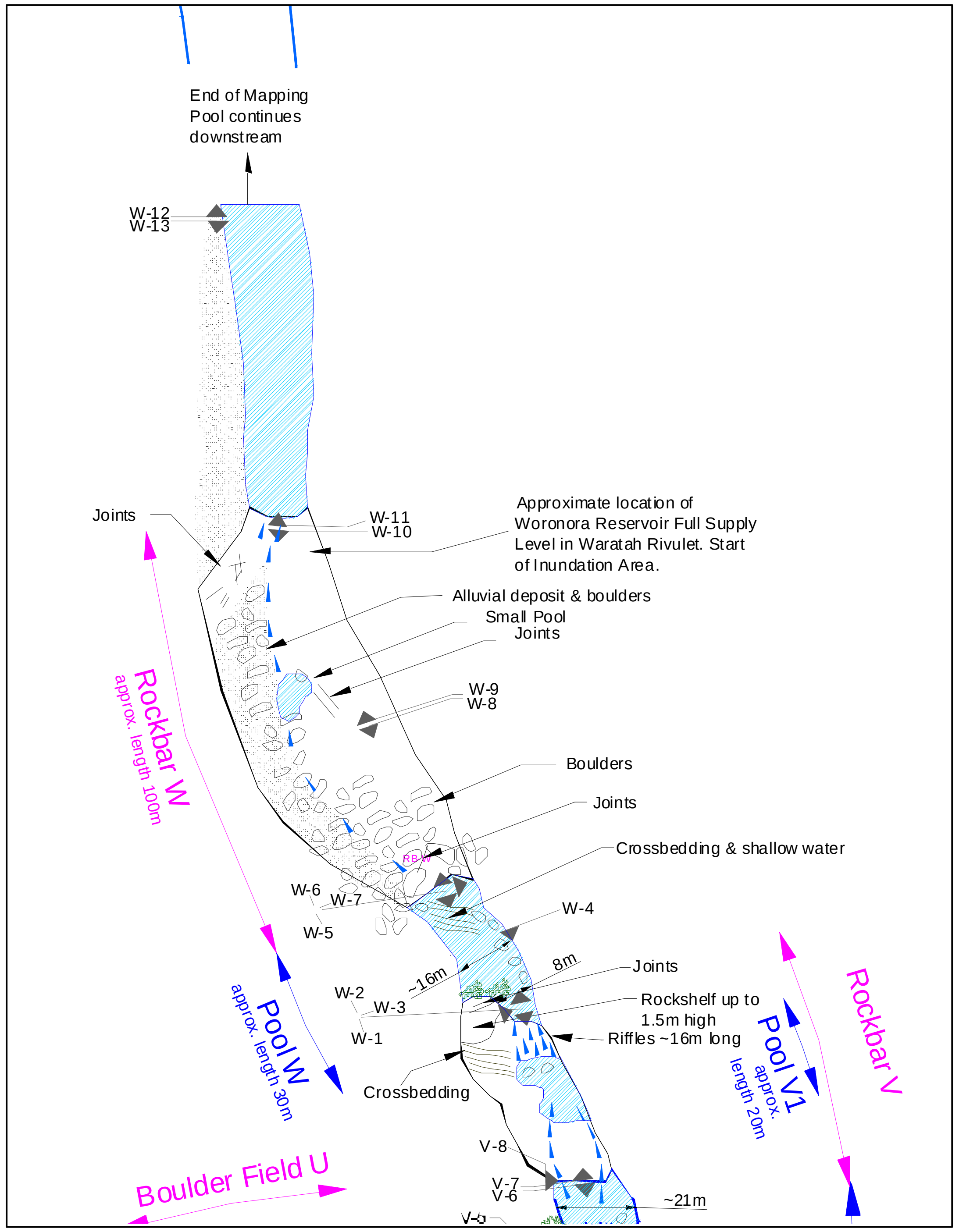
**W-6** Downstream end of Pool W looking Downstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| W-1 | 311153 | 6215601 | 170 |
| W-2 | 311153 | 6215601 | 350 |
| W-3 | 311153 | 6215601 | 70 |
| W-4 | 311150 | 6215621 | 160 |
| W-5 | 311134 | 6215630 | 170 |
| W-6 | 311134 | 6215630 | 350 |
| W-7 | 311134 | 6215630 | 70 |

Pool W notes (as at 24 Dec 2008)

- Width varies from approximately 8m to 16m. Water depth varies from approximately 0.2m to 1.7m.
- Base of the pool is sandstone with boulders up to 5m size, alluvial deposit and aquatic vegetation.
- Cross bedding present in the pool base.
- Rockbar W is described on separate sheet.



# ROCKBAR W - STREAM MAPPING SUMMARY

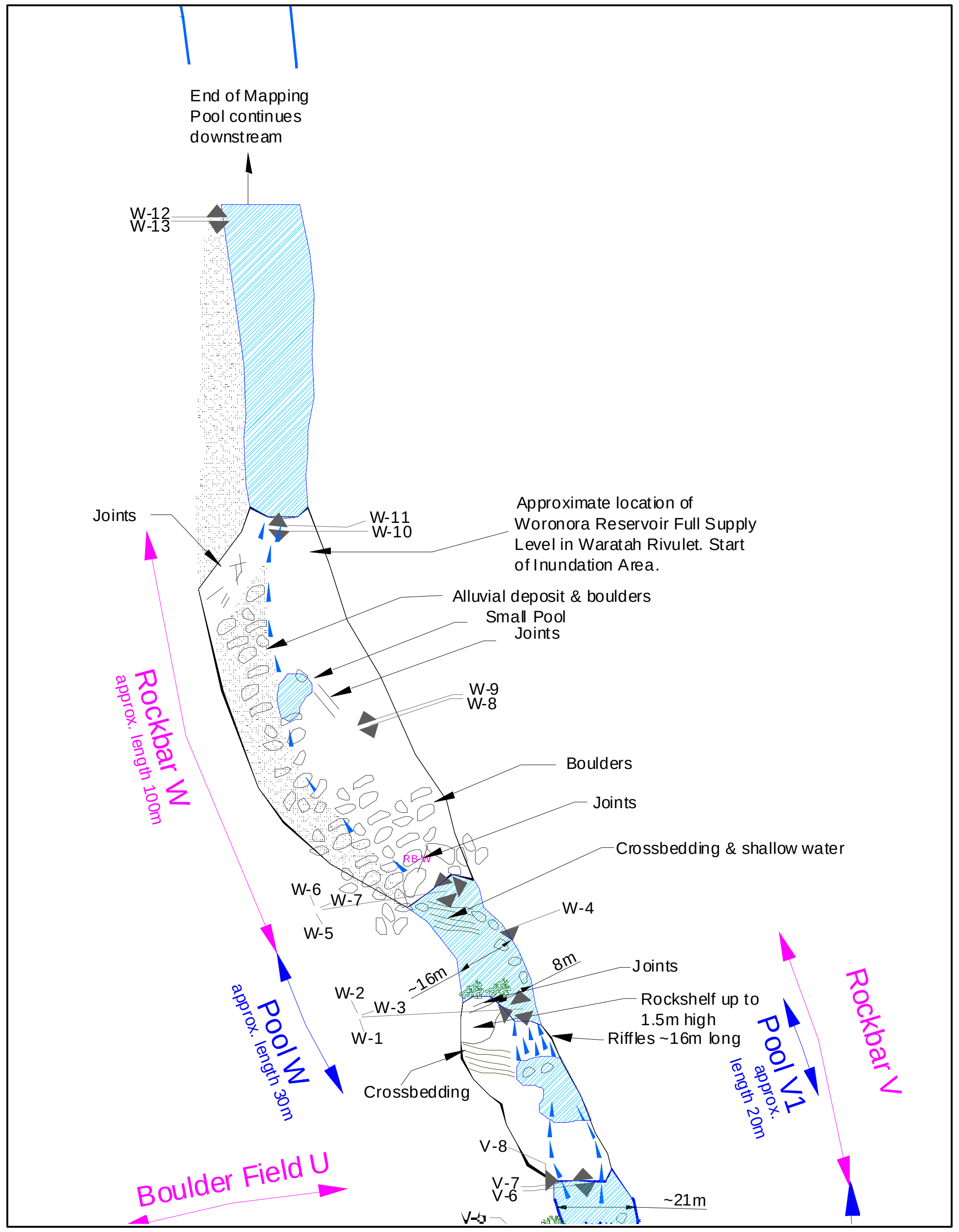
**W-8** Midway along Rockbar W looking Upstream

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

**W-9** Midway along Rockbar W looking Downstream

Rockbar W notes (as at 24 Dec 2008)

- Rockbar W width varies from approximately 15m to 34m and length is approximately 100m.
- There are numerous boulders at the upstream end of the rockbar varying up to approximately 5m maximum size covering most of the rockbar.
- There are large deposits of alluvial material and boulders along the western side.
- Water flows along a shallow channel between the exposed sandstone and the alluvial deposits. There is a small pool about midway along the rockbar measuring approximately 6m wide by 10m long and 0.3m depth.
- The surface water flows into Pool X at about the estimated location of the full supply level of Woronora Reservoir.




**W-10** Downstream end of Rockbar W looking Upstream

**W-11** Downstream end of Rockbar W looking Downstream (Pool X)

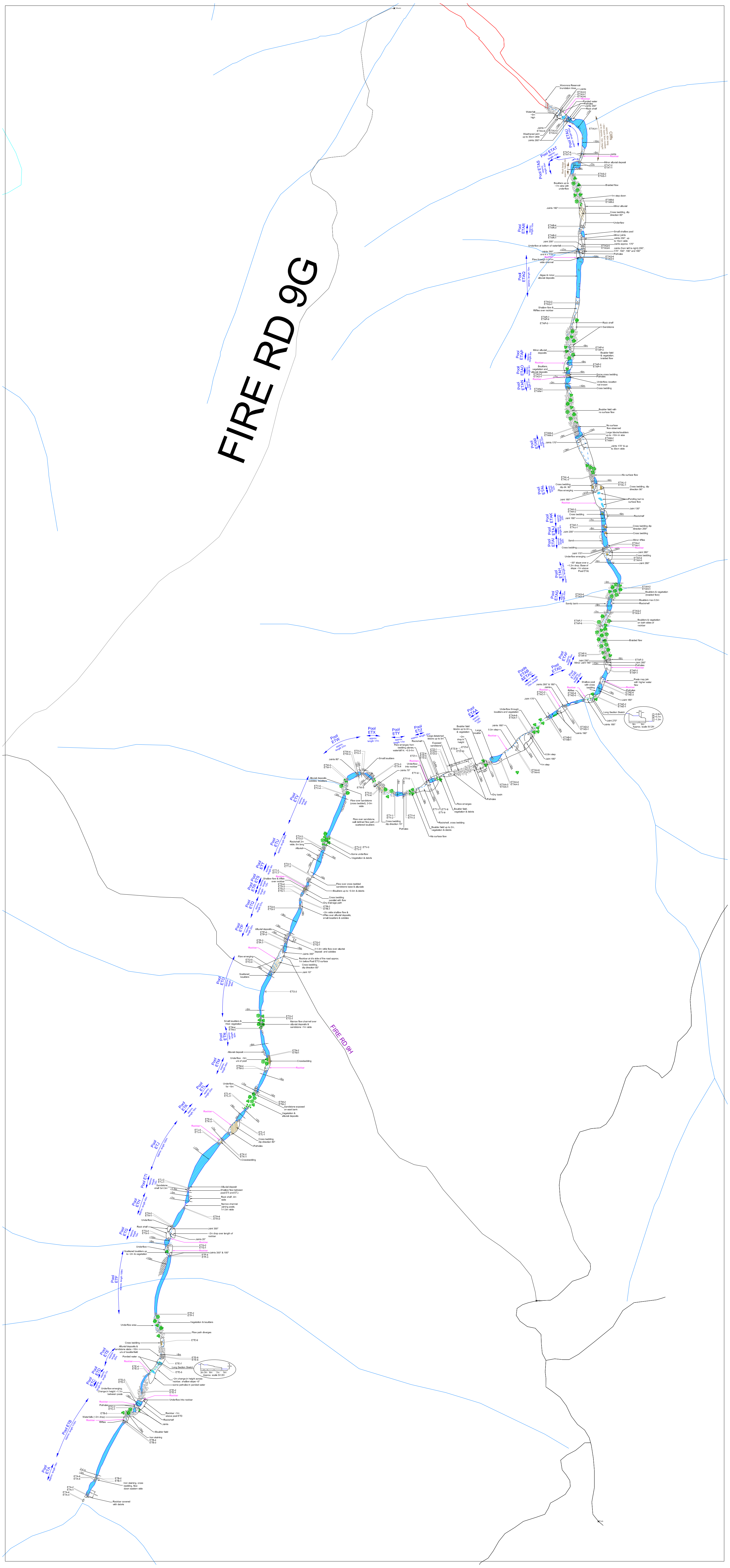
**W-13** End of mapping (Pool X) looking Upstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| W-8 | 311115 | 6215671 | 165 |
| W-9 | 311115 | 6215671 | 340 |
| W-10 | 311092 | 6215720 | 180 |
| W-11 | 311092 | 6215720 | 0 |
| W-12 | 311078 | 6215796 | 0 |
| W-13 | 311078 | 6215796 | 180 |

# APPENDIX 2

# EASTERN TRIBUTARY STREAM MAPPING AND PHOTOGRAPHIC RECORD


FIRE RD 9G
FIRE RD 9H

# POOL ETA STREAM MAPPING SUMMARY

**ETA-1** Upstream end of Pool ETA looking Upstream

**ETA-4** Rockbar Upstream of Pool ETA looking Downstream

**ETA-2** Upstream end of Pool ETA looking Downstream

**ETA-5** Downstream end of Pool ETA looking Upstream

**ETA-3** Rockbar Upstream of Pool ETA looking Upstream

**ETA-6** Downstream end of Pool ETA looking Downstream

<u>Pool ETA notes (as at 29 Dec 2008)</u>

- Width varies from approximately 2m to 6m
- Water depth varies from approximately 0.1m over approximately 12m length at the upstream end of the pool to approximately 0.3m
- Base of the pool is sandstone with several boulders up to approximately 1m size.
- Iron staining/deposits present over base of pool
- Rockbar upstream of the pool is approximately 3m wide and mostly covered with vegetation debris
- Rockbar downstream of the pool is approximately 3m wide and 6m long.
- Water flows along the eastern side of the rockbar and iron staining and cross bedding are present.

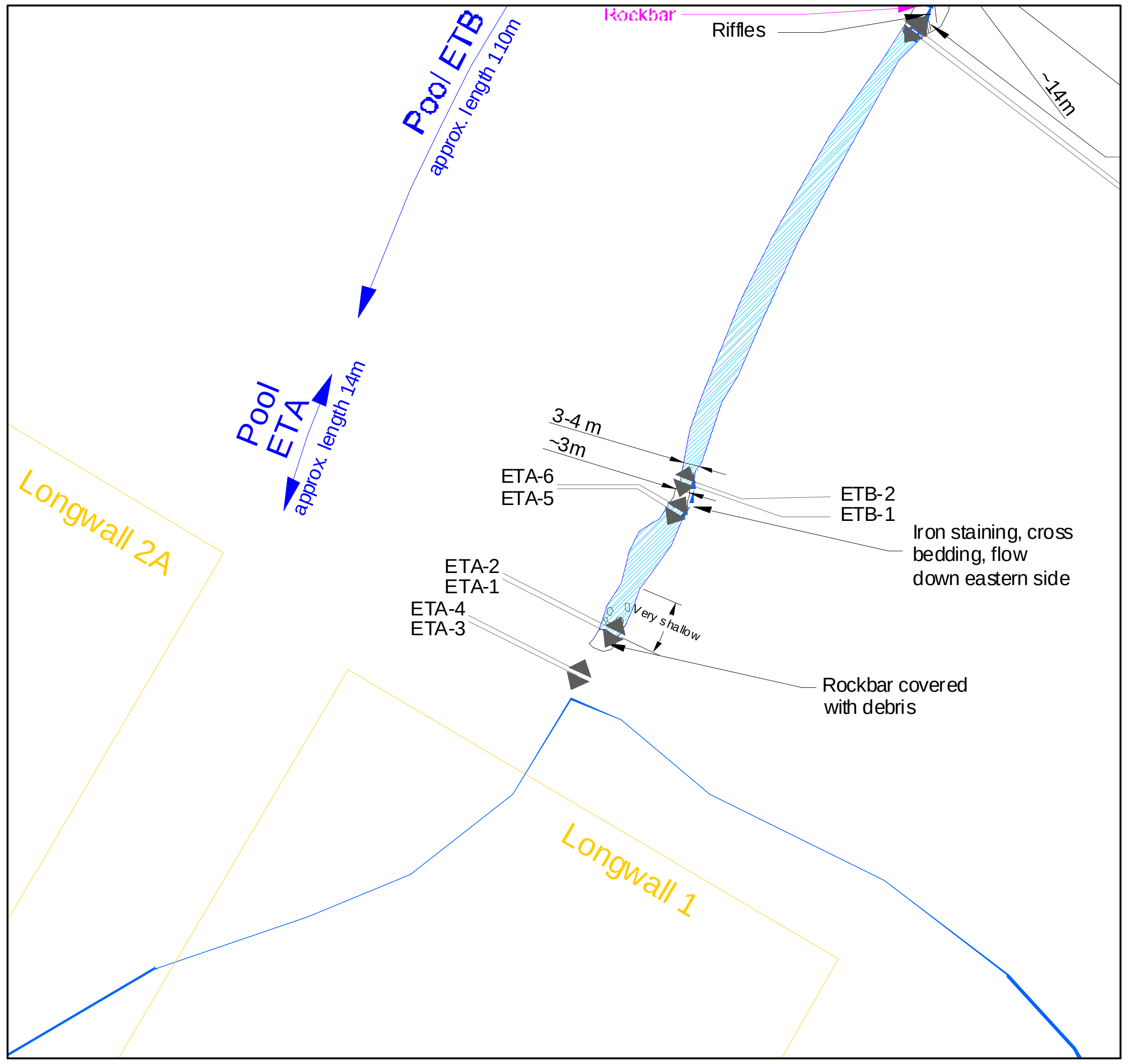



Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| ETA-1 | 311285 | 6213180 | 206 |
| ETA-2 | 311285 | 6213180 | 26 |
| ETA-3 | 311277 | 6213171 | 206 |
| ETA-4 | 311277 | 6213171 | 26 |
| ETA-5 | 311298 | 6213207 | 211 |
| ETA-6 | 311298 | 6213207 | 31 |

# POOL ETB STREAM MAPPING SUMMARY

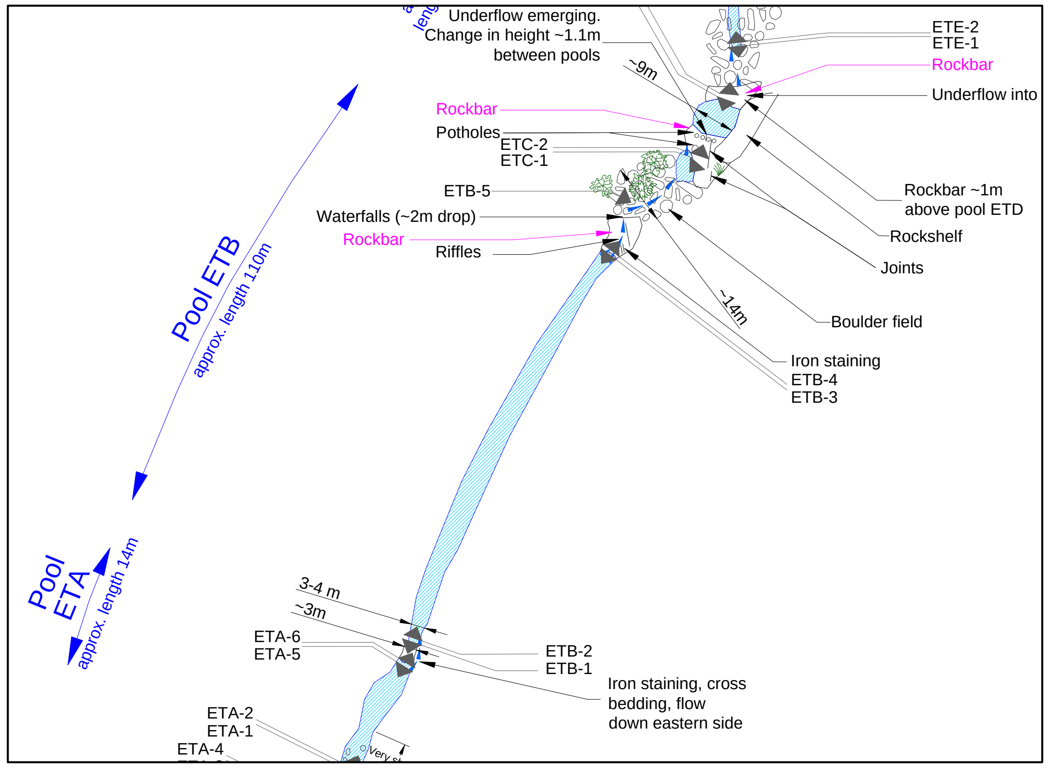
**ETB- 1** Upstream end of Pool ETB looking Upstream

**ETB- 2** Upstream end of Pool ETB looking Downstream

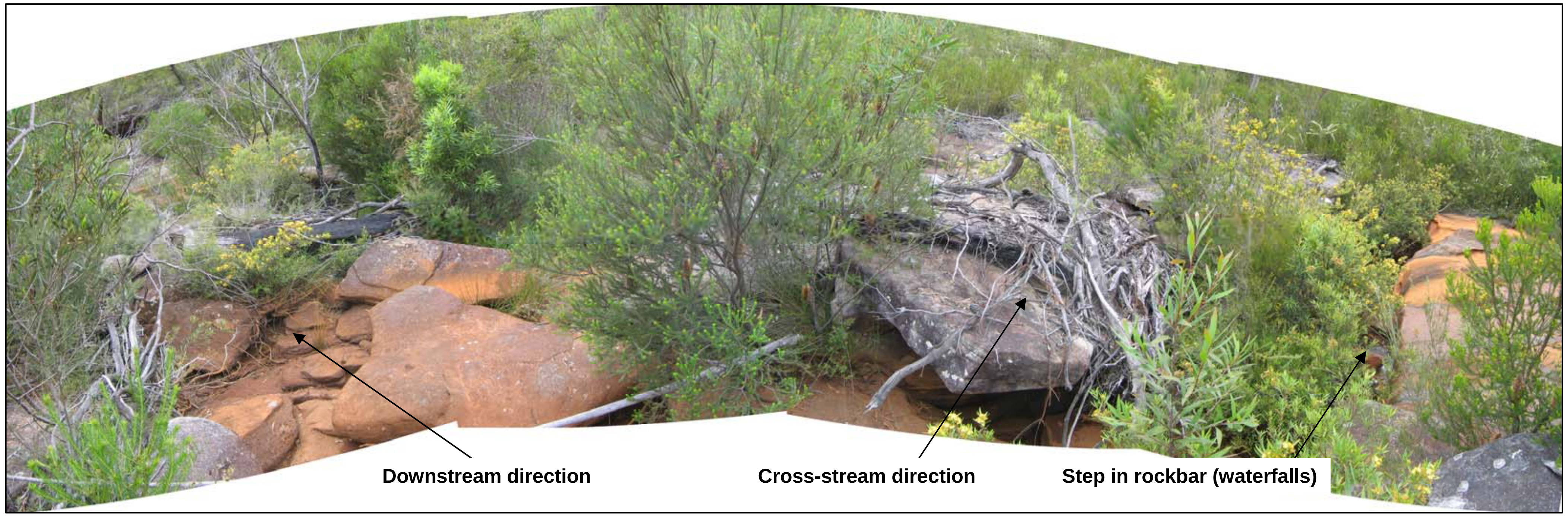
**ETB-3** Downstream end of Pool ETB looking Upstream

<u>Pool ETB notes (as at 29 Dec 2008)</u>

- Width varies from approximately 3m to 5m
- Water depth varies from approximately 0.7m at the downstream end to 1.5m at the upstream end.
- Base of the pool could not be seen in many locations but confirmed as sandstone at some locations
- Rockbar at the downstream end of Pool ETB has an approximate 2m waterfall. Water then flows into a boulder field.




**ETB-4** Downstream end of Pool ETB looking Downstream




**ETB-5** From Western bank- composite from step in rockbar to Downstream direction

Photo Details

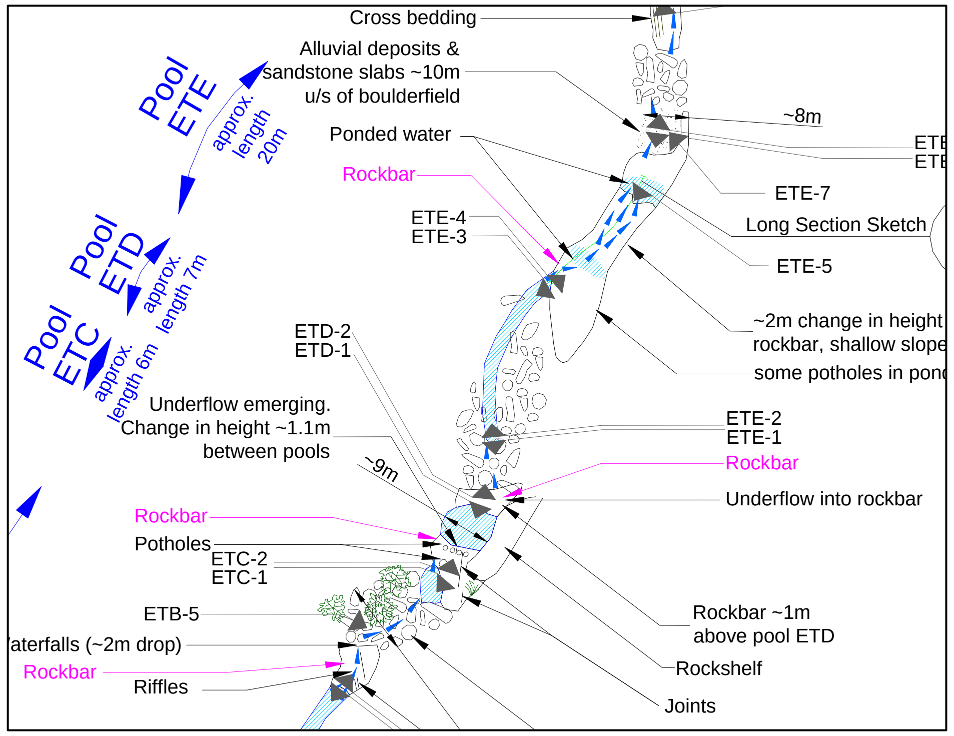
| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| ETB-1 | 311300 | 6213213 | 199 |
| ETB-2 | 311300 | 6213213 | 19 |
| ETB-3 | 311350 | 6213311 | 208 |
| ETB-4 | 311350 | 6213311 | 38 |
| ETB-5 | 311354 | 6213325 | 120 |

# POOL ETC STREAM MAPPING SUMMARY

**ETC-1** Downstream end of Pool ETC looking Upstream

Pool ETC notes (as at 29 Dec 2008)

- Width is approximately 4m and length is approximately 6m.
- Average water depth is approximately 0.4m.
- Base of the pool is sandstone.
- Rockbar at downstream end of the pool is approximately 13m wide.




**ETC-2** Downstream end of Pool ETC looking Downstream

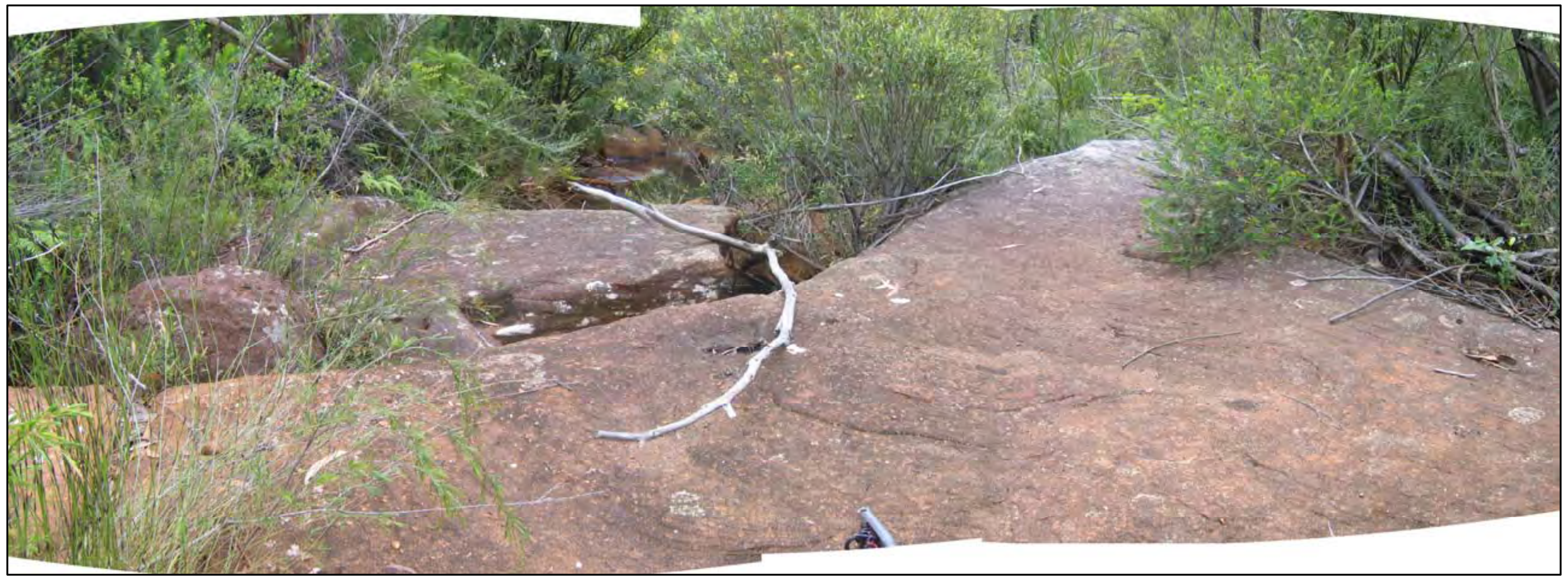
Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| ETC-1 | 311373 | 6213335 | 221 |
| ETC-2 | 311373 | 6213335 | 19 |

# POOL ETD STREAM MAPPING SUMMARY

**ETD-1** Downstream end of Pool ETD looking Upstream

**ETC-2** (cropped) Downstream end of Pool ETC looking Downstream showing pool ETD in the background



**ETD-2** Downstream end of Pool ETD looking Downstream

Pool ETD notes (as at 29 Dec 2008)

- Pool width is approximately 9m and length is approximately 7m.
- Average water depth is 0.4m. Maximum depth is approximately 0.8m.
- Base of the pool is sandstone with alluvial deposits and scattered boulders up to approximately 1m size.
- Iron staining present on exposed sandstone.

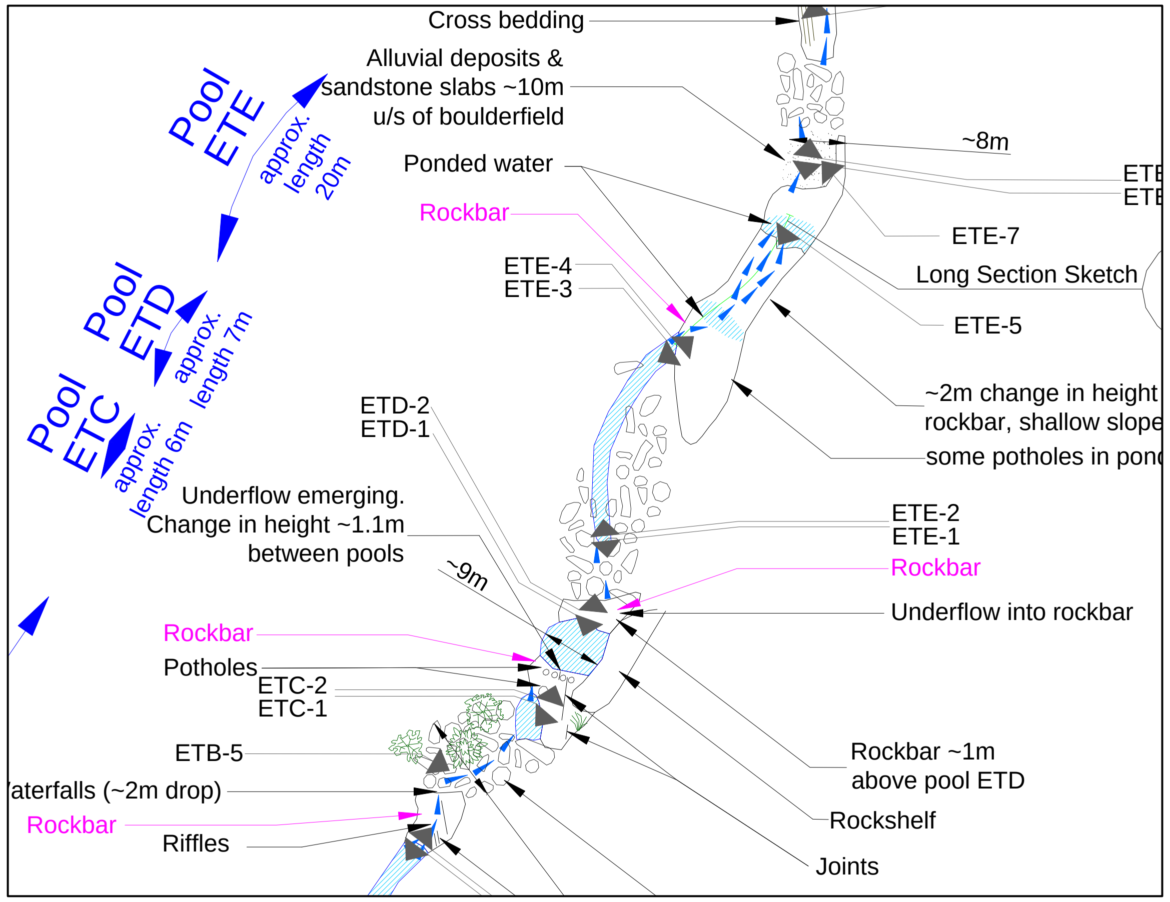



Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| ETC-2 | 311373 | 6213335 | 19 |
| ETD-1 | 311380 | 6213351 | 200 |
| ETD-2 | 311380 | 6213351 | 6 |

# POOL ETE STREAM MAPPING SUMMARY

**ETE-1** Upstream end of Pool ETE looking Upstream

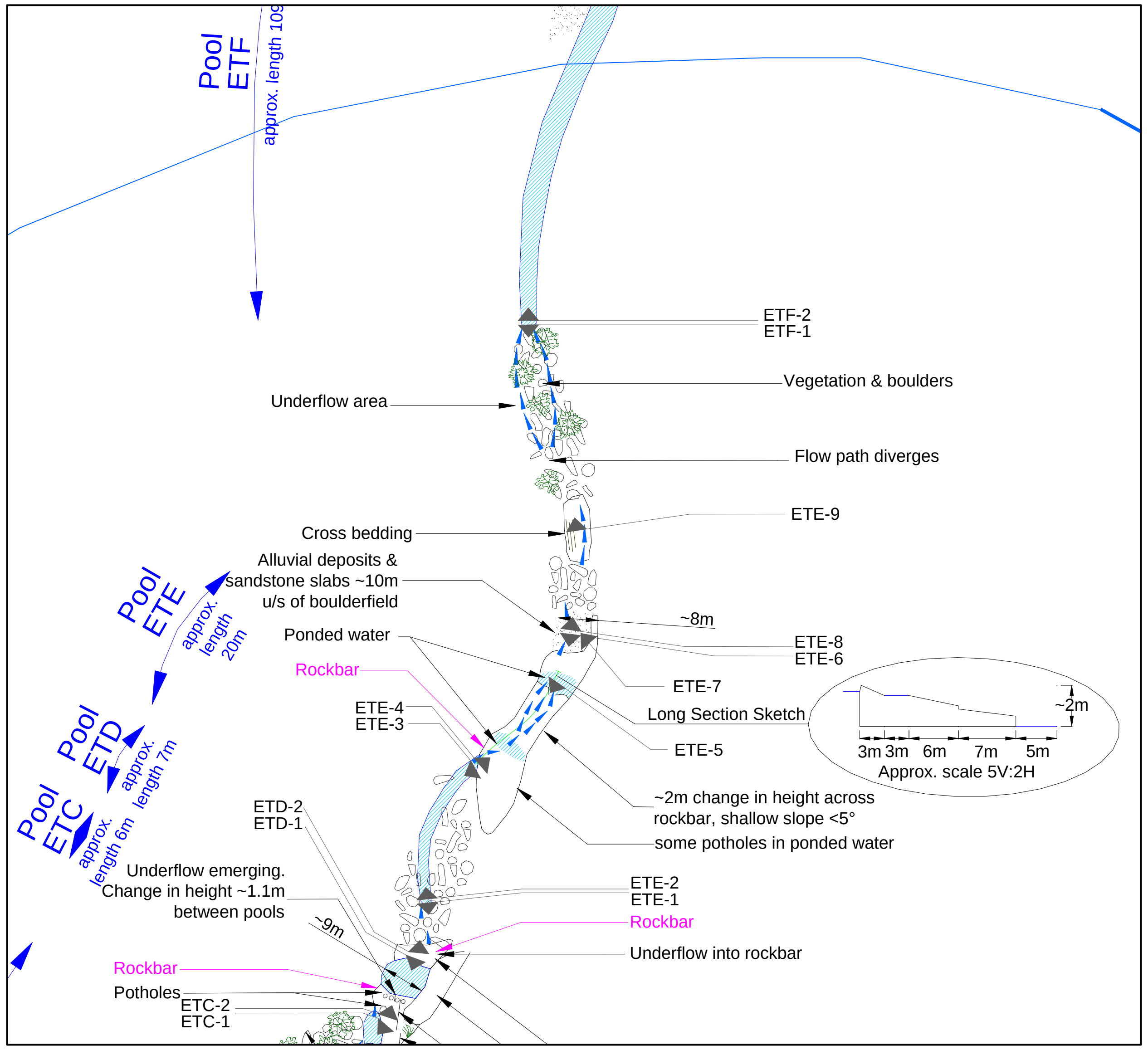
**ETE-2** Upstream end of Pool ETE looking Downstream

Pool ETE notes (as at 29 Dec 2008)

- Width varies from approximately 2m to 5m
- Average water depth is approximately 0.4m. Maximum depth is approximately 0.5m.
- Base of the pool is sandstone with alluvial deposits and several boulders up to approximately 2m size.
- Thick vegetation encroaches at sides of the pool.
- Boulder field present on most of the east side of the pool.

(Notes continued on second sheet)

**ETE-3** Downstream end of Pool ETE looking Upstream




**ETE-4** Downstream end of Pool ETE looking Downstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| ETE-1 | 311382 | 6213364 | 174 |
| ETE-2 | 311382 | 6213364 | 354 |
| ETE-3 | 311395 | 6213396 | 241 |
| ETE-4 | 311395 | 6213396 | 50 |

# POOL ETE DOWNSTREAM MAPPING SUMMARY

**ETE-5** On Rockbar Downstream end of Pool ETE looking Upstream

**ETE-7** Sandstone slabs between Rockbar and Boulder Field

**ETE-9** Exposed Sandstone within Boulder Field

<u>Pool ETE Downstream notes (as at 29 Dec 2008)</u>

- Water flows as shallow flow and riffles from Pool ETE over a large rockbar which has potholes and cross bedding.
- Some ponded water present on the rockbar.
- Rockbar drops approximately 2m in height as shown in sketch below.
- Sandstone is broken up into slab shaped pieces, up to approximately 150mm thickness at the downstream end of the rockbar.
- Flow continues mostly through boulder field with a small section of exposed cross bedded sandstone (Photo ETE-9).

**ETE-6** Between Rockbar and Boulder Field looking Upstream

**ETE-8** Between Rockbar and Boulder Field looking Downstream

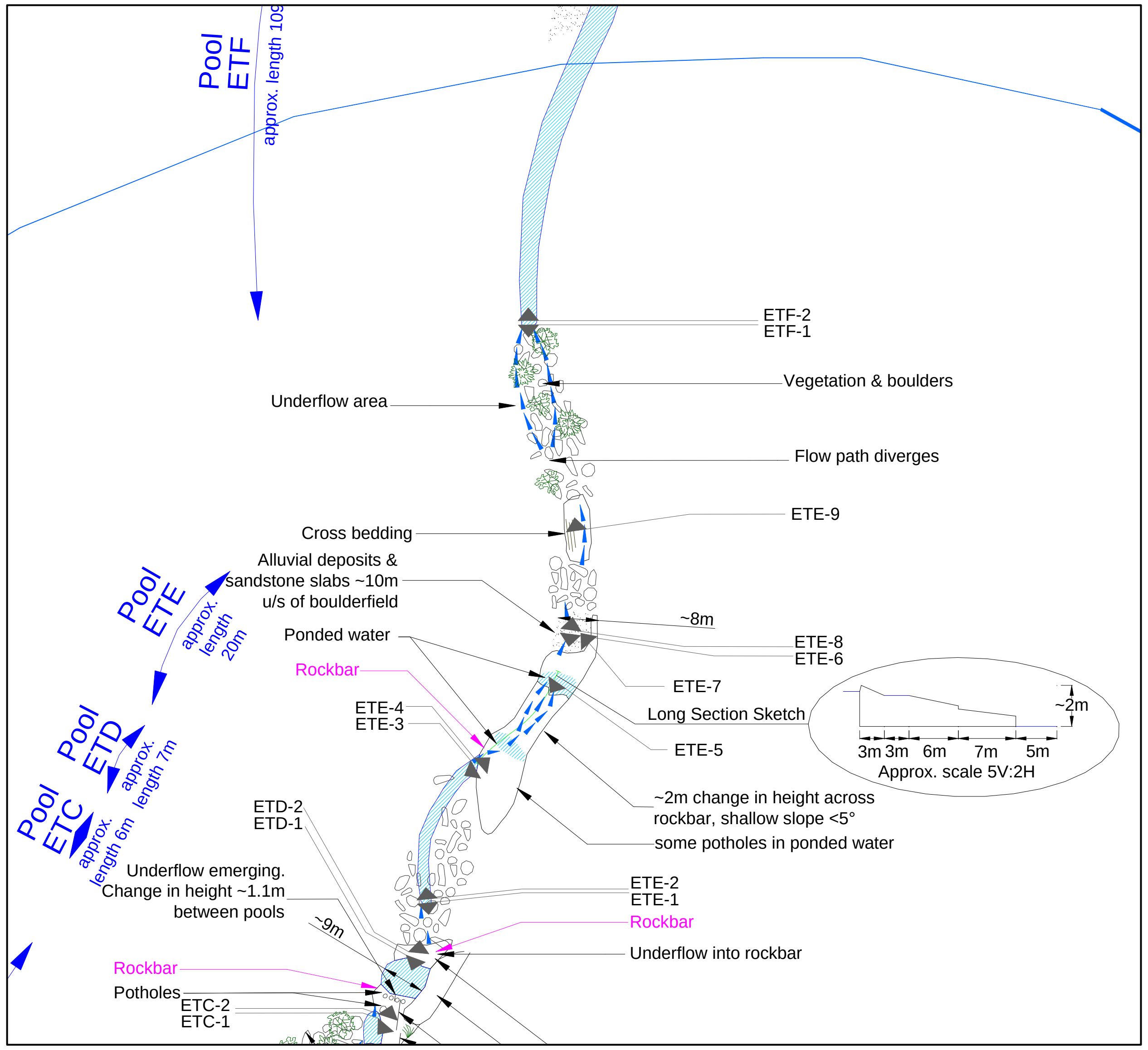



Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| ETE-5 | 311413 | 6213416 | 215 |
| ETE-6 | 311418 | 6213429 | 188 |
| ETE-7 | 311418 | 6213429 | 320 |
| ETE-8 | 311418 | 6213429 | 8 |
| ETE-9 | 311418 | 6213454 | 351 |

# POOL ETF STREAM MAPPING SUMMARY

**ETF-1** Upstream end of Pool ETF looking Upstream

**ETF-2** Upstream of Pool ETF looking Downstream

**ETF-3** Downstream end of Pool ETF looking Upstream

**ETF-4** Downstream end of Pool ETF looking Downstream

Pool ETF notes (as at 29 Dec 2008)

- Width varies from approximately 1m at the upstream end to 5m at the downstream end, with an average of approximately 5m.
- Water depth varies from approximately 0.1m to an estimated 1 to 1.5m maximum depth with an average of approximately 0.6m.
- Alluvial deposits, scattered boulders (up to ~ 0.5m size) and vegetation debris present at the upstream end of the pool.
- Large alluvial deposit approximately 10m wide on the western bank at the downstream end of the pool.
- Base of the pool is sandstone with alluvial deposits mainly on the western side.
- Rockbar downstream of the pool is approximately 14m wide and has vegetation debris and scattered boulders on the surface.
- Pool ETG is approximately 0.6m below Pool ETF.

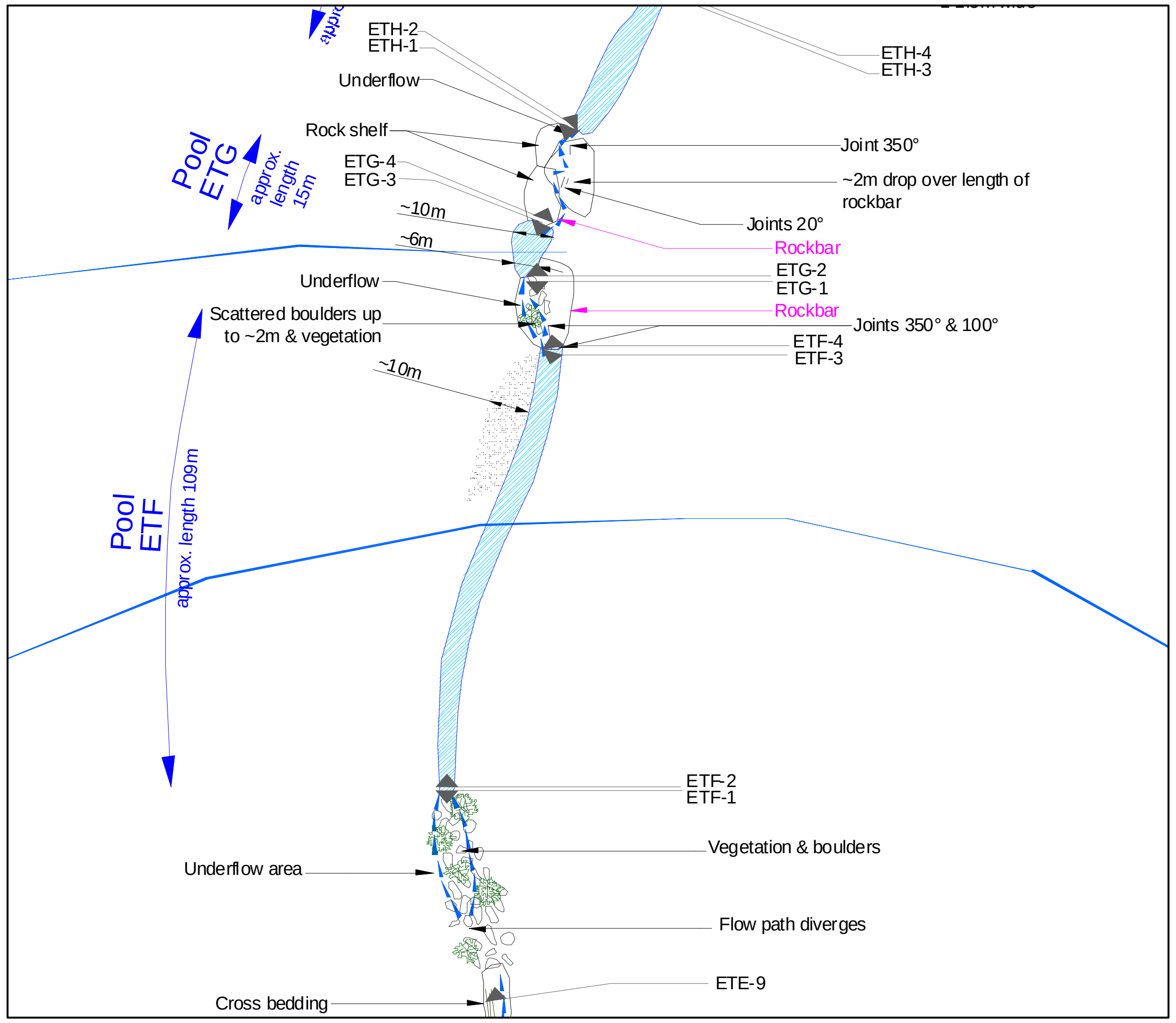



Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| ETF-1 | 311407 | 6213505 | 180 |
| ETF-2 | 311407 | 6213505 | 0 |
| ETF-3 | 311433 | 6213609 | 192 |
| ETF-4 | 311433 | 6213609 | 350 |

# POOL ETG STREAM MAPPING SUMMARY

**ETG-1** Upstream end of Pool ETG looking Upstream

**ETG-2** Upstream end of Pool ETG looking Downstream

**ETG-3** Downstream end of Pool ETG looking Upstream

**ETG-4** Downstream end of Pool ETG looking Downstream

Pool ETG notes (as at 29 Dec 2008)

- Width varies from approximately 6m to 10m. Length is approximately 15m.
- Base of the pool is sandstone with alluvial deposits.
- Water flows into a narrow channel at the downstream end of the pool. The channel has a maximum depth of approximately 1m.
- Cross bedding present in the rockbar downstream of the pool.
- Pool ETH is approximately 2m below Pool ETG.

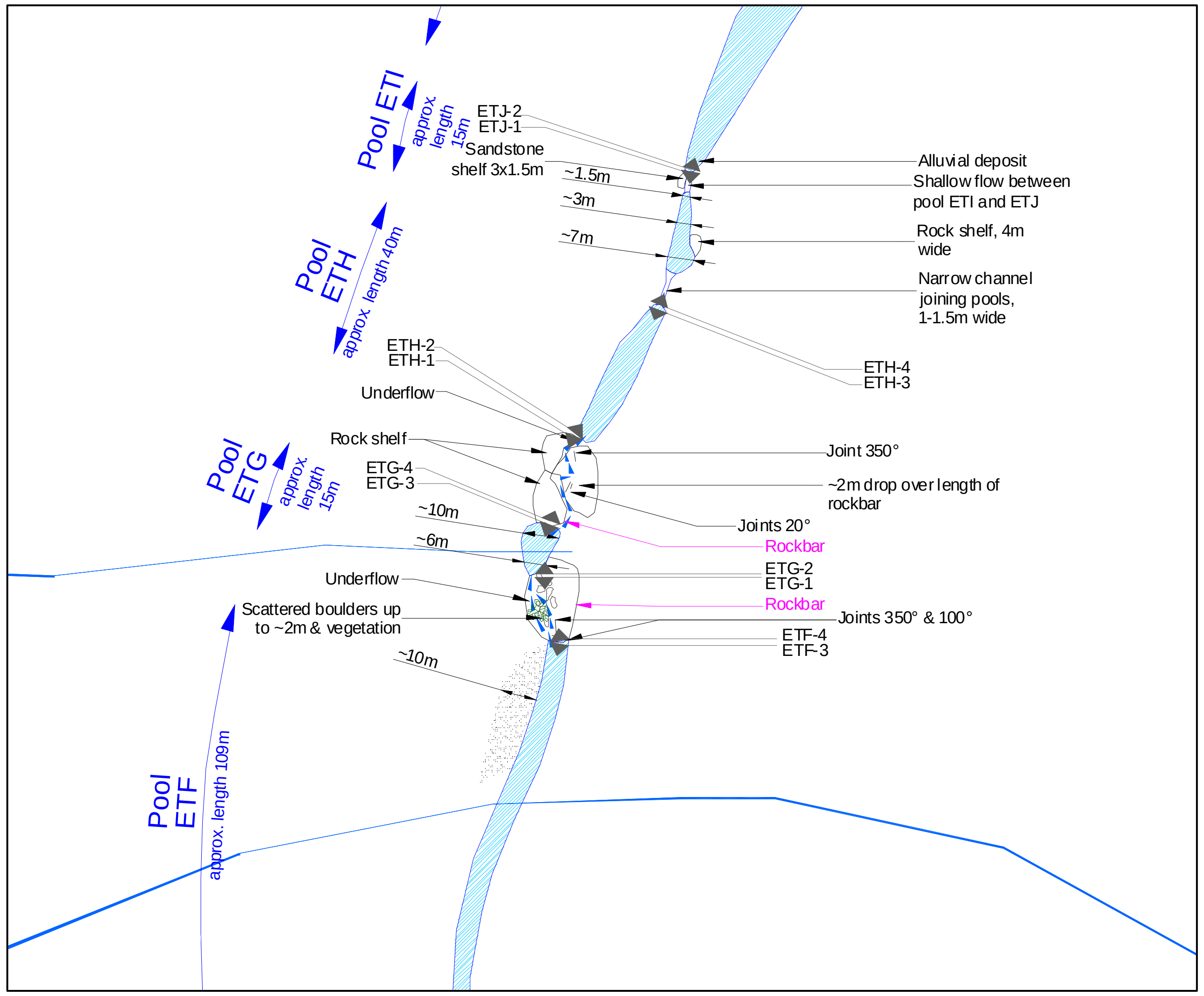



Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| ETG-1 | 311429 | 6213626 | 180 |
| ETG-2 | 311429 | 6213626 | 0 |
| ETG-3 | 311436 | 6213636 | 202 |
| ETG-4 | 311436 | 6213636 | 22 |

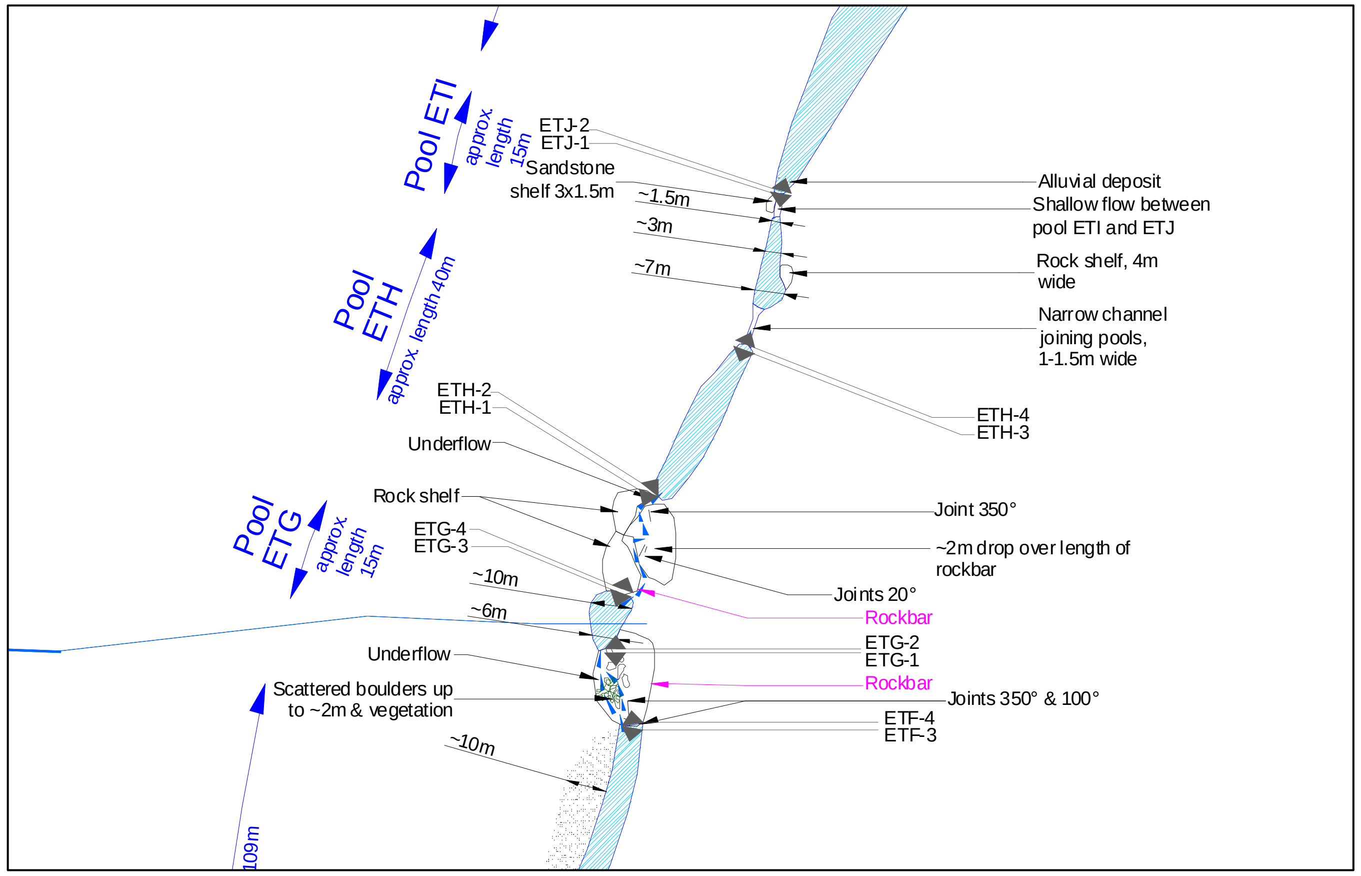
# POOLS ETH & ETI STREAM MAPPING SUMMARY

**ETH-1** Upstream end of Pool ETH looking Upstream

**ETH-2** Upstream end of Pool ETH looking Downstream

<u>Pools ETH and ETI notes (as at 29 Dec 2008)</u>

- Width varies from approximately 1m to 6m with an average of approximately 5m.
- Average water depth is approximately 1.5m.
- Base appears to be mainly sandstone and alluvial deposits however much of the base was not visible.
- Water flows into a narrow channel approximately 1m to 1.5m wide and 0.5m deep at the downstream end of the pool.
- The channel is approximately 15m to 20m long and joins into Pool ETI.
- Pool ETI width varies from approximately 1.5m to 7m with an average of approximately 3m.
- Base of Pool ETI is sanstone and alluvial deposits.




**ETH-3** Downstream end of Pool ETH looking Upstream

**ETH-4** Downstream end of Pool ETH looking Downstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| ETH-1 | 311436 | 6213663 | 200 |
| ETH-2 | 311436 | 6213663 | 38 |
| ETH-3 | 311458 | 6213695 | 201 |
| ETH-4 | 311458 | 6213695 | 21 |

# POOL ETJ STREAM MAPPING SUMMARY

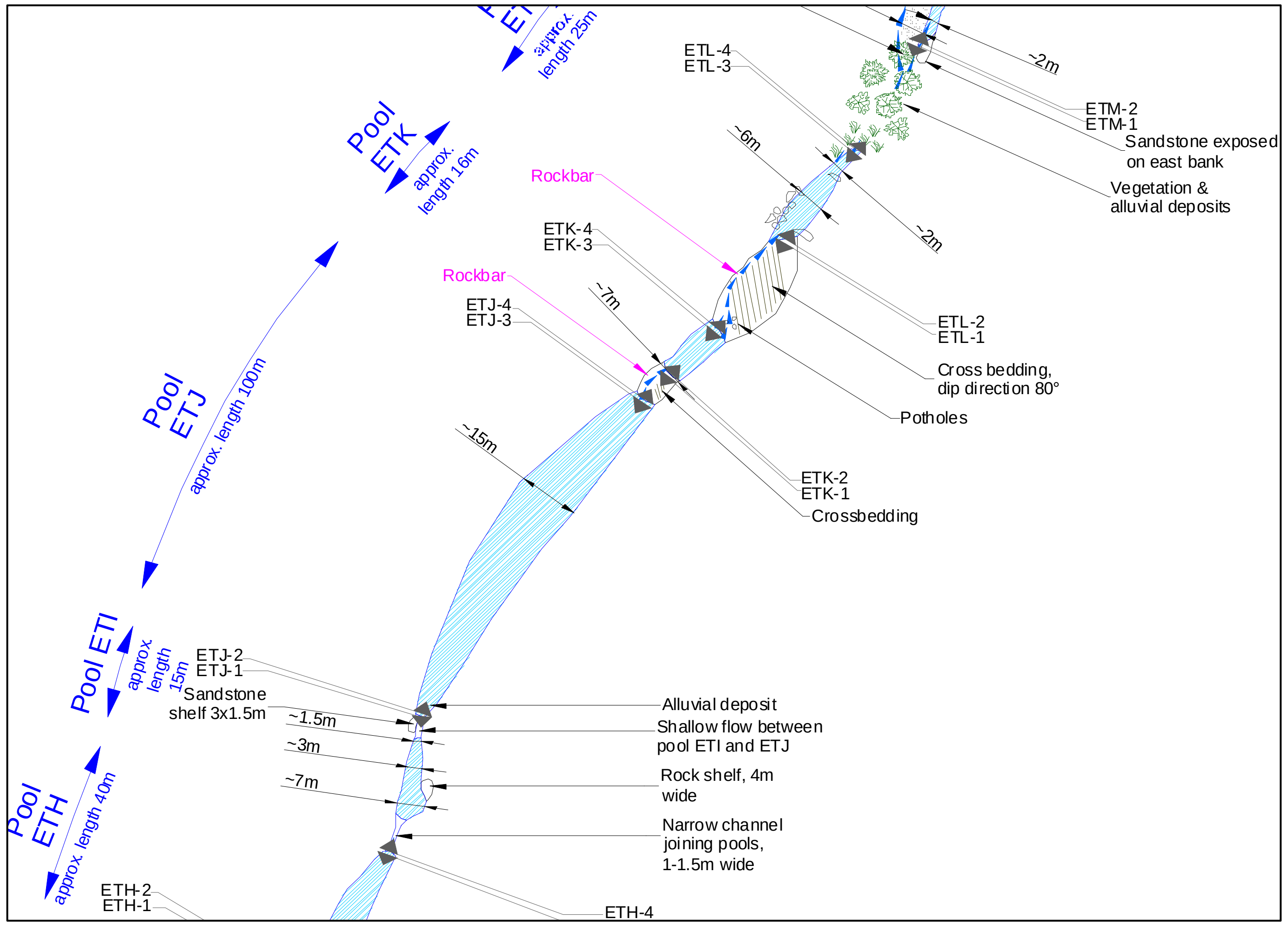
**ETJ-1** Upstream end of Pool ETJ looking Upstream

**ETJ-2** Upstream end of Pool ETJ looking Downstream

Pool ETJ notes (as at 29 Dec 2008)

- Width varies from approximately 1.5m to 15m with an average of approximately 7m.
- Water depth varies from approximately 1m to approximately 1.5m
- Base of the pool is sandstone with alluvial deposits and boulders up to approximately 0.5m size.
- Rockbar downstream of the pool is approximately 7m wide and 9m long.

**ETJ-3** Downstream end of Pool ETJ looking Upstream




**ETJ-4** Downstream end of Pool ETJ looking Downstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| ETJ-1 | 311466 | 6213731 | 189 |
| ETJ-2 | 311466 | 6213731 | 17 |
| ETJ-3 | 311520 | 6213810 | 217 |
| ETJ-4 | 311520 | 6213810 | 37 |

# POOL ETK STREAM MAPPING SUMMARY

**ETK-1** Upstream end of Pool ETK looking Upstream

**ETK-2** Upstream end of Pool ETK looking Downstream

**ETK-3** Downstream end of Pool ETK looking Upstream

**ETK-4** Downstream of Pool ETK looking Downstream

Pool ETK notes (as at 29 Dec 2008)

- Width varies from approximately 7m to 9m. Length is approximately 16m.
- Average water depth is approximately 0.7m.
- Base of the pool is sandstone and alluvial deposits.
- Rockbar downstream of the pool has potholes and weathered cross bedding.
- Water flows along the western side of the rockbar.
- Pool ETL is approximately 1.6m below Pool ETK.

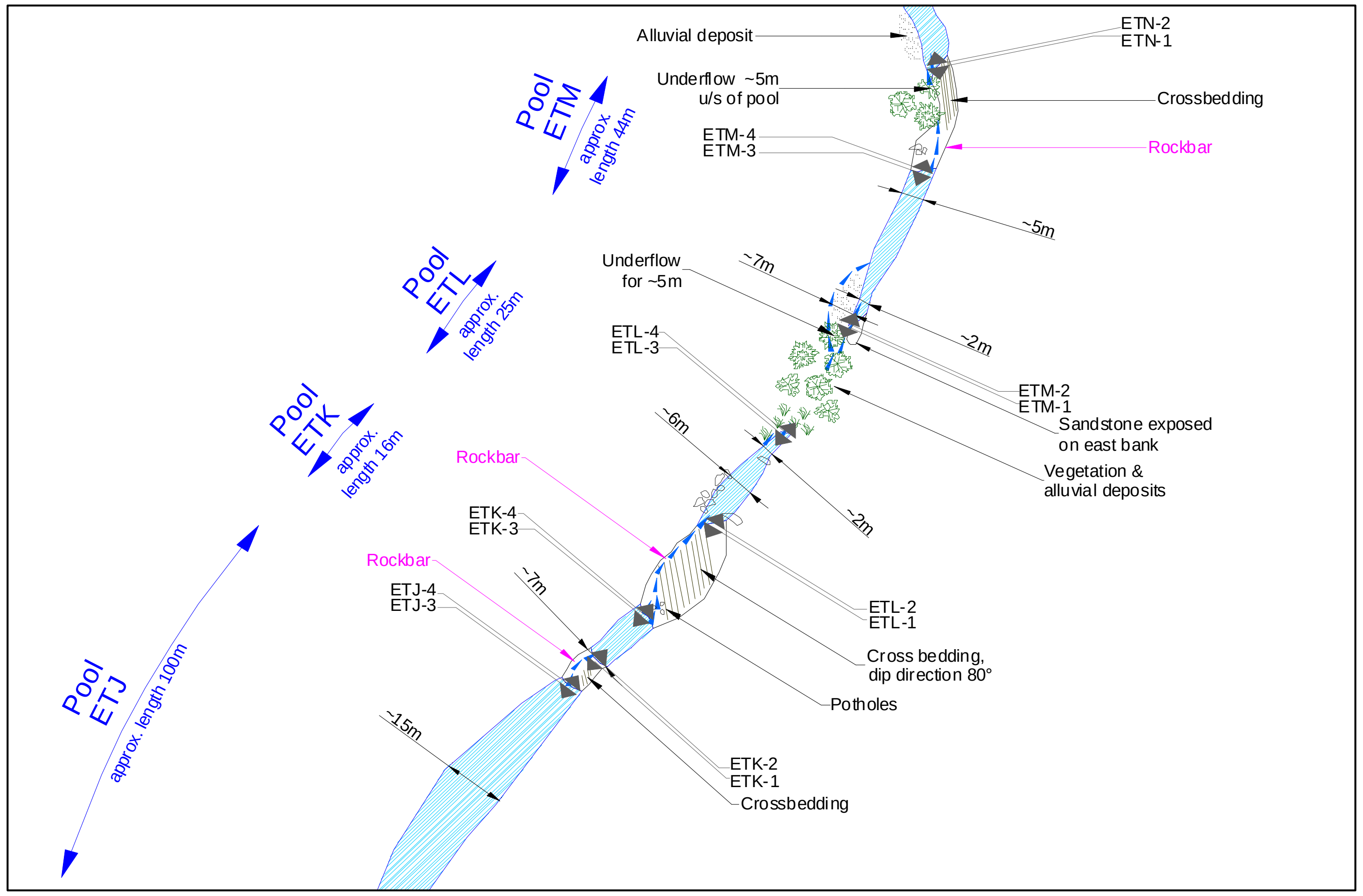



Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| ETK-1 | 311526 | 6213817 | 217 |
| ETK-2 | 311526 | 6213817 | 37 |
| ETK-3 | 311538 | 6213829 | 217 |
| ETK-4 | 311538 | 6213829 | 37 |

# POOL ETL STREAM MAPPING SUMMARY

**ETL-1** Upstream end of Pool ETL looking Upstream

**ETL-2** Upstream end of Pool ETL looking Downstream

**ETL-3** Downstream end of Pool ETL looking Upstream

**ETL-4** Downstream of Pool ETL looking Downstream

Pool ETL notes (as at 29 Dec 2008)

- Width varies from approximately 2m to 6m.
- Average water depth is approximately 0.5m.
- Base of the pool is sandstone with alluvial deposits and boulders up to approximately 1m size.
- Pool flows into vegetated area with alluvial deposits (difficult access in this area to confirm flow path).
- Flow diverges approximately halfway between Pools ETL and ETM.

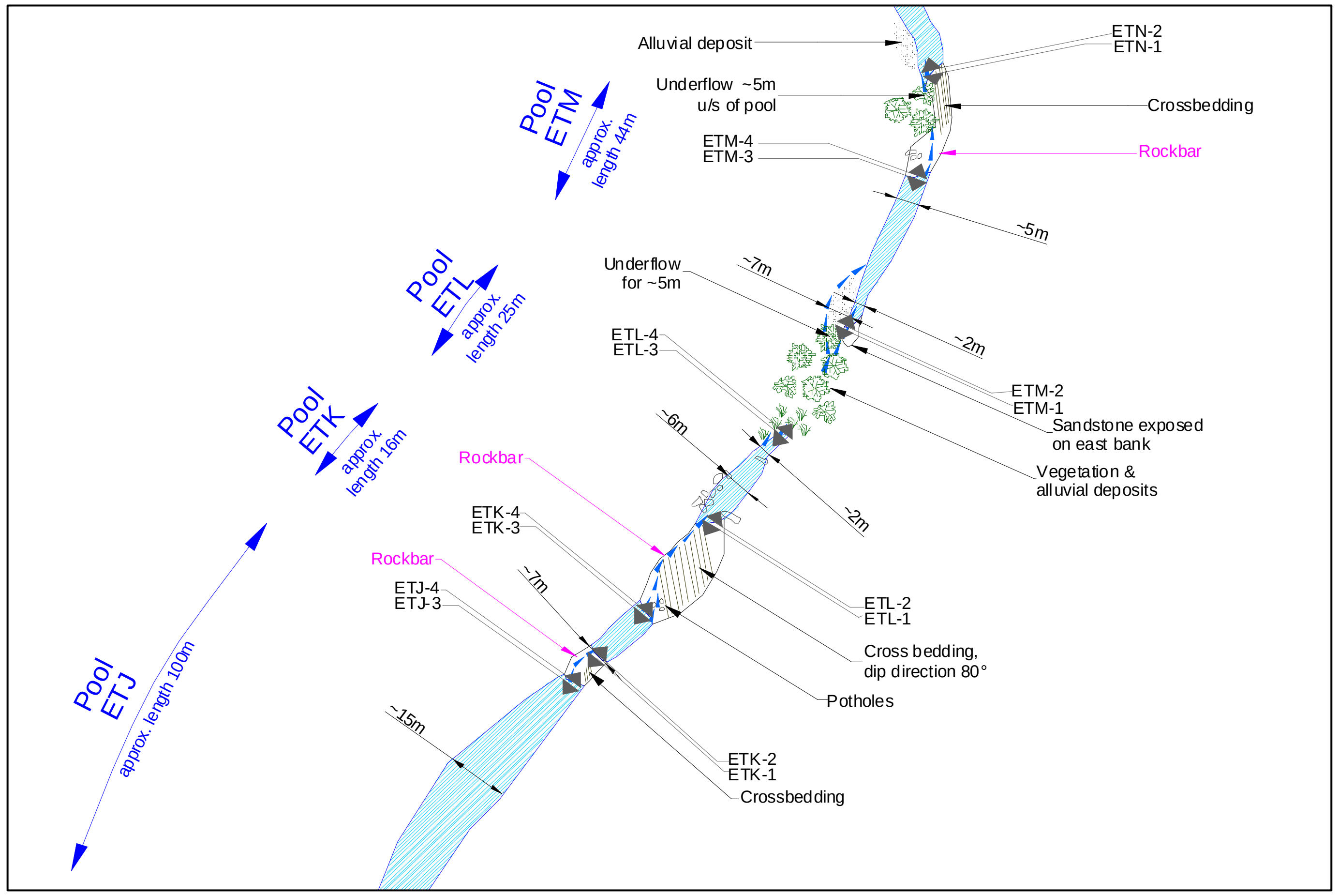



Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| ETL-1 | 311555 | 6213852 | 213 |
| ETL-2 | 311555 | 6213852 | 33 |
| ETL-3 | 311572 | 6213875 | 220 |
| ETL-4 | 311572 | 6213875 | 40 |

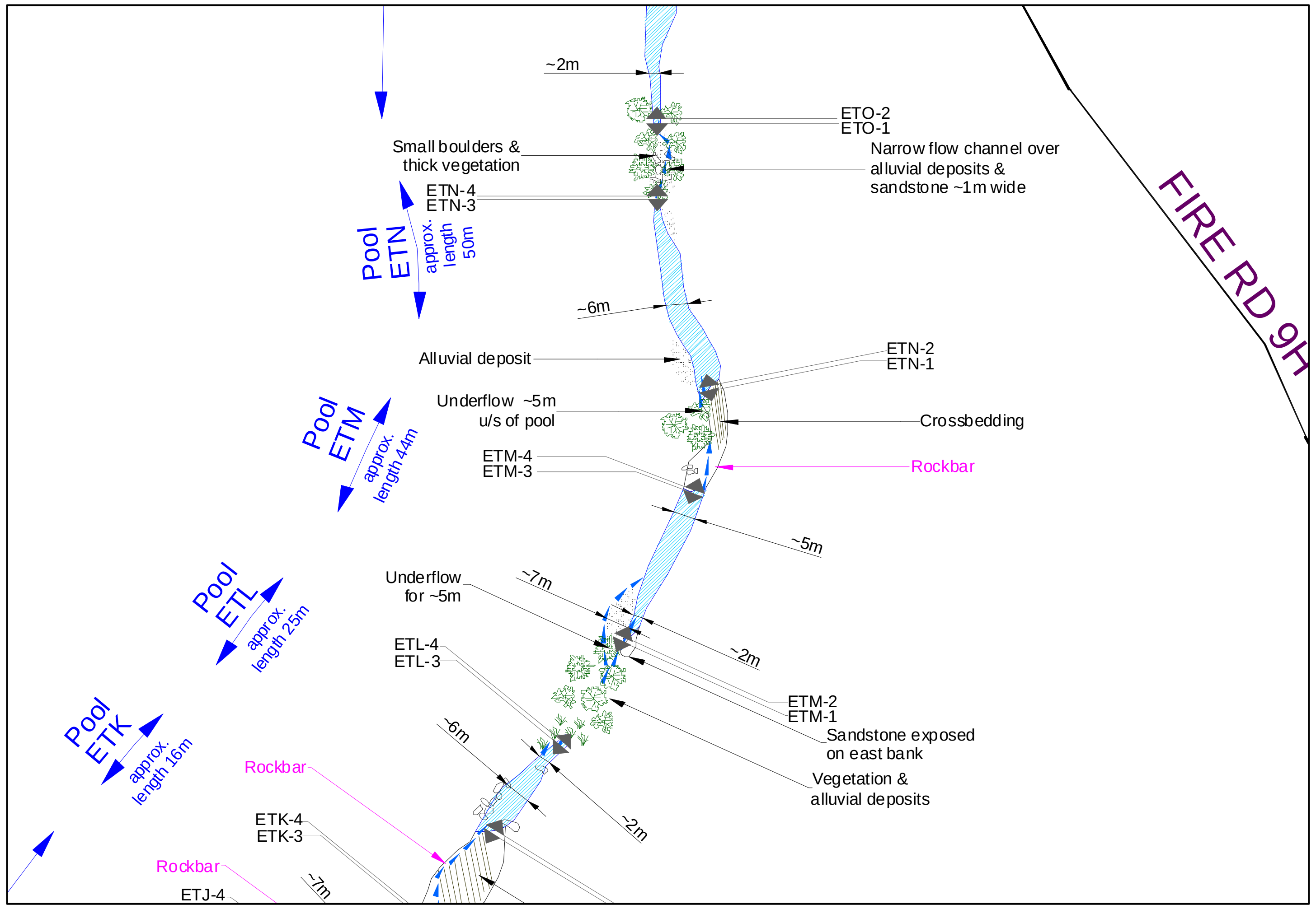
# POOL ETM STREAM MAPPING SUMMARY

**ETM-1** Upstream end of Pool ETM looking Upstream

**ETM-2** Upstream end of Pool ETM looking Downstream

<u>Pool ETM notes (as at 29 Dec 2008)</u>

- Width varies from approximately 2m to 5m.
- Base of the pool is sandstone with several boulders up to approximately 1m size.
- Rockbar downstream of the pool is approximately 9m wide.
- Cross bedding present in the rockbar.
- Some underflow at the downstream end of the rockbar.




**ETM-3** Downstream end of Pool ETM looking Upstream

**ETM-4** Downstream of Pool ETM looking Downstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| ETM-1 | 311587 | 6213902 | 205 |
| ETM-2 | 311587 | 6213902 | 25 |
| ETM-3 | 311605 | 6213941 | 201 |
| ETM-4 | 311605 | 6213941 | 21 |

# POOL ETN STREAM MAPPING SUMMARY

**ETN-1** Upstream end of Pool ETN looking Upstream

**ETN-2** Upstream end of Pool ETN looking Downstream

**ETN-3** Downstream end of Pool ETN looking Upstream

**ETN-4** Downstream end of Pool ETN looking Downstream

Pool ETN notes (as at 29 Dec 2008)

- Width varies from approximately 3m to 6m
- Average water depth is approximately 0.3m. Maximum depth is approximately 1m.
- Base of the pool is sandstone with alluvial deposits and cross bedding.
- Rockbar at upstream end of the pool is approximately 1m above Pool ETN on the eastern side and approximately 0.3m above the pool on the western side.

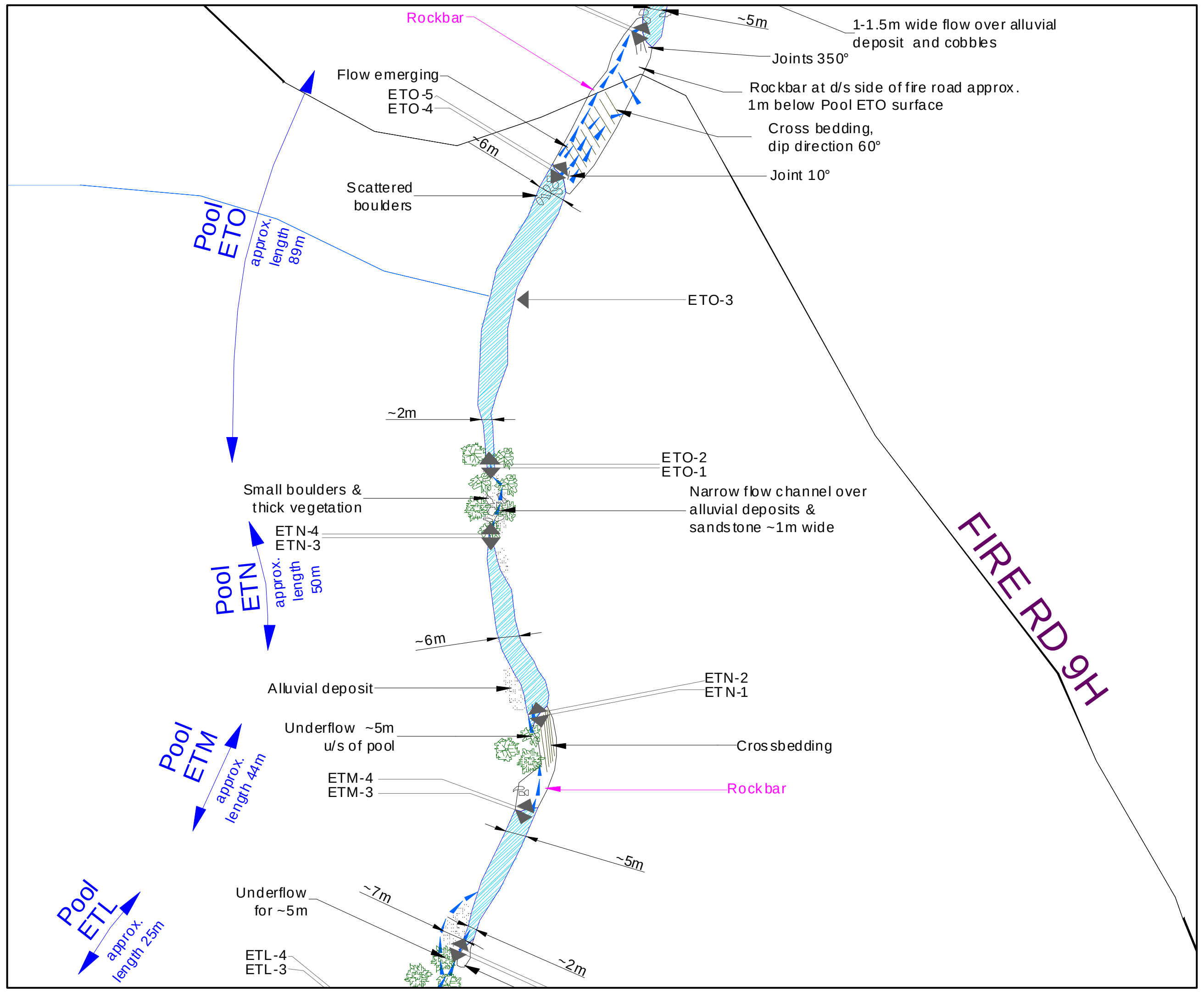



Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| ETN-1 | 311608 | 6213968 | 168 |
| ETN-2 | 311608 | 6213968 | 348 |
| ETN-3 | 311595 | 6214018 | 180 |
| ETN-4 | 311595 | 6214018 | 0 |

# POOL ETO STREAM MAPPING SUMMARY

**ETO-1** Upstream end of Pool ETO looking Upstream

**ETO- 2** Upstream end of Pool ETO looking Downstream

**ETO-3** Tributary approximately midway along Pool ETO

<u>Pool ETO notes (as at 29 Dec 2008)</u>

- Width varies from approximately 2m to 6m.
- Maximum water depth is approximately 1m at the downstream end of the pool.
- Base of the pool is sandstone with minor alluvial deposits and scattered boulders up to approximately 1m size at the downstream end.
- Rockbar downstream of the pool is approximately 5m wide.
- Water flows over most of the rockbar width at the upstream end and along the western side at the downstream end. Cross bedding is present.

**ETO-4** Downstream end of Pool ETO looking Upstream

**ETO-5** Downstream end of Pool ETO looking Downstream

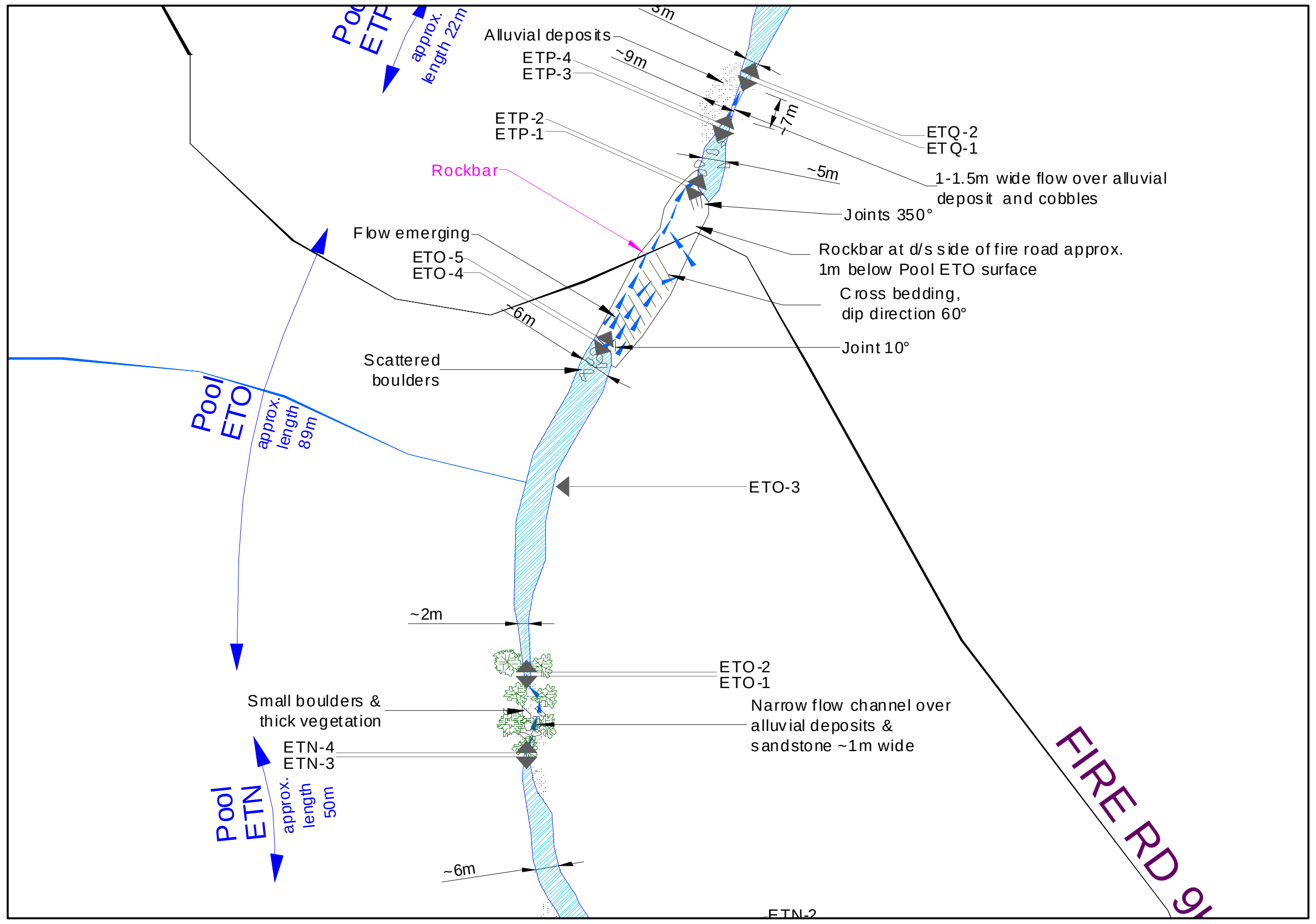



Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| ETO-1 | 311596 | 6214037 | 180 |
| ETO-2 | 311596 | 6214037 | 0 |
| ETO-3 | 311603 | 6214084 | 270 |
| ETO-4 | 311613 | 6214119 | 212 |
| ETO-5 | 311613 | 6214119 | 32 |

# POOL ETP STREAM MAPPING SUMMARY

**ETP-1** Upstream end of Pool ETP looking Upstream

**ETP-2** Upstream end of Pool ETP looking Downstream

**ETP-3** Downstream end of Pool ETP looking Upstream

**ETP-4** Downstream end of Pool ETP looking Downstream

Pool ETP notes (as at 29 Dec 2008)

- Width varies from approximately 3m to 5m
- Average water depth is approximately 0.3m.
- Base of the pool is sandstone with alluvial deposits and boulders up to approximately 0.5m size.
- Cross bedding is present in the base of the pool.

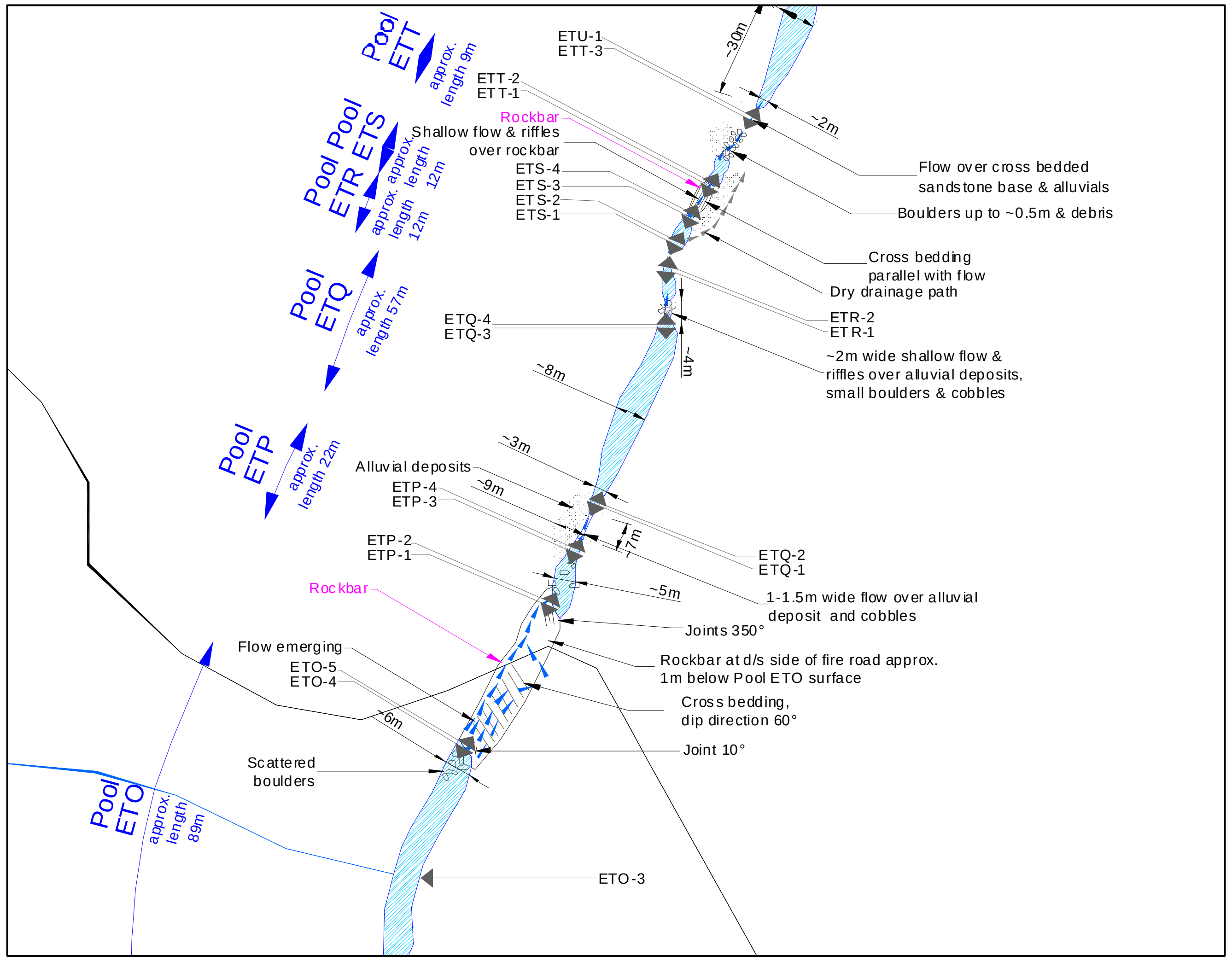



Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| ETP-1 | 311634 | 6214158 | 205 |
| ETP-2 | 311634 | 6214158 | 25 |
| ETP-3 | 311641 | 6214173 | 205 |
| ETP-4 | 311641 | 6214173 | 25 |

# POOL ETQ STREAM MAPPING SUMMARY

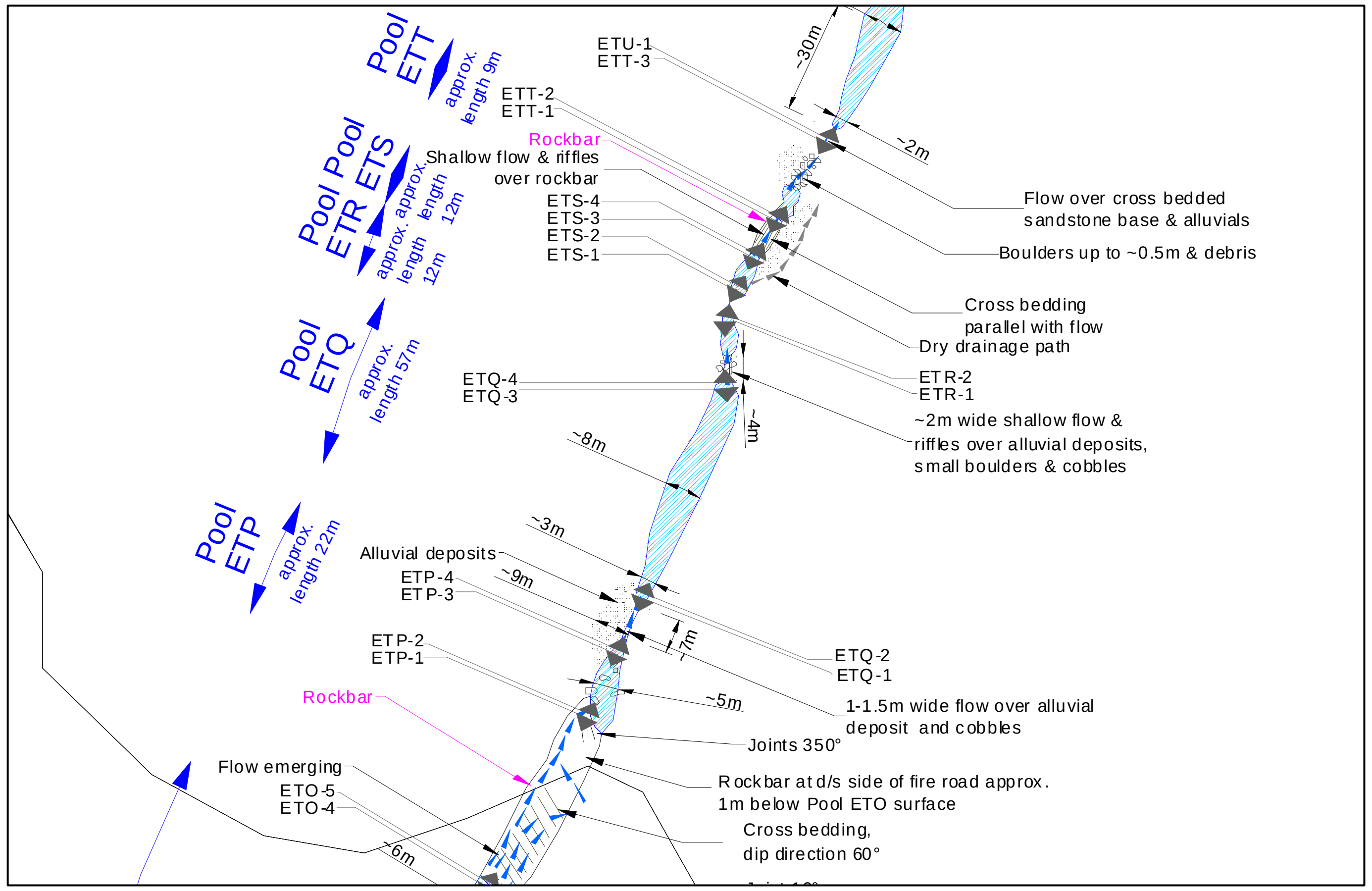
**ETQ-1** Upstream end of Pool ETQ looking Upstream

**ETQ-2** Upstream end of Pool ETQ looking Downstream

Pool ETQ notes (as at 29 Dec 2008)

- Width varies from approximately 3m to 8m
- Water depth varies from approximately 0.2m to approximately 1m. Average water depth is approximately 0.6m.
- Base of the pool is sandstone with alluvial deposits. Several sandstone cobbles at the upstream end of the pool.
- Water flows from Pool ETQ over alluvial deposits, small boulders and cobbles.

**ETQ-3** Downstream end of Pool ETQ looking Upstream




**ETQ-4** Downstream end of Pool ETQ looking Downstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| ETQ-1 | 311648 | 6214186 | 205 |
| ETQ-2 | 311648 | 6214186 | 25 |
| ETQ-3 | 311666 | 6214234 | 180 |
| ETQ-4 | 311666 | 6214234 | 0 |

# POOL ETR STREAM MAPPING SUMMARY

**ETR-1** Downstream end of Pool ETR looking Upstream

**ETR-2** Downstream end of Pool ETR looking Downstream

Pool ETR notes (as at 29 Dec 2008)

- Width varies from approximately 2m to 4m
- Average water depth is approximately 0.6m.
- Base of the pool is sandstone but is mostly covered with alluvial deposits, boulders and cobbles.
- Flow continues over exposed sandstone to Pool ETS.

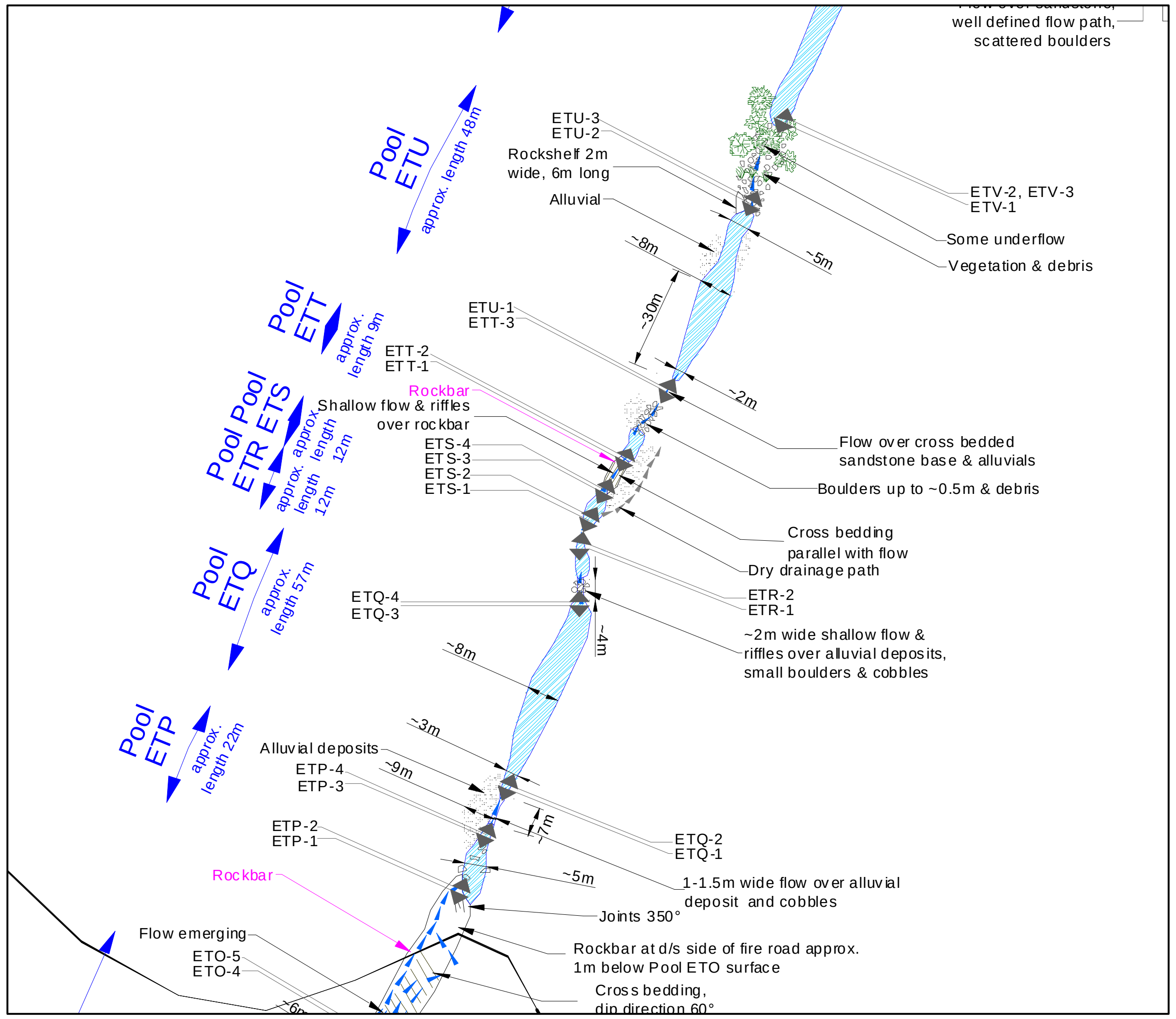



Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| ETR-1 | 311666 | 6214249 | 180 |
| ETR-2 | 311666 | 6214249 | 10 |

# POOL ETS STREAM MAPPING SUMMARY

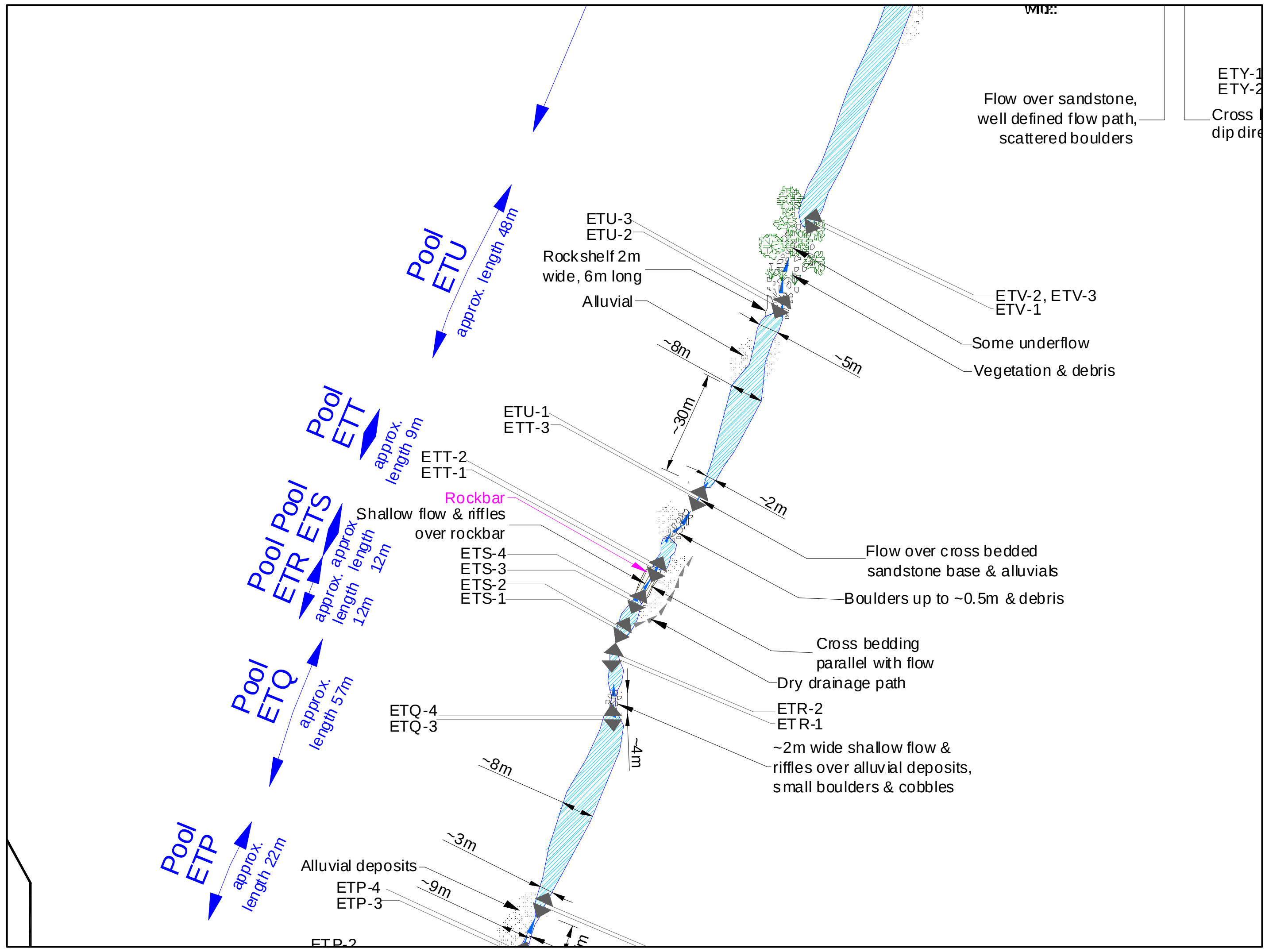
**ETS-1** Upstream end of Pool ETS looking Upstream

**ETS-2** Upstream end of Pool ETS looking Downstream

Pool ETS notes (as at 29 Dec 2008)

- Width varies from approximately 2m to 4m
- Water depth varies from approximately 0.2m to 0.6m. Average water depth is approximately 0.3m
- Large alluvial deposit on eastern side of the pool. A dry drainage path is present through the alluvial deposits.
- Pool base is sandstone with alluvial deposits, cobbles and boulders.
- Water flows from the pool as riffles over crossbedded sandstone rockbar.

**ETS-3** Downstream end of Pool ETS looking Upstream




**ETS-4** Downstream end of Pool ETS looking Downstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| ETS-1 | 311668 | 6214256 | 209 |
| ETS-2 | 311668 | 6214256 | 29 |
| ETS-3 | 311672 | 6214264 | 209 |
| ETS-4 | 311672 | 6214264 | 29 |

# POOL ETT STREAM MAPPING SUMMARY

**ETT-1** Upstream end of Pool ETT looking Upstream

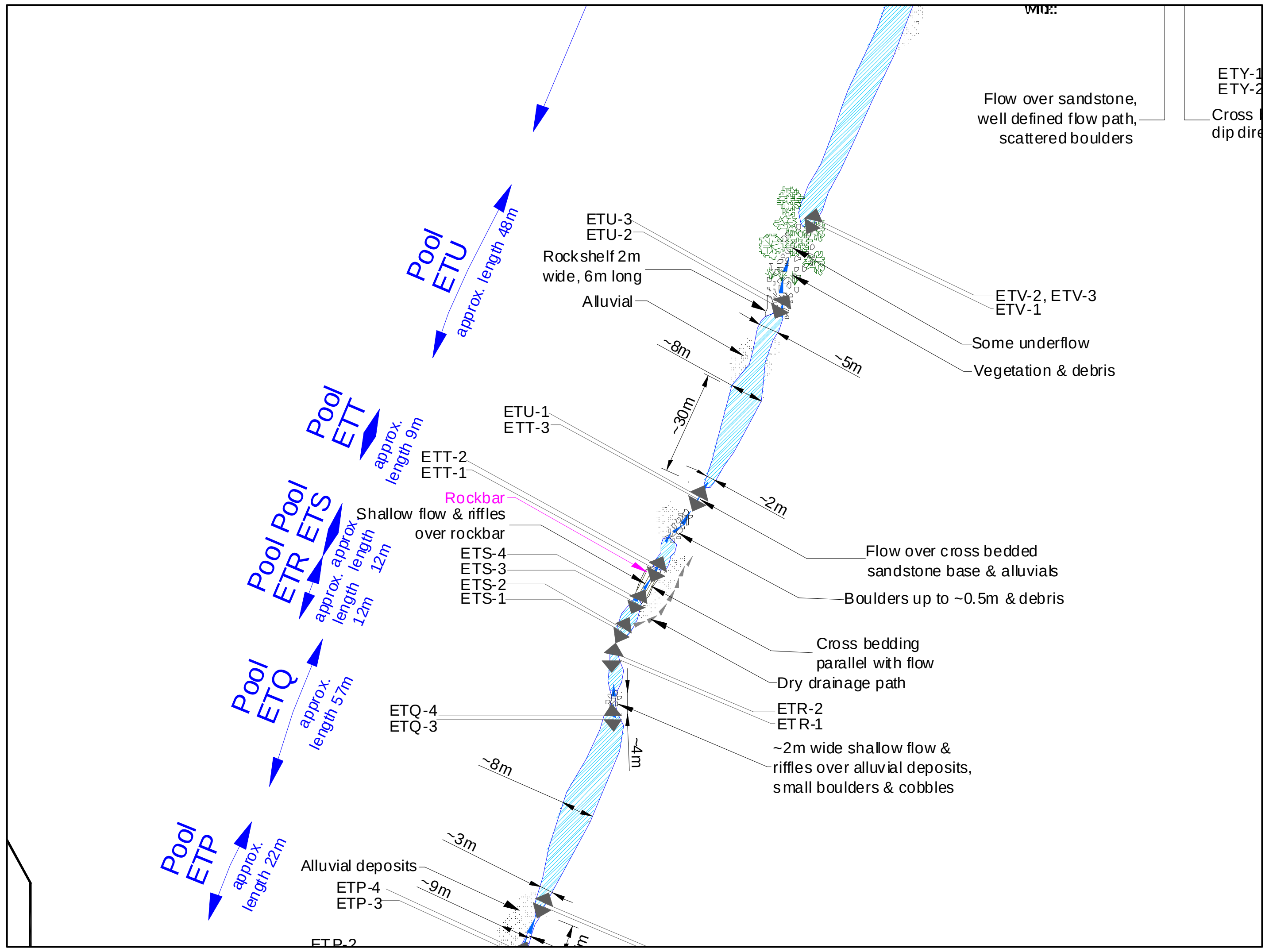
**ETT-2** Upstream end of Pool ETT looking Downstream

Pool ETT notes (as at 29 Dec 2008)
- Width varies from approximately 2m to 4m
- Water depth varies from approximately 0.2m to 0.6m with an average of approximately 0.3m.
- Base of the pool is sandstone with allluvial deposits, boulders and cobbles.
- Large alluvial deposit on eastern side of the pool. A dry drainage path is present through the alluvial deposits.
- Cross bedding present.
- Downstream of the pool, water flows over cross bedded sandstone and alluvial deposits.
- Boulders up to about 0.5m size and debris are present at the downstream end of the pool.

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| ETT-1 | 311614 | 6214277 | 209 |
| ETT-2 | 311614 | 6214277 | 29 |
| ETT-3 | 311689 | 6214291 | 209 |

**ETT-3** Upstream end of Pool ETU looking Upstream



# POOL ETU STREAM MAPPING SUMMARY

**ETT-3** Upstream end of Pool ETU looking Upstream

**ETU- 1** Upstream end of Pool ETU looking Downstream

**ETU-2** Downstream end of Pool ETU looking Upstream

**ETU-3** Downstream end of Pool ETU looking Downstream

Pool ETU notes (as at 29 Dec 2008)

- Width varies from approximately 2m to 8m.
- Water depth varies up to a maximum of approximately 1.5m to 2m.
- Base of the pool is sandstone with alluvial deposits and boulders.
- Thick vegetation and debris present downstream of the pool.
- Some underflow between Pools ETU and ETV.

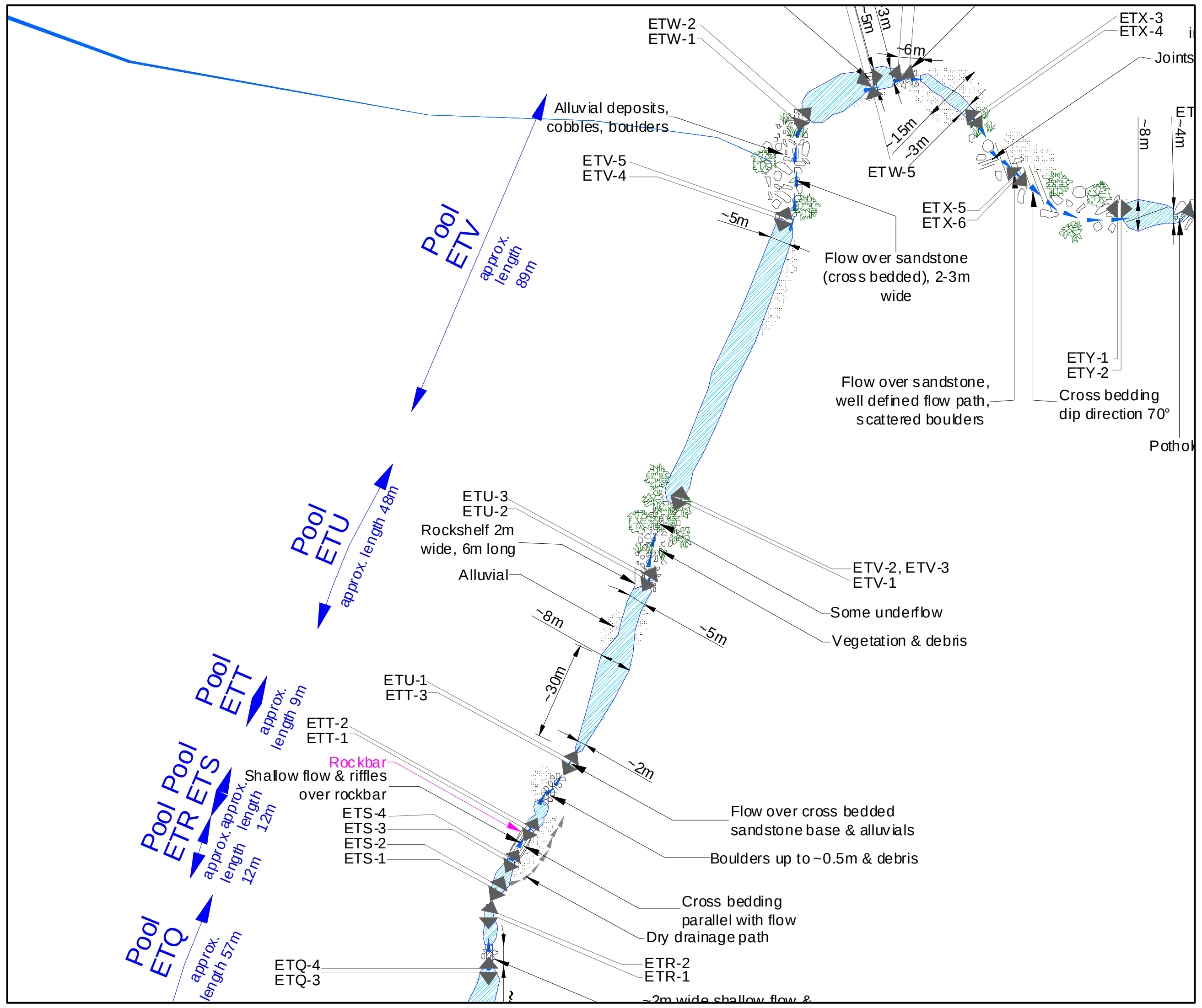



Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| ETT-3 | 311689 | 6214291 | 209 |
| ETU-1 | 311689 | 6214291 | 29 |
| ETU-2 | 311709 | 6214340 | 209 |
| ETU-3 | 311709 | 6214340 | 29 |

# POOL ETV STREAM MAPPING SUMMARY



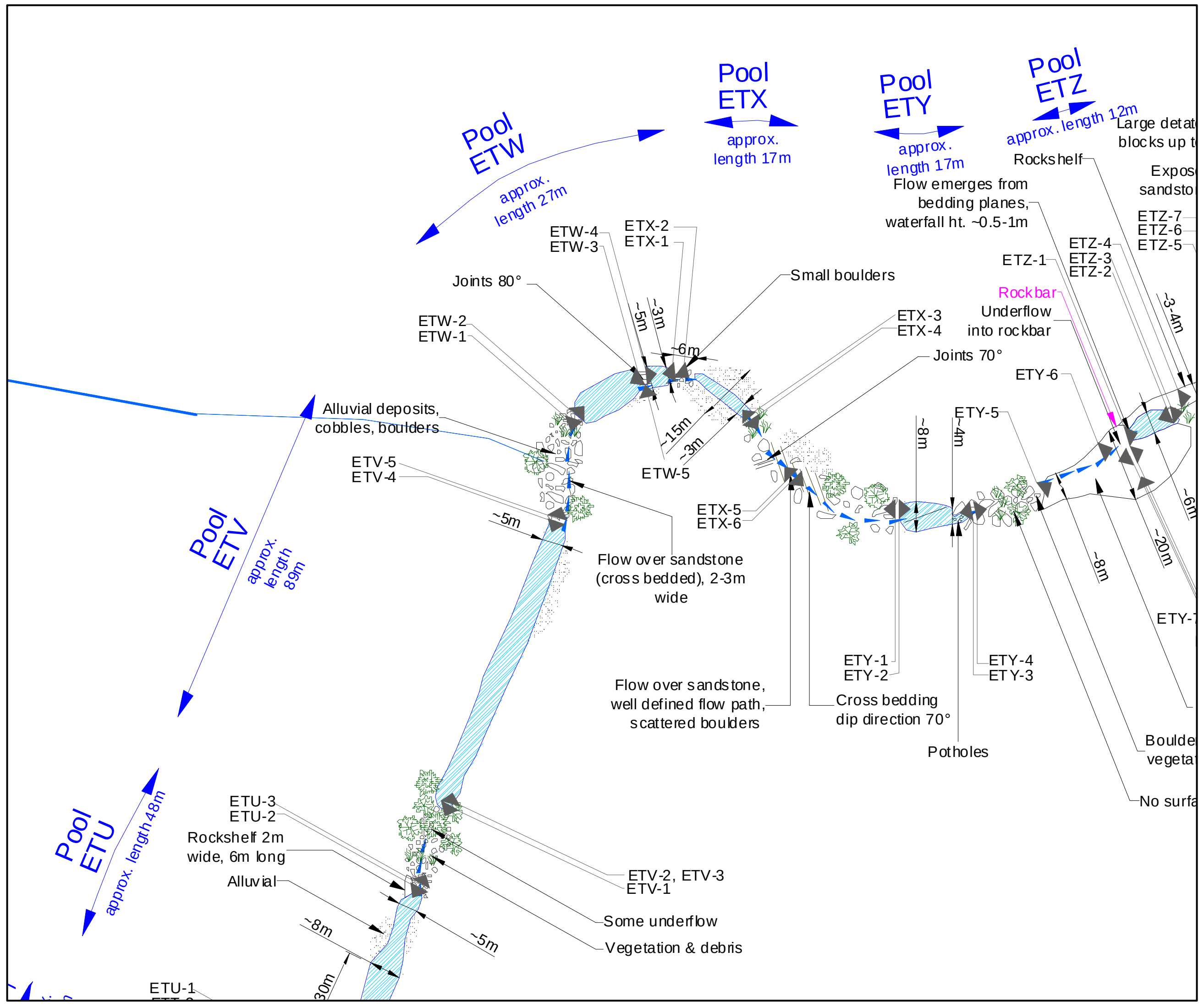
Pool ETV notes (as at 29 Dec 2008)

- Average width is approximately 5m.
- Water depth varies from approximately 0.3m to 1m. Average water depth is approximately 0.6m over most of the pool. A length of approximately 20m at the downstream end of the pool has an average depth of approximately 0.3m.
- Base of the pool is sandstone with alluvial deposits and boulders up to approximately 1.5m size.
- Flow out of the pool is over cross bedded sandstone.
- Most of the surface between Pools ETV and ETW comprises alluvial deposits, cobbles and boulders.

**ETV-1** Upstream end of Pool ETV looking Upstream

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

**ETV-4** Downstream end of Pool ETV looking Upstream




**ETV-5** Downstream end of Pool ETV looking Downstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| ETV-1 | 311717 | 6214361 | 206 |
| ETV-2 | 311717 | 6214361 | 14 |
| ETV-3 | 311717 | 6214361 | 14 |
| ETV-4 | 311745 | 6214437 | 199 |
| ETV-5 | 311745 | 6214437 | 19 |

# POOL ETW STREAM MAPPING SUMMARY

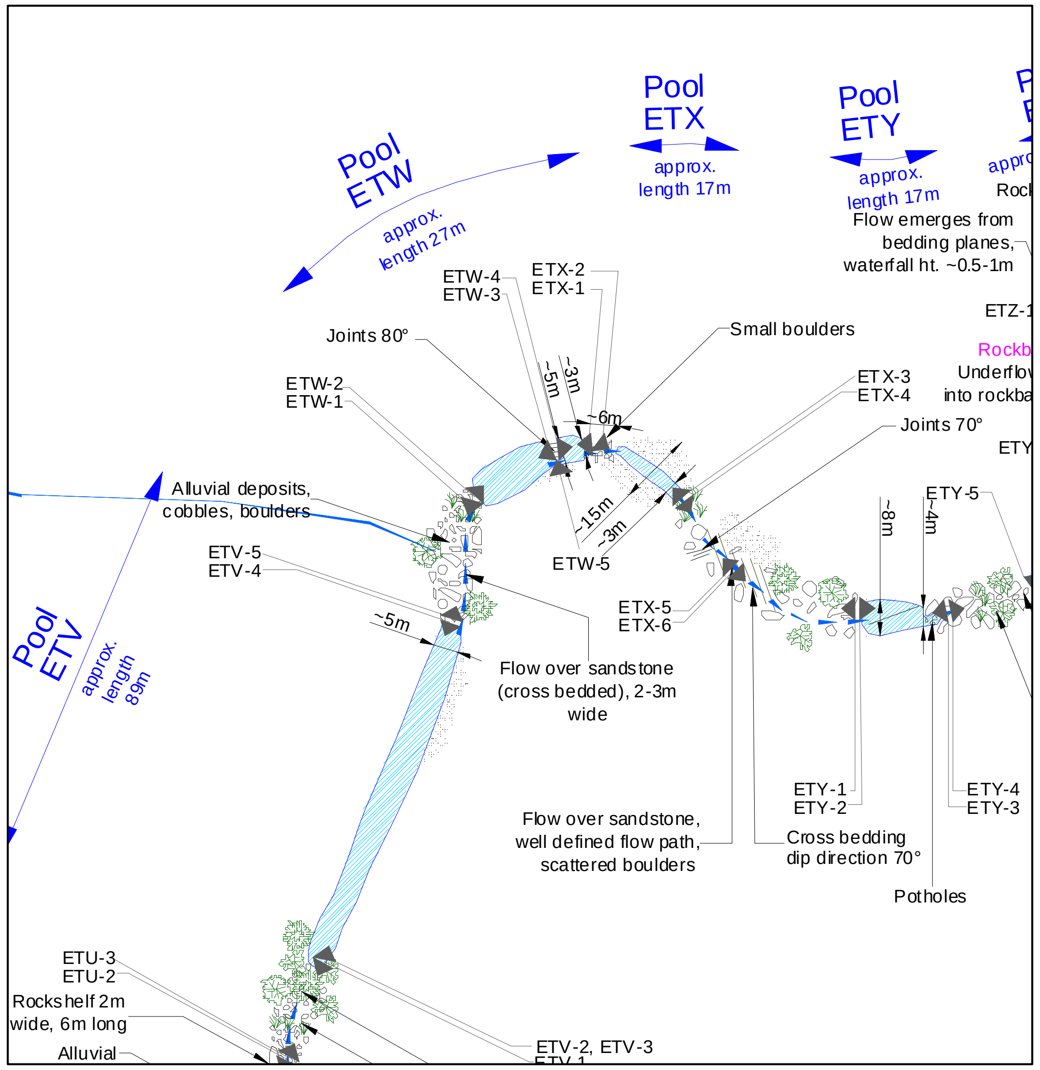
**ETW-1** Upstream end of Pool ETW looking Upstream

**ETW-2** Upstream end of Pool ETW looking Downstream

<u>Pool ETW notes (as at 29 Dec 2008)</u>

- Width varies from approximately 3m to 5m.
- Water depth varies up to a maximum of approximately 1.5m to 2m.
- Base of the pool is sandstone with alluvial deposits and several boulders up to approximately 1m size.
- A small rockbar almost separates a smaller section of the pool downstream. The rockbar is approximately 5m wide and 1m to 3m long. Water flows over the rockbar across eroded joints.
- The smaller section of pool downstream of the rockbar is approximately 0.1m to 0.6m deep with an average of approximately 0.4m.

**ETW-3** Approximately 8m from Downstream end of Pool ETW looking Upstream




**ETW-4** Approximately 8m from Downstream end of Pool ETW looking Downstream

**ETW-5** Small Rock bar at downstream end of Pool ETW

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| ETW-1 | 311750 | 6214465 | 196 |
| ETW-2 | 311750 | 6214465 | 41 |
| ETW-3 | 311769 | 6214476 | 263 |
| ETW-4 | 311769 | 6214476 | 83 |
| ETW-5 | 311769 | 6214476 | 310 |

# POOL ETX STREAM MAPPING SUMMARY

**ETX-1** Upstream end of Pool ETX looking Upstream to Pool ETW

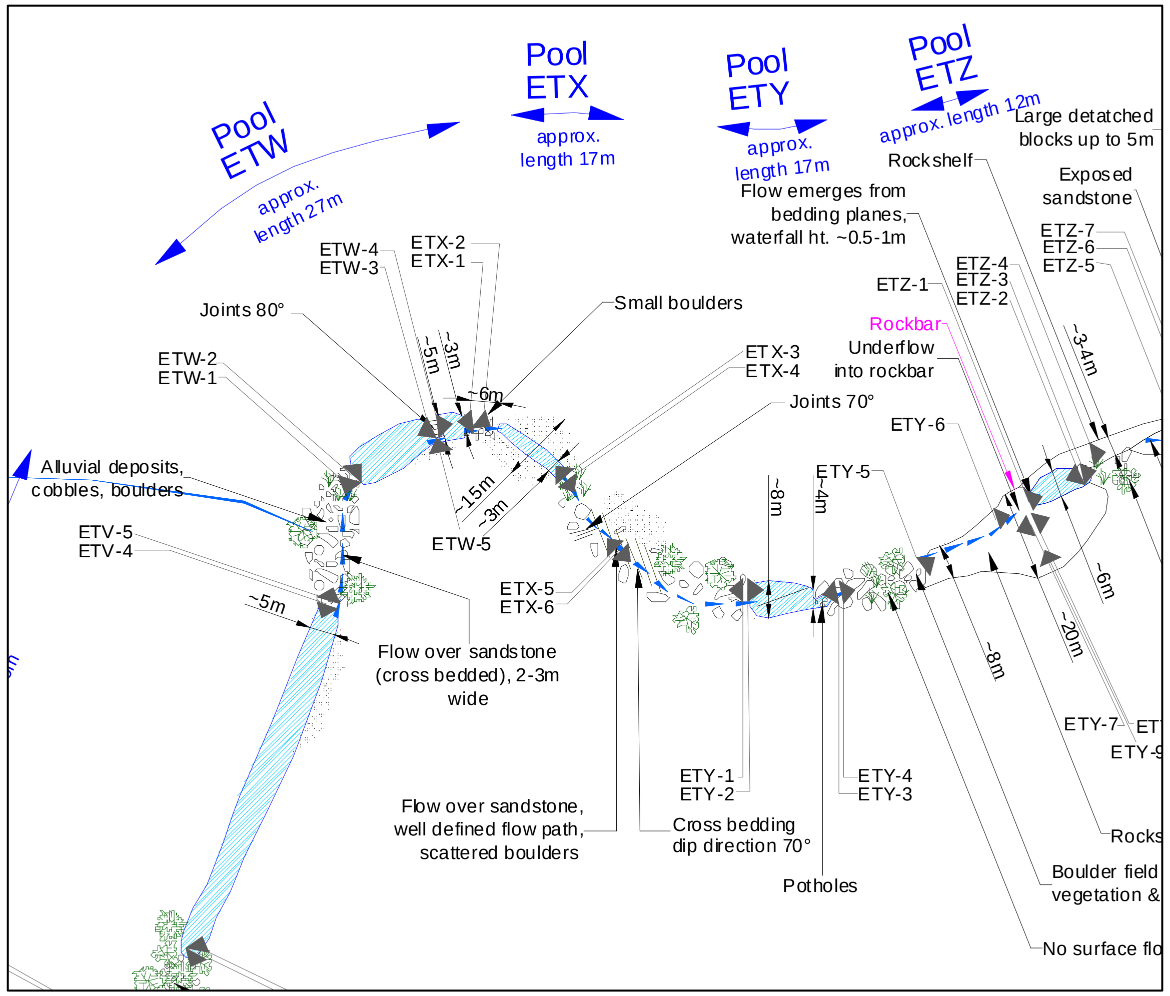
**ETX-2** Upstream end of Pool ETX looking Downstream

**ETX-3** Downstream end of Pool ETX looking Upstream

**ETX-4** Downstream end of Pool ETX looking Downstream

Pool ETX notes (as at 29 Dec 2008)

- Width is an average of approximately 3m.
- The pool is located between alluvial deposits with a total width of approximately 15m.
- Water depth varies from approximately 0.1m to 0.5m with an average of approximately 0.3m.
- Base of the pool is sandstone with alluvial deposits, cobbles and boulders.




**ETX-5** In Boulder Field looking Upstream

**ETX-6** In Boulder Field looking Downstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| ETX-1 | 311776 | 6214477 | 264 |
| ETX-2 | 311776 | 6214477 | 125 |
| ETX-3 | 311797 | 6214464 | 316 |
| ETX-4 | 311797 | 6214464 | 145 |
| ETX-5 | 311808 | 6214449 | 315 |
| ETX-6 | 311808 | 6214449 | 135 |

# POOL ETY STREAM MAPPING SUMMARY

**ETY-3** Downstream of Pool ETY looking Upstream

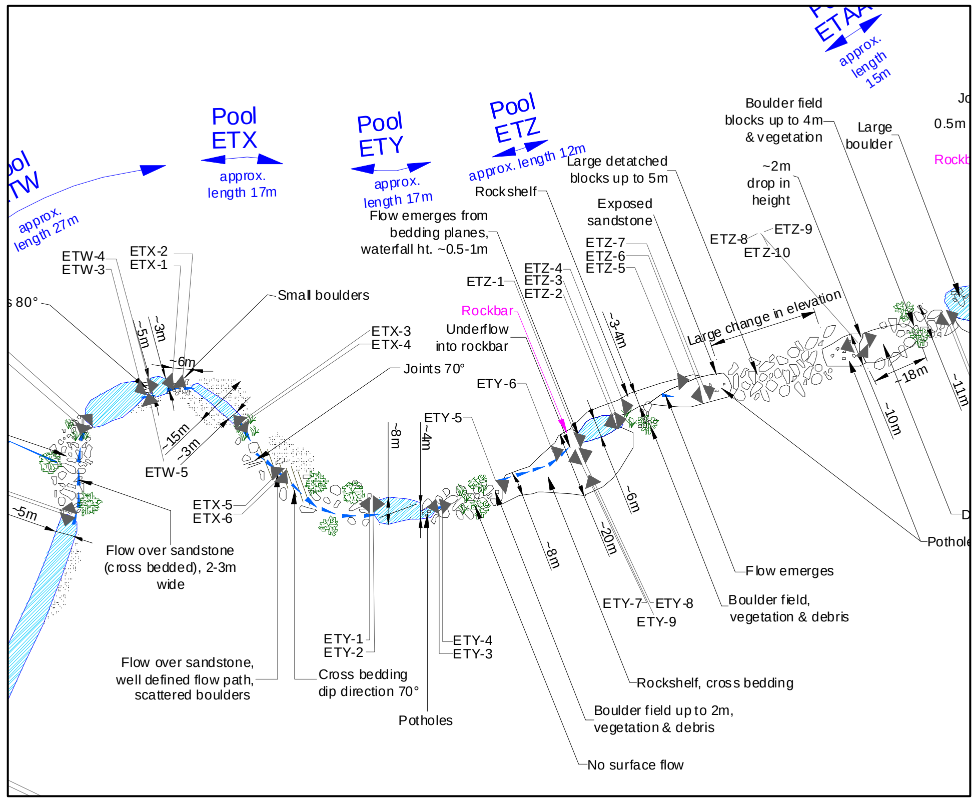
Pool ETY notes (as at 29 Dec 2008)

- Width varies from approximately 4m to 8m.
- Water depth varies from approximately 0.1m to 0.5m with an average of approximately 0.3m.
- Base of the pool is cross bedded sandstone with alluvial deposits, some potholes and boulders.

(notes for downstream section continued on following sheet)

**ETY-1** Upstream end of Pool ETY looking Upstream

**ETY-2** Upstream end of Pool ETY looking Downstream




**ETY-4** Downstream of Pool ETY looking Downstream

**ETY-5** Rockbar Downstream of Pool ETY looking Downstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| ETY-1 | 311836 | 6214440 | 270 |
| ETY-2 | 311836 | 6214440 | 90 |
| ETY-3 | 311856 | 6214440 | 259 |
| ETY-4 | 311856 | 6214440 | 79 |

# POOL ETY DOWNSTREAM MAPPING SUMMARY

**ETY-5** On Rockbar Downstream of Pool ETY looking Downstream

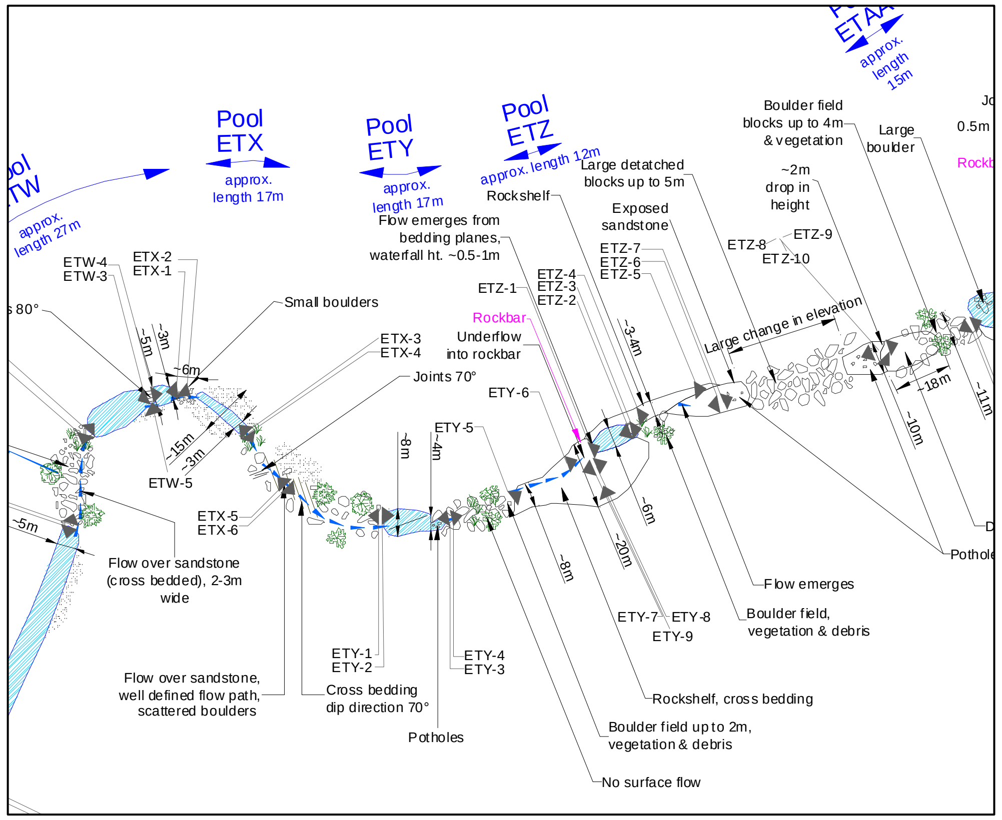
**ETY-7** Midpoint on Rockbar Downstream of Pool ETY looking Upstream

Pool ETY Downstream notes (as at 29 Dec 2008)

- Water from Pool ETY enters a boulder field with boulders up to approximately 2m size, vegetation and debris.
- No surface flow was observed in the boulder field.
- Flow emerges onto a rock shelf approximately 8m to 20m wide. Cross bedding present.
- Flow emerges from bedding planes and enters Pool ETZ via a waterfall 0.5m to 1m high.
- Pool ETZ estimated to be approximately 4m below Pool ETY.

**ETY-6** Underflow on Rockbar Downstream of Pool ETY

**ETY-8** Midpoint on Rockbar Downstream of Pool ETY looking Downstream




**ETY-9** Midpoint on Rockbar Downstream of Pool ETY looking toward the West bank

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| ETY-5 | 311874 | 6214446 | 54 |
| ETY-6 | 311890 | 6214455 | 69 |
| ETY-7 | 311898 | 6214454 | 245 |
| ETY-8 | 311898 | 6214454 | 65 |
| ETY-9 | 311902 | 6214446 | 335 |

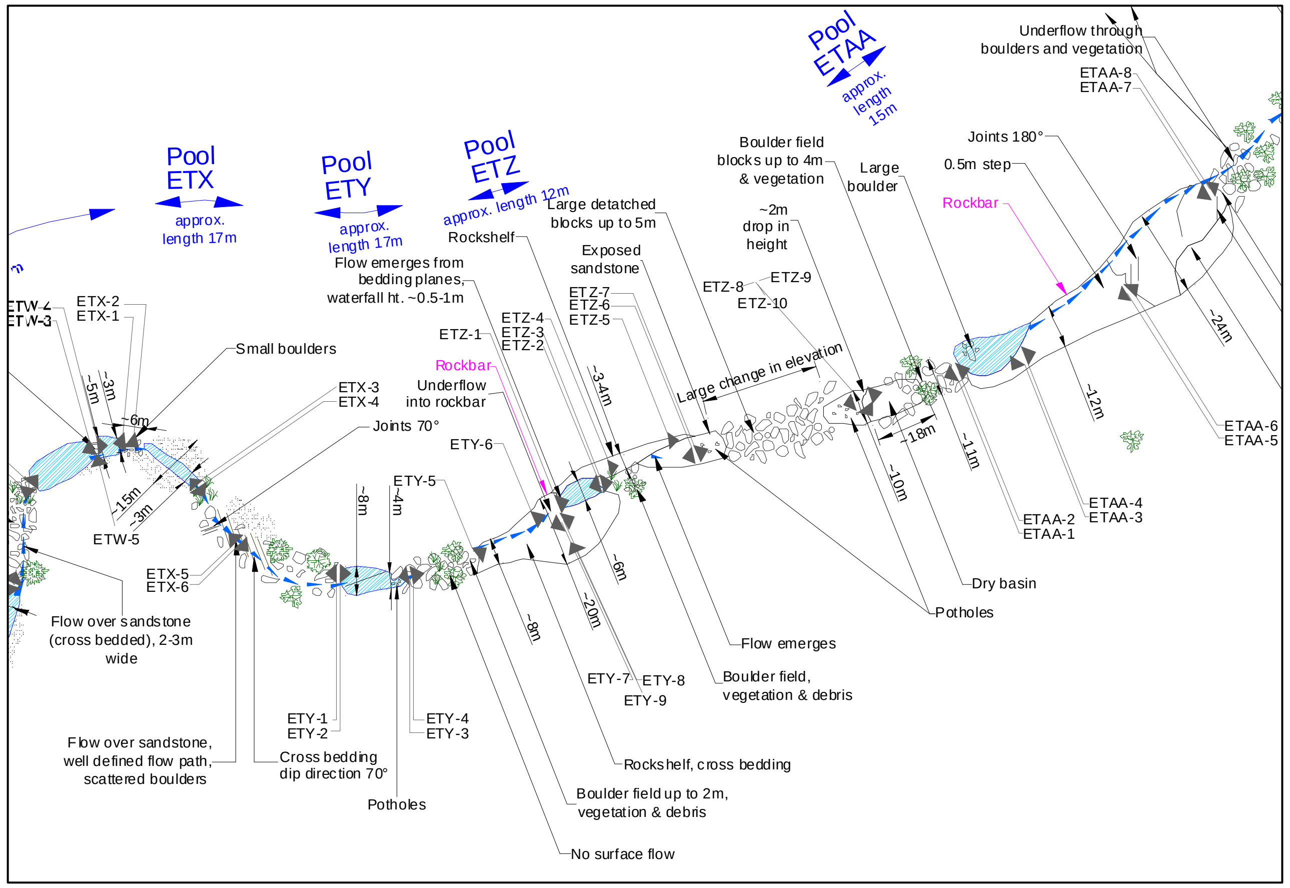
# POOL ETZ STREAM MAPPING SUMMARY

**ETZ-1** Upstream end of Pool ETZ looking Downstream

Pool ETZ notes (as at 29 Dec 2008)

- Width varies from approximately 4m to 6m.
- Maximum water depth is approximately 0.6m.
- Base of the pool is sandstone with minor alluvial deposits.

(Notes continued on second sheet)




**ETZ-2** Downstream end of Pool ETZ looking Upstream

**ETZ-3** Downstream end of Pool ETZ looking Downstream

**ETZ-4** Exposed sandstone at Downstream end of Pool ETZ looking Downstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| ETZ-1 | 311896 | 6214459 | 69 |
| ETZ-2 | 311910 | 6214468 | 248 |
| ETZ-3 | 311909 | 6214465 | 79 |
| ETZ-4 | 311911 | 6214470 | 79 |

# POOL ETZ DOWNSTREAM MAPPING SUMMARY

**ETZ-5** Exposed sandstone Downstream end of Pool ETZ looking Downstream

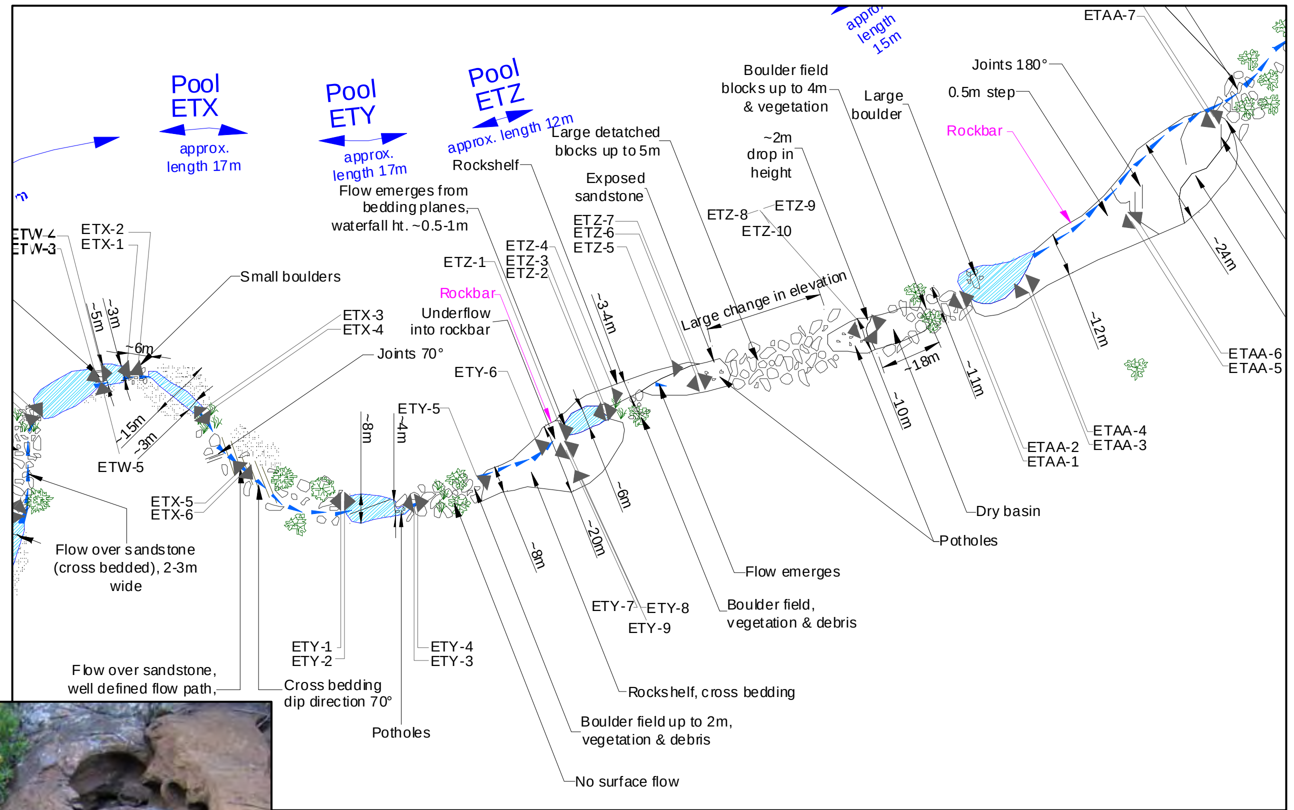
**ETZ-6** Flow emerging Downstream end of Pool ETZ

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

<u>Pool ETZ downstream notes (as at 29 Dec 2008)</u>

- Rockbar downstream of Pool ETZ is approximately 3m to 4m wide.
- Boulder field located on the south eastern side of the rockbar.
- Water emerges approximately 15m downstream of Pool ETZ
- There is a large change in vertical height over the boulder field located between exposed sandstone (could not be measured on site).
- Several potholes observed in exposed sandstone.
- A possible dry pool is located close to the upstream end of Pool ETAA.
- Boulder fields have sandstone blocks up to approximately 4m to 5m size.

**ETZ-8** Exposed sandstone with potholes looking upstream to boulder field




**ETZ-9** Possible dry pool looking Downstream

**ETZ-10** Cracking at step down in sandstone

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| ETZ-5 | 311927 | 6214477 | 80 |
| ETZ-6 | 311935 | 6214473 | 259 |
| ETZ-7 | 311935 | 6214473 | 68 |
| ETZ-8 | 311981 | 6214488 | 250 |
| ETZ-9 | 311981 | 6214488 | 70 |
| ETZ-10 | 311981 | 6214488 | 140 |

# POOL ETAA STREAM MAPPING SUMMARY

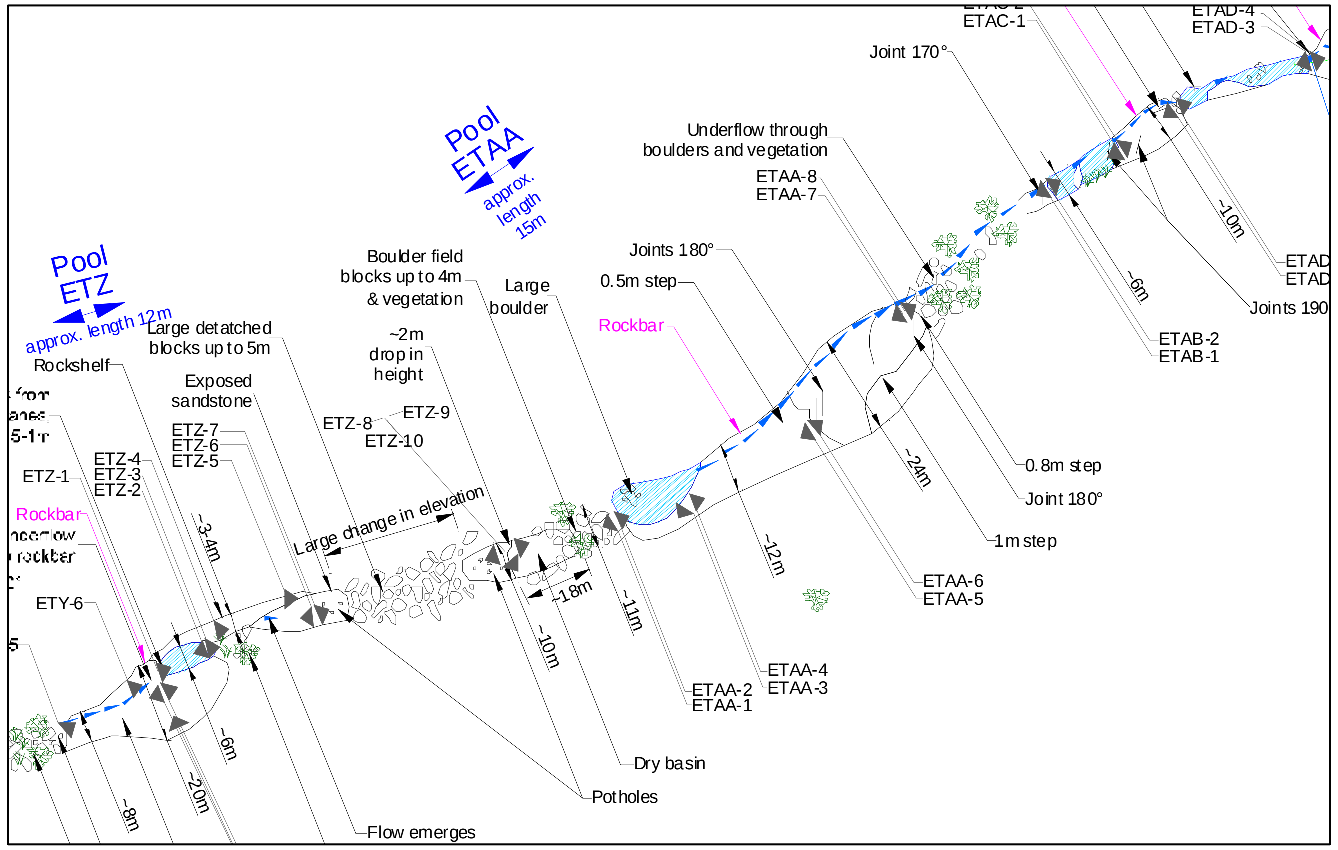
**ETAA-1** Upstream end of Pool ETAA looking Upstream

**ETAA-2** Upstream end of Pool ETAA looking Downstream

Pool ETAA notes (as at 19 Dec 2008)

- Width varies from approximately 4m to 9m
- Water depth varies from approximately 0.1m to 1m with an average of approximately 0.5m.
- Base of the pool is sandstone with minor alluvial deposits and boulders.
- Rock ledges present on south east side (~0.5m high) and north west side (~1m).
- Rockbar downstream of the pool is approximately 12m wide and approximately 24m wide further downstream.

(Notes continued on second sheet)




**ETAA-3** Downstream end of Pool ETAA looking Upstream along south east bank.

**ETAA-4** Downstream end of Pool ETAA looking Downstream

Photo Details

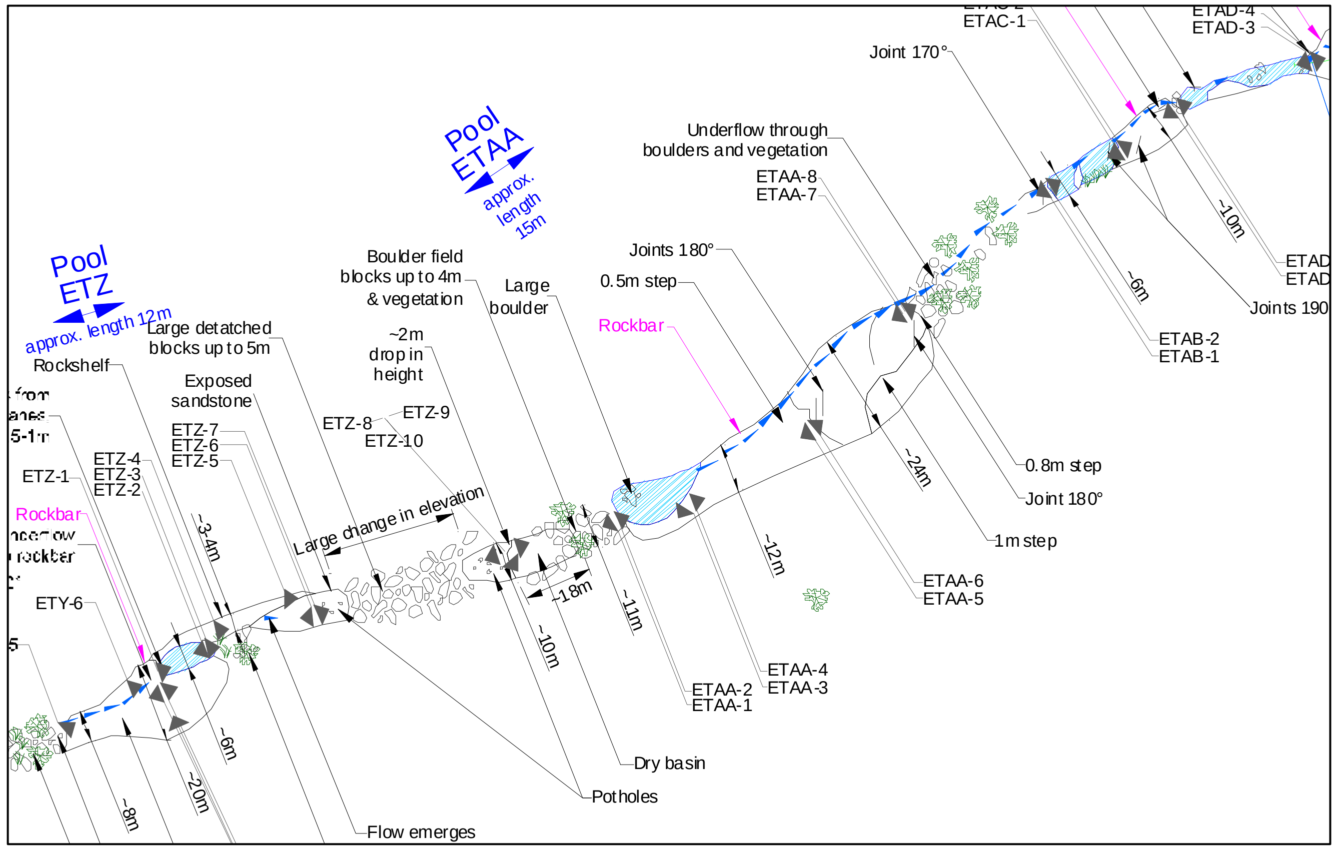
| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| ETAA-1 | 312007 | 6214496 | 242 |
| ETAA-2 | 312007 | 6214496 | 68 |
| ETAA-3 | 312025 | 6214500 | 213 |
| ETAA-4 | 312025 | 6214500 | 68 |

# POOL ETAA DOWNSTREAM MAPPING SUMMARY

**ETAA-5** On rockbar Downstream of Pool ETAA looking Upstream

Pool ETAA Downstream notes (as at 19 Dec 2008)

- Flow continues along the north western edge of the rockbar.
- There is an approximate 0.5m step approximately midway along the rockbar where the flow forms a small waterfall.
- A small area of ponded water is located on the south eastern side of the rockbar below an approximate 1m step in the rockbar (Photo ETAA-7).
- Water flow continues into a boulder field downstream of the rockbar.




**ETAA-6** On rockbar Downstream of Pool ETAA looking Downstream

**ETAA-7** Downstream end of rockbar Downstream of Pool ETAA looking Upstream

**ETAA-8** Downstream end of rockbar Downstream of Pool ETAA looking Downstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| ETAA-5 | 312054 | 6214518 | 237 |
| ETAA-6 | 312054 | 6214518 | 46 |
| ETAA-7 | 312077 | 6214546 | 237 |
| ETAA-8 | 312077 | 6214546 | 57 |

# POOLS ETAB & ETAC STREAM MAPPING SUMMARY

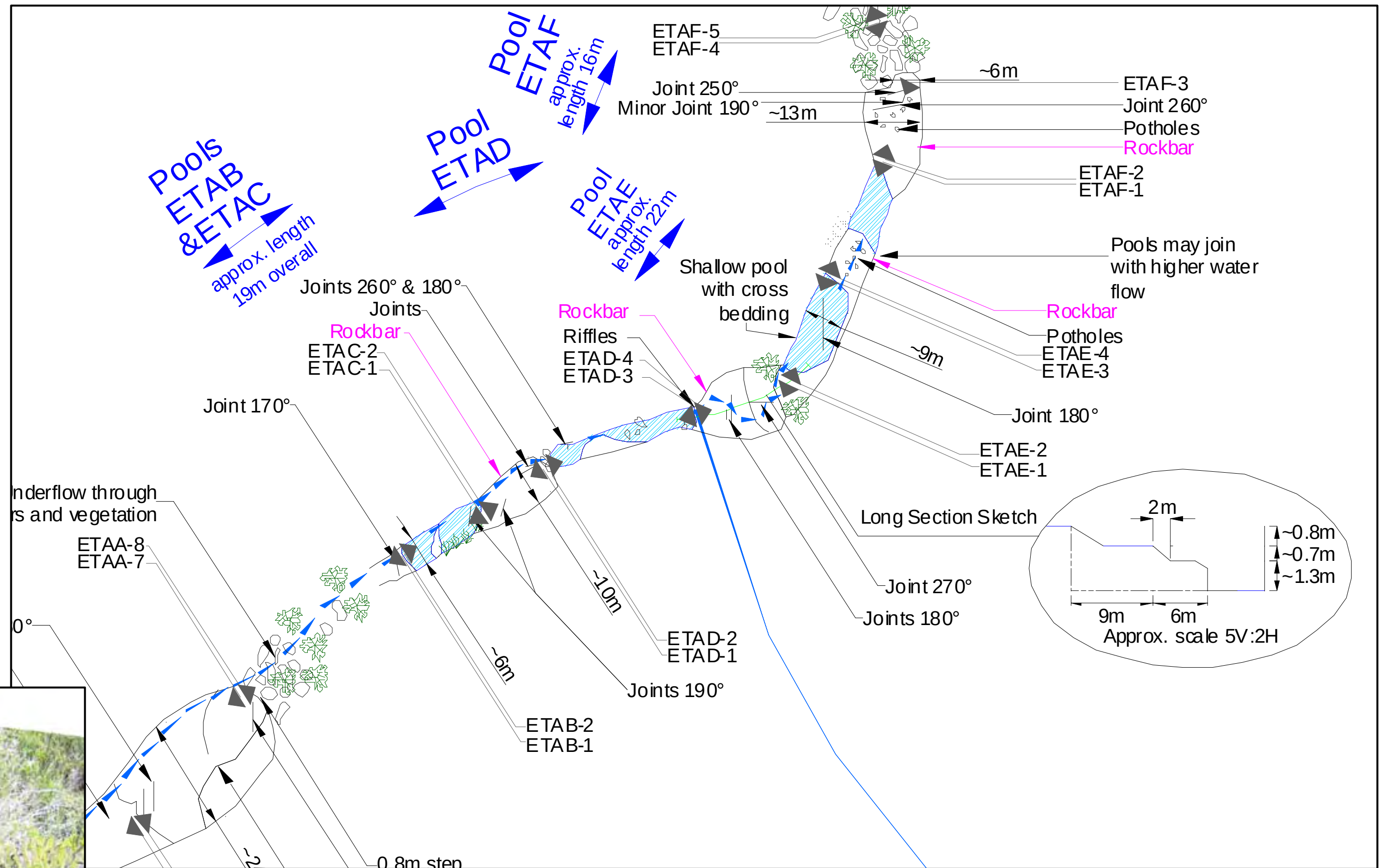
**ETAB-1** Upstream end of Pool ETAB looking Upstream

**ETAB-2** Upstream end of Pool ETAB looking Downstream

<u>Pools ETAB and ETAC notes (as at 19 Dec 2008)</u>

- Pools ETAB and ETAC are separated by a small rockbar. Water flows around the rockbar and the two pool levels are almost the same.
- Pool ETAB is approximately 6m wide and 10m long.
- Pool ETAC is approximately 6m wide and 9m long.
- Water depth is generally very shallow to a maximum of approximately 0.5m.
- Bases of the pools are sandstone with minor alluvial deposits.

**ETAC-1** Downstream end of Pool ETAC looking Upstream




**ETAC-2** Downstream end of Pool ETAC looking Downstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| ETAB-1 | 312112 | 6214577 | 237 |
| ETAB-2 | 312112 | 6214577 | 57 |
| ETAC-1 | 312129 | 6214586 | 237 |
| ETAC-2 | 312129 | 6214586 | 57 |

# POOL ETAD STREAM MAPPING SUMMARY

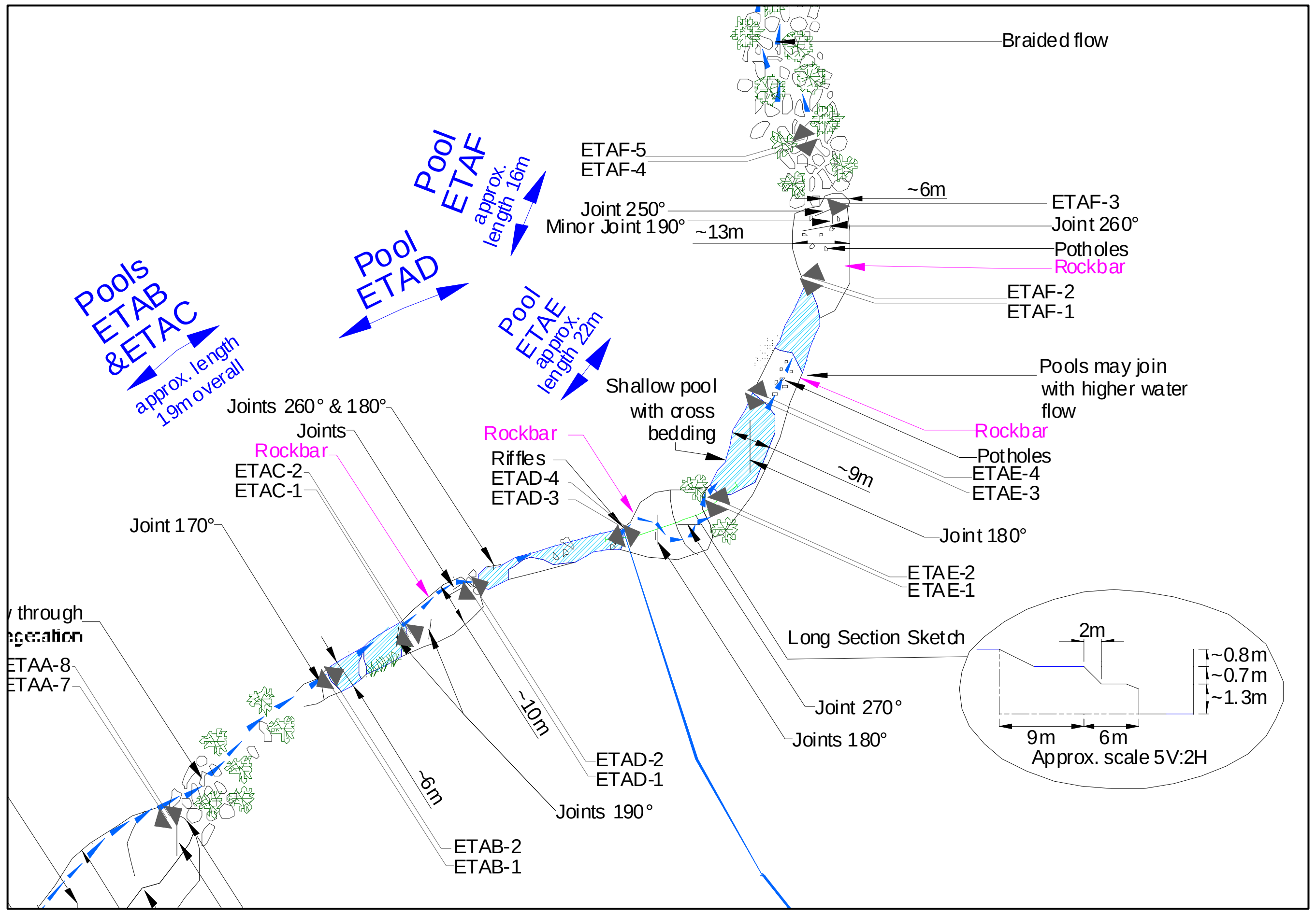
**ETAD-1** Upstream end of Pool ETAD looking Upstream

**ETAD-2** Upstream end of Pool ETAD looking Downstream

Pool ETAD notes (as at 19 Dec 2008)

- Width varies from approximately 1m to 5m.
- Water depth varies from approximately 0.1m to 0.5m.
- Base of the pool is sandstone with minor alluvial deposits and some scattered cobbles and boulders up to approximately 2m size.
- Rockbar downstream of the pool is wide and near level. Some cross bedding is present.
- Pool ETAE is approximately 2.8m below Pool ETAD (see sketch below).

**ETAD-3** Downstream end of Pool ETAD looking Upstream




**ETAD-4** Downstream end of Pool ETAD looking Downstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| ETAD-1 | 312130 | 6214594 | 237 |
| ETAD-2 | 312143 | 6214596 | 70 |
| ETAD-3 | 312175 | 6214607 | 254 |
| ETAD-4 | 312175 | 6214607 | 74 |

# POOL ETAE STREAM MAPPING SUMMARY

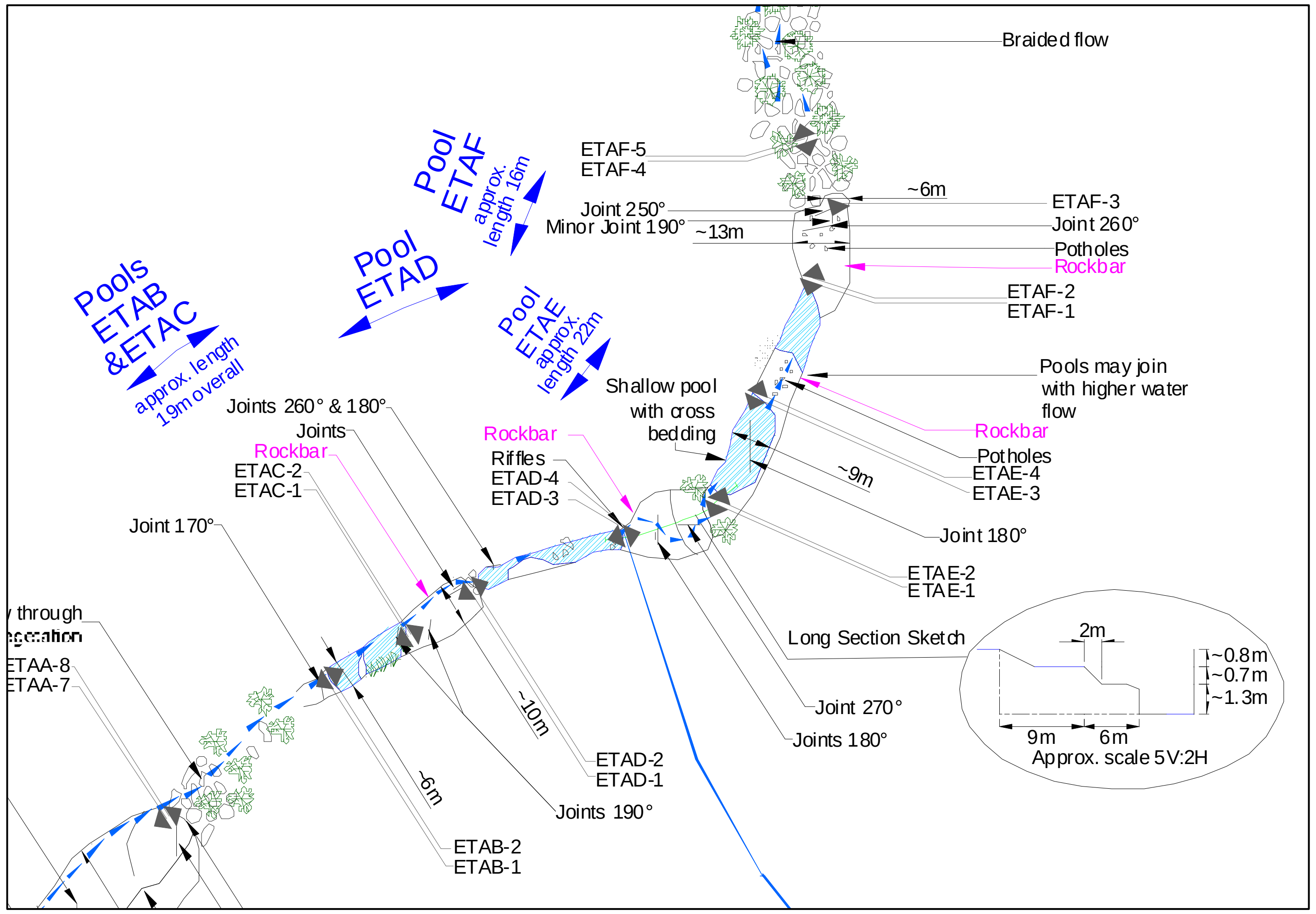
**ETAE-1** Upstream end of Pool ETAE looking Upstream

**ETAE-2** Upstream end of Pool ETAE looking Downstream

Pool ETAE notes (as at 19 Dec 2008)

- Width varies from approximately 2m to 9m.
- Water depth varies up to approximately 0.5m.
- Base of the pool is sandstone with minor alluvial deposits.
- Cross bedding present in the base of the pool.
- Rockbar downstream of the pool has cross bedding and potholes.
- Water flows over the middle of the rockbar as shallow flow and riffles. Pools ETAE and ETAF may become one large pool with higher water levels.

**ETAE-3** Downstream end of Pool ETAE looking Upstream




**ETAE-4** Downstream end of Pool ETAE looking Downstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| ETAE-1 | 312195 | 6214614 | 204 |
| ETAE-2 | 312195 | 6214614 | 24 |
| ETAE-3 | 312204 | 6214638 | 204 |
| ETAE-4 | 312204 | 6214638 | 24 |

# POOL ETAF STREAM MAPPING SUMMARY

**ETAF-1** Downstream end of Pool ETAF looking Upstream

**ETAF-2** Downstream end of Pool ETAF looking Downstream

**ETAF-3** Downstream end of Pool ETAF (Downstream end of rockbar) looking Upstream

<u>Pool ETAF notes (as at 19 Dec 2008)</u>

- Width varies from approximately 2m to 7m.
- Water depth varies from approximately 0.1m to 0.5m.
- Base of the pool is sandstone with minor alluvial deposits.
- Cross bedding and potholes are present in the base of the pool.
- Water flows to a small pool/ponded area on the east side of the rockbar (Photo ETAF-3) but no other surface flow observed over rockbar downstream of the pool.
- Rockbar downstream of the pool is approximately 13m wide
- Joints and potholes present in the rockbar.

(Notes continued on second sheet)

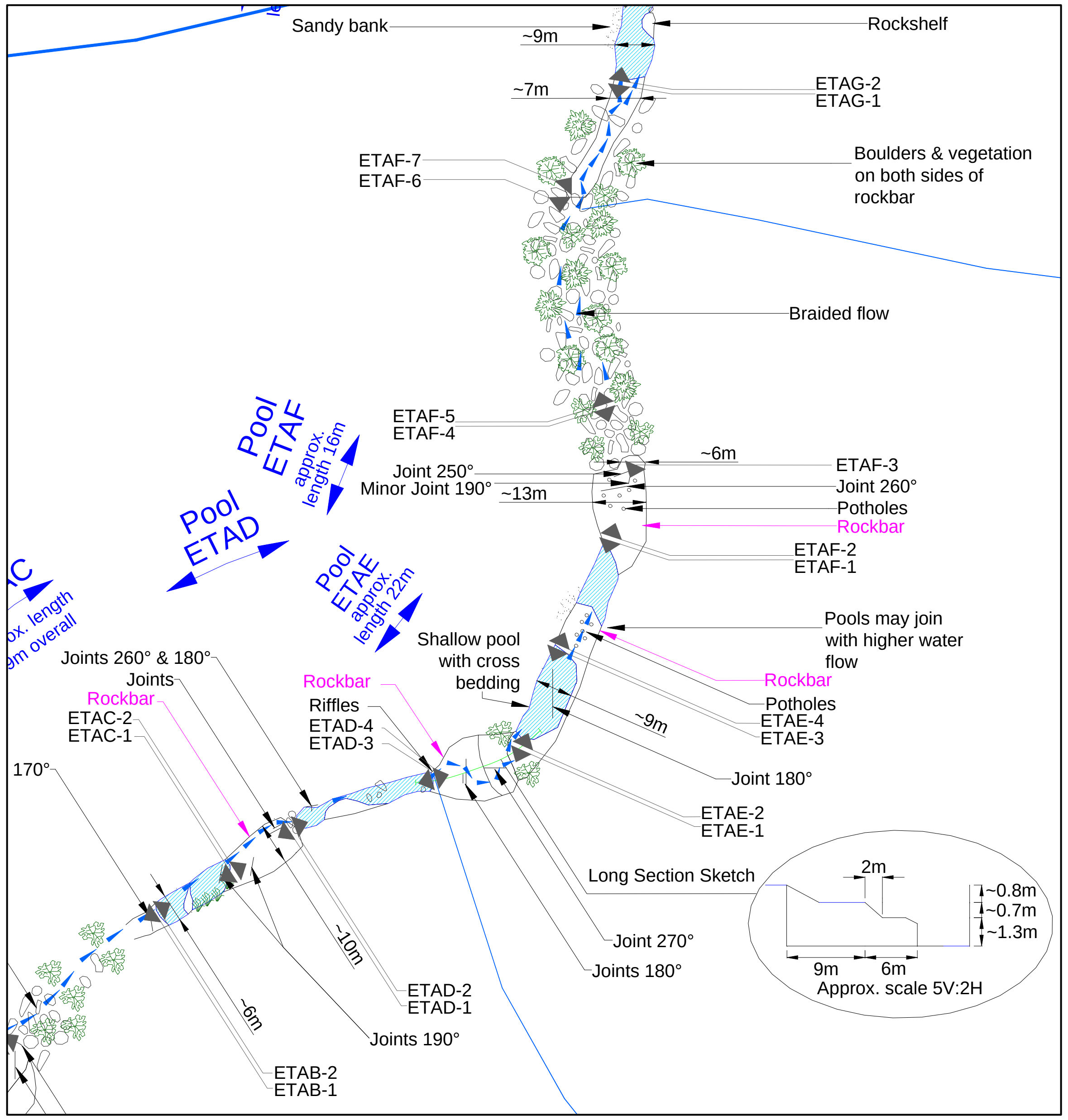



Photo Details

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

# POOL ETAF DOWNSTREAM MAPPING SUMMARY

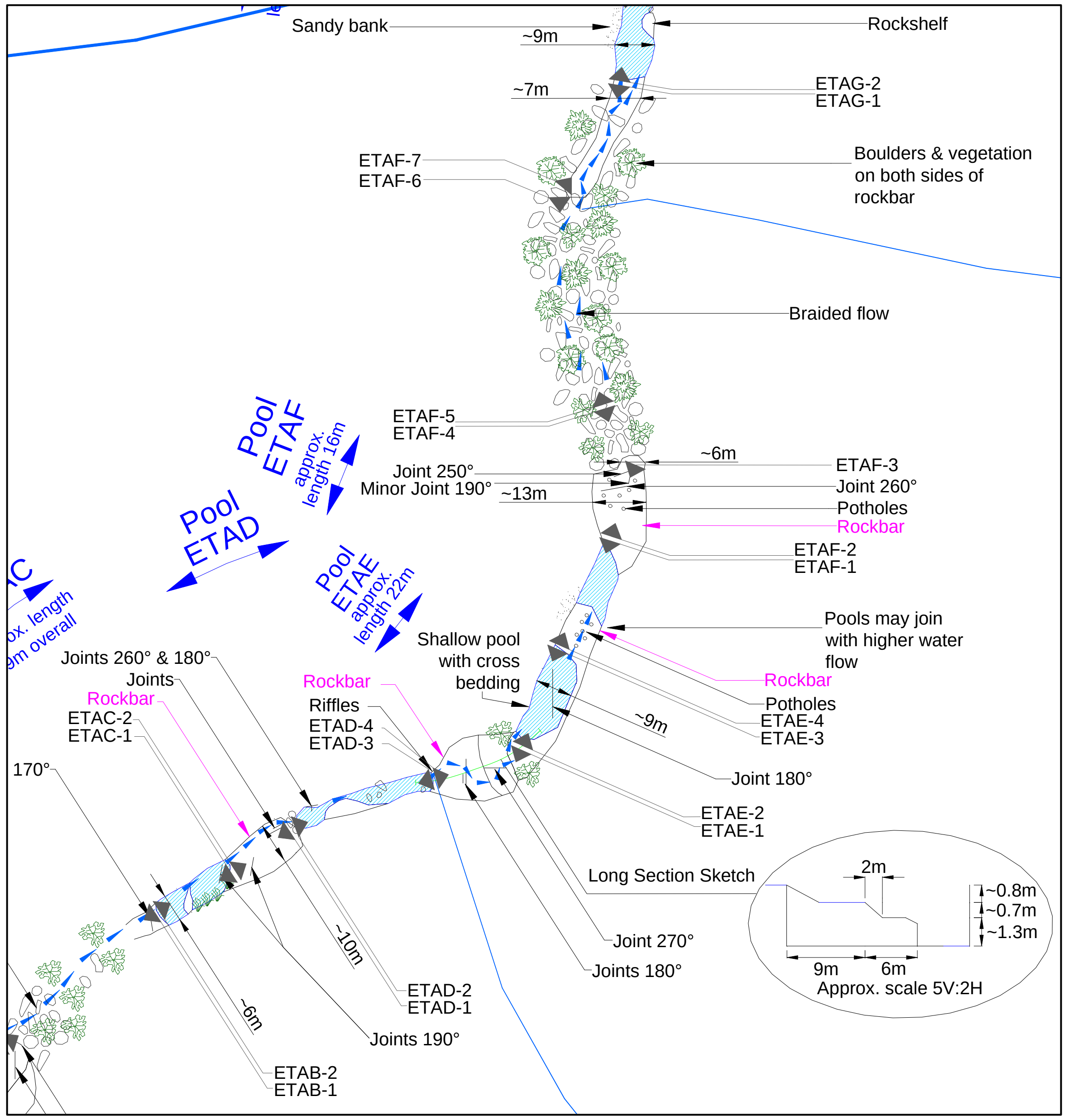
**ETAF-4** In boulder field Downstream of Pool ETAF looking Upstream

**ETAF-5** In boulder field Downstream of Pool ETAF looking Downstream

<u>Pool ETAF Downstream notes (as at 19 Dec 2008)</u>

- Further downstream of the rockbar below Pool ETAF, water flows through a boulder field with boulders up to approximately 3m size.
- Water flows onto exposed sandstone downstream of the boulder field, before entering Pool ETAG.

**ETAF-6** Downstream end of boulder field Downstream of Pool ETAF looking Upstream




**ETAF-7** Downstream end of boulder field Downstream of Pool ETAF looking Downstream

Photo Details

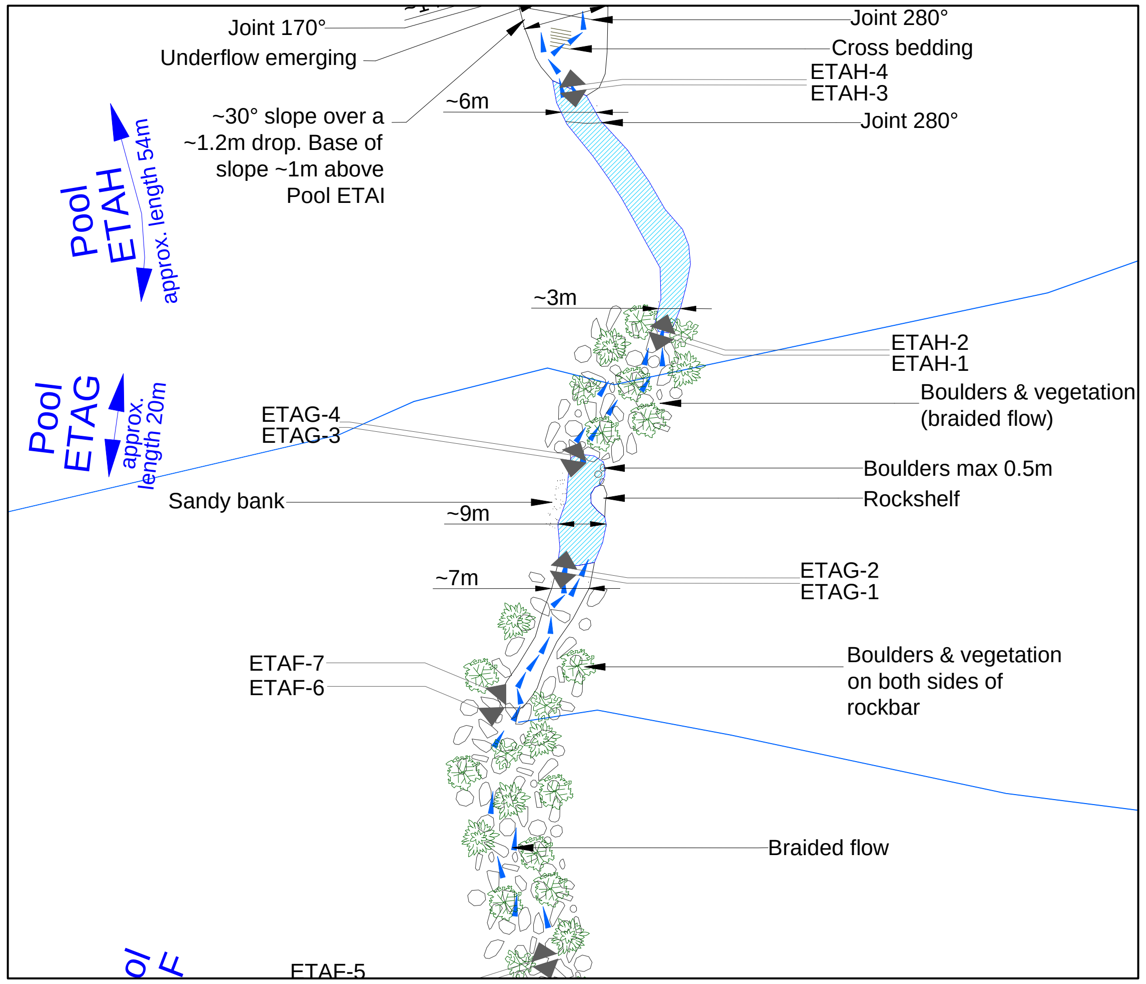
| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| ETAF-4 | 312214 | 6214693 | 162 |
| ETAF-5 | 312214 | 6214693 | 342 |
| ETAF-6 | 312204 | 6214742 | 180 |
| ETAF-7 | 312204 | 6214742 | 40 |

# POOL ETAG STREAM MAPPING SUMMARY

**ETAG-1** Upstream end of Pool ETAG looking Upstream

Pool ETAG notes (as at 19 Dec 2008)

- Width varies from approximately 3m to 9m.
- Water depth varies from approximately 0.1m to 1m.
- Base of the pool is sandstone with alluvial deposits, mainly on the western side.
- Boulders up to approximately 0.5m are present at the downstream eastern end of the pool.
- Algae deposits present.
- Water flows into a boulder field downstream of the pool. Boulders up to approximately 3m size.




**ETAG-2** Upstream end of Pool ETAG looking Downstream

**ETAG-3** Downstream end of Pool ETAG looking Upstream

**ETAG-4** Downstream end of Pool ETAG looking Downstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| ETAG-1 | 312217 | 6214767 | 189 |
| ETAG-2 | 312217 | 6214767 | 9 |
| ETAG-3 | 312219 | 6214788 | 188 |
| ETAG-4 | 312219 | 6214788 | 26 |

# POOL ETAH STREAM MAPPING SUMMARY

**ETAH-1** Upstream end of Pool ETAH looking Upstream

**ETAH-2** Upstream end of Pool ETAH looking Downstream

**ETAH-3** Downstream end of Pool ETAH looking Upstream

**ETAH-4** Downstream end of Pool ETAH looking Downstream

<u>Pool ETAH notes (as at 19 Dec 2008)</u>

- Width varies from approximately 3m to 6m.
- Water depth varies from approximately 0.3m to 1.5m.
- Base of the pool is sandstone with alluvial deposits.
- Water depth is very shallow with some sandstone exposed over approximately 8m at the downstream end of the pool.
- Rockbar downstream of the pool is cross bedded.
- Water flows over most of the rockbar surface with some ponded areas and some underflow.
- Pool ETAI is more than 2m below Pool ETAH.

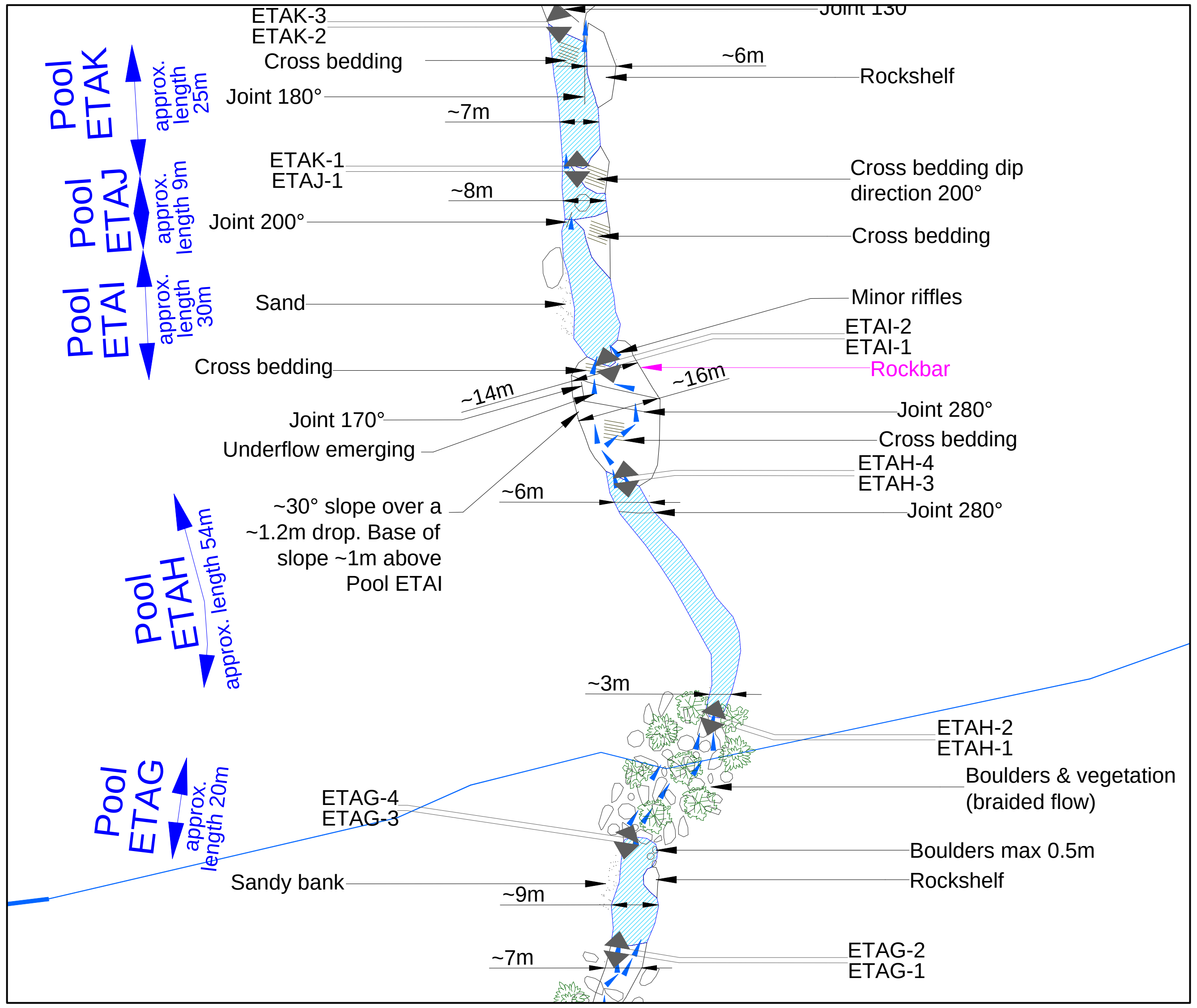



Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| ETAH-1 | 312236 | 6214812 | 197 |
| ETAH-2 | 312236 | 6214812 | 17 |
| ETAH-3 | 312220 | 6214859 | 172 |
| ETAH-4 | 312220 | 6214859 | 352 |

# POOLS ETAI & ETAJ STREAM MAPPING SUMMARY

**ETAI-1** Upstream end of Pool ETAI looking Upstream

**ETAI-2** Upstream end of Pool ETAI looking Downstream

**ETAJ-1** Downstream end Pool ETAJ looking Upstream

Pools ETAI and ETAJ notes (as at 19 Dec 2008)

- Width varies from approximately 2m to 8m.
- Water depth varies from approximately 0.2m to 1m.
- Base of the pool is sandstone with alluvial deposits and scattered boulders.
- Large sand bank present on the western side of the pool.
- Sandstone is cross bedded.
- Only small rockbars separate Pools ETAI, AJ and AK. Pools may join to become one large pool with higher water levels.

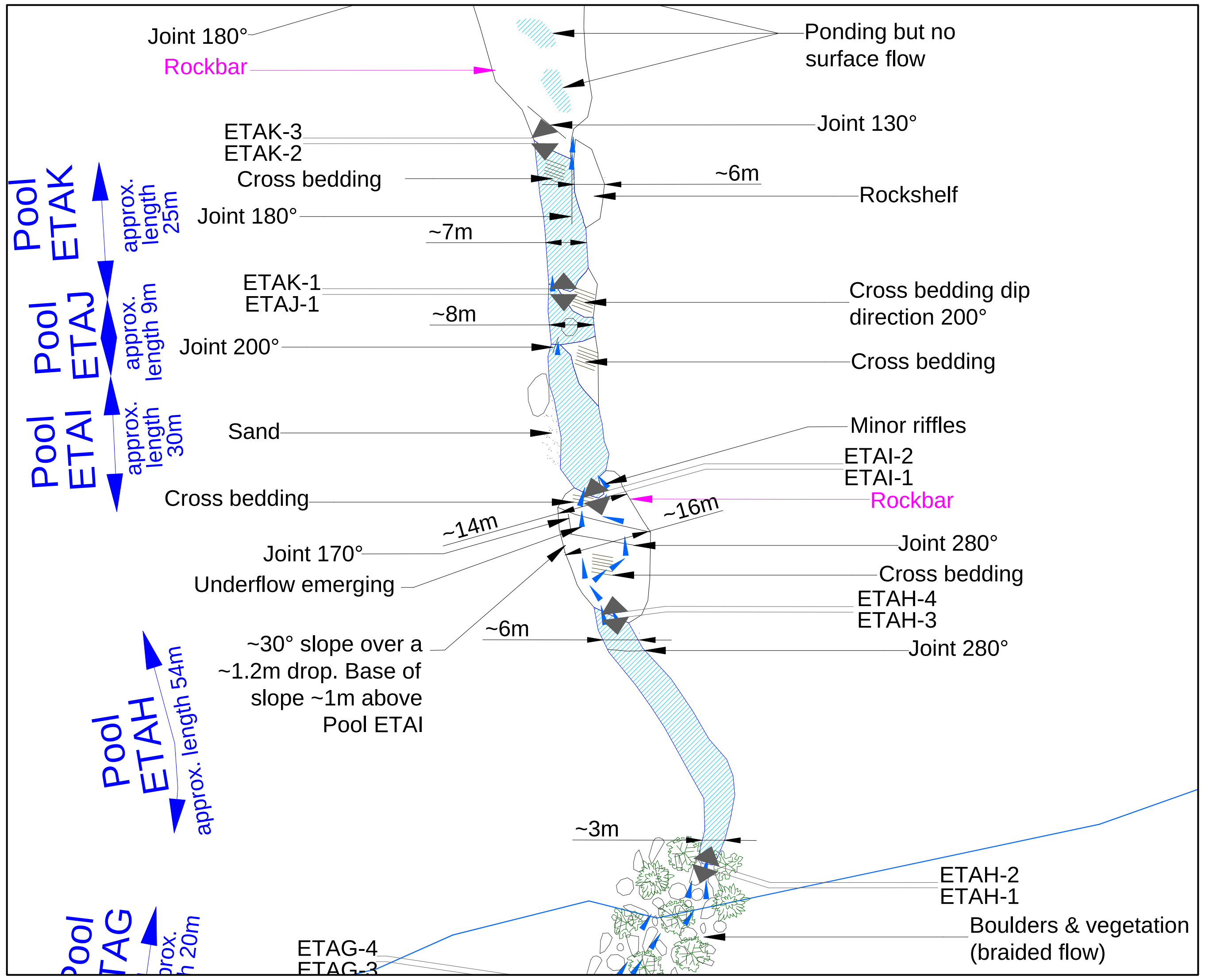



Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| ETAI-1 | 312216 | 621481 | 164 |
| ETAI-2 | 312216 | 621481 | 344 |
| ETAJ-1 | 312210 | 6214919 | 180 |

# POOL ETAK STREAM MAPPING SUMMARY

**ETAK-1** Upstream end of Pool ETAK looking Downstream

**ETAK-2** Downstream end of Pool ETAK looking Upstream

**ETAK-3** Downstream end Pool ETAK looking Downstream

Pool ETAK notes (as at 19 Dec 2008)
- Width varies from approximately 4m to 7m.
- Water depth varies from approximately 0.2m to 0.5m.
- Base of the pool is sandstone with minor alluvial deposits.
- Sandstone is cross bedded and weathered.
- Rockbar downstream of Pool ETAK has several small pools/ponded areas but no surface flow observed.
- Maximum width of rockbar is approximately 21m.

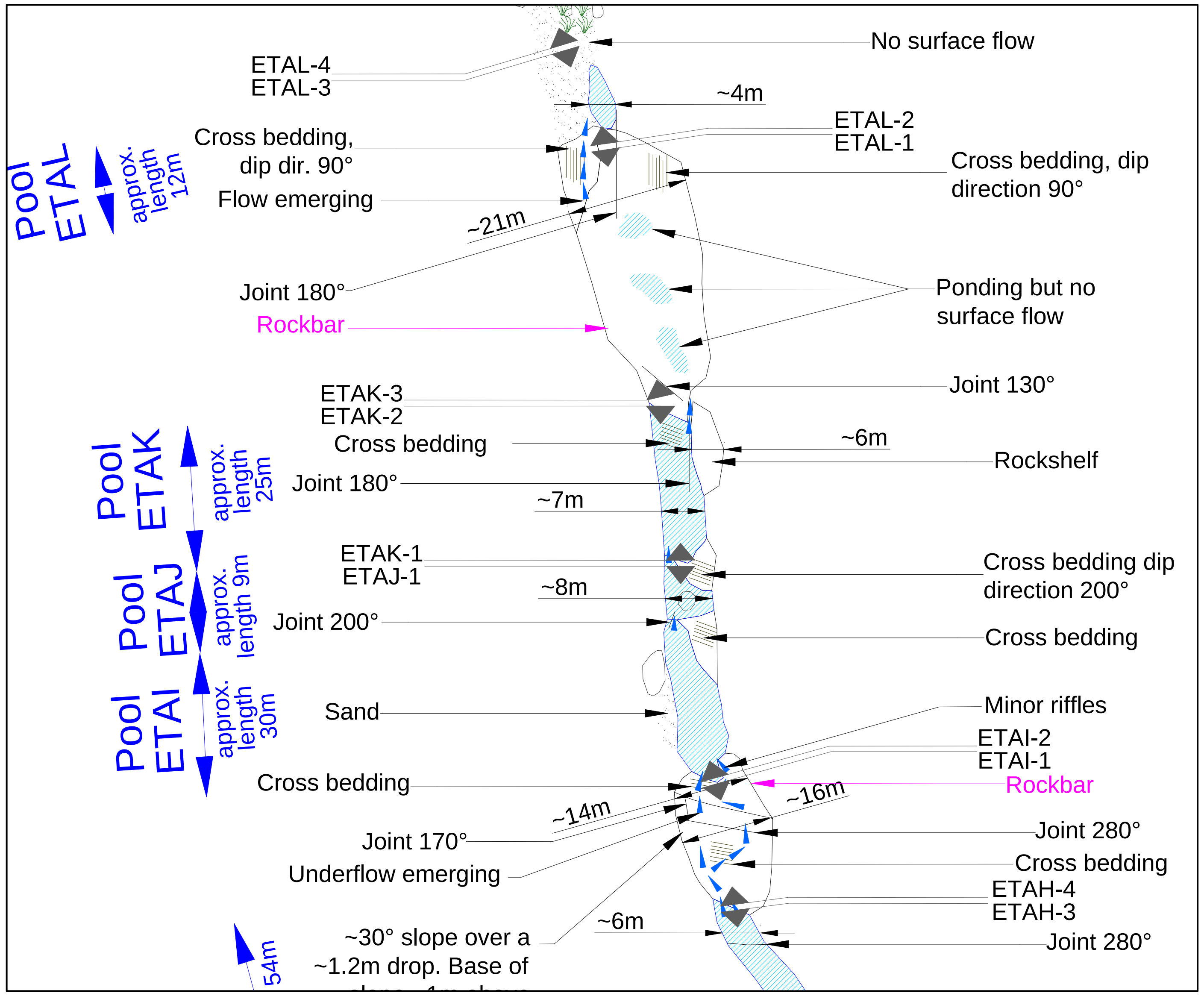



Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| ETAK-1 | 312210 | 6214919 | 0 |
| ETAK-2 | 312207 | 6214948 | 180 |
| ETAK-3 | 312207 | 6214948 | 347 |

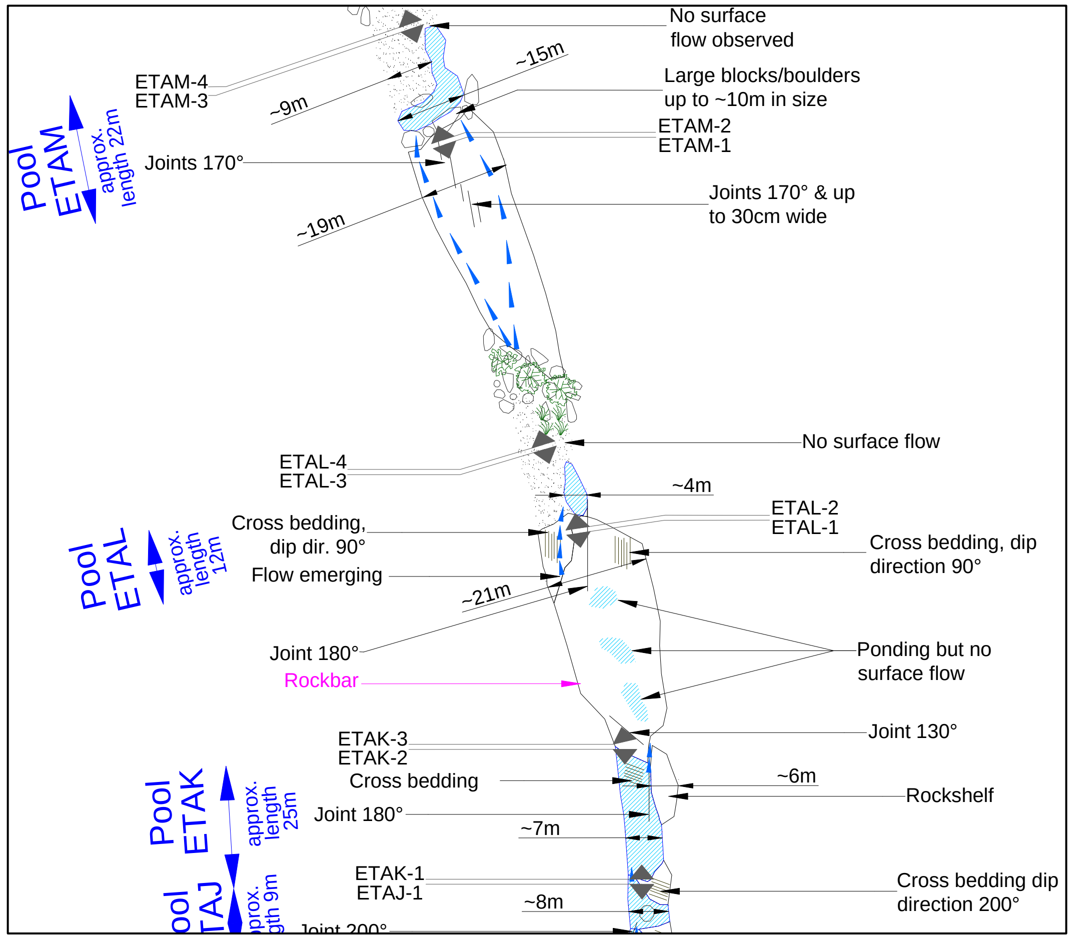
# POOL ETAL STREAM MAPPING SUMMARY

**ETAL-1** Upstream end of Pool ETAL looking Upstream

**ETAL-2** Upstream end of Pool ETAL looking Downstream

Pool ETAL notes (as at 19 Dec 2008)

- Pool ETAL is approximately 1.5m below the upstream rockbar.
- Width varies from approximately 2m to 4m. Length is approximately 12m.
- Water depth varies from approximately 0.1m to 0.8m.
- Base of the pool is sandstone with alluvial deposits.
- Large alluvial deposits on the western and downstream sides of the pool.
- Algae present in the pool.
- No surface flow observed downstream of the pool.
- Flow emerges approximately 30m downstream of the pool from a small boulder field onto exposed sandstone.




**ETAL-3** Downstream end of Pool ETAL looking Upstream

**ETAL-4** Downstream end of Pool ETAL looking Downstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| ETAL-1 | 312197 | 6214992 | 171 |
| ETAL-2 | 312197 | 6214992 | 351 |
| ETAL-3 | 312190 | 6215010 | 163 |
| ETAL-4 | 312190 | 6215010 | 343 |

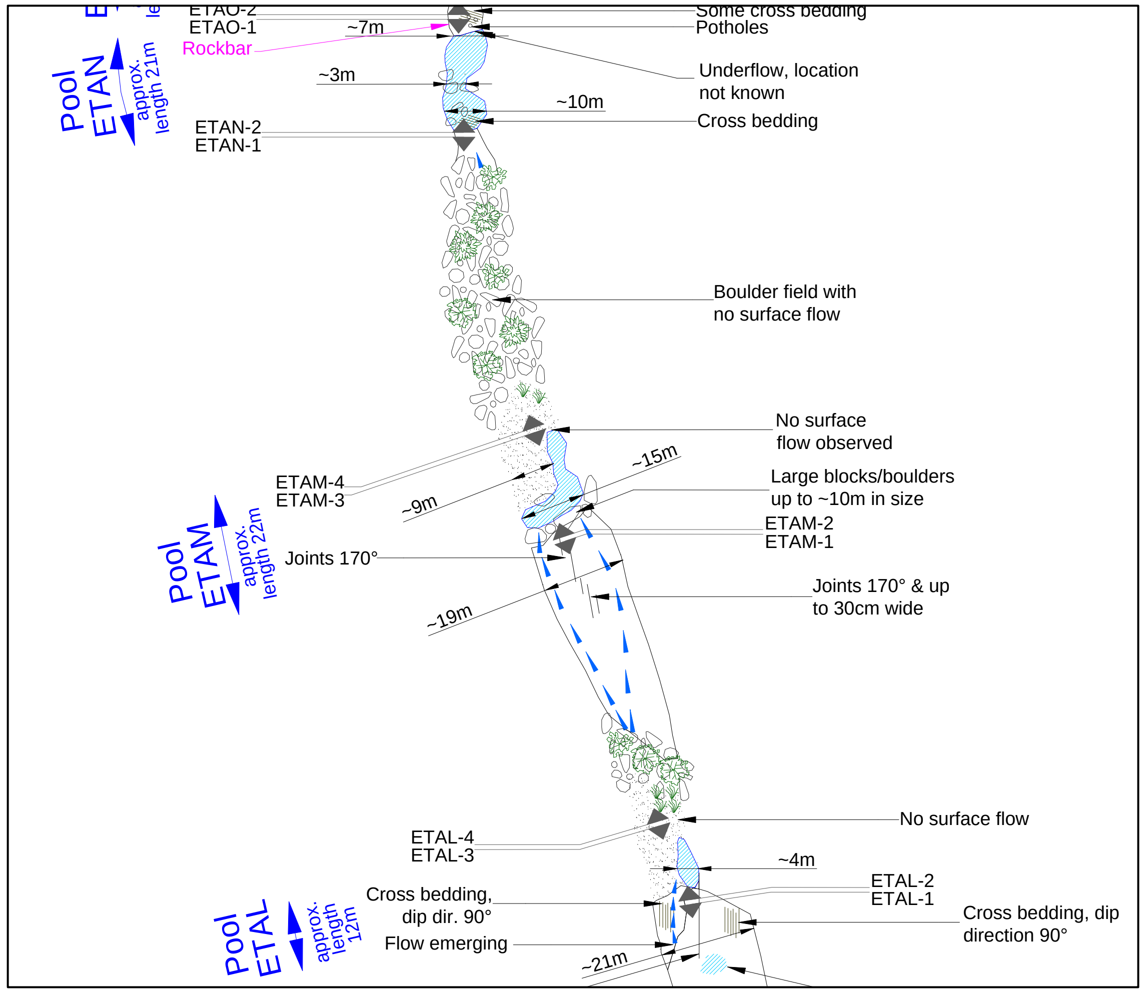
# POOL ETAM STREAM MAPPING SUMMARY

**ETAM-1** Upstream end of Pool ETAM looking Upstream

**ETAM-2** Upstream end of Pool ETAM looking Downstream

Pool ETAM notes (as at 19 Dec 2008)

- Pool ETAM is approximately 3m below the upstream rockbar.
- Width varies from approximately 15m at the upstream end to 2m at the downstream end.
- Water depth varies up to approximately 0.8m
- Base of the pool is alluvial deposit.
- There is a large alluvial deposit on the west bank approximately 9m wide and 25m long.
- Cross bedding present in exposed sandstone.
- Large detached blocks/boulders are present at the upstream end of the pool.
- No surface flow observed downstream of the pool.
- Alluvial deposits present on the downstream side of the pool then boulder field.




**ETAM-3** Downstream end of Pool ETAM looking Upstream

**ETAM-4** Downstream end of Pool ETAM looking Downstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| ETAM-1 | 312169 | 6215073 | 161 |
| ETAM-2 | 312169 | 6215073 | 341 |
| ETAM-3 | 312162 | 6215098 | 161 |
| ETAM-4 | 312162 | 6215098 | 341 |

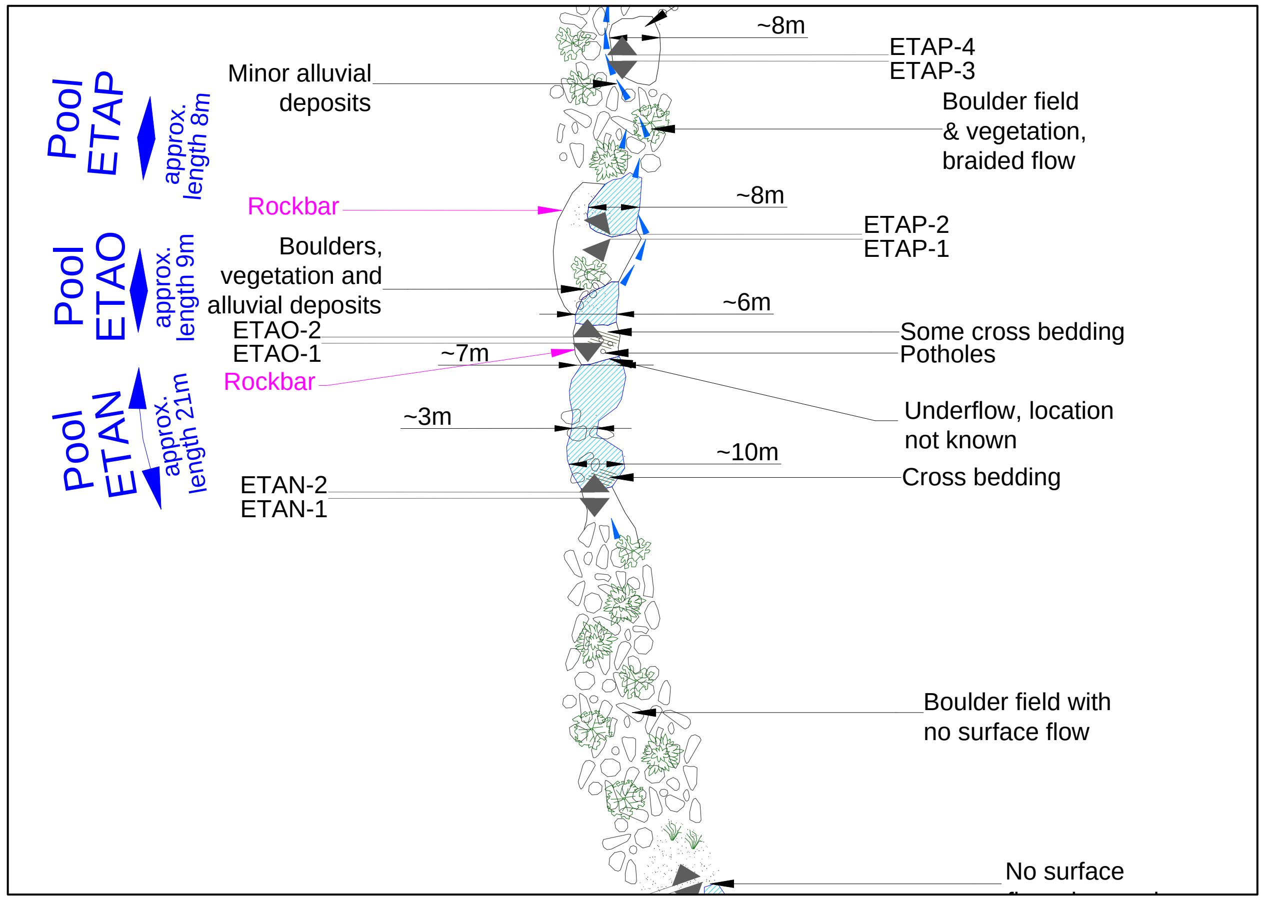
# POOLS ETAN & ETAO STREAM MAPPING SUMMARY

**ETAN-1** Upstream end of Pool ETAN looking Upstream

**ETAN-2** Upstream end of Pool ETAN looking Downstream

Pools ETAN and ETAO notes (as at 19 Dec 2008)

- Widths vary from approximately 3m to 7m.
- Water depth varies up to 0.9m.
- Base of the pool is sandstone with alluvial deposits and scattered boulders up to approximately 4m size.
- Rockbar separating Pool ETAN and ETAO is approximately 7m wide and 7m long. Some cross bedding and potholes are present in the rockbar.
- Water flows around the eastern side of the rockbar downstream of Pool ETAO.




**ETAO-1** Upstream end of Pool ETAO looking Upstream

**ETAO-2** Upstream end of Pool ETAO looking Downstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| ETAN-1 | 312146 | 6215164 | 180 |
| ETAN-2 | 312146 | 6215164 | 0 |
| ETAO-1 | 312145 | 6215190 | 180 |
| ETAO-2 | 312145 | 6215190 | 0 |

# POOL ETAP STREAM MAPPING SUMMARY

**ETAP-1** Upstream end of Pool ETAP looking Upstream

**ETAP-3** Braided flow Downstream of Pool ETAP looking Upstream

Pool ETAP notes (as at 19 Dec 2008)

- Pool width is approximately 6m and length is approximately 8m.
- Average water depth is approximately 0.6m.
- Base of the pool is sandstone with alluvial deposits, mainly on the western half of the pool and scattered small boulders.
- Stream becomes braided flow through boulder field downstream of the pool. Some sandstone bedrock is exposed in the boulder field.
- End of the boulder field is approximately 60m downstream of the pool where flow continues along western side of exposed sandstone.

**ETAP-2** Upstream end of Pool ETAP looking Downstream

**ETAP-4** Sandstone Downstream of Pool ETAP looking Downstream

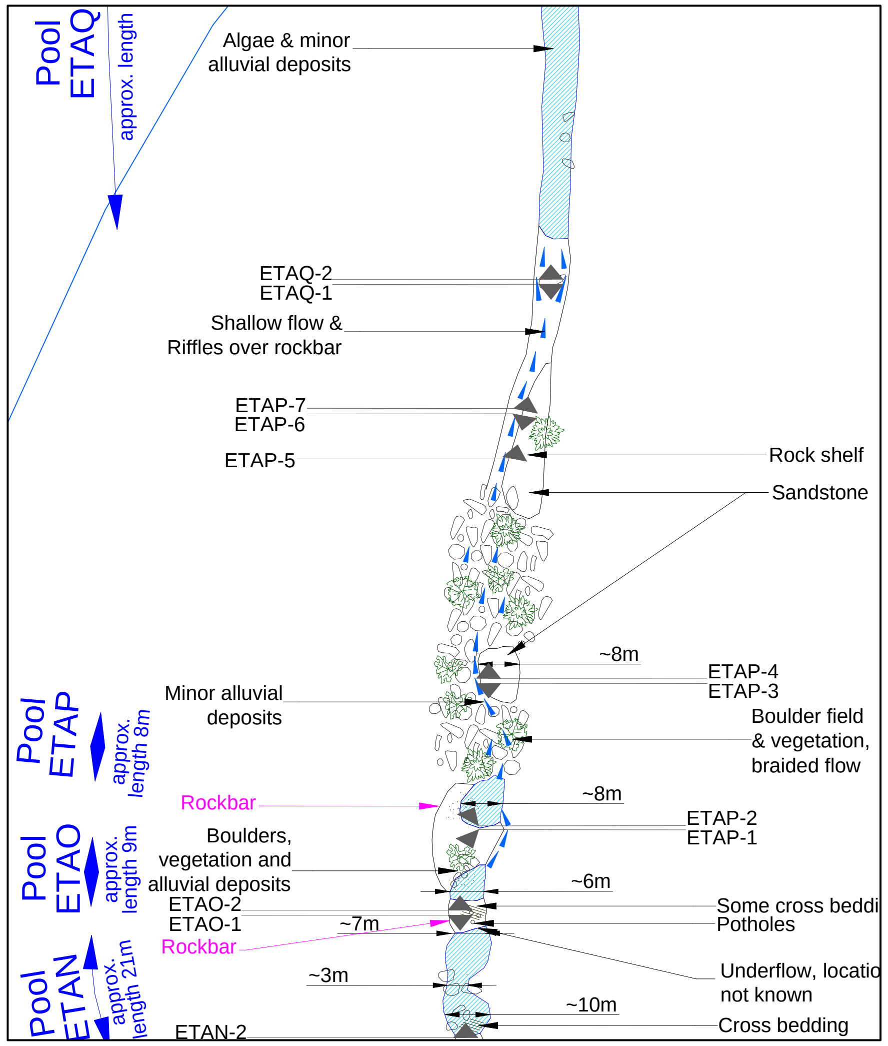



Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| ETAP-1 | 312148 | 6215208 | 159 |
| ETAP-2 | 312148 | 6215208 | 29 |
| ETAP-3 | 312151 | 6215238 | 180 |
| ETAP-4 | 312151 | 6215238 | 0 |
| ETAP-5 | 312156 | 6215283 | 11 |
| ETAP-6 | 312158 | 6215293 | 191 |
| ETAP-7 | 312158 | 6215293 | 11 |

**ETAP-5** Sandstone Downstream of Pool ETAP looking Downstream

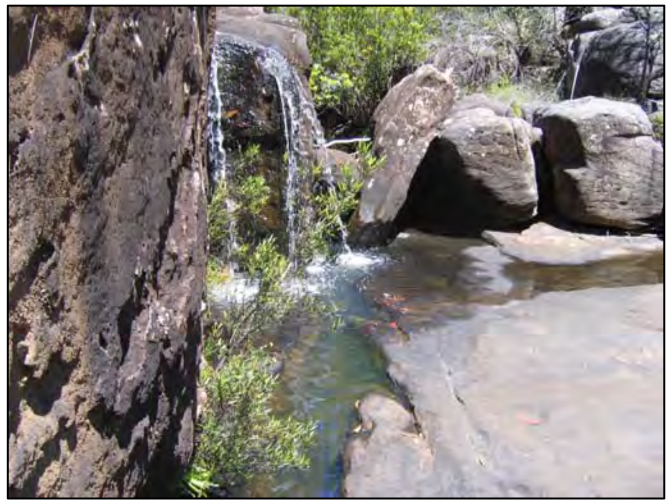
**ETAP-6** Sandstone Downstream of Pool ETAP looking Upstream

**ETAP-7** Sandstone Downstream of Pool ETAP looking downstream

# POOL ETAQ STREAM MAPPING SUMMARY

**ETAQ-1** Upstream end of Pool ETAQ looking Upstream

**ETAQ-2** Upstream end of Pool ETAQ looking Downstream



**ETAQ-5** Waterfall Downstream of Pool ETAQ

Pool ETAQ notes (as at 19 Dec 2008)

- Width varies from approximately 6m to 12m.
- Water depth varies from approximately 0.1m to 1m.
- Base of the pool is sandstone with alluvial deposits and some boulders up to approximately 2m size.
- Rockbar downstream of the pool varies from approximately 12m to 17m wide. Cross bedding present in the rockbar.
- Water flows from the pool in a channel 0.5m to 1m wide and up to 1m deep. Potholes present around the channel. Water continues as underflow from the channel and emerges near a waterfall.
- The top of the waterfall is approximately 15m downstream of Pool ETAQ and is approximately 1m below the pool level. The waterfall is approximately 3m high.
- Water ponds at the base of the waterfall, then continues as underflow and some minor surface flow.

**ETAQ-3** Downstream end of Pool ETAQ looking Upstream

**ETAQ-6** Underflow toward Eastern bank at Waterfall

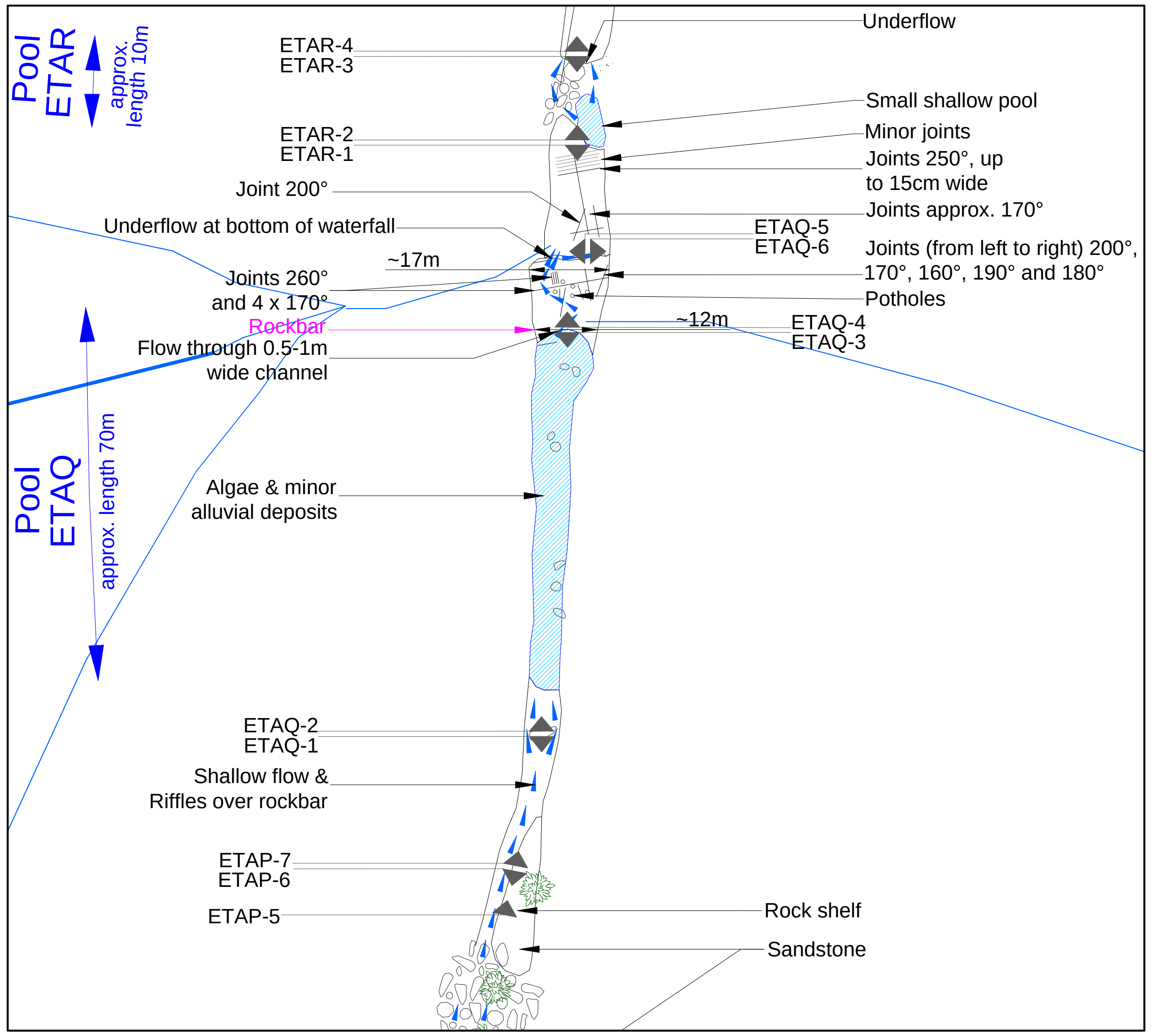



Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| ETAQ-1 | 312164 | 6215320 | 180 |
| ETAQ-2 | 312164 | 6215320 | 0 |
| ETAQ-3 | 312169 | 6215401 | 180 |
| ETAQ-4 | 312169 | 6215401 | 0 |
| ETAQ-5 | 312173 | 6215418 | 270 |
| ETAQ-6 | 312173 | 6215418 | 90 |

**ETAQ-4** Downstream end of Pool ETAQ looking Downstream

# POOL ETAR STREAM MAPPING SUMMARY

**ETAR-1** Upstream end of Pool ETAR looking Upstream

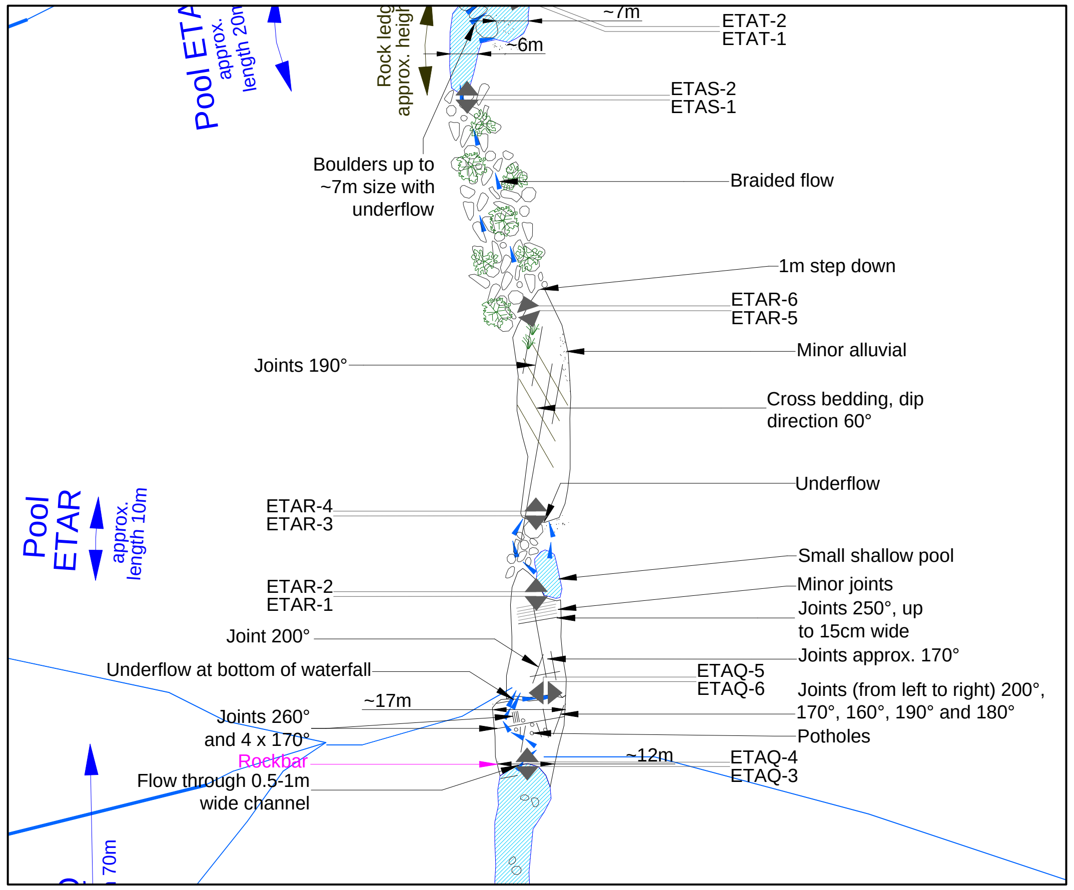
**ETAR-4** Downstream of Pool ETAR looking Downstream

<u>Pool ETAR notes (as at 19 Dec 2008)</u>

- Width is approximately 5m.
- Water depth varies up to approximately 0.4m.
- Base of the pool is sandstone with minor alluvial deposits and cobbles and boulders up to approximately 5m size.
- Rockbar downstream of the pool has cross bedding and joints.
- No surface flow observed over the rockbar.
- Water flow continues through boulder field which starts approximately midway between Pools ETAR and ETAS.

**ETAR-2** Upstream end of Pool ETAR looking Downstream

**ETAR-6** Downstream end of rockbar looking Downstream




**ETAR-3** Downstream end of Pool ETAR looking Upstream

**ETAR-5** Downstream end of rockbar Downstream of Pool ETAR looking Upstream (camera error)

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| ETAR-1 | 312171 | 6215439 | 180 |
| ETAR-2 | 312171 | 6215439 | 0 |
| ETAR-3 | 312171 | 6215457 | 180 |
| ETAR-4 | 312171 | 6215457 | 0 |
| ETAR-5 | 312169 | 6215502 | 160 |
| ETAR-6 | 312169 | 6215502 | 342 |

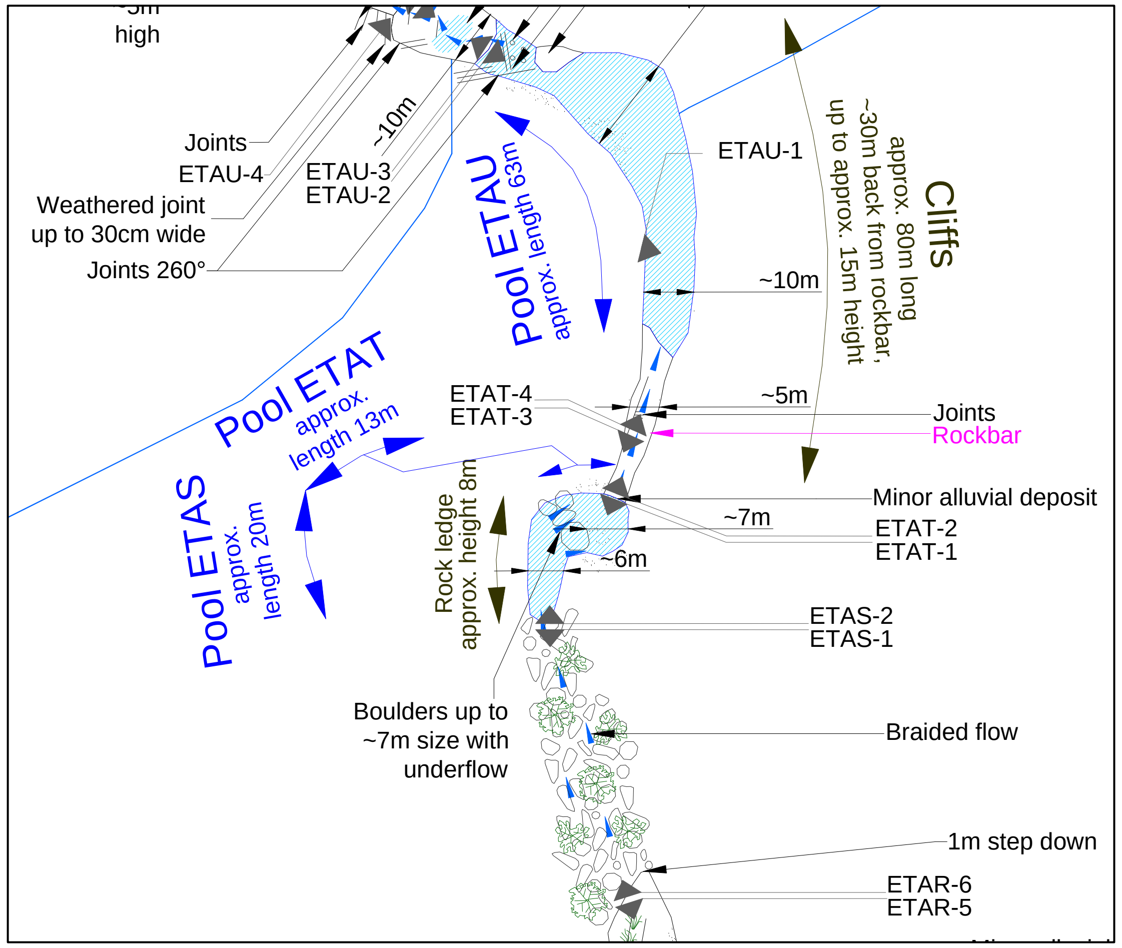
# POOLS ETAS & ETAT STREAM MAPPING SUMMARY

**ETAS-1** Upstream end of Pool ETAS looking Upstream

**ETAS-2** Upstream end of Pool ETAS looking Downstream

Pools ETAS and ETAT notes (as at 19 Dec 2008)

- Width varies from approximately 2m to 7m.
- Water depth varies from approximately 0.1m to 1.5m.
- Base of the pools is sandstone with alluvial deposits and boulders up to approximately 5m size.
- Separation between Pools ETAS and ETAT appears to be mainly detached block and boulders. Water level in both pools appears to be similar.
- Rockbar downstream of Pool ETAT is cross bedded and mostly covered with water.
- Pool ETAU approximately the same level as Pool ETAT.




**ETAT-1** Downstream end of Pool ETAT looking Upstream

**ETAT-2** Downstream end of Pool ETAT looking Downstream

**ETAT-3** On rockbar Downstream of Pool ETAT looking Upstream

**ETAT-4** On rockbar Downstream of Pool ETAT looking Downstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| ETAS-1 | 312156 | 6215549 | 180 |
| ETAS-2 | 312156 | 6215549 | 0 |
| ETAT-1 | 312166 | 6215572 | 201 |
| ETAT-2 | 312166 | 6215572 | 21 |
| ETAT-3 | 312170 | 6215583 | 204 |
| ETAT-4 | 312170 | 6215583 | 24 |

# POOL ETAU STREAM MAPPING SUMMARY

**ETAU-1** Mid point of Pool ETAU looking toward the Eastern bank

**ETAU-2** Downstream end of Pool ETAU looking Upstream

**ETAU-3** Downstream end of Pool ETAU looking Downstream

Pool ETAU notes (as at 19 Dec 2008)

- Width varies from approximately 10m to 17m.
- Water depth varies from approximately 0.3m to 1.5m.
- Base of the pool is sandstone with alluvial deposits.
- Cross bedding present.
- Rockbar downstream of the pool has cross bedding and ponded water on surface.
- A waterfall approximately 5m high is located approximately 17m downstream of Pool ETAU.

(Notes continued on second sheet)

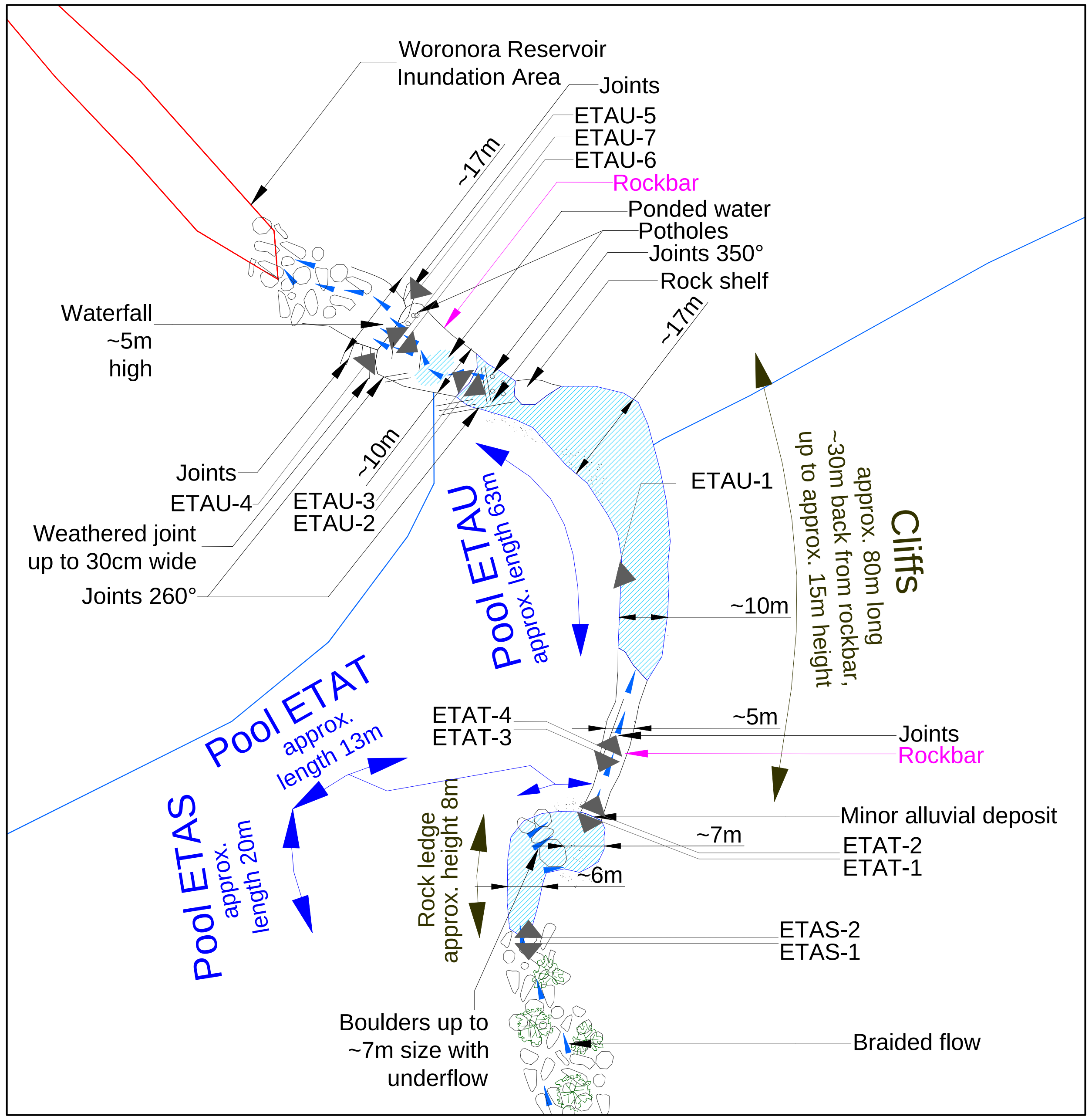



Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| ETAU-1 | 312174 | 6215615 | 104 |
| ETAU-2 | 312145 | 6215650 | 123 |
| ETAU-3 | 312145 | 6215650 | 303 |

# POOL ETAU DOWNSTREAM MAPPING SUMMARY

**ETAU-4** Looking toward Eastern bank at waterfall Downstream of Pool ETAU

**ETAU-5** Looking toward Western bank at waterfall Downstream of Pool ETAU

Pool ETAU Downstream notes (as at 19 Dec 2008)

- Waterfall is approximately 5m high.
- Several large detached blocks present on both banks downstream of the waterfall.
- Flow continues along the eastern side from the base of the waterfall into the inundation area of Woronora Reservoir.

**ETAU-6** On waterfall Downstream of Pool ETAU looking Upstream

**ETAU-7** On waterfall Downstream of Pool ETAU looking Downstream

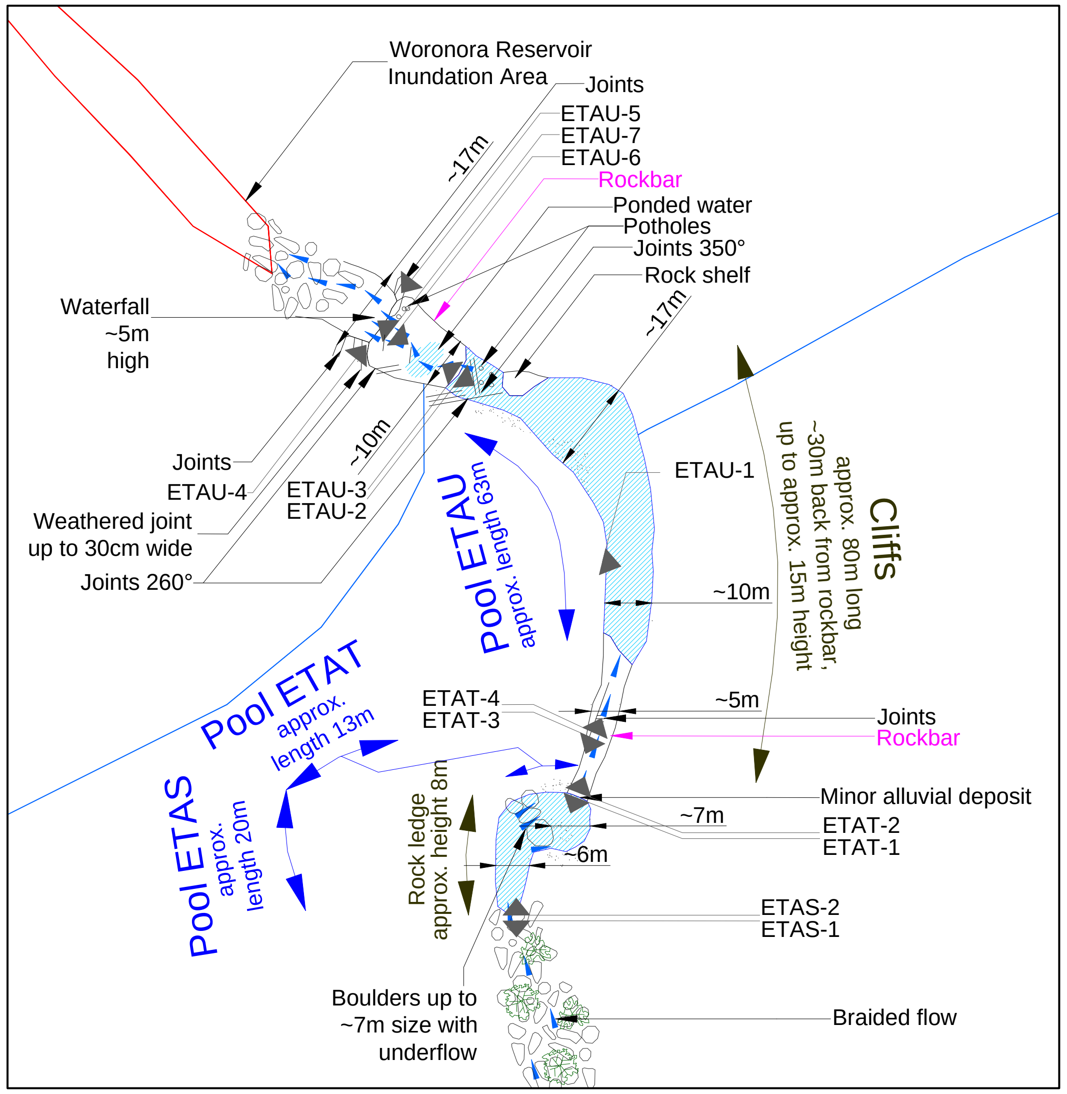


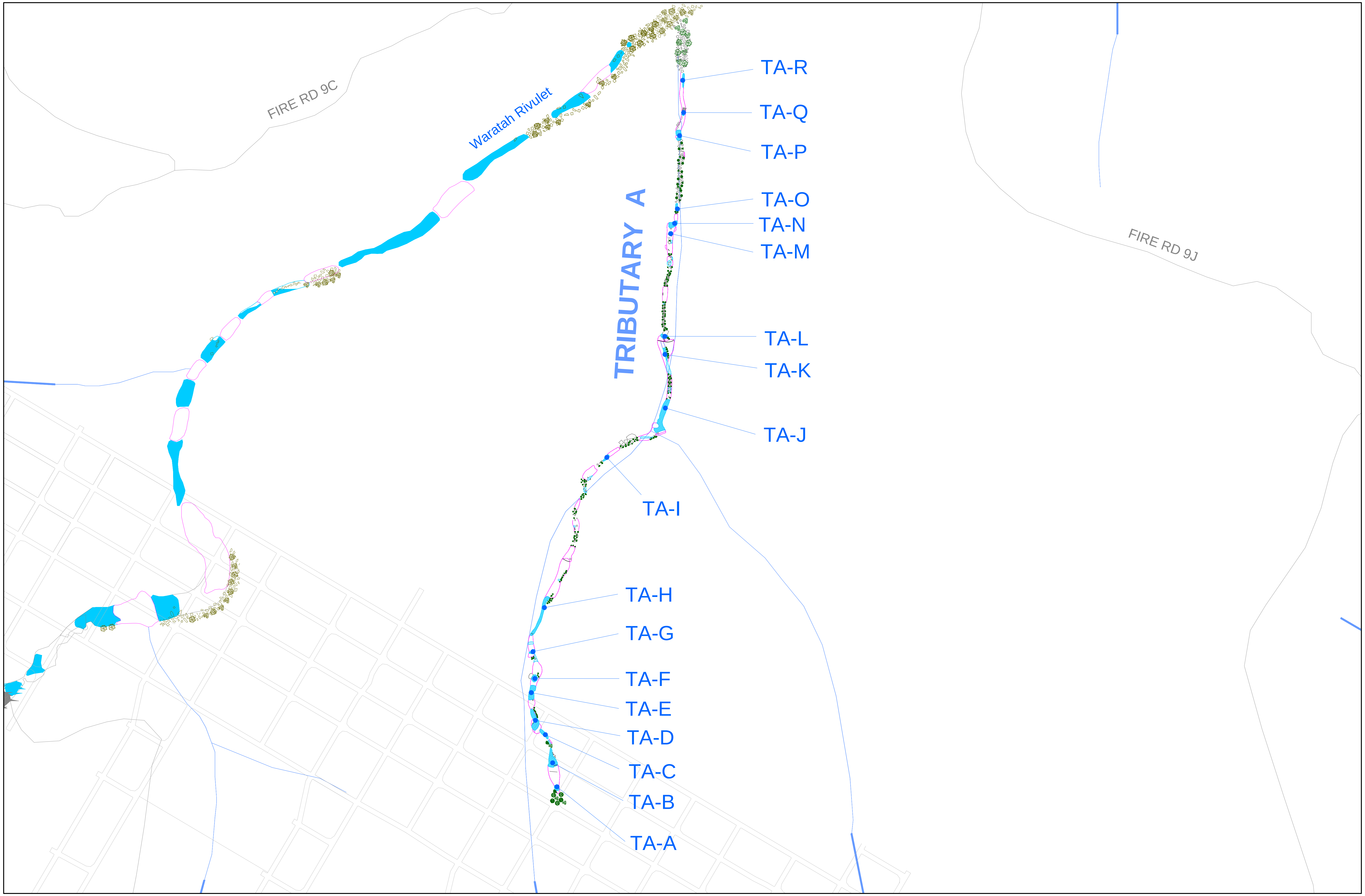

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| ETAU-4 | 312128 | 6215655 | 18 |
| ETAU-5 | 312134 | 6215665 | 218 |
| ETAU-6 | 312133 | 6215658 | 127 |
| ETAU-7 | 312133 | 6215658 | 307 |

# APPENDIX 3

# TRIBUTARY A STREAM MAPPING AND PHOTOGRAPHIC RECORD

# TRIBUTARY A – GENERAL LAYOUT



# TRIBUTARY A STREAM MAPPING SUMMARY

**TA01-1** Downstream end of Pool TA-A looking Upstream

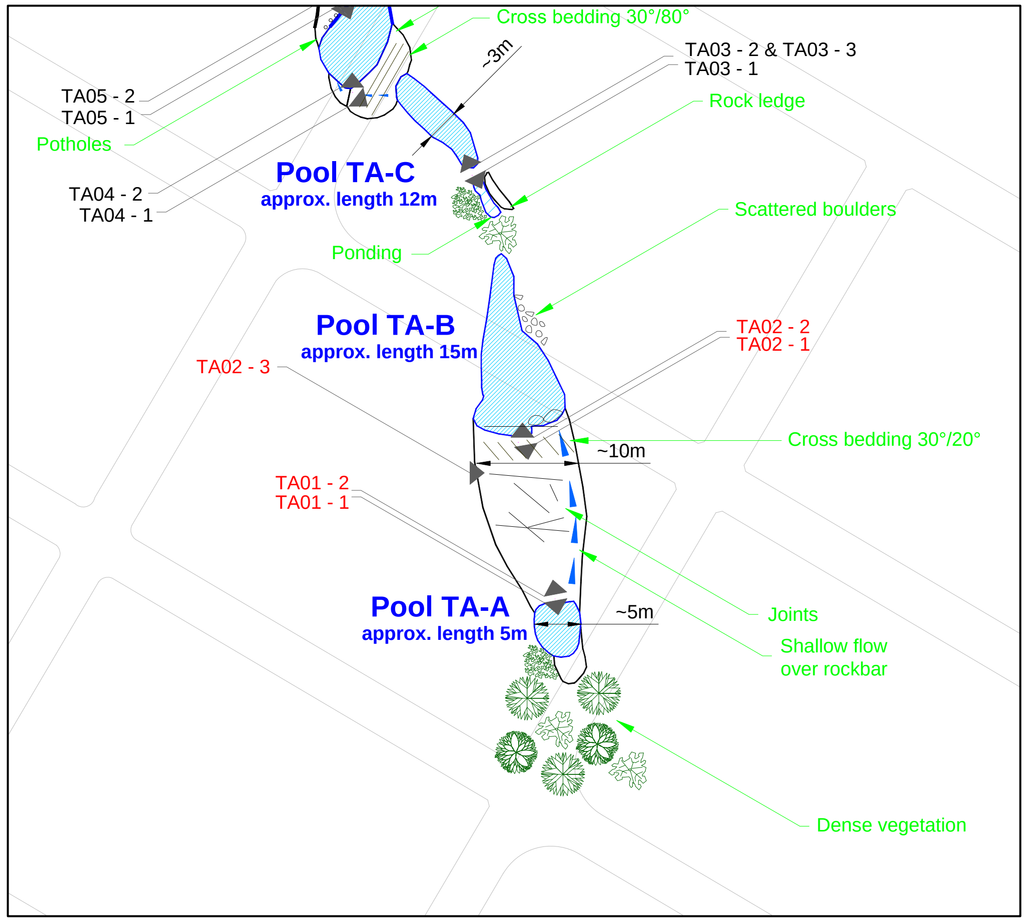
**TA01-2** Downstream end of Pool TA-A looking Downstream

Notes (as at 5 January 2010)

- Pool TA-A approximately 5m long, 5m wide and 0.3m deep
- Base of the pool is sandstone
- Rockbar upstream of the pool is approximately 3m wide with scattered vegetation debris
- Rockbar downstream of the pool is approximately 10m wide and 17m long, with many joints and cross bedding at the downstream end
- Flow path along the eastern side of the rockbar toward Pool TA-B

- Pool TA-B approximately 15m long, 8m wide and 0.5m deep
- Base of the pool is sandstone with scattered boulders

**TA02-1** Upstream end of Pool TA-B looking Upstream




**TA02-2** Upstream end of Pool TA-B looking Downstream

**TA02-3** Joint across rockbar between Pools TA-A and TA-B

Photo Details

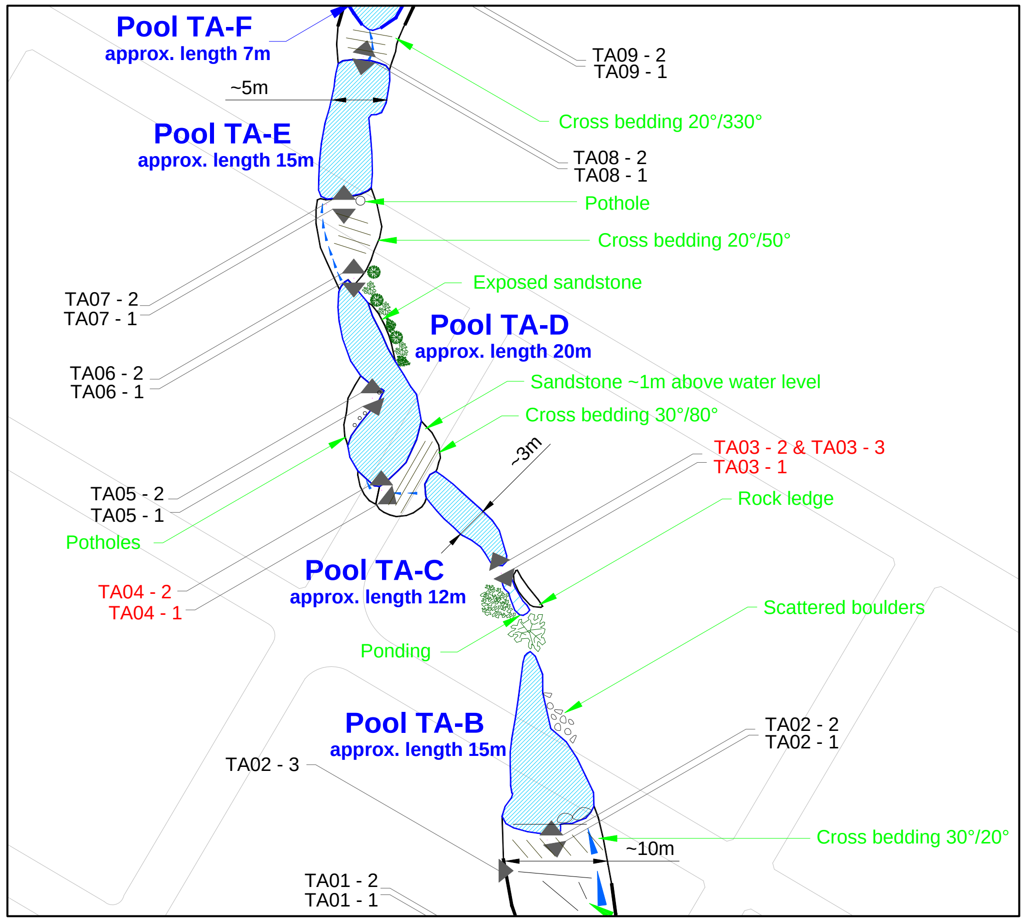
| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TA01-1 | 310238 | 6214098 | 170 |
| TA01-2 | 310238 | 6214098 | 350 |
| TA02-1 | 310234 | 6214115 | 170 |
| TA02-2 | 310234 | 6214115 | 0 |
| TA02-3 | 310234 | 6214115 | 90 |

# TRIBUTARY A STREAM MAPPING SUMMARY

**TA03-1** Upstream end of Pool TA-C looking Upstream

Notes (as at 5 January 2010)

- Pool TA-C approximately 12m long, 3m wide and 0.2m deep
- Base of the pool is sandstone
- Ponding and vegetation upstream of pool
- Flow path along western side of rockbar toward Pool TA-D




**TA03-2 and TA03-3** Upstream end of Pool TA-C looking Downstream

**TA04-1** Upstream end of Pool TA-D looking Upstream

**TA04-2** Upstream end of Pool TA-D looking Downstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TA03-1 | 310229 | 6214144 | 155 |
| TA03-2 | 310229 | 6214144 | 335 |
| TA03-3 | 310229 | 6214144 | 335 |
| TA04-1 | 310216 | 6214153 | 130 |
| TA04-2 | 310216 | 6214153 | 0 |

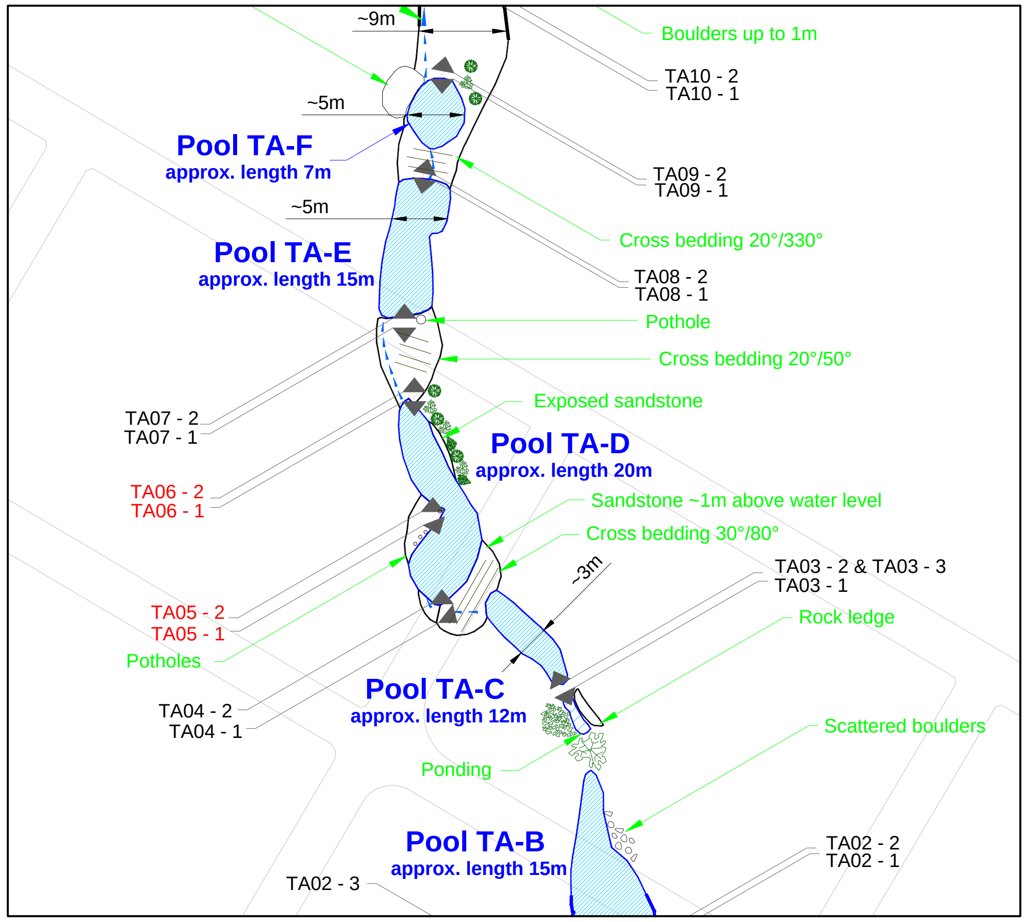
# TRIBUTARY A STREAM MAPPING SUMMARY

**TA05-1** Midway along Pool TA-D looking Upstream

Notes (as at 5 January 2010)

- Pool TA-D approximately 20m long, up to 9m wide and up to 1m deep at the upstream end
- Base of the pool is sandstone
- Sandstone ledge upstream of pool is approximately 1m above water level

**TA05-2** Midway along Pool TA-D looking Downstream




**TA06-1** Downstream end of Pool TA-D looking Upstream

**TA06-2** Downstream end of Pool TA-D looking Downstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TA05-1 | 310215 | 6214163 | 160 |
| TA05-2 | 310215 | 6214163 | 0 |
| TA06-1 | 310213 | 6214176 | 180 |
| TA06-2 | 310213 | 6214176 | 0 |

# TRIBUTARY A STREAM MAPPING SUMMARY

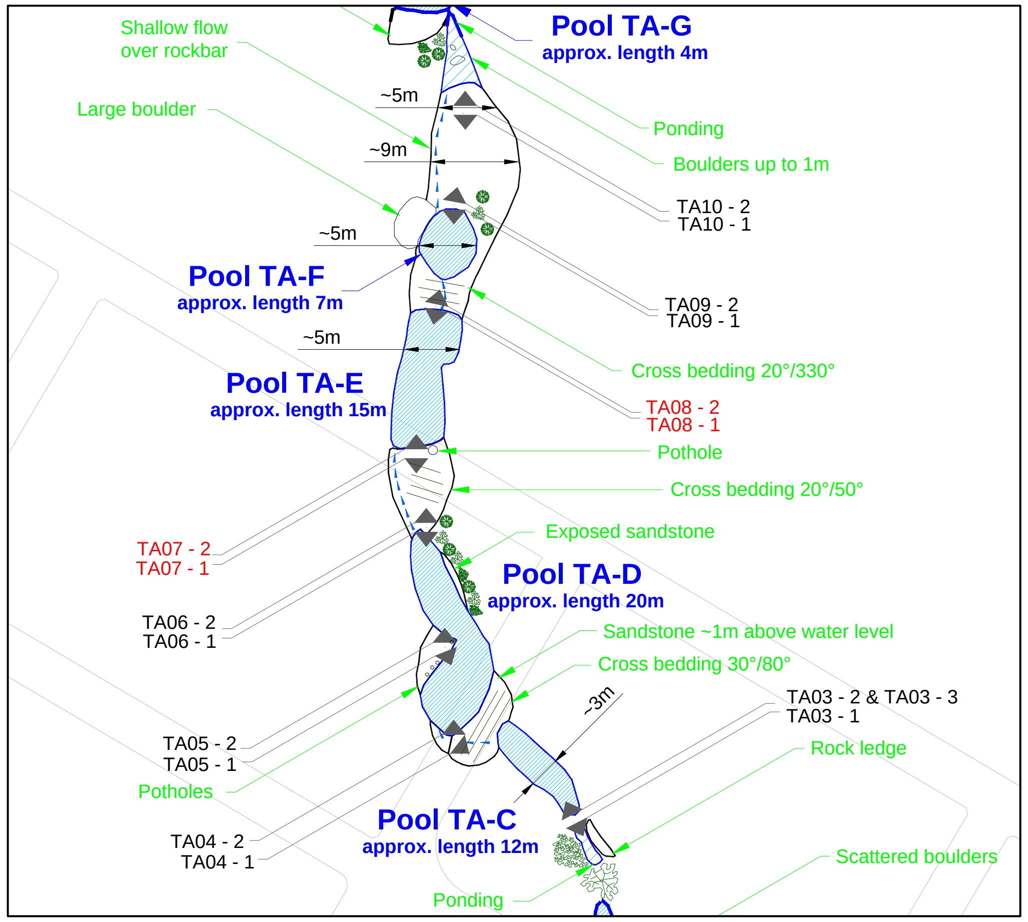
**TA07-1** Upstream end of Pool TA-E looking Upstream

**TA07-2** Upstream end of Pool TA-E looking Downstream

Notes (as at 5 January 2010)

- Pool TA-E approximately 15m long, 3 to 5m wide and 0.6m deep
- Base of the pool is sandstone
- Rockbar upstream of the pool is approximately 7m wide with cross bedding
- Flow path along western side of rockbar toward Pool TA-E

**TA08-1** Downstream end of Pool TA-E looking Upstream




**TA08-2** Downstream end of Pool TA-E looking Downstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TA07-1 | 310210 | 6214184 | 180 |
| TA07-2 | 310210 | 6214184 | 0 |
| TA08-1 | 310214 | 6214200 | 190 |
| TA08-2 | 310214 | 6214200 | 10 |

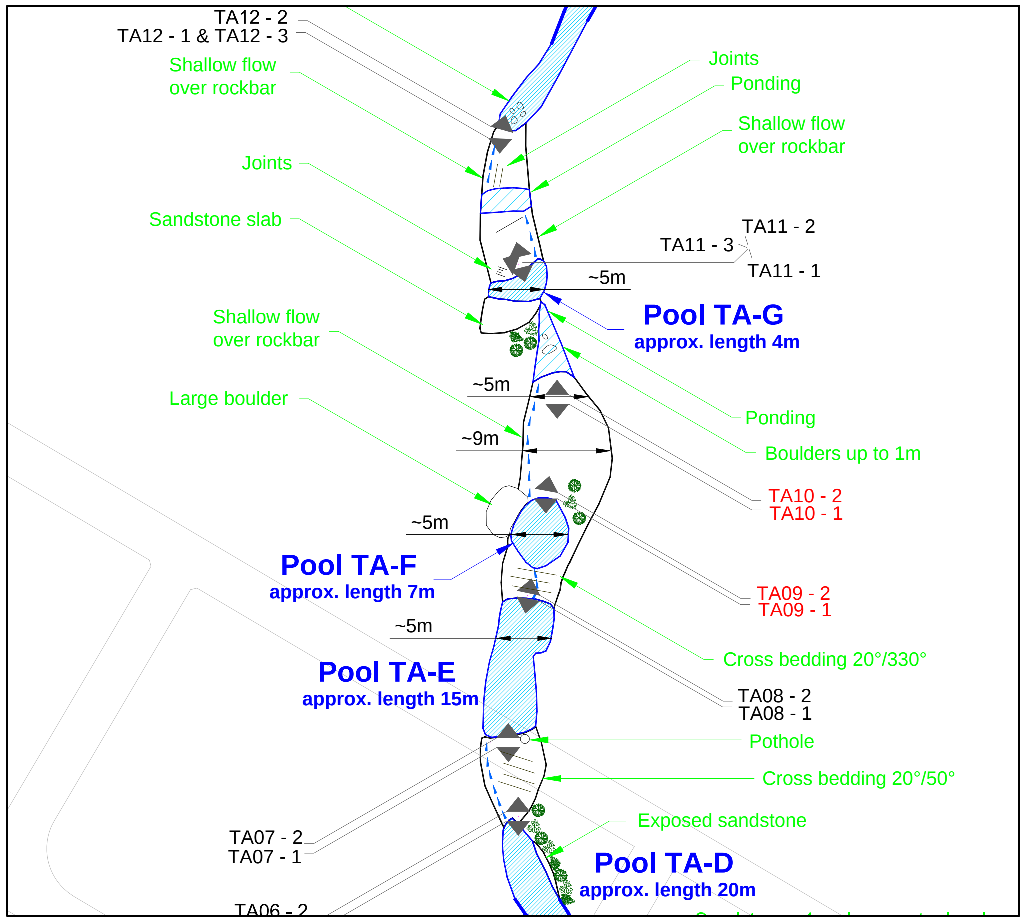
# TRIBUTARY A STREAM MAPPING SUMMARY

**TA09-1** Downstream end of Pool TA-F looking Upstream

**TA09-2** Downstream end of Pool TA-F looking Downstream

Notes (as at 5 January 2010)

- Pool TA-F approximately 7m long, 3 to 5m wide and 0.3m deep
- Base of the pool is sandstone with minor alluvial deposits and algae
- Rockbar upstream of the pool is approximately 5m wide and 3m long with cross bedding
- Rockbar downstream of the pool is approximately 9m wide at the upstream end and 5m wide at the downstream end
- Flow path along western side of rockbar




**TA10-1** Rockbar downstream of Pool TA-F looking Upstream

**TA10-2** Rockbar downstream of Pool TA-F looking Downstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TA09-1 | 310216 | 6214211 | 180 |
| TA09-2 | 310216 | 6214211 | 10 |
| TA10-1 | 310217 | 6214221 | 180 |
| TA10-2 | 310217 | 6214221 | 0 |

# TRIBUTARY A STREAM MAPPING SUMMARY

**TA11-1** Downstream end of  Pool TA-G looking Upstream

**TA11-2** Downstream end of Pool TA-G looking Downstream

Notes (as at 5 January 2010)

- Pool TA-G approximately 4m long, 5m wide and 0.2m deep
- Base of the pool is sandstone
- Sandstone ledge and ponding upstream of the pool
- Rockbar downstream of the pool is approximately 14m long with ponding in the centre and many joints
- Flow path along eastern side of rockbar toward ponding, then along western side toward Pool TA-H

- Pool TA-H approximately 43m long, 3m wide and up to 1m deep
- Base of the pool is sandstone with alluvial deposits, scattered boulders at the upstream end, and dead trees at the downstream end

**TA11-3** Joints

**TA12-1** Upstream end of Pool TA-H looking Upstream

**TA12-2** Upstream end of Pool TA-H looking Downstream

**TA12-3** Joints

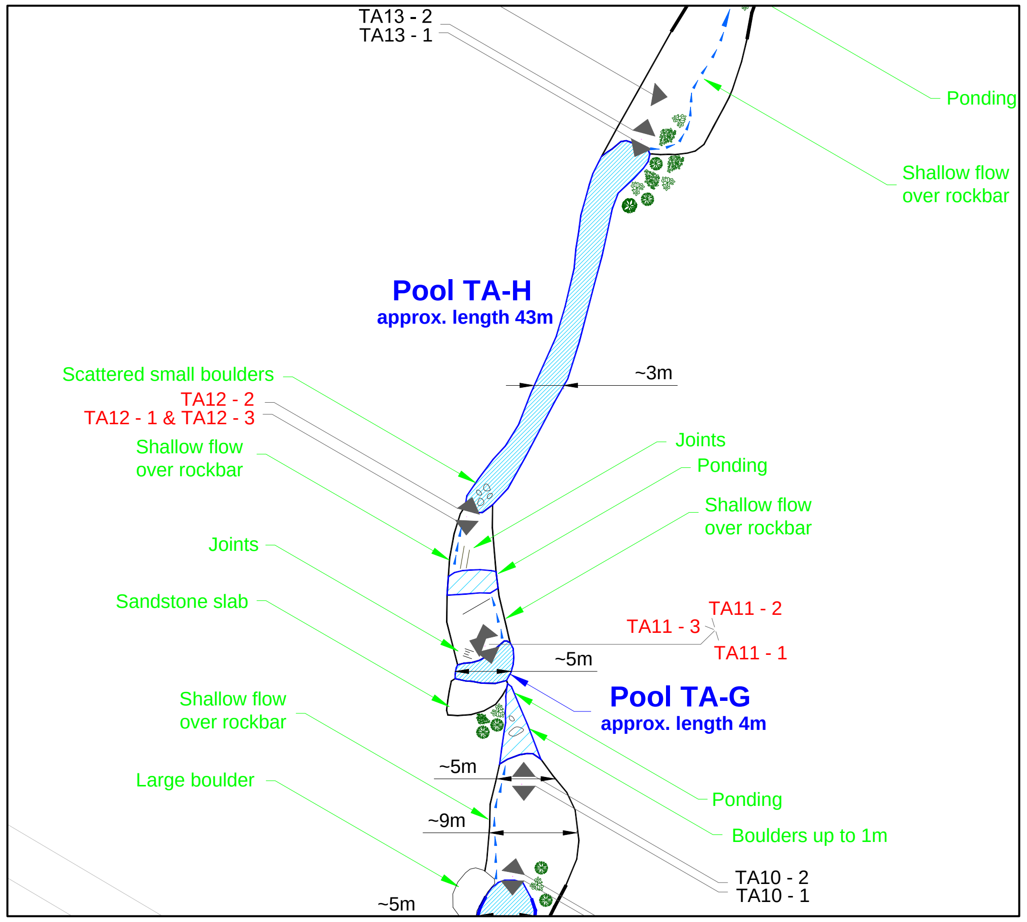



Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TA11-1 | 310213 | 6214236 | 165 |
| TA11-2 | 310213 | 6214236 | 345 |
| TA11-3 | 310213 | 6214236 | 290 |
| TA12-1 | 310211 | 6214250 | 180 |
| TA12-2 | 310211 | 6214250 | 15 |
| TA12-3 | 310211 | 6214250 | 180 |

# TRIBUTARY A STREAM MAPPING SUMMARY

**TA13-1** Downstream end of Pool TA-H looking Upstream

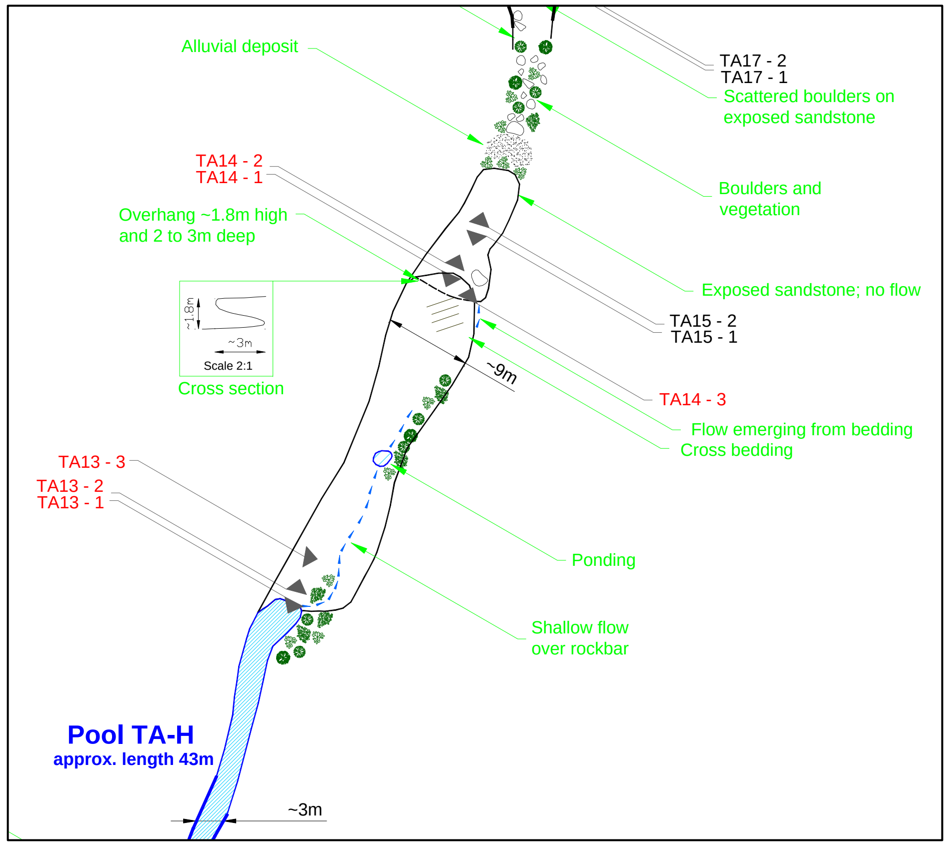
**TA13-2** Downstream end of Pool TA-H looking Downstream

Notes (as at 5 January 2010)

- Rockbar downstream of Pool TA-H is approximately 43m long and up to 9m wide
- Cross bedding is present at the downstream end
- Flow path part way along eastern side of the rockbar
- Flow emerges from bedding at overhang
- Overhang at the downstream end is approximately 1.8m high and 2 to 3m deep

**TA13-3** East Bank at downstream end of Pool TA-H

**TA14-1** Rockbar downstream of Pool TA-H looking Upstream




**TA14-2** Overhang looking Downstream (western side)

**TA14-3** Overhang looking Downstream (eastern side)

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TA13-1 | 310230 | 6214291 | 210 |
| TA13-2 | 310230 | 6214291 | 15 |
| TA13-3 | 310230 | 6214291 | 100 |
| TA14-1 | 310249 | 6214330 | 25 |
| TA14-2 | 310249 | 6214330 | 205 |
| TA14-3 | 310249 | 6214330 | 25 |

# TRIBUTARY A STREAM MAPPING SUMMARY

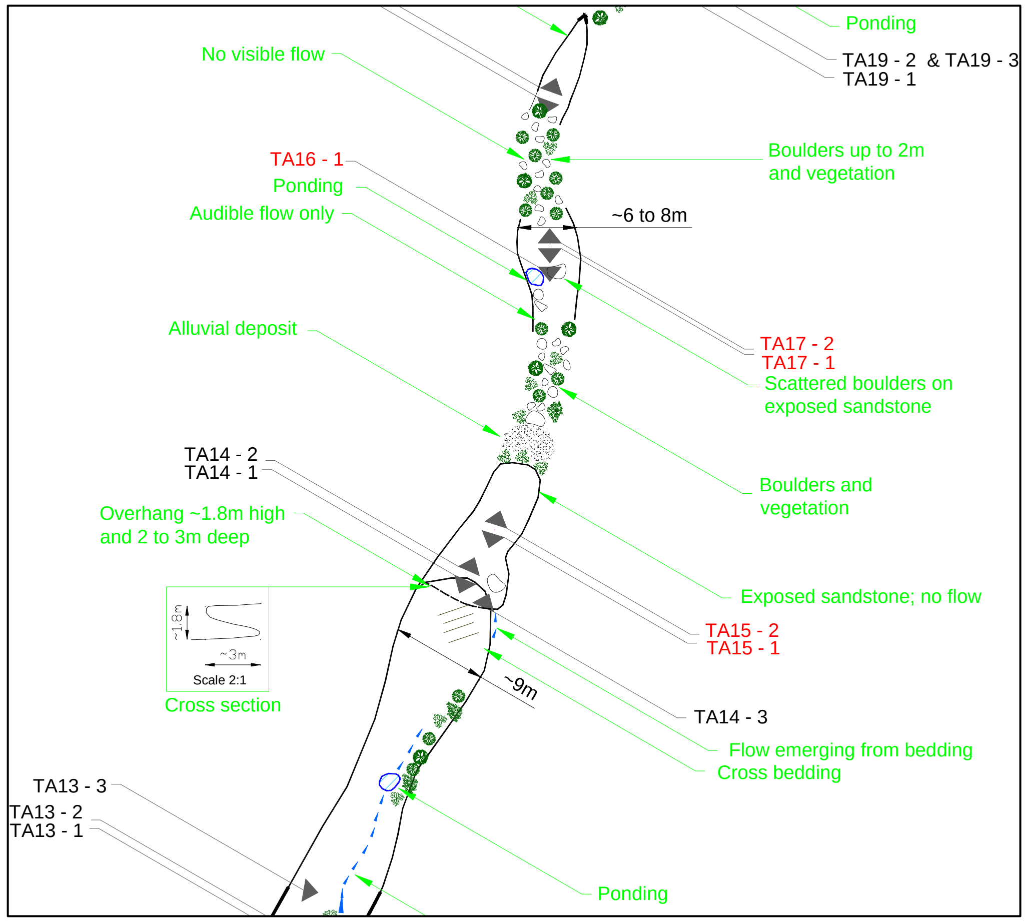
**TA15-1** Rockbar downstream of overhang looking Upstream

**TA15-2** Rockbar downstream of overhang looking Downstream

Notes (as at 5 January 2010)

- Rockbar approximately 13m long and up to 7m wide
- No visible flow across rockbar
- Alluvial deposit and vegetation at downstream end of rockbar leading into boulder field

- Boulder field opens up to rockbar 6 to 8m wide with scattered boulders and ponding
- Audible flow only
- Rockbar leads into boulder field at downstream end




**TA16-1** Rockbar looking Upstream

**TA17-1** Rockbar looking Upstream

**TA17-2** Rockbar looking Downstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TA15-1 | 310252 | 6214335 | 195 |
| TA15-2 | 310252 | 6214335 | 15 |
| TA16-1 | 310258 | 6214366 | 180 |
| TA17-1 | 310258 | 6214364 | 180 |
| TA17-2 | 310258 | 6214364 | 0 |

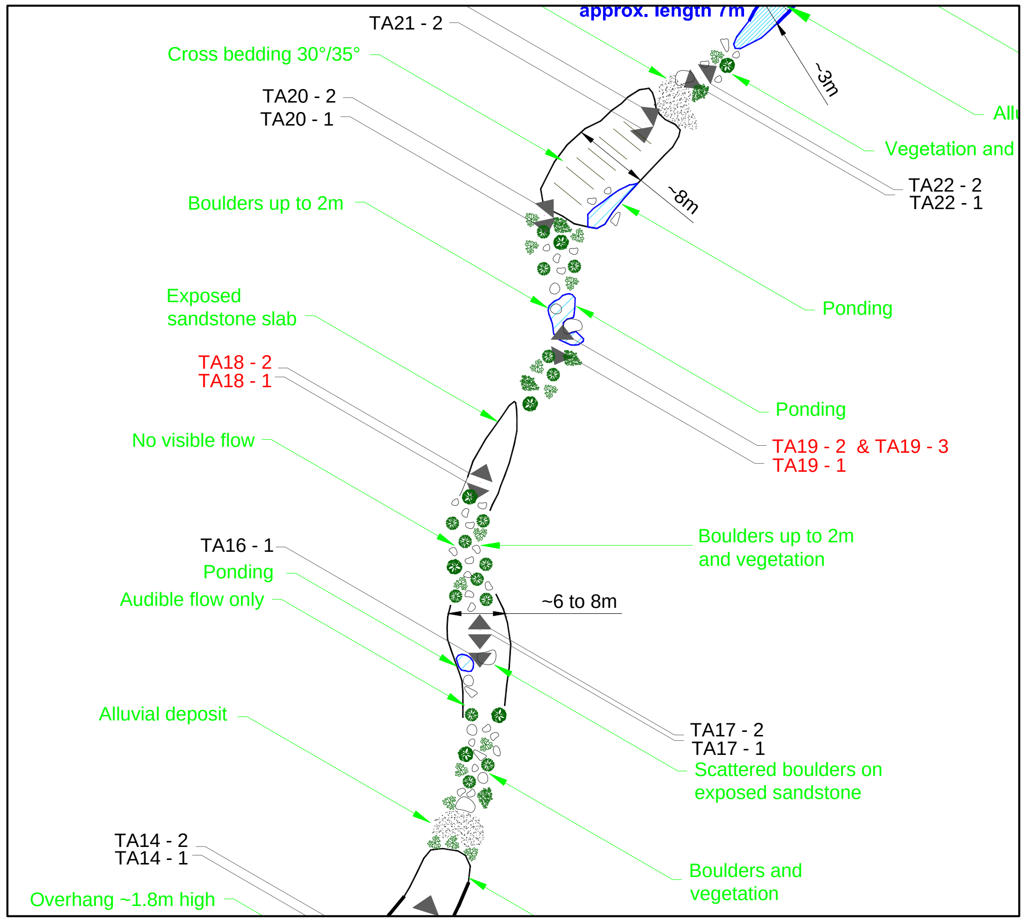
# TRIBUTARY A STREAM MAPPING SUMMARY

**TA18-1** Upstream end of rockbar looking Upstream

**TA18-2** Upstream end of rockbar looking Downstream

Notes (as at 5 January 2010)

- No visible flow through boulder field and vegetation
- Rockbar downstream of boulder field is approximately 9m long and 4m wide, with vegetation at the downstream end
- Vegetation opens to ponding with scattered boulders up to 2m




**TA19-1** Downstream of vegetation looking Upstream

**TA19-2** Downstream of vegetation looking Downstream

**TA19-3** Downstream of vegetation looking Downstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TA18-1 | 310258 | 6214382 | 200 |
| TA18-2 | 310258 | 6214382 | 20 |
| TA19-1 | 310267 | 6214397 | 210 |
| TA19-2 | 310267 | 6214397 | 0 |
| TA19-3 | 310267 | 6214397 | 0 |

# TRIBUTARY A STREAM MAPPING SUMMARY

**TA20-1** Upstream end of rockbar looking Upstream

**TA20-2** Upstream end of rockbar looking Downstream

**TA21-1** Downstream end of rockbar looking Downstream

**TA21-2** Ponding at eastern side of rockbar

<u>Notes (as at 5 January 2010)</u>

- Rockbar is approximately 12m long and 8m wide with cross bedding and scattered vegetation debris
- Shallow ponding at eastern side of rockbar, with no visible flow downstream
- Alluvial deposit at downstream end of rockbar

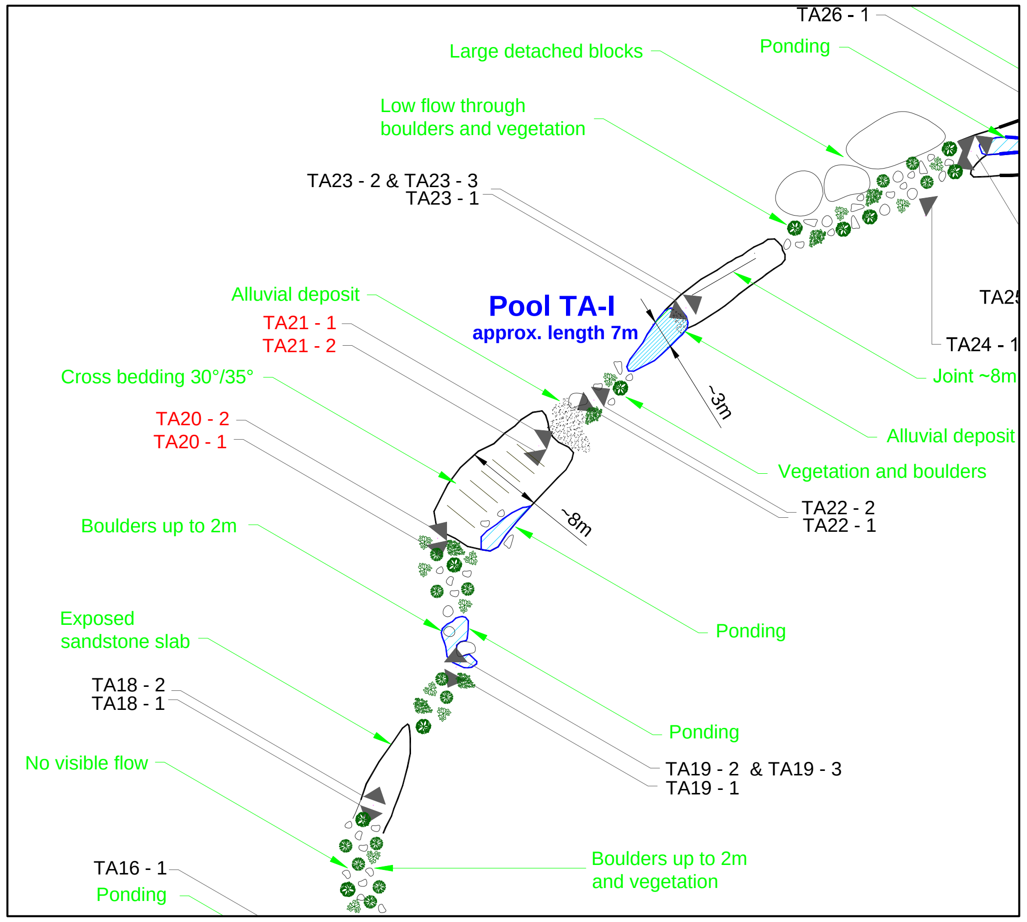



Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TA20-1 | 310265 | 6214411 | 170 |
| TA20-2 | 310265 | 6214411 | 40 |
| TA21-1 | 310276 | 6214421 | 55 |
| TA21-2 | 310276 | 6214421 | 170 |

# TRIBUTARY A STREAM MAPPING SUMMARY

**TA22-1** Near Upstream end of Pool TA-I looking Upstream

**TA22-2** Near Upstream end of Pool TA-I looking Downstream

**TA23-1** Downstream end of Pool TA-I looking Upstream

**TA23-2** Downstream end of Pool TA-I looking Downstream

**TA23-3** Joint downstream of Pool TA-I

Notes (as at 5 January 2010)

- Pool TA-I is approximately 7m long, 3m wide and 0.3m deep
- Base of the pool is sandstone with minor alluvial deposits at the downstream end, leaf litter and boulders up to 1m
- Boulder field and vegetation upstream of pool
- Rockbar downstream of the pool is approximately 12m long
- 8m long joint runs along rockbar on western side

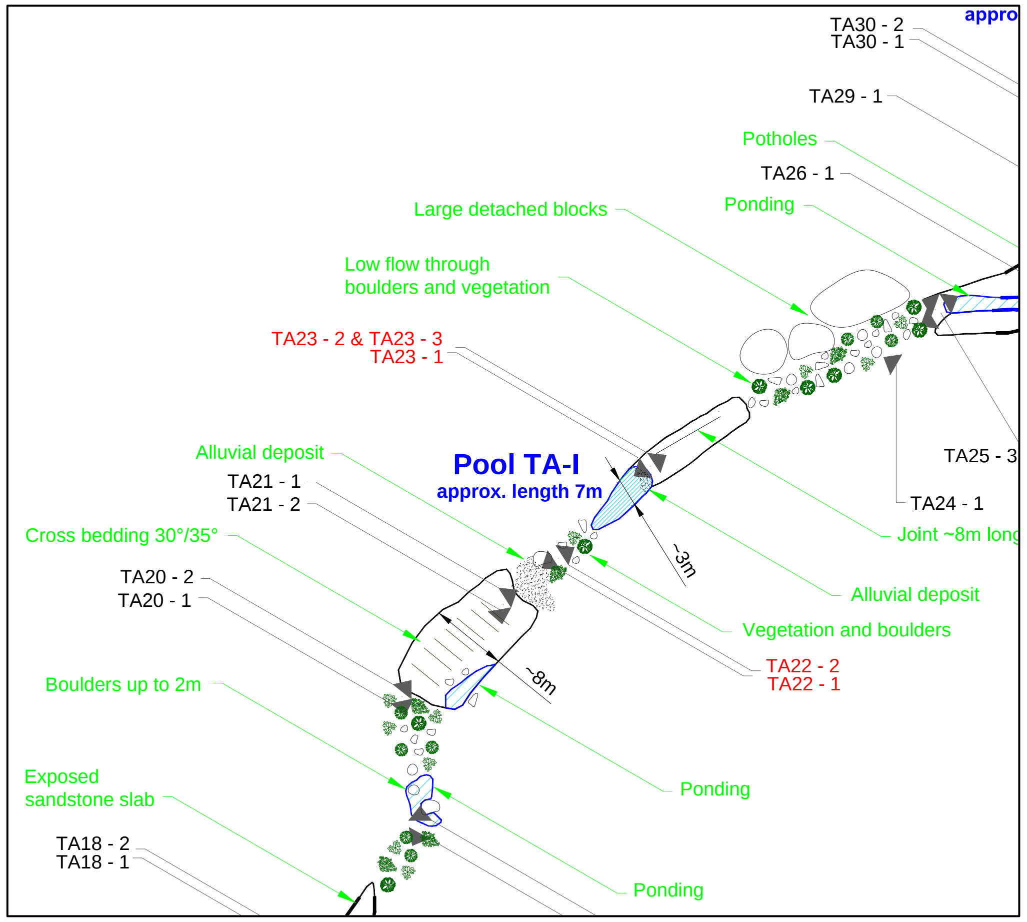



Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TA22-1 | 310282 | 6214426 | 235 |
| TA22-2 | 310282 | 6214426 | 55 |
| TA23-1 | 310292 | 6214436 | 235 |
| TA23-2 | 310292 | 6214436 | 55 |
| TA23-3 | 310292 | 6214436 | 55 |

# TRIBUTARY A STREAM MAPPING SUMMARY

Notes (as at 5 January 2010)

- Low flow through boulder field, with shallow ponding and potholes downstream
- Large detached blocks on western bank up to 10m in size
- Large sandstone outcrop on eastern bank approximately 2m high

**TA24-1** Large detached blocks on western bank

**TA25-1** Downstream end of boulder field looking Upstream

**TA25-2** Downstream end of boulder field looking Downstream

**TA25-3** Large detached blocks on western bank

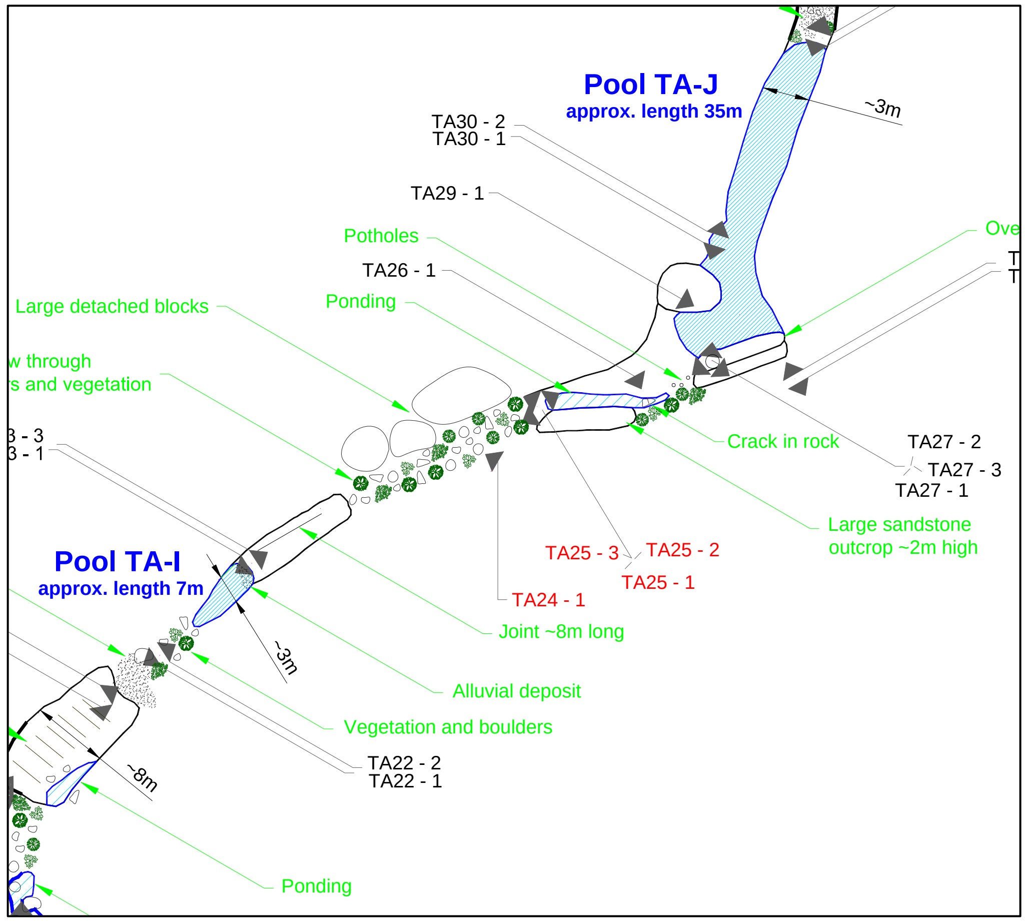



Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TA24-1 | 310318 | 6214446 | 300 |
| TA25-1 | 310323 | 6214453 | 240 |
| TA25-2 | 310323 | 6214453 | 60 |
| TA25-3 | 310323 | 6214453 | 290 |

# TRIBUTARY A STREAM MAPPING SUMMARY

**TA26-1** Cracking in rock

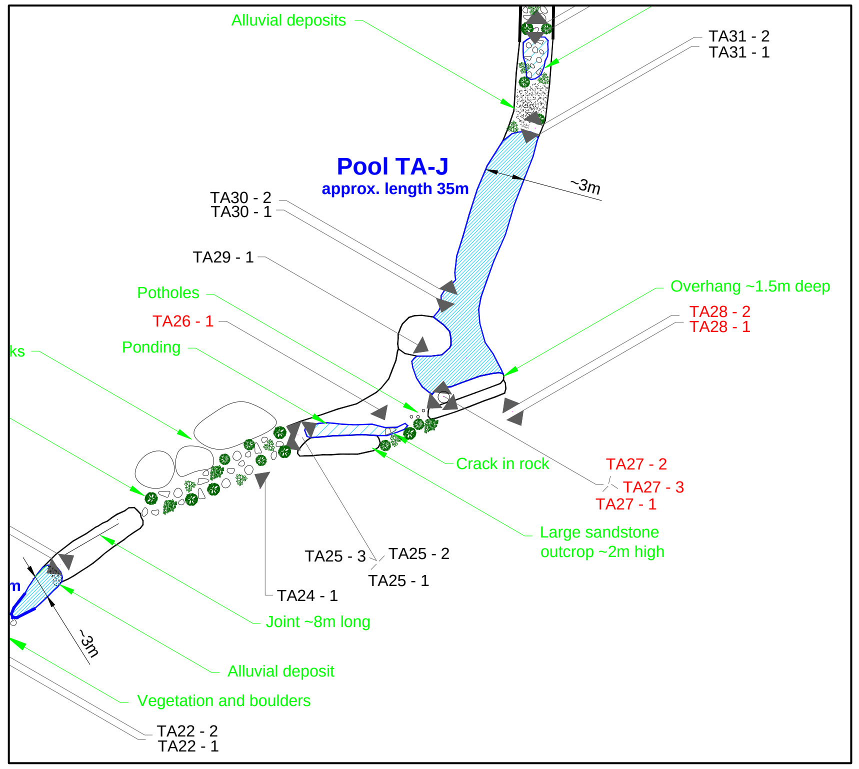
**TA27-1** Upstream end of Pool TA-J looking Upstream

Notes (as at 5 January 2010)

- Cracking through rock surface at downstream end of ponding
- Exposed sandstone upstream of Pool TA-J
- No visible flow from minor tributary into Tributary A at confluence, but minor flow visible further downstream
- Approximate 3m change in height from Pool TA-J to minor tributary

**TA27-2** Upstream end of Pool TA-J looking Downstream

**TA27-3** Confluence of Tributary A and minor tributary




**TA28-1** Minor tributary looking Upstream

**TA28-2** Minor tributary looking Downstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TA26-1 | 310335 | 6214454 | 150 |
| TA27-1 | 310342 | 6214458 | 230 |
| TA27-2 | 310342 | 6214458 | 5 |
| TA27-3 | 310342 | 6214458 | 125 |
| TA28-1 | 310351 | 6214456 | 150 |
| TA28-2 | 310351 | 6214456 | 330 |

# TRIBUTARY A STREAM MAPPING SUMMARY

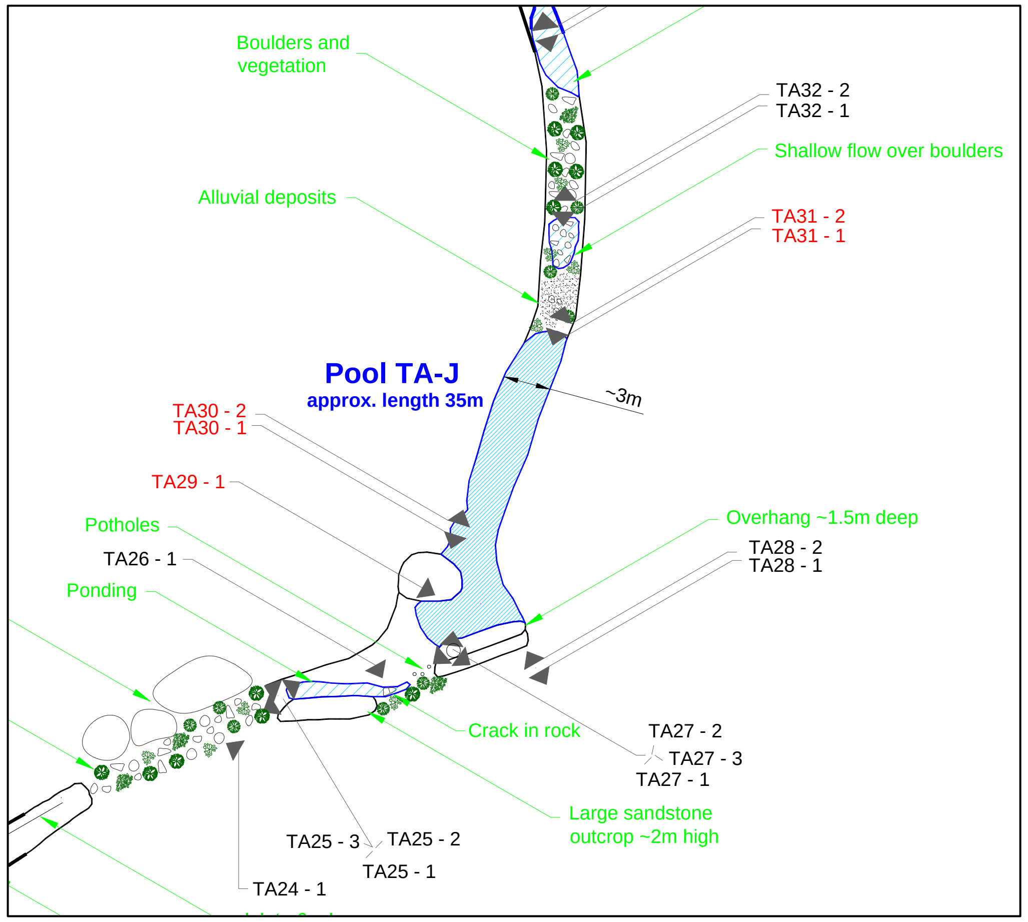
**TA29-1** Upstream end of Pool TA-J looking to minor tributary

**TA30-1** Part  way along Pool TA-J looking Upstream

Notes (as at 5 January 2010)

- Pool TA-J approximately 35m long, 2 to 3m wide and up to 0.2m deep
- Base of the pool is sandstone with some alluvial deposits, and vegetation debris at the downstream end
- Overhang at upstream end of pool is approximately 1.5m deep
- Alluvial deposits and vegetation at downstream end of pool

**TA30-2** Part  way along Pool TA-J looking Downstream




**TA31-1** Downstream end of Pool TA-J looking Upstream

**TA31-2** Downstream end of Pool TA-J looking Downstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TA29-1 | 310345 | 6214463 | 120 |
| TA30-1 | 310342 | 6214471 | 200 |
| TA30-2 | 310342 | 6214471 | 15 |
| TA31-1 | 310354 | 6214493 | 200 |
| TA31-2 | 310354 | 6214493 | 15 |

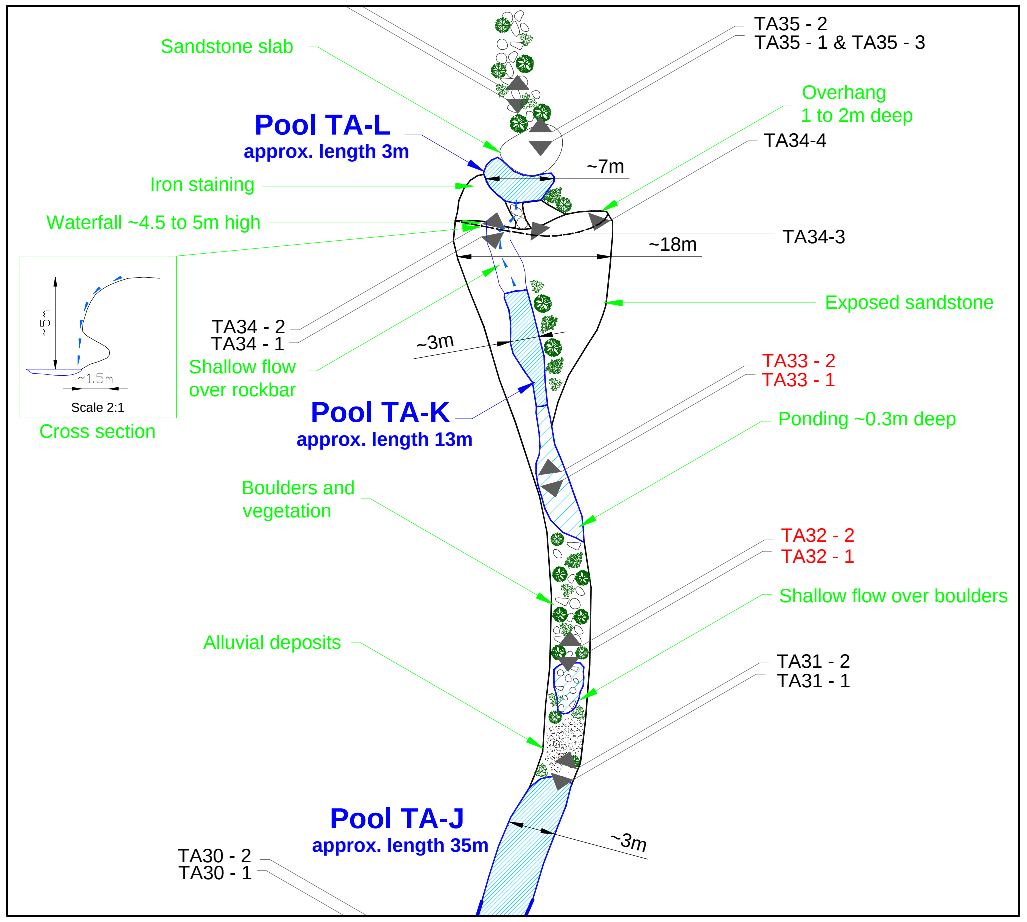
# TRIBUTARY A STREAM MAPPING SUMMARY

**TA32-1** Upstream end of boulder field looking Upstream

**TA32-2** Upstream end of boulder field looking Downstream

Notes (as at 5 January 2010)

- Ponding and shallow flow through boulder field
- Ponding upsteam of Pool TA-K up to 2m wide and 0.3m deep
- Pool TA-K approximately 12m long, 3m wide and 0.4m deep
- Base of pool is sandstone




**TA33-1** Rockbar upstream of Pool TA-K looking Upstream

**TA33-2** Rockbar upstream of Pool TA-K looking Downstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TA32-1 | 310354 | 6214506 | 180 |
| TA32-2 | 310354 | 6214506 | 0 |
| TA33-1 | 310352 | 6214525 | 165 |
| TA33-2 | 310352 | 6214525 | 350 |

# TRIBUTARY A STREAM MAPPING SUMMARY

**TA34-1** At top of waterfall looking upstream toward Pool TA-K

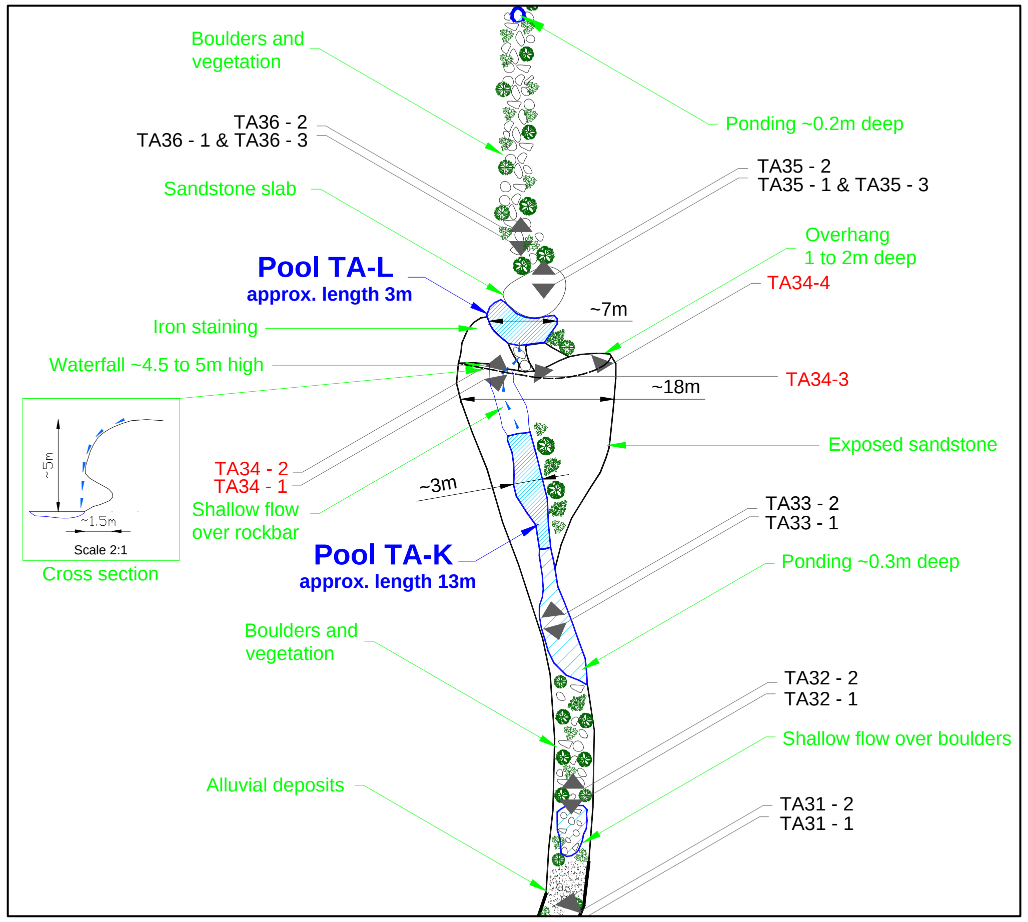
Notes (as at 5 January 2010)

- Waterfall drops approximately 4.5 to 5m
- Depth of overhang is approximately 1.5m
- Rockbar upstream of waterfall is approximately 18m wide

- Pool TA-L approximately 3m long, 7m wide and up to 0.7m deep at western side
- Base of the pool is sandstone with minor alluvial deposits
- Iron staining evident at western side and beneath waterfall

**TA34-2** At top of waterfall looking Downstream

**TA34-3** Pool TA-L below waterfall




**TA34-4** At top of waterfall looking toward west bank

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TA34-1 | 310346 | 6214552 | 170 |
| TA34-2 | 310346 | 6214552 | 15 |
| TA34-3 | 310351 | 6214552 | 325 |
| TA34-4 | 310357 | 6214553 | 200 |

# TRIBUTARY A STREAM MAPPING SUMMARY

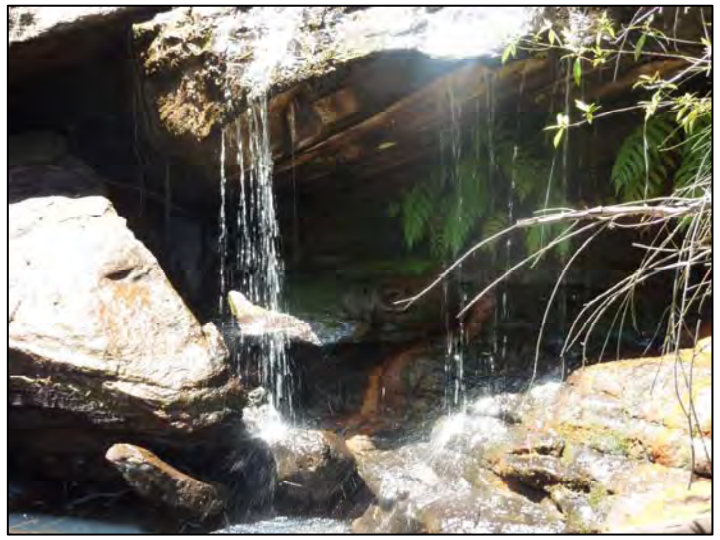
**TA35-1** Downstream end of Pool TA-L looking Upstream

**TA35-2** Downstream end of Pool TA-L looking Downstream

Notes (as at 5 January 2010)

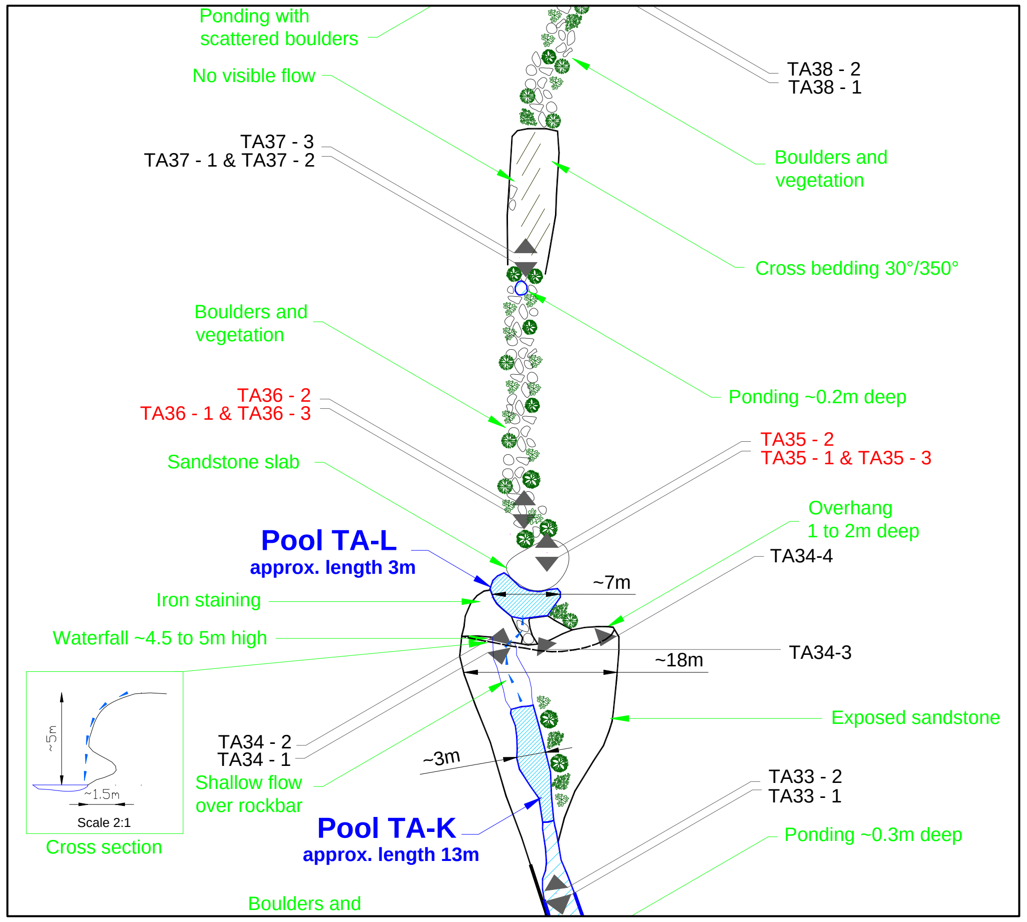
- Waterfall drops approximately 4.5 to 5m
- Depth of overhang is approximately 1.5m

- Pool TA-L approximately 3m long, 7m wide and up to 0.7m deep at western side
- Base of the pool is sandstone with minor alluvial deposits
- Iron staining evident at western side and beneath waterfall
- Boulder field and vegetation downstream of pool



**TA35-3** Overhang

**TA36-1** Downstream of Pool TA-L looking Upstream




**TA36-2** Downstream of Pool TA-L looking Downstream

**TA36-3** Waterfall

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TA35-1 | 310351 | 6214562 | 180 |
| TA35-2 | 310351 | 6214562 | 0 |
| TA35-3 | 310351 | 6214562 | 180 |
| TA36-1 | 310347 | 6214564 | 180 |
| TA36-2 | 310347 | 6214564 | 0 |
| TA36-3 | 310347 | 6214564 | 180 |

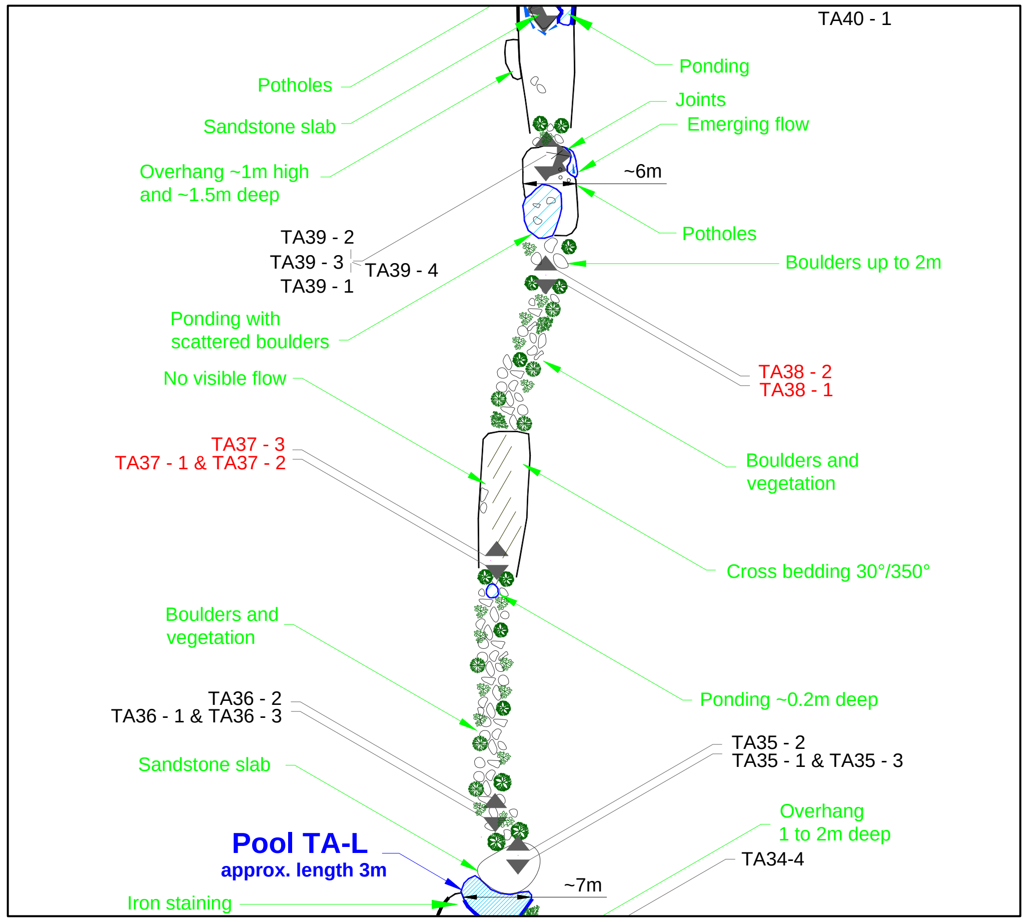
# TRIBUTARY A STREAM MAPPING SUMMARY

**TA37-1 and TA37-2** Upstream end of rockbar looking Upstream

Notes (as at 5 January 2010)

- Rockbar approximately 15m long and 5m wide
- Cross bedding and scattered debris
- No visible flow across rockbar
- Boulder field, vegetation and ponding upstream of rockbar
- Boulder field and vegetation downstream of rockbar

**TA37-3** Upstream end of rockbar looking Downstream




**TA38-1** Downstream end of boulder field looking Upstream

**TA38-2** Downstream end of boulder field looking Downstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TA37-1 | 310348 | 6214594 | 180 |
| TA37-2 | 310348 | 6214594 | 180 |
| TA37-3 | 310348 | 6214594 | 0 |
| TA38-1 | 310354 | 6214625 | 180 |
| TA38-2 | 310354 | 6214625 | 0 |

# TRIBUTARY A STREAM MAPPING SUMMARY

**TA39-1** Downstream end of rockbar looking Upstream

**TA39-2** Downstream end of rockbar looking Downstream

**TA39-3** Emerging flow on eastern side

**TA39-4** Joints and potholes

Notes (as at 5 January 2010)

- Rockbar approximately 9m long and 6m wide
- Ponding at upstream end of rockbar on western side
- Flow emerges at downstream end of rockbar on eastern side
- Joints and potholes at downstream end

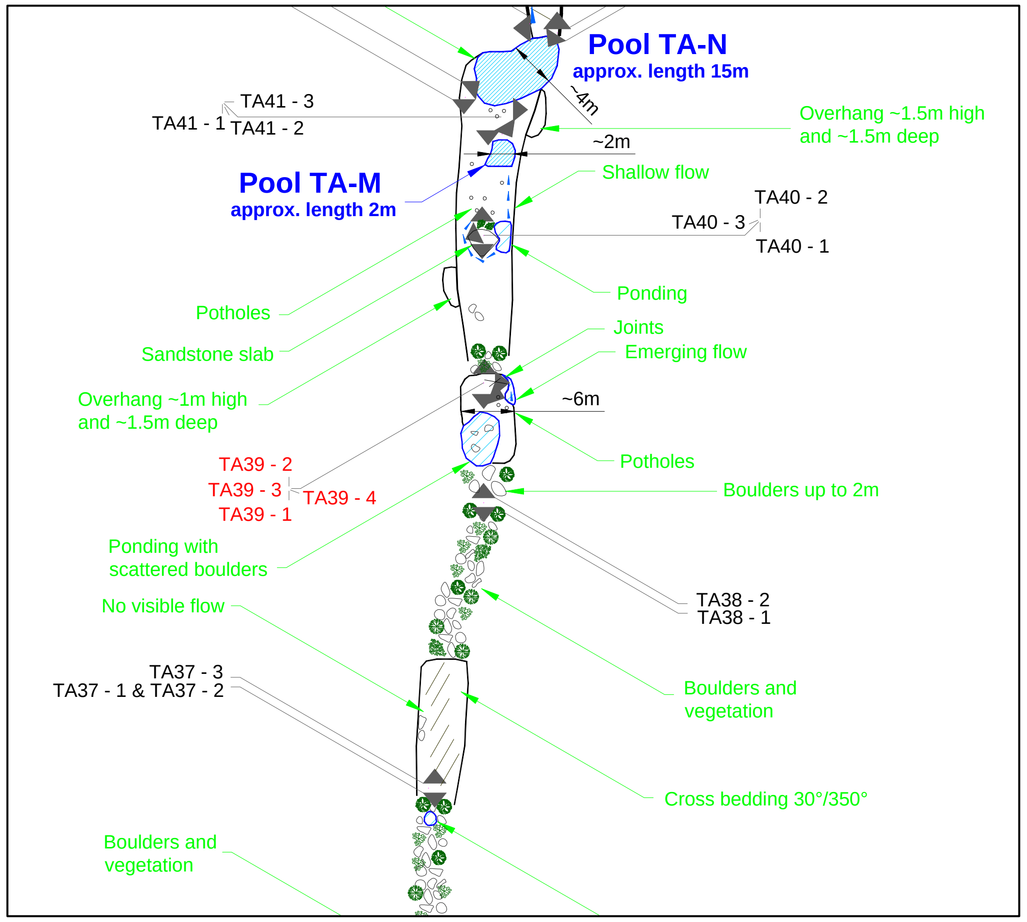



Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TA39-1 | 310354 | 6214638 | 180 |
| TA39-2 | 310354 | 6214638 | 0 |
| TA39-3 | 310354 | 6214638 | 110 |
| TA39-4 | 310354 | 6214638 | 90 |

# TRIBUTARY A STREAM MAPPING SUMMARY

**TA40-1** Rockbar upstream of Pool TA-M looking Upstream

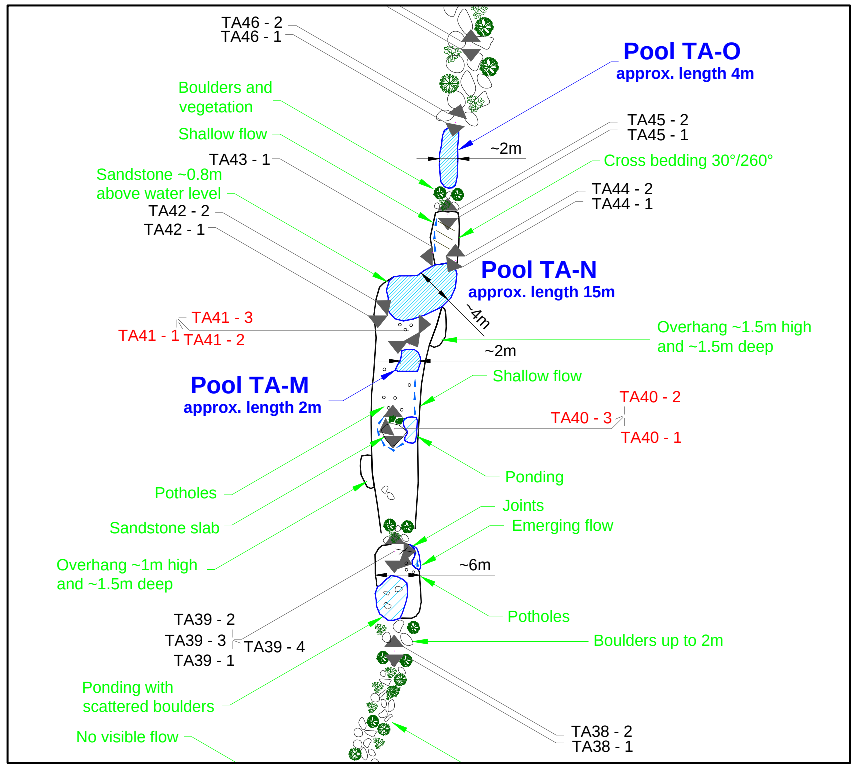
**TA40-2** Rockbar upstream of Pool TA-M looking Downstream

<u>Notes (as at 5 January 2010)</u>

- Pool TA-M approximately 2.5m long, 2m wide and 0.6m deep
- Base of the pool is sandstone with alluvial deposits and small boulders
- Rockbar upstream of pool has ponding and many potholes
- No visible flow at upstream end of rockbar
- Flow path at downstream end of rockbar along eastern side toward Pool TA-M

**TA40-3** Overhang on west bank

**TA41-1** Downstream end of Pool TA-M looking Upstream




**TA41-2** Pool TA-M

**TA41-3** Overhang on east bank

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TA40-1 | 310354 | 6214654 | 180 |
| TA40-2 | 310354 | 6214654 | 0 |
| TA40-3 | 310354 | 6214654 | 245 |
| TA41-1 | 310356 | 6214665 | 180 |
| TA41-2 | 310356 | 6214665 | 150 |
| TA41-3 | 310356 | 6214665 | 90 |

# TRIBUTARY A STREAM MAPPING SUMMARY

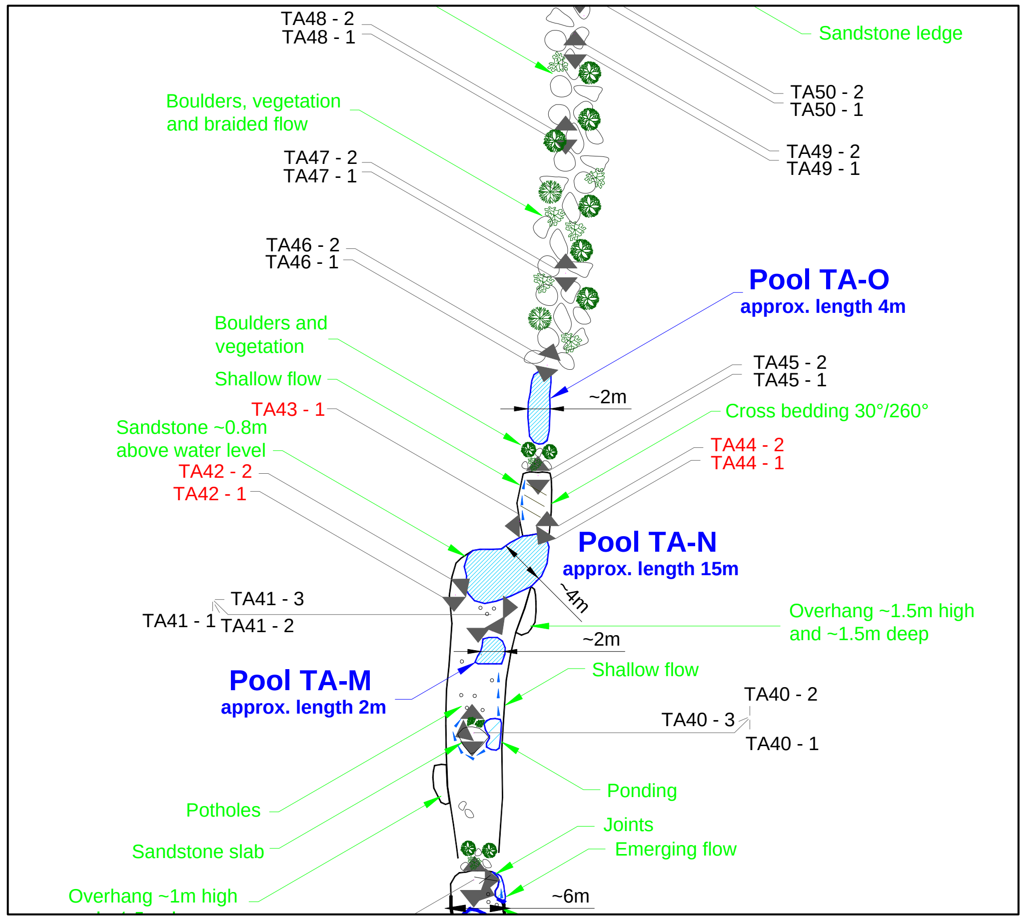
**TA42-1** Upstream end of Pool TA-N looking Upstream

**TA42-2** Upstream end of Pool TA-N looking Downstream

Notes (as at 5 January 2010)

- Pool TA-N approximately 15m long, 4m wide and 0.8m deep
- Base of the pool is sandstone with alluvial deposits
- Rockbar at upstream end is approximately 0.8m above water level
- Rockbar at downstream end is approximately 6m long and 3m wide with cross bedding
- Flow path down western side of rockbar

**TA44-1** Downstream end of Pool TA-N looking Upstream




**TA43-1** Overhang on west bank

**TA44-2** Downstream end of Pool TA-N looking Downstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TA42-1 | 310352 | 6214669 | 180 |
| TA42-2 | 310352 | 6214669 | 50 |
| TA43-1 | 310359 | 6214677 | 270 |
| TA44-1 | 310362 | 6214676 | 215 |
| TA44-2 | 310362 | 6214676 | 0 |

# TRIBUTARY A STREAM MAPPING SUMMARY

**TA45-1** Downstream end of rockbar looking Upstream

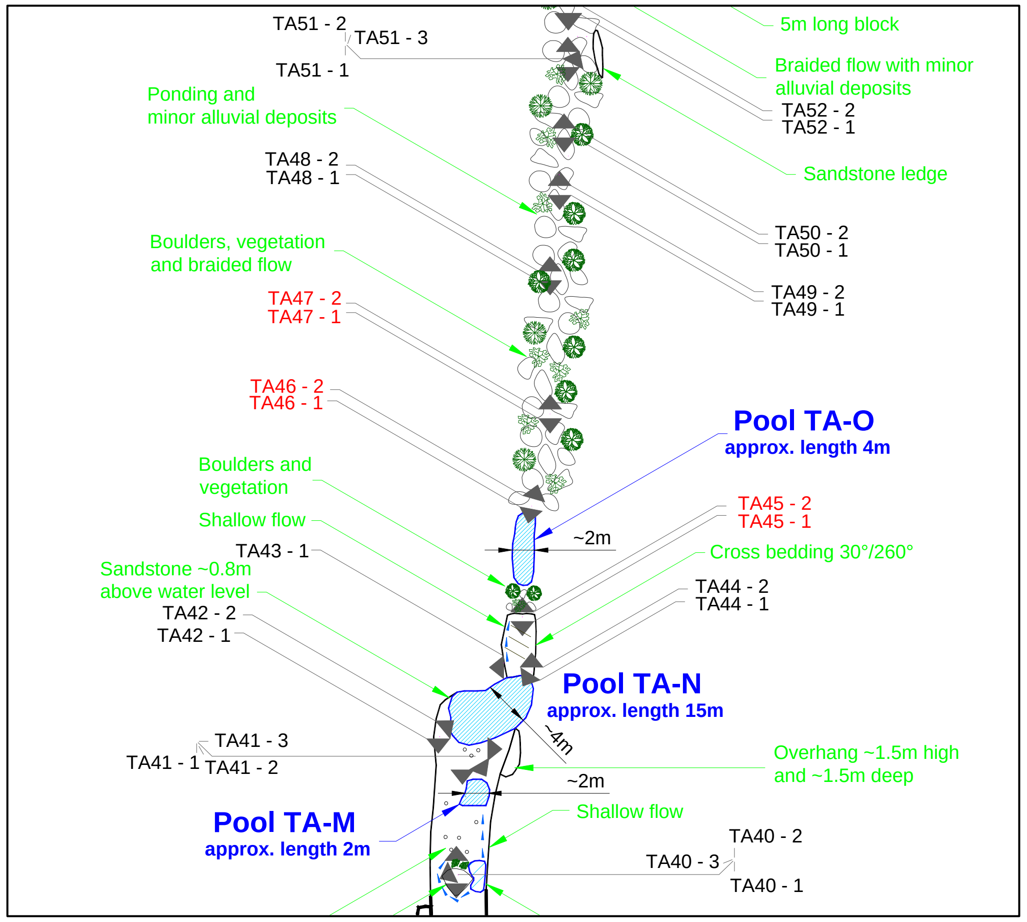
**TA45-2** Downstream end of rockbar looking Downstream

Notes (as at 5 January 2010)

- Pool TA-O approximately 4m long, 2m wide and 0.2m deep
- Base of the pool is sandstone with alluvial deposits and small boulders
- Boulders, vegetation and braided flow downstream of pool

**TA46-1** Downstream end of Pool TA-O looking Upstream

**TA46-2** Downstream end of Pool TA-O looking Downstream




**TA47-1** Boulder field looking Upstream

**TA47-2** Boulder field looking Downstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TA45-1 | 310361 | 6214682 | 180 |
| TA45-2 | 310361 | 6214682 | 0 |
| TA46-1 | 310362 | 6214694 | 190 |
| TA46-2 | 310362 | 6214694 | 15 |
| TA47-1 | 310364 | 6214704 | 180 |
| TA47-2 | 310364 | 6214704 | 0 |

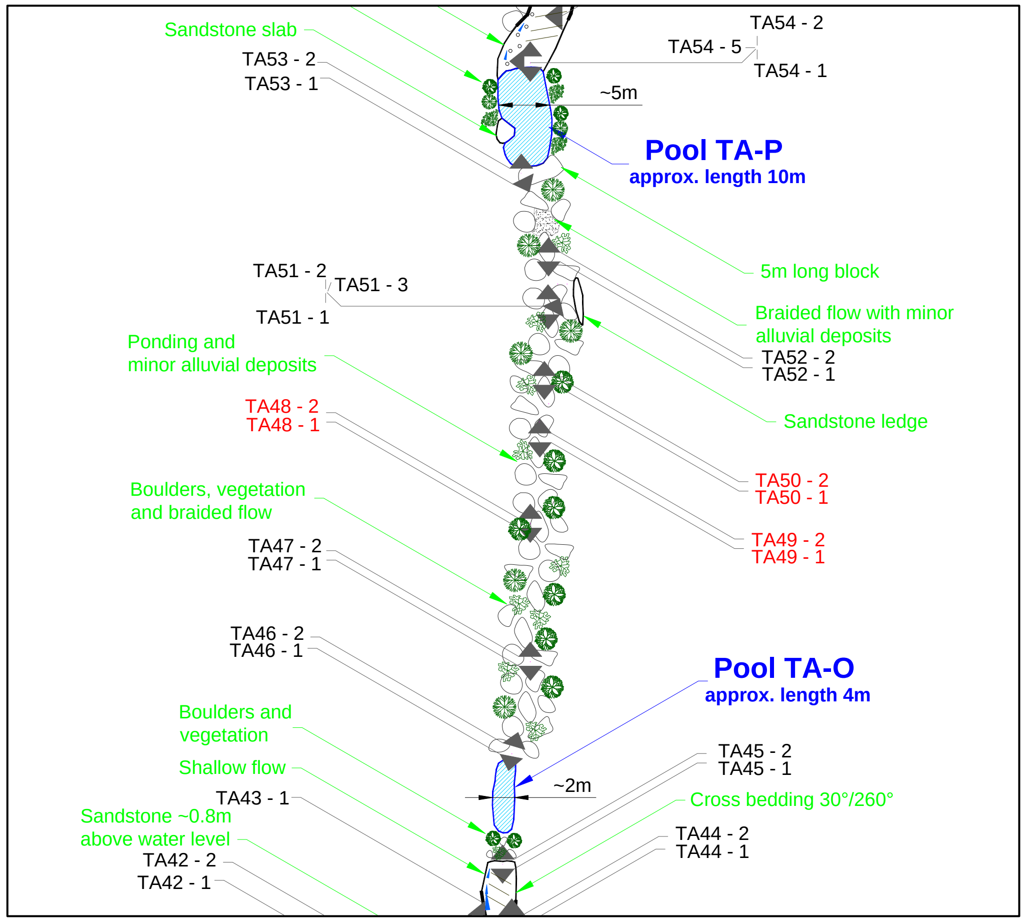
# TRIBUTARY A STREAM MAPPING SUMMARY

**TA48-1** Boulder field looking Upstream

**TA48-2** Boulder field looking Downstream

Notes (as at 5 January 2010)

- Boulder field with vegetation, braided flow, minor alluvial deposits and minor ponding
- Boulder field extends over approximately 55m




**TA49-1** Boulder field looking Upstream

**TA49-1** Boulder field looking Downstream

**TA50-1** Boulder field looking Upstream

**TA50-2** Boulder field looking Downstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TA48-1 | 310364 | 6214719 | 180 |
| TA48-2 | 310364 | 6214719 | 0 |
| TA49-1 | 310365 | 6214730 | 180 |
| TA49-2 | 310365 | 6214730 | 0 |
| TA50-1 | 310366 | 6214732 | 180 |
| TA50-2 | 310366 | 6214732 | 0 |

# TRIBUTARY A STREAM MAPPING SUMMARY

**TA51-1** At sandstone ledge looking Upstream

**TA51-2** At sandstone ledge looking Downstream

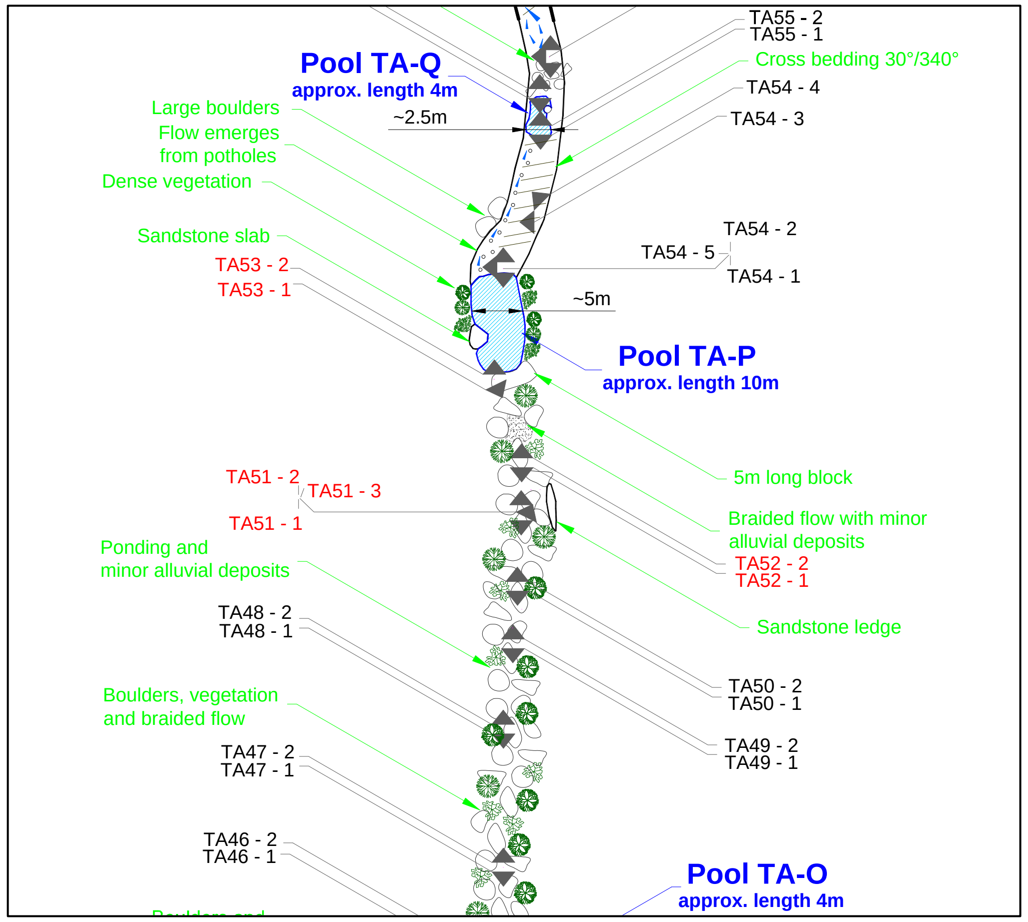
**TA51-3** East bank

Notes (as at 5 January 2010)

- Boulder field with vegetation, braided flow, minor alluvial deposits and minor ponding
- Boulder field extends over approximately 55m

**TA52-1** Boulder field looking Upstream

**TA52-2** Boulder field looking Downstream




**TA53-1** Upstream end of Pool TA-P looking Upstream

**TA53-2** Upstream end of Pool TA-P looking Downstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TA51-1 | 310367 | 6214745 | 180 |
| TA51-2 | 310367 | 6214745 | 0 |
| TA51-3 | 310367 | 6214745 | 20 |
| TA52-1 | 310368 | 6214745 | 180 |
| TA52-2 | 310368 | 6214745 | 0 |
| TA53-1 | 310363 | 6214757 | 160 |
| TA53-2 | 310363 | 6214757 | 0 |

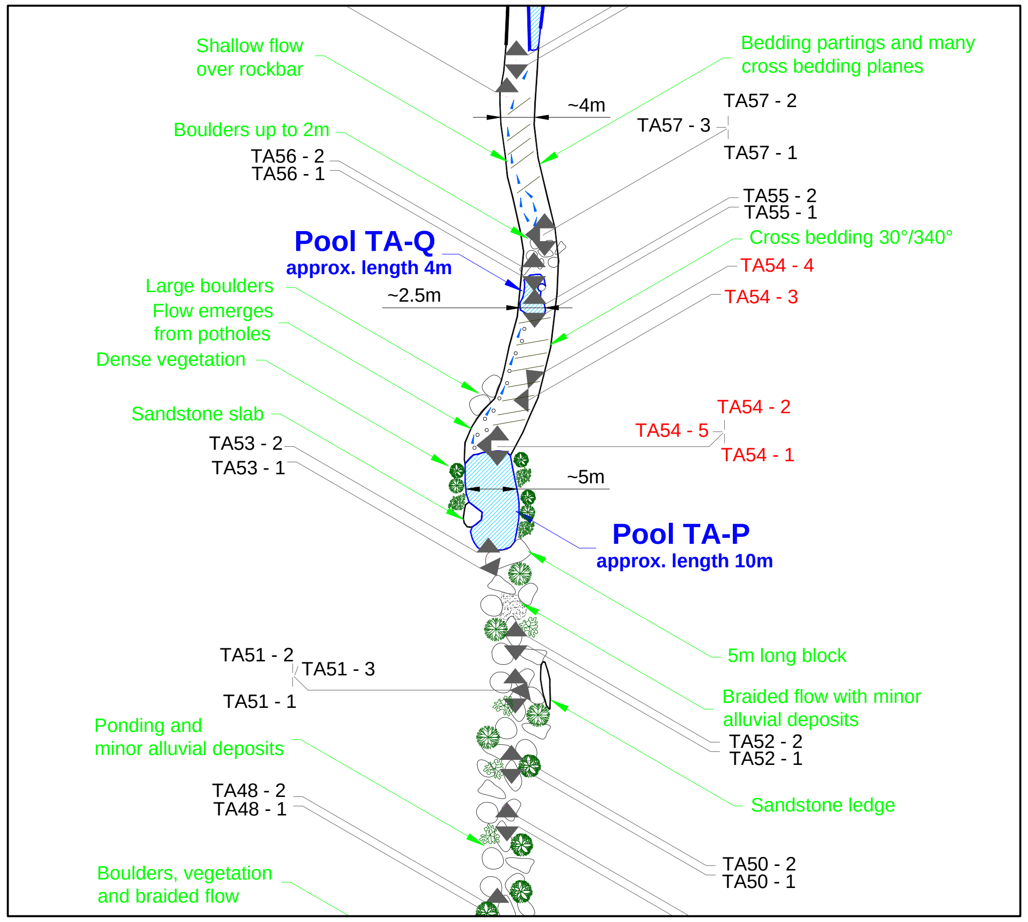
# TRIBUTARY A STREAM MAPPING SUMMARY

**TA54-1** Downstream end of Pool TA-P looking Upstream

**TA54-2** Downstream end of Pool TA-P looking Downstream

Notes (as at 5 January 2010)

- Pool TA-P approximately 10m long, 5m wide and 0.7 to 1m deep
- Base of the pool is sandstone with alluvial deposits and boulders up to 1m
- Rockbar downstream of the pool is approximately 14m long and 4m wide
- Cross bedding along length of rockbar with many potholes
- Flow path down western side of rockbar




**TA54-3** Cross bedding

**TA54-4** Potholes at downstream end of rockbar

**TA54-5** Potholes at upstream end of rockbar

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TA54-1 | 310364 | 6214769 | 180 |
| TA54-2 | 310364 | 6214769 | 0 |
| TA54-3 | 310368 | 6214775 | 270 |
| TA54-4 | 310368 | 6214775 | 315 |
| TA54-5 | 310364 | 6214769 | 270 |

# TRIBUTARY A STREAM MAPPING SUMMARY

**TA55-1** Upstream end of Pool TA-Q looking Upstream

**TA55-2** Upstream end of Pool TA-Q looking Downstream

**TA56-1** Downstream end of Pool TA-Q looking Upstream

**TA56-2** Downstream end of Pool TA-Q looking Downstream

Notes (as at 5 January 2010)

- Pool TA-Q approximately 4m long, 2.5m wide and 0.5m deep
- Base of the pool is sandstone with alluvial deposits and algae
- Rockbar with scattered boulders and minor ponding downstream of pool

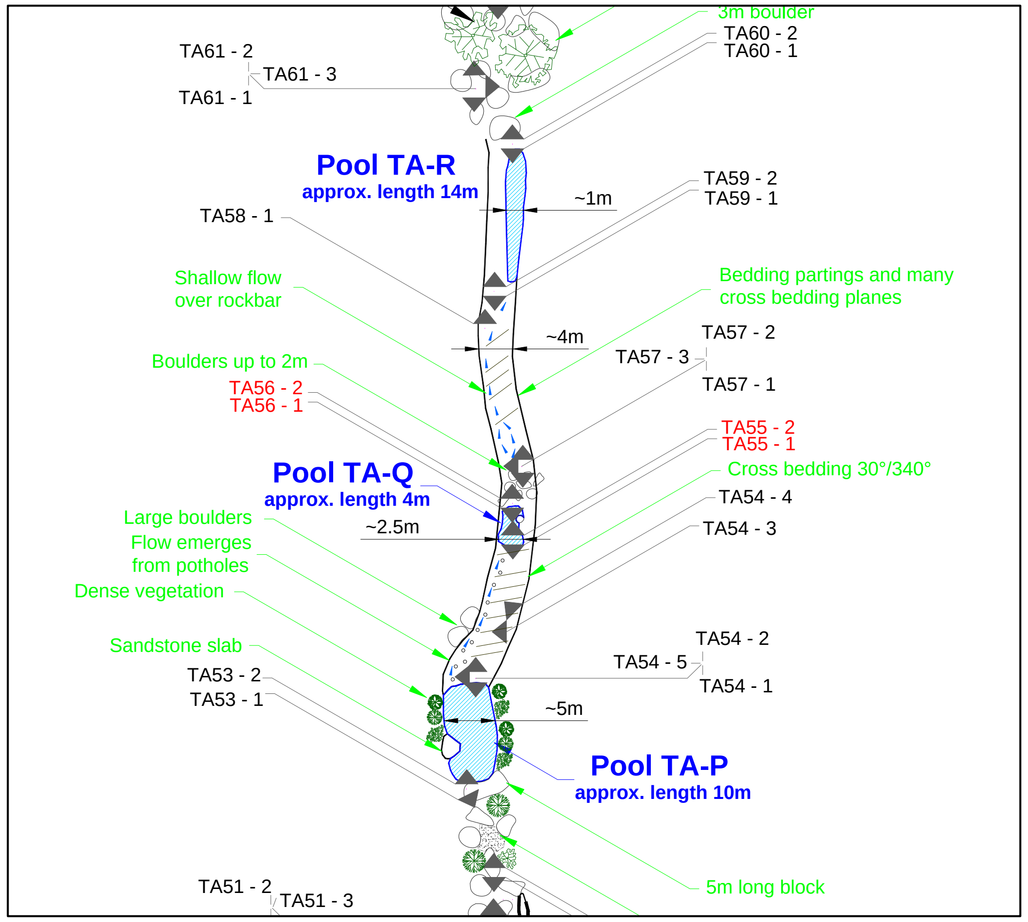



Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TA55-1 | 310368 | 6214784 | 180 |
| TA55-2 | 310368 | 6214784 | 0 |
| TA56-1 | 310368 | 6214788 | 180 |
| TA56-2 | 310368 | 6214788 | 0 |

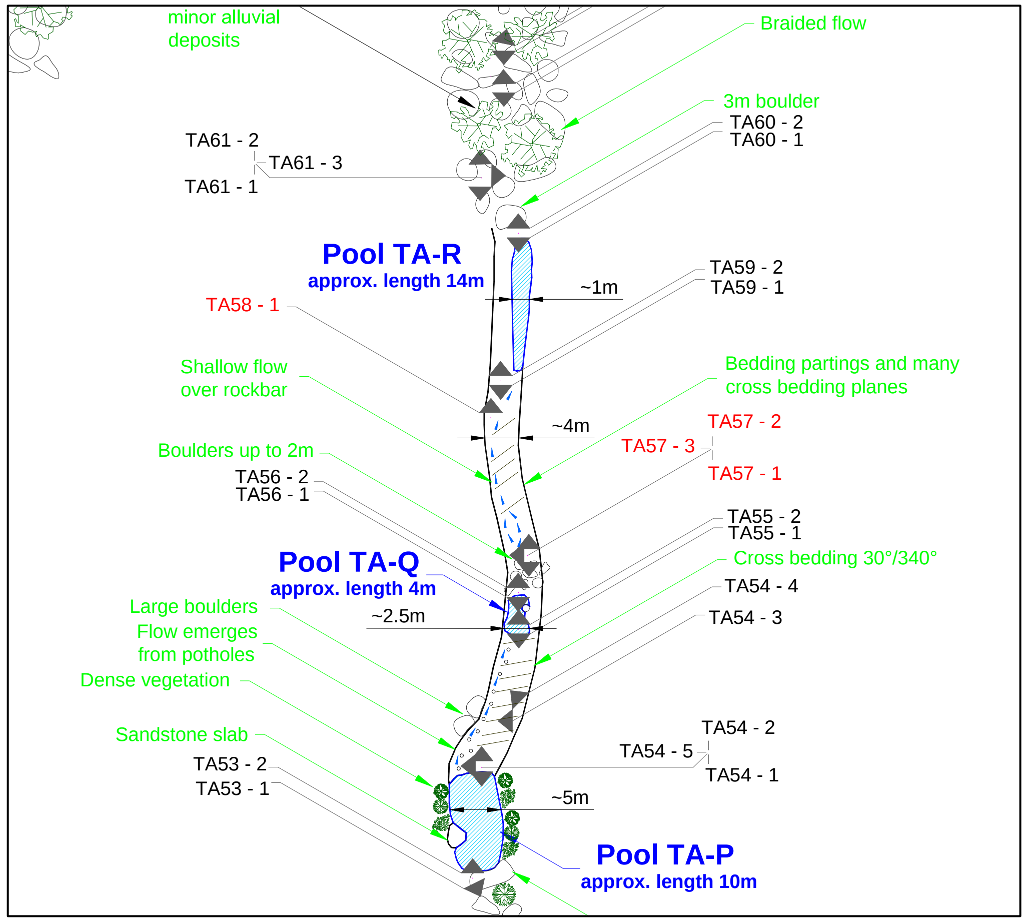
# TRIBUTARY A STREAM MAPPING SUMMARY

**TA57-1** Upstream end of rockbar looking Upstream

Notes (as at 5 January 2010)

- Rockbar approximately 20m long and 4m wide
- Cross bedding
- Flow path along western side of rockbar toward Pool TA-R

**TA57-2** Upstream end of rockbar looking Downstream





**TA57-3** West bank

**TA58-1** Downstream end of rockbar looking Downstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TA57-1 | 310369 | 6214792 | 180 |
| TA57-2 | 310369 | 6214792 | 0 |
| TA57-3 | 310369 | 6214792 | 270 |
| TA58-1 | 310365 | 6214807 | 0 |

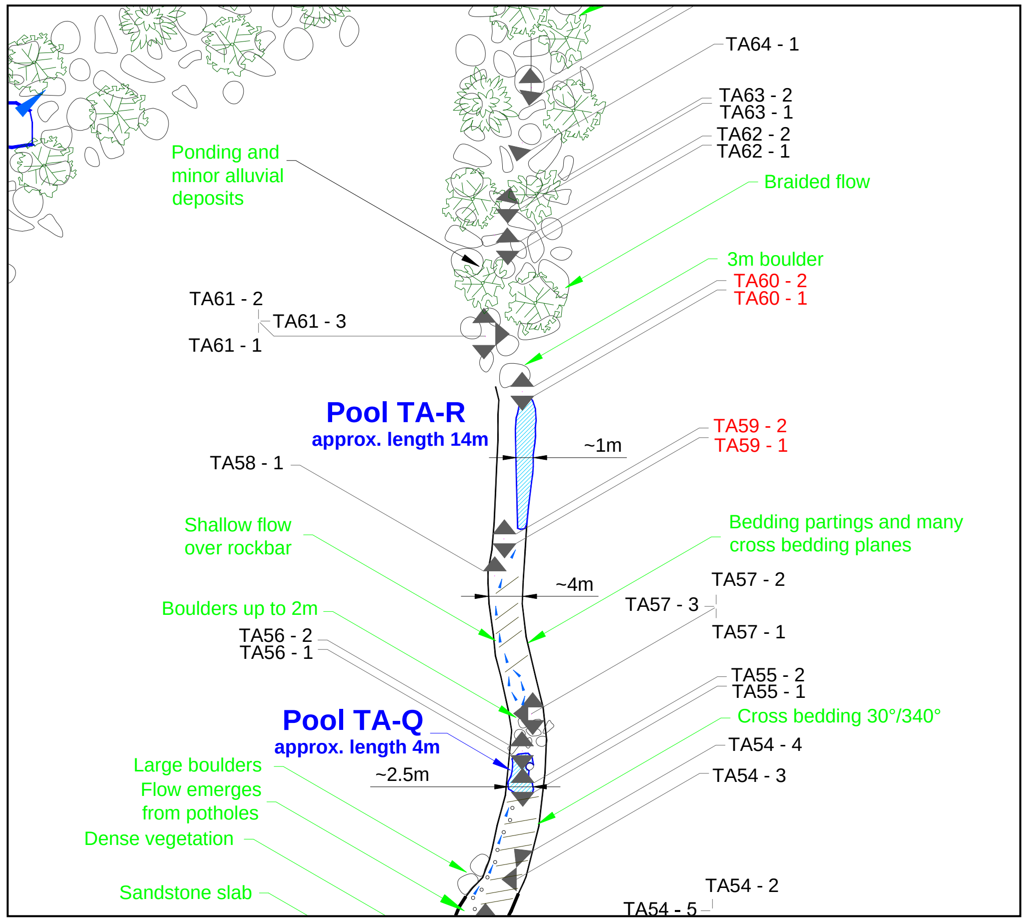
# TRIBUTARY A STREAM MAPPING SUMMARY

**TA59-1** Upstream end of Pool TA-R looking Upstream

**TA59-2** Upstream end of Pool TA-R looking Downstream

<u>Notes (as at 5 January 2010)</u>

- Pool TA-R approximately 14m long, 1m wide and 0.3m deep
- Base of the pool is sandstone with minor alluvial deposits
- Boulder field, vegetation and braided flow downstream of pool




**TA60-1** Downstream end of Pool TA-R looking Upstream

**TA60-2** Downstream end of Pool TA-R looking Downstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TA59-1 | 310366 | 6214811 | 180 |
| TA59-2 | 310366 | 6214811 | 0 |
| TA60-1 | 310368 | 6214827 | 180 |
| TA60-2 | 310368 | 6214827 | 0 |

# TRIBUTARY A STREAM MAPPING SUMMARY

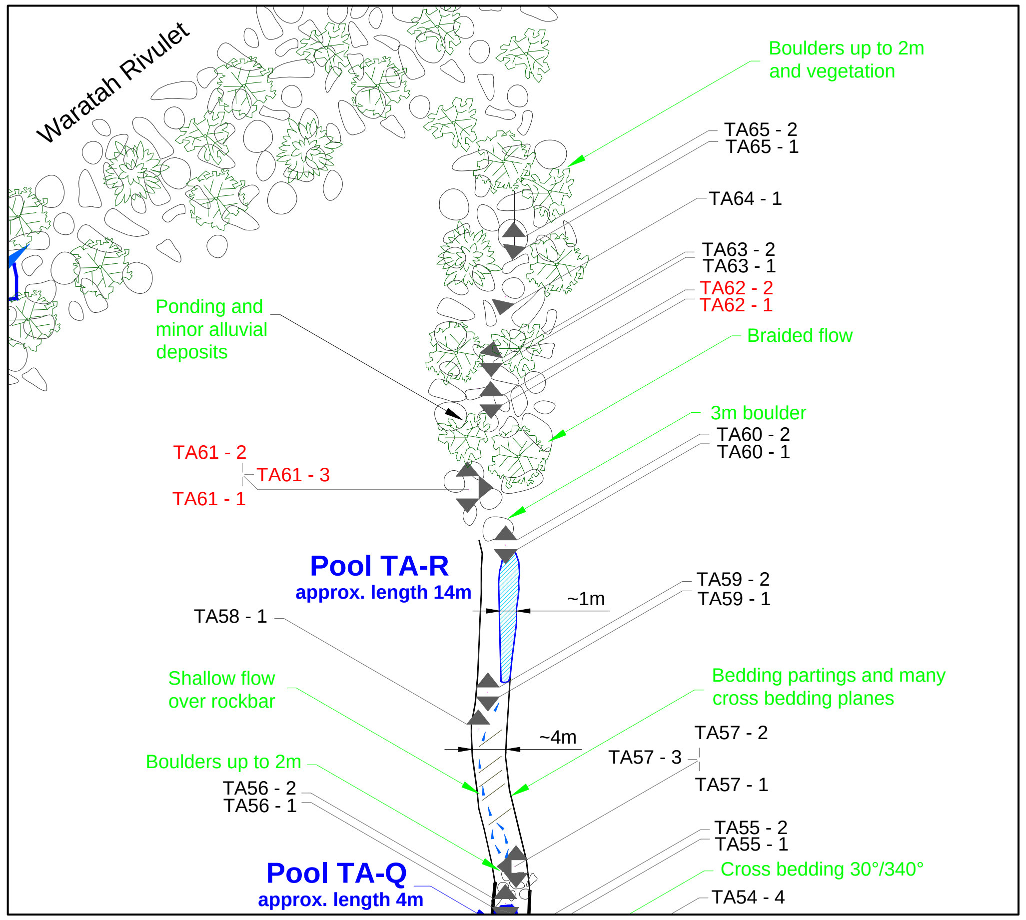
**TA61-1** Boulder field looking Upstream

**TA61-2** Boulder field looking Downstream

Notes (as at 5 January 2010)

- Boulder field extends over approximately 50m
- Boulders up to 2m, vegetation and braided flow

**TA61-3** East bank





**TA62-1** Boulder field looking Upstream

**TA62-2** Boulder field looking Downstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TA61-1 | 310364 | 6214833 | 180 |
| TA61-2 | 310364 | 6214833 | 0 |
| TA61-3 | 310364 | 6214833 | 90 |
| TA62-1 | 310365 | 6214844 | 180 |
| TA62-2 | 310365 | 6214844 | 0 |

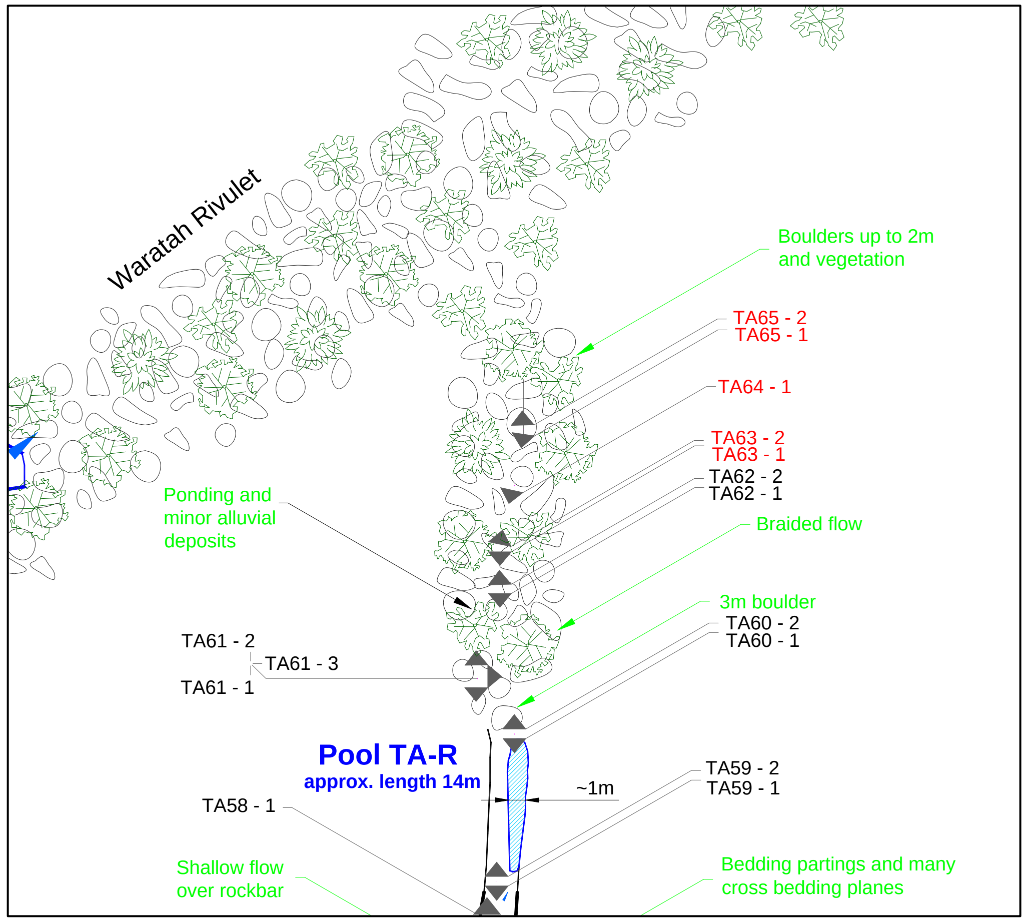
# TRIBUTARY A STREAM MAPPING SUMMARY

**TA63-1** Boulder field looking Upstream

**TA63-2** Boulder field looking Downstream

Notes (as at 5 January 2010)

- Boulder field extends over approximately 50m
- Boulders up to 2m, vegetation and braided flow




**TA64-1** Boulder field looking Upstream

**TA65-1** Boulder field looking Upstream

**TA65-2** Boulder field looking Downstream toward Waratah Rivulet

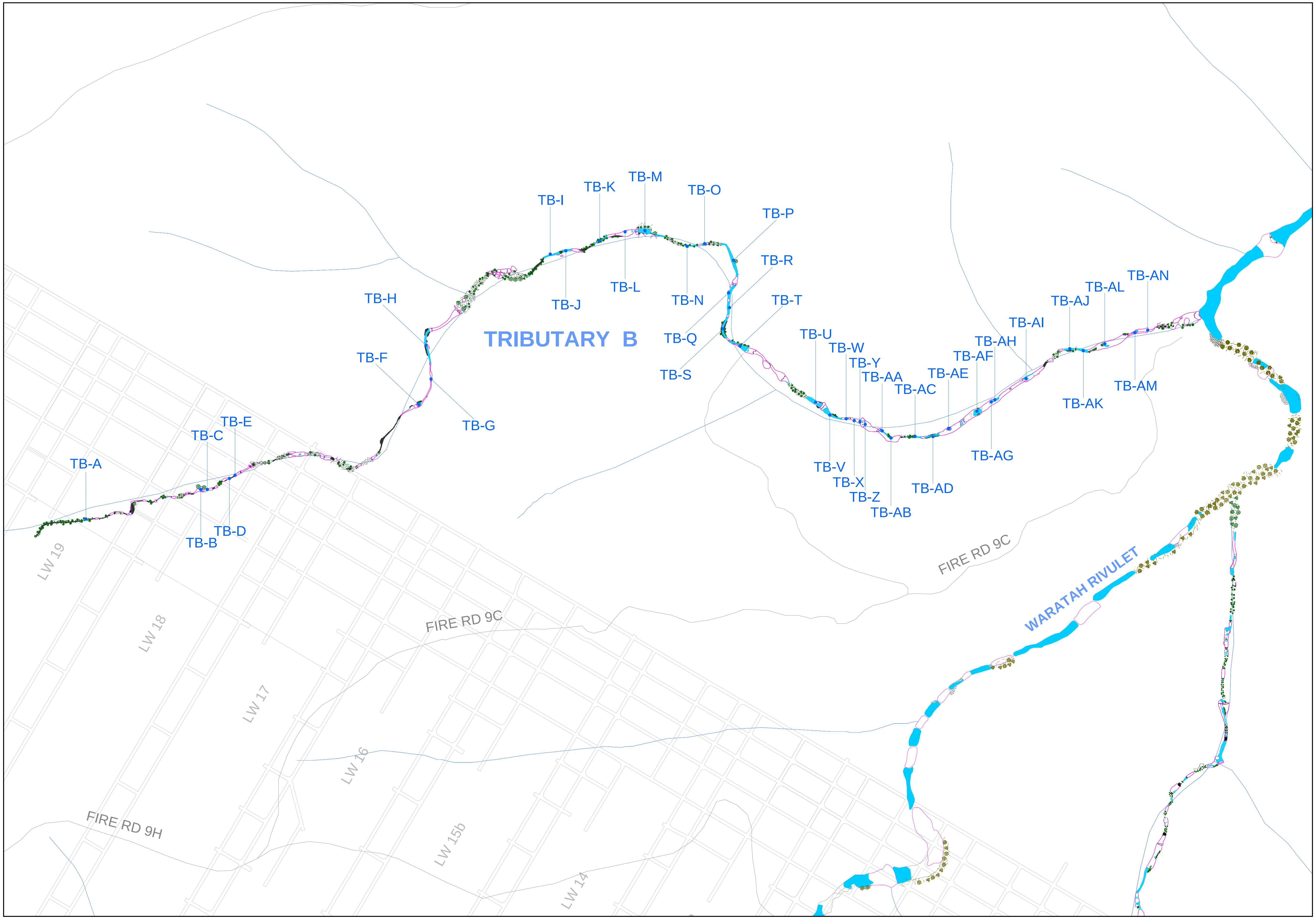
Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TA63-1 | 310365 | 6214846 | 180 |
| TA63-2 | 310365 | 6214846 | 10 |
| TA64-1 | 310368 | 6214854 | 190 |
| TA65-1 | 310369 | 6214860 | 190 |
| TA65-2 | 310369 | 6214860 | 0 |

# APPENDIX 4

# TRIBUTARY B STREAM MAPPING AND PHOTOGRAPHIC RECORD

# TRIBUTARY B – GENERAL LAYOUT



# TRIBUTARY B STREAM MAPPING SUMMARY

## Legend:

| | | | |
|---|---|---|---|
| A-1 | Photo Direction Arrow | | Water flow |
| | Pool | | Pooled Water |
| | Rockbar | | Alluvial Deposits (Sand) |
| | Boulders | | Potholes |
| | Cross bedding | | Vegetation - shrubs, bushes and small trees |
| | Joint | | Slope Direction |

# TRIBUTARY B STREAM MAPPING SUMMARY

**TB001-1** Upstream end of Tributary B looking toward northern bank

**TB002-1** Upstream end of Tributary B looking Upstream

**TB002-2** Upstream end of Tributary B looking Downstream

**TB002-3** Upstream end of Tributary B looking down

**TB003-1** Upstream end of Tributary B looking down

**TB004-1** Upstream end of Tributary B looking toward northern bank

Notes (as at 22 December 2009)

- Damp, sandy creek bed with alluvial deposits
- No flow visible
- Dense vegetation

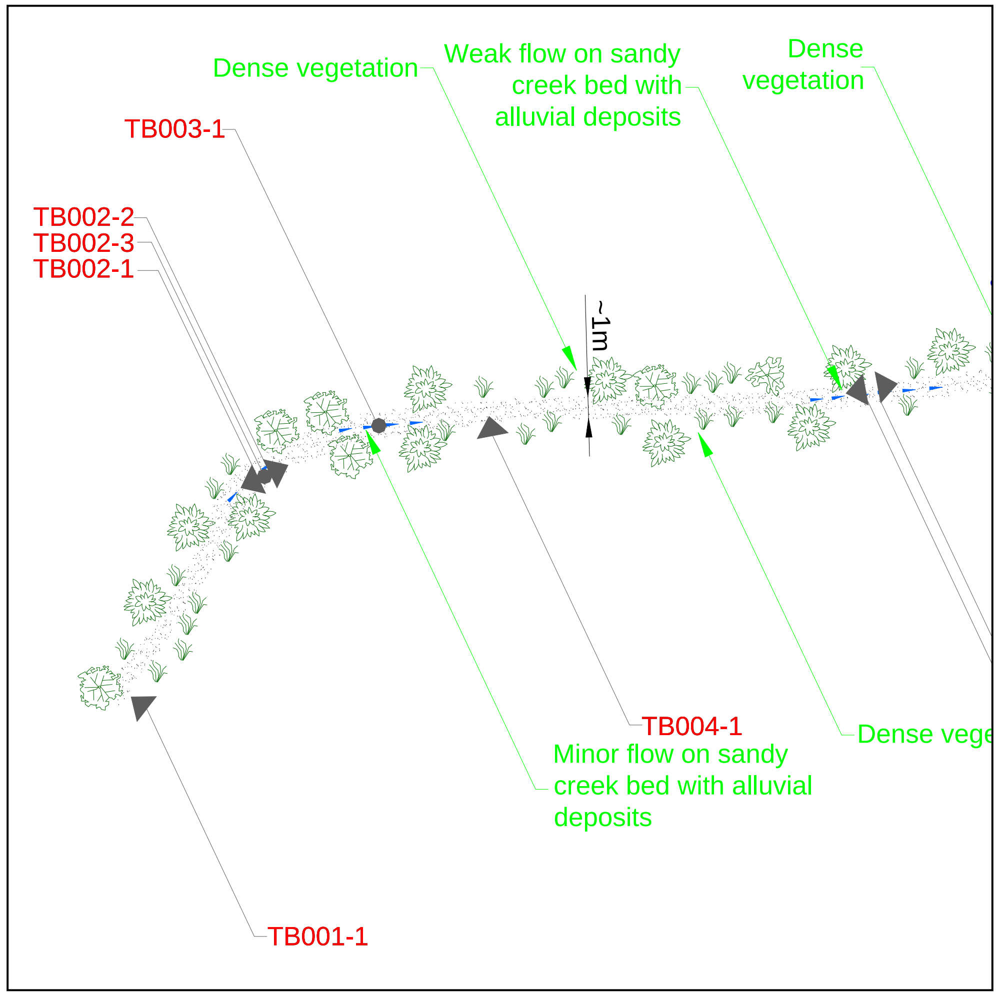



Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TB001-1 | 308457 | 6214818 | 310 |
| TB002-1 | 308466 | 6214836 | 240 |
| TB002-2 | 308466 | 6214836 | 65 |
| TB002-3 | 308466 | 6214836 | - |
| TB003-1 | 308475 | 6214840 | - |
| TB004-1 | 308484 | 6214839 | 350 |

# TRIBUTARY B STREAM MAPPING SUMMARY

**TB005-1** Upstream from Pool TB-A looking Upstream

**TB005-2** Upstream from Pool TB-A looking Downstream

**TB006-1** Midway along Pool TB-A looking Upstream

**TB006-2** Midway along Pool TB-A looking Downstream

**TB007-1** Downstream from Pool TB-A looking Upstream

**TB007-2** Downstream from Pool TB-A looking Downstream

Notes (as at 22 December 2009)

- Pool TB-A approximately 8m long, 1m wide and 0.2m deep
- Base of the pool is alluvial with leaf litter
- Vegetation encroaches on pool from both sides
- Dense vegetation upstream of the pool
- Alluvial deposits downstream of the pool

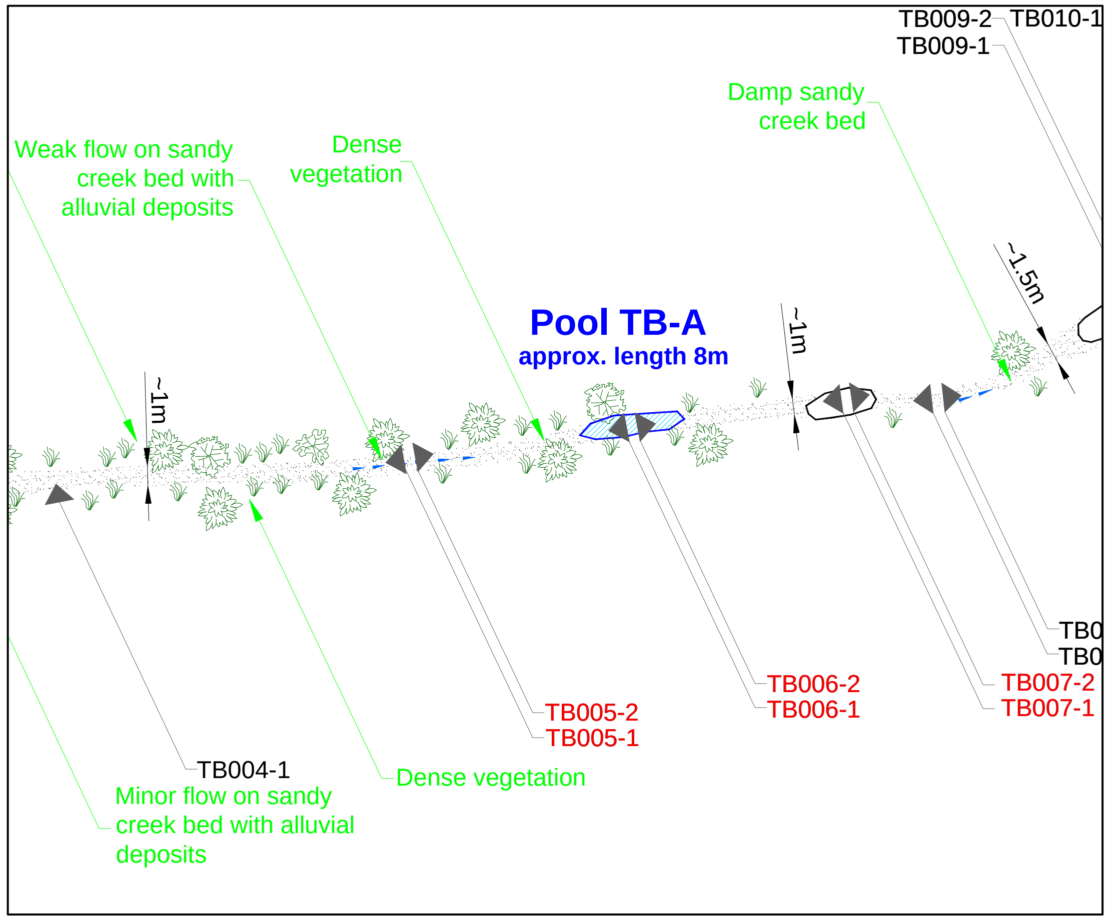



Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TB005-1 | 308514 | 6214843 | 260 |
| TB005-2 | 308514 | 6214843 | 80 |
| TB006-1 | 308532 | 6214849 | 260 |
| TB006-2 | 308532 | 6214849 | 85 |
| TB007-1 | 308551 | 6214848 | 265 |
| TB007-2 | 308551 | 6214848 | 80 |

# TRIBUTARY B STREAM MAPPING SUMMARY

**TB008-1** Downstream from Pool TB-A looking Upstream

**TB008-2** Downstream from Pool TB-A looking Downstream

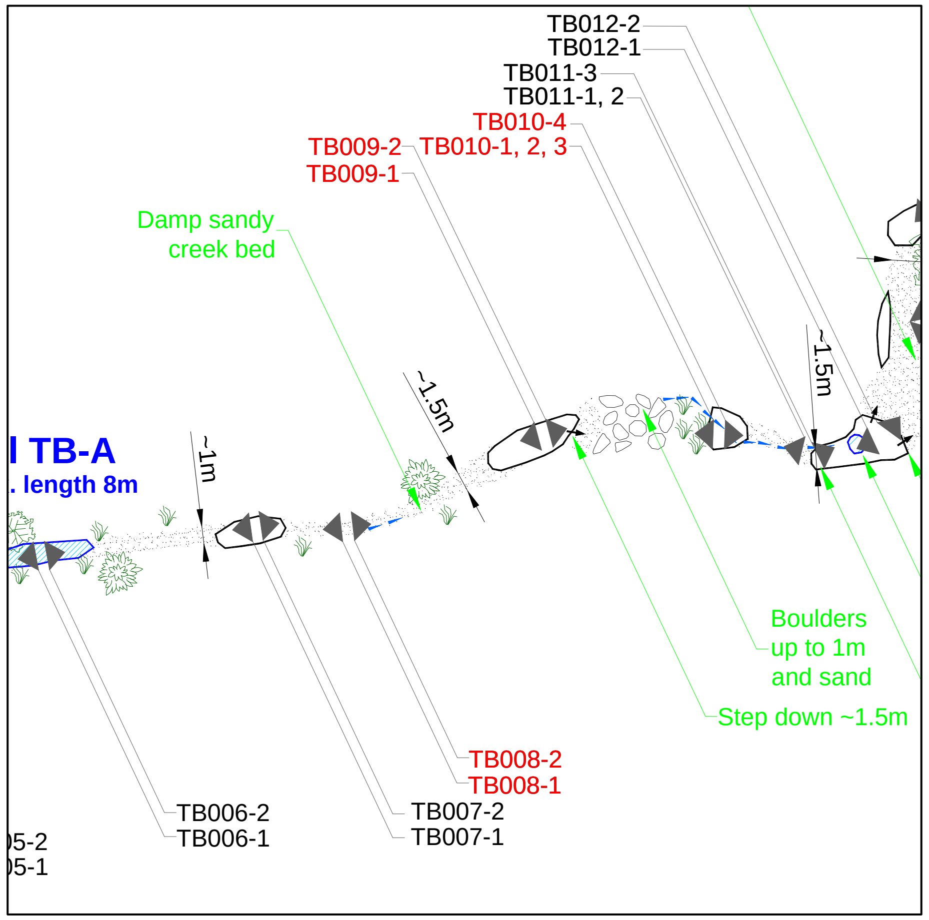
**TB009-1** Downstream from Pool TB-A looking Upstream

<u>Notes (as at 22 December 2009)</u>

- Damp, sandy creek bed approximately 1m wide
- Flow path along southern side downstream of TB008
- Sandy banks with vegetation
- Rockbar at TB009 approximately 1.5m wide, with boulders downstream

**TB009-2** Downstream from Pool TB-A looking Downstream

**TB010-1** Downstream from Pool TB-A looking Upstream




**TB010-2** Downstream from Pool TB-A looking Upstream

**TB010-3** Downstream from Pool TB-A looking Upstream

**TB010-4** Downstream from Pool TB-A looking Downstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TB008-1 | 308559 | 6214848 | 265 |
| TB008-2 | 308559 | 6214848 | 80 |
| TB009-1 | 308576 | 6214856 | 250 |
| TB009-2 | 308576 | 6214856 | 80 |
| TB010-1 | 308591 | 6214856 | 275 |
| TB010-2 | 308591 | 6214856 | 275 |
| TB010-3 | 308591 | 6214856 | 275 |
| TB010-4 | 308591 | 6214856 | 95 |

# TRIBUTARY B STREAM MAPPING SUMMARY

**TB011-1** Rockbar looking Upstream

**TB011-2** Rockbar looking Upstream

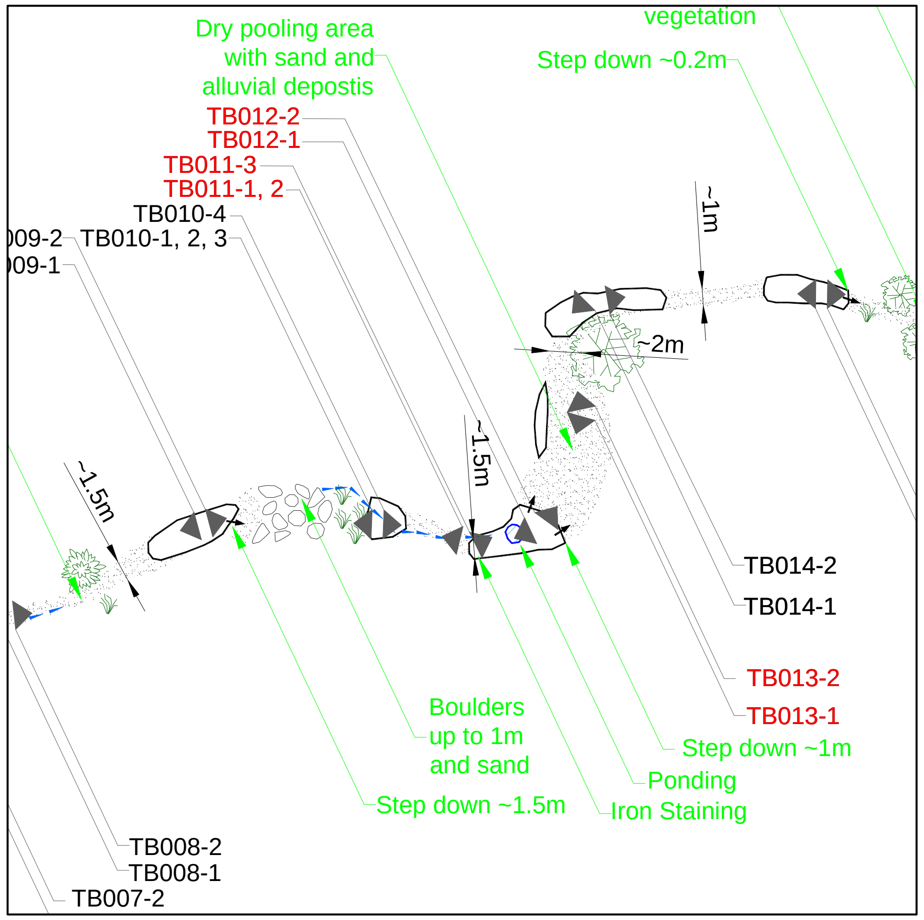
**TB011-3** Rockbar looking Downstream

Notes (as at 22 December 2009)

- Rockbar at TB011 approximately 1.5m wide at upstream end
- Rockbar has ponding and iron staining downstream
- Step down approximately 1m at TB013 with alluvial deposits downstream

**TB012-1** Rockbar looking Upstream

**TB012-2** Rockbar looking Downstream




**TB013-1** Dry creek bed looking Upstream

**TB013-2** Dry creek bed looking Downstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TB011-1 | 308599 | 6214854 | 285 |
| TB011-2 | 308599 | 6214854 | 285 |
| TB011-3 | 308599 | 6214854 | 65 |
| TB012-1 | 308603 | 6214854 | 245 |
| TB012-2 | 308603 | 6214854 | 70 |
| TB013-1 | 308610 | 6214866 | 195 |
| TB013-2 | 308610 | 6214866 | 345 |

# TRIBUTARY B STREAM MAPPING SUMMARY

**TB014-1** Rockbar looking Upstream

**TB014-2** Rockbar looking Downstream

**TB015-1** Rockbar looking Upstream

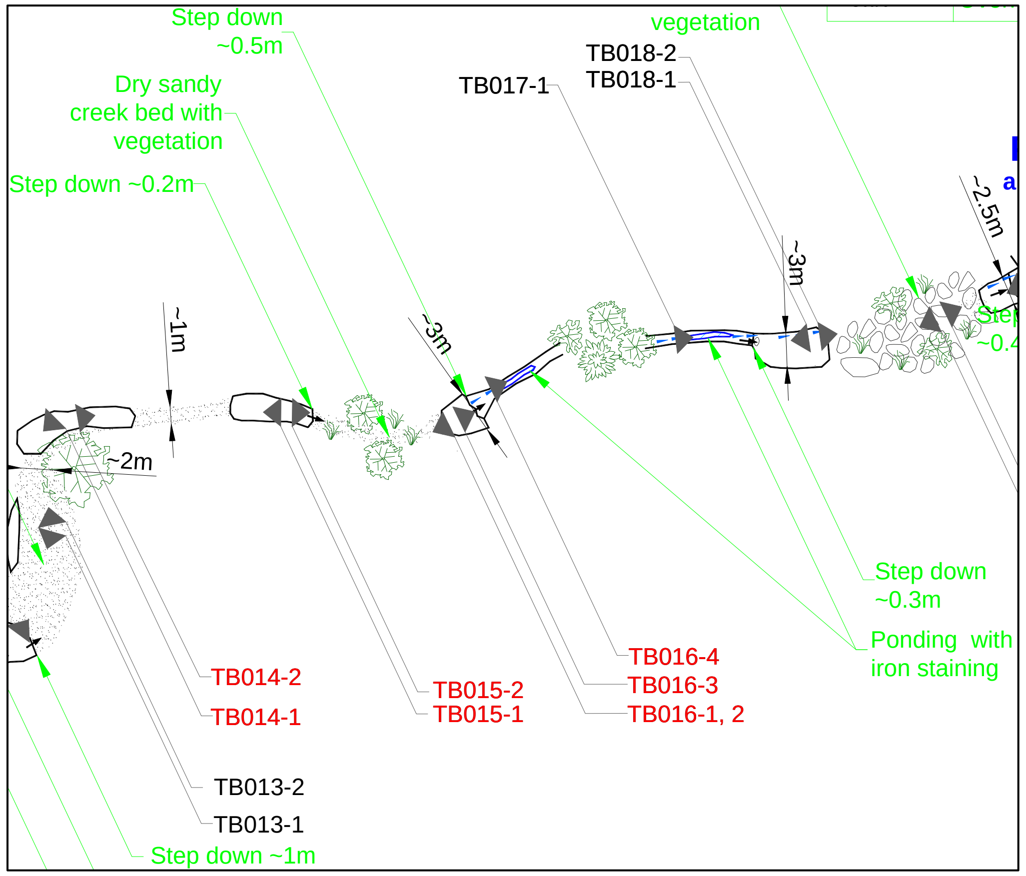
Notes (as at 22 December 2009)

- Rockbar at TB014 approximately 1m wide, with alluvial deposits upsteam and downstream
- Rockbar at TB015 approximately 1.5m wide, with alluvial deposits upsteam and vegetation downstream
- Ponding with iron staining at TB016

**TB015-2** Rockbar looking Downstream

**TB016-** Looking Upstream

**TB016-2** Looking Upstream




**TB016-3** Looking Downstream

**TB016-4** Ponding and iron staining looking Downstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TB014-1 | 308610 | 6214875 | 285 |
| TB014-2 | 308610 | 6214875 | 85 |
| TB015-1 | 308628 | 6214876 | 180 |
| TB015-2 | 308628 | 6214876 | 90 |
| TB016-1 | 308644 | 6214875 | 245 |
| TB016-2 | 308644 | 6214875 | 245 |
| TB016-3 | 308644 | 6214875 | 65 |
| TB016-4 | 308644 | 6214875 | 65 |

# TRIBUTARY B STREAM MAPPING SUMMARY

**TB017-1** Upstream from Pool TB-B looking Downstream

**TB018-1** Upstream from Pool TB-B looking Upstream

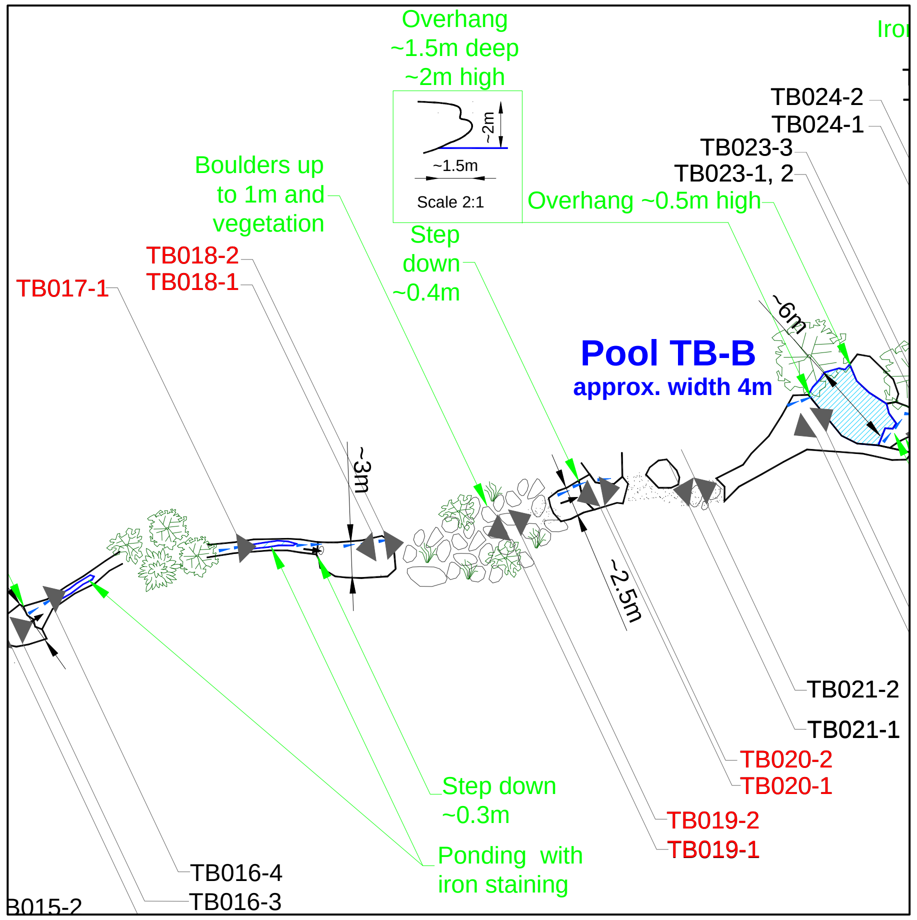
**TB018-2** Upstream from Pool TB-B looking Downstream

Notes (as at 22 December 2009)

- Rockbar at TB018 approximately 6m long and 3m wide, with ponding and iron staining upstream
- Flow path along northern side of rockbar
- Vegetation and boulders up to 1m at TB019
- Rockbar at TB020 approximately 6m long and 2.5m wide
- Overhang on western bank approximately 2m high

**TB019-1** Upstream from Pool TB-B looking Upstream

**TB019-2** Upstream from Pool TB-B looking Downstream




**TB020-1** Upstream from Pool TB-B looking Upstream

**TB020-2** Upstream from Pool TB-B looking Downstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TB017-1 | 308664 | 6214883 | 85 |
| TB018-1 | 308676 | 6214883 | 260 |
| TB018-2 | 308676 | 6214883 | 80 |
| TB019-1 | 308690 | 6214879 | 245 |
| TB019-2 | 308690 | 6214879 | 65 |
| TB020-1 | 308694 | 6214887 | 240 |
| TB020-2 | 308694 | 6214887 | 80 |

# TRIBUTARY B STREAM MAPPING SUMMARY

**TB021-1** Upstream from Pool TB-B looking Upstream

**TB021-2** Upstream from Pool TB-B looking Downstream

**TA022-2** Upstream end of Pool TB-B looking Downstream

**TB022-1** Upstream end of Pool TB-B looking Upstream

**TB022-3** Upstream end of Pool TB-B looking to overhang on eastern bank

Notes (as at 22 December 2009)

- Pool TB-B approximately 6m long, 4m wide and up to 1m deep
- Base of the pool is sandstone
- Rockbar upstream of the pool is approximately 8m wide at the downstream end
- Flow path along northern side of rockbar into Pool TB-B
- Overhang at upsteam end of pool approximately 2m high and 1.5m deep
- Overhang at eastern side of pool approximately 0.5m high

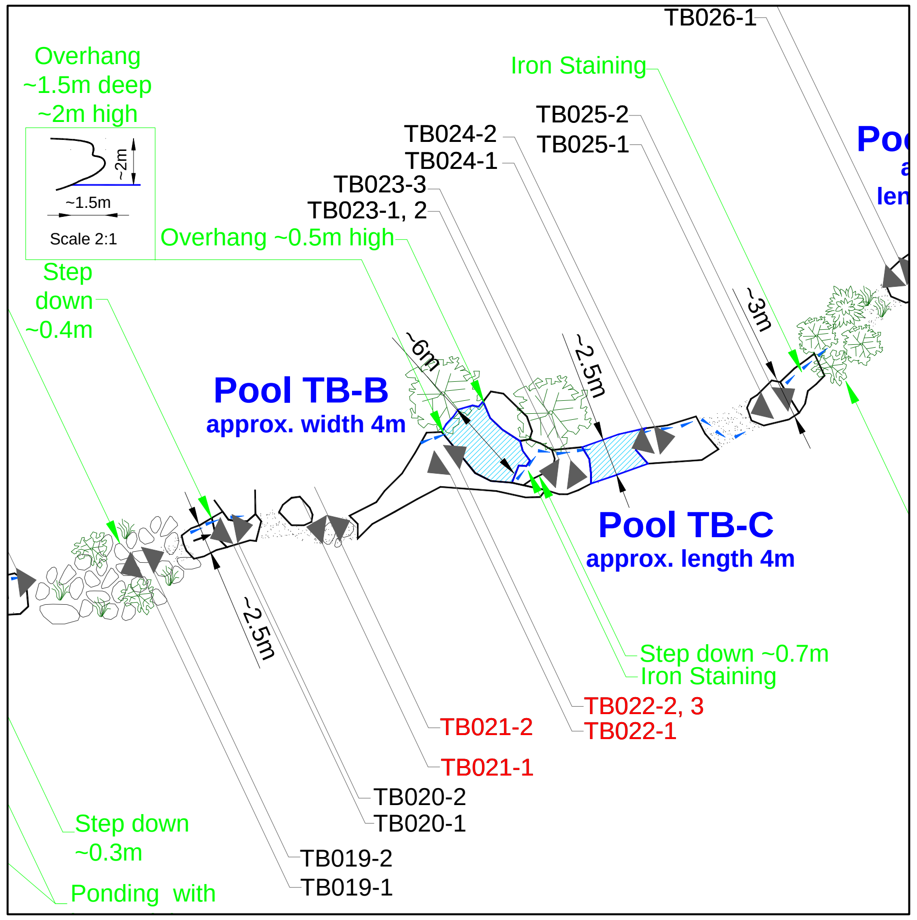



Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TB021-1 | 308703 | 6214887 | 280 |
| TB021-2 | 308703 | 6214887 | 65 |
| TB022-1 | 308717 | 6214892 | 240 |
| TB022-2 | 308717 | 6214892 | 60 |
| TB022-3 | 308717 | 6214892 | 60 |

# TRIBUTARY B STREAM MAPPING SUMMARY

**TB023-1** Downstream end of Pool TB-B looking Upstream

**TB023-2** Upstream from Pool TB-C looking Upstream

**TB023-3** Upstream from Pool TB-C looking Downstream

Notes (as at 22 December 2009)

- Pool TB-C approximately 4m long, 2.5m wide and 0.2m deep
- Base of the pool is sandstone with scattered vegetation at the upstream end
- Flow path along northern side of rockbar into Pool TB-C
- Rockbar upstream of the pool is approximately 5m long and 2.5m wide

**TB024-1** Downstream end of Pool TB-C looking Upstream

**TB024-2** Downstream end of Pool TB-C looking Downstream

**TB025-1** Downstream from Pool TB-C looking Upstream

**TB025-2** Downstream from Pool TB-C looking Downstream

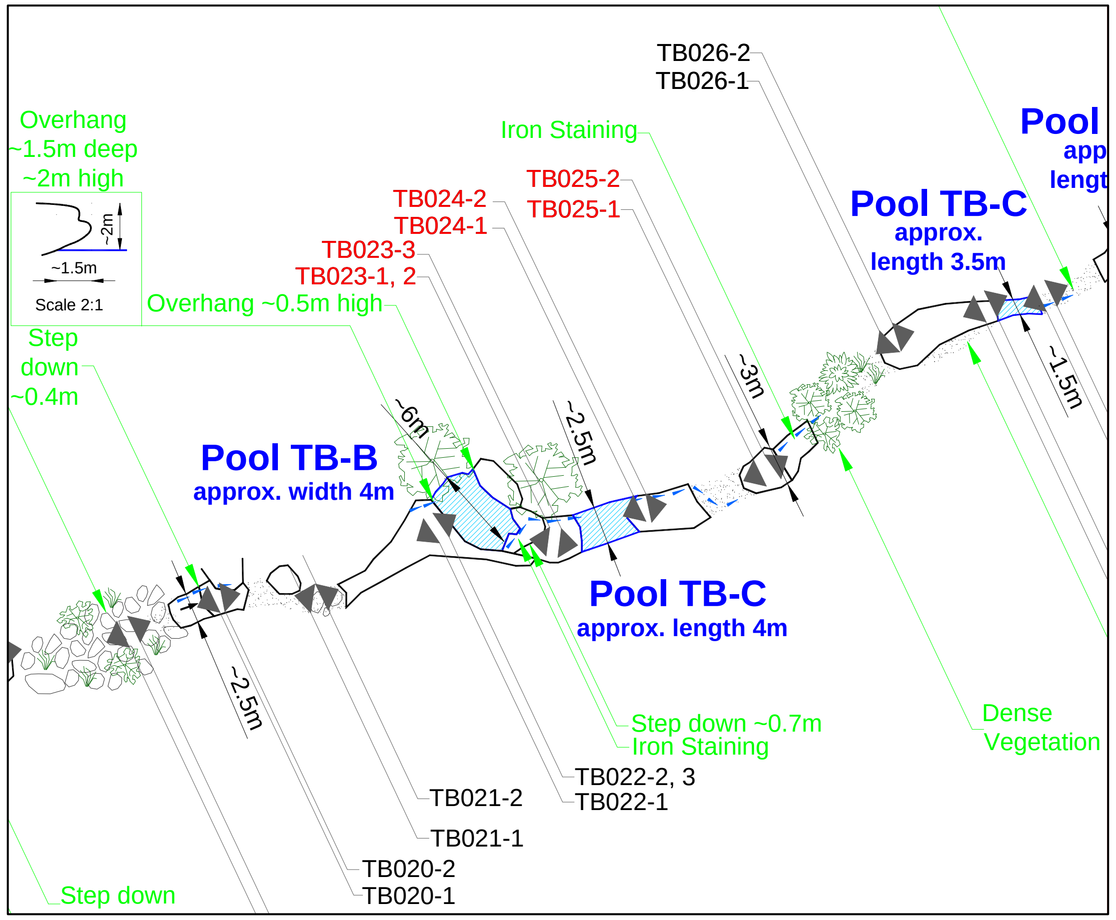



Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TB023-1 | 308720 | 6214893 | 275 |
| TB023-2 | 308720 | 6214893 | 275 |
| TB023-3 | 308720 | 6214893 | 95 |
| TB024-1 | 308731 | 6214895 | 245 |
| TB024-2 | 308731 | 6214895 | 80 |
| TB025-1 | 308742 | 6214897 | 245 |
| TB025-2 | 308742 | 6214897 | 55 |

# TRIBUTARY B STREAM MAPPING SUMMARY

**TB026-1** Upstream from Pool TB-D looking Upstream

**TB026-2** Upstream from Pool TB-D looking Downstream

**TB027-1** Upstream end of Pool TB-D looking Upstream

Notes (as at 22 December 2009)

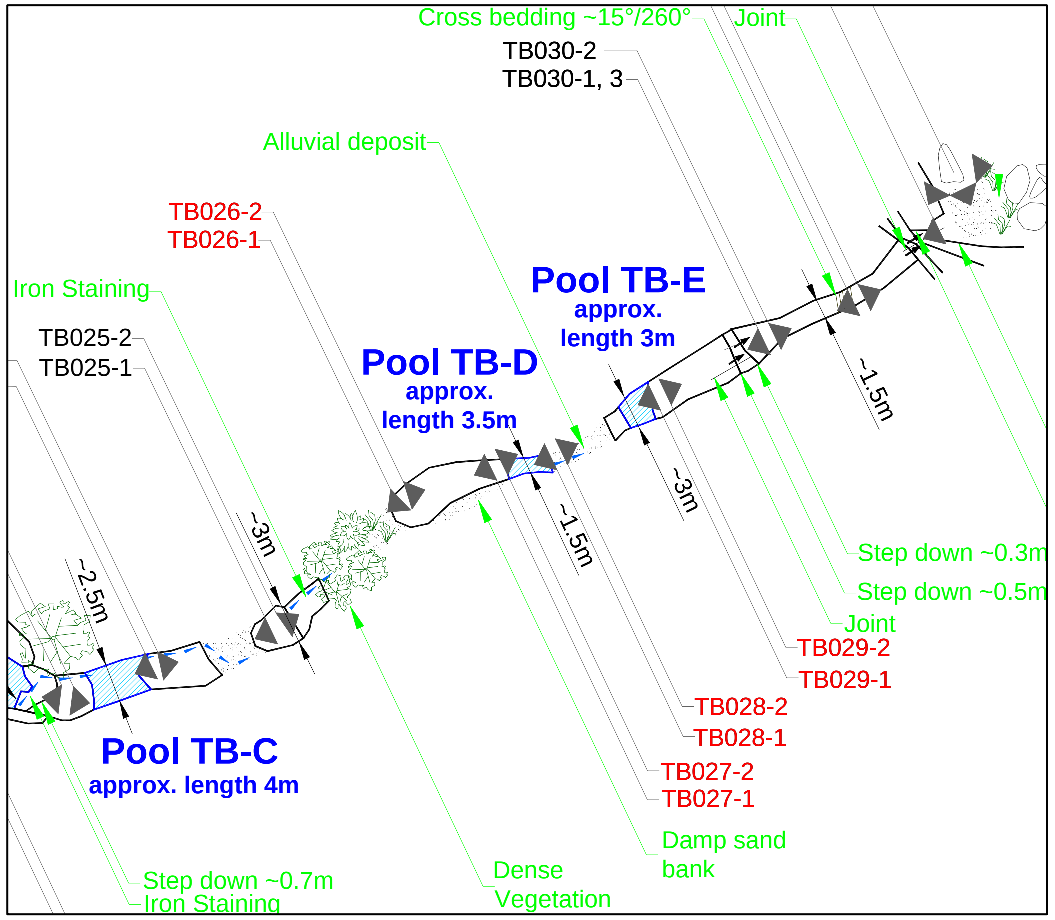
- Pool TB-D approximately 3.5m long, 1.5m wide and 0.2m deep
- Base of the pool is sandstone with alluvial deposits
- Rockbar upstream of the pool is approximately 10m long with scattered vegetation debris
- Rockbar and alluvial deposits downstream of the pool

- Pool TB-E approximately 3m long, 3m wide and 0.5m deep
- Base of the pool is sandstone with alluvial deposits

**TB027-2** Upstream end of Pool TB-D looking Downstream

**TB028-1** Downstream end of Pool TB-D looking Upstream

**TB028-2** Downstream end of Pool TB-D looking Downstream




**TB029-1** Downstream end of Pool TB-E looking Upstream

**TB029-2** Downstream end Pool TB-E looking Downstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TB026-1 | 308752 | 6214909 | 215 |
| TB026-2 | 308752 | 6214909 | 70 |
| TB027-1 | 308760 | 6214912 | 245 |
| TB027-2 | 308760 | 6214912 | 65 |
| TB028-1 | 308765 | 6214911 | 245 |
| TB028-2 | 308765 | 6214911 | 65 |
| TB029-1 | 308774 | 6214918 | 245 |
| TB029-2 | 308774 | 6214918 | 65 |

# TRIBUTARY B STREAM MAPPING SUMMARY

**TB030-1** Downstream from Pool TB-E looking Upstream

**TB030-2** Downstream from Pool TB-E looking Downstream

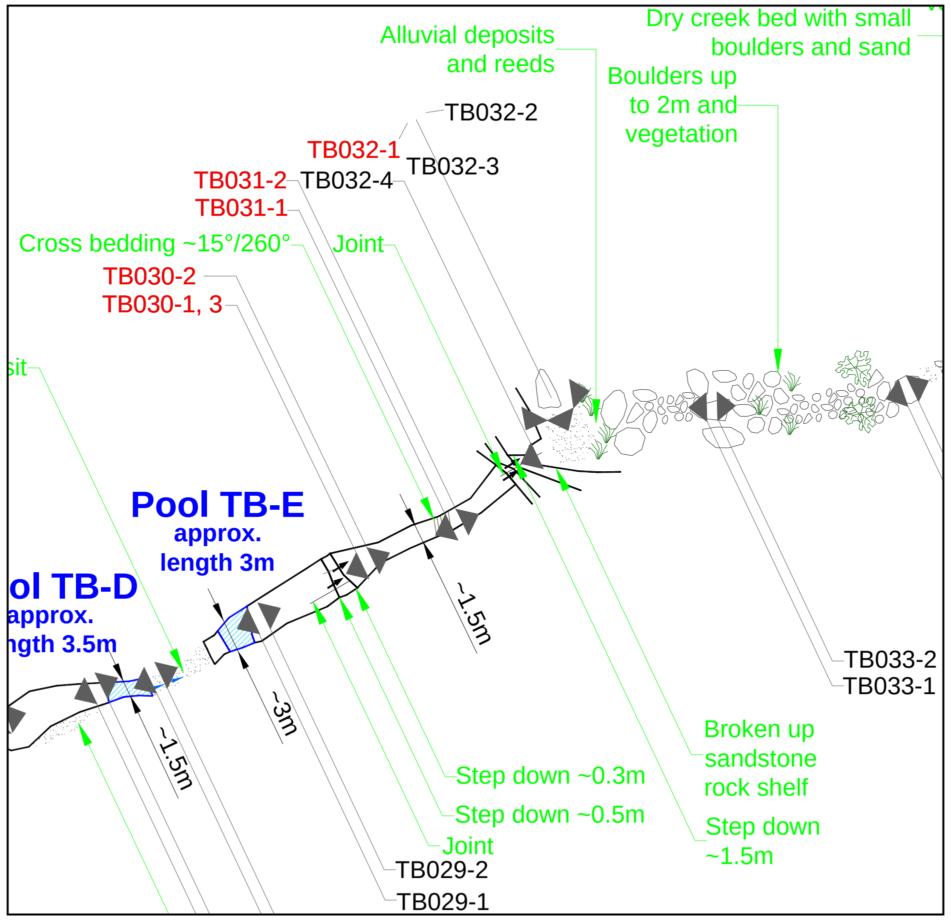
**TB030-3** Downstream from Pool TB-E looking Upstream

Notes (as at 22 December 2009)

- Approximate 0.8m change in height along rockbar downstream of Pool TB-E toward TB030
- Rockbar at TB031 approximately 1.5m wide with cross bedding and scattered vegetation debris

**TB031-1** Downstream from Pool TB-E looking Upstream

**TB031-2** Downstream from Pool TB-E looking Downstream




**TB032-1** Downstream from Pool TB-E looking Upstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TB030-1 | 308781 | 6214922 | 245 |
| TB030-2 | 308781 | 6214922 | 65 |
| TB030-3 | 308781 | 6214922 | 245 |
| TB031-1 | 308791 | 6214927 | 245 |
| TB031-2 | 308791 | 6214927 | 65 |
| TB032-1 | 308799 | 6214937 | 205 |

# TRIBUTARY B STREAM MAPPING SUMMARY

**TB032-2** Downstream from Pool TB-E looking Downstream

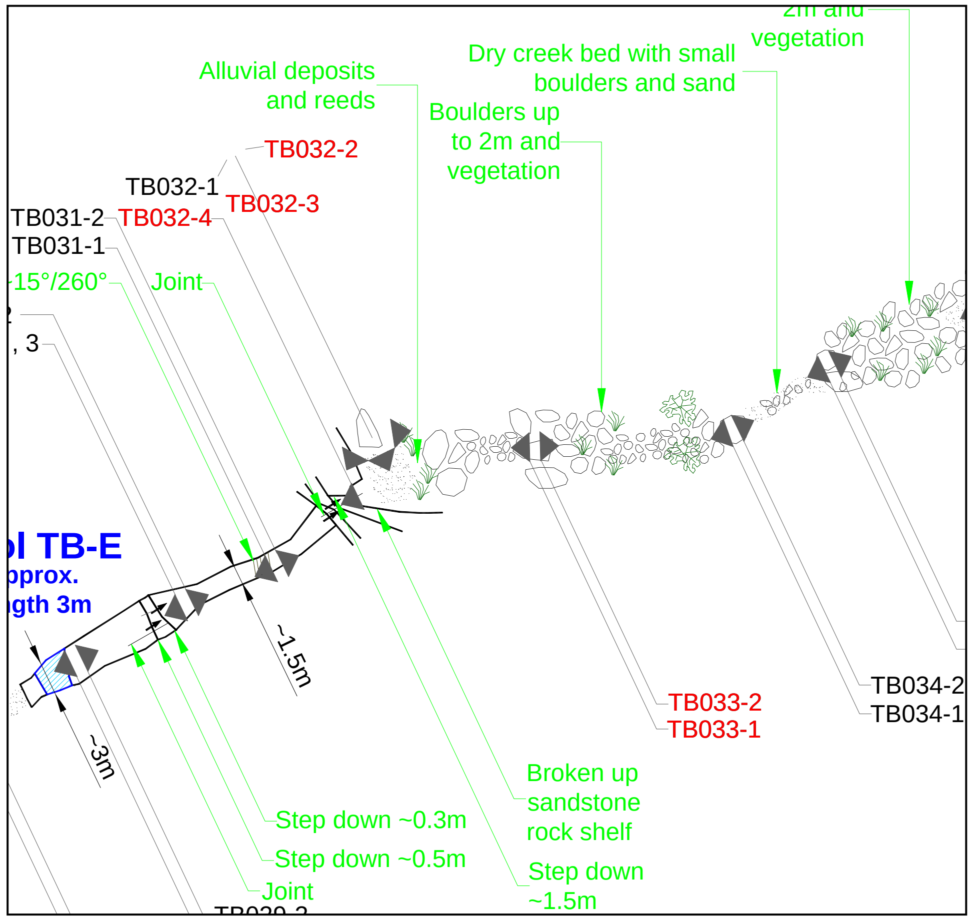
**TB032-3** Downstream from Pool TB-E looking toward southern bank

Notes (as at 22 December 2009)

- Alluvial deposits and reeds at TB032
- Boulders up to 2m and vegetation downstream
- No flow visible
- Approximate 1.5m change in height at TB032

**TB032-4** Joint

**TB033-1** Downstream from Pool TB-E looking Upstream




**TB033-2** Downstream from Pool TB-E looking Downstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TB032-2 | 308799 | 6214937 | 85 |
| TB032-3 | 308799 | 6214937 | 155 |
| TB032-4 | 308799 | 6214937 | 245 |
| TB033-1 | 308813 | 6214936 | 270 |
| TB033-2 | 308813 | 6214936 | 90 |

# TRIBUTARY B STREAM MAPPING SUMMARY

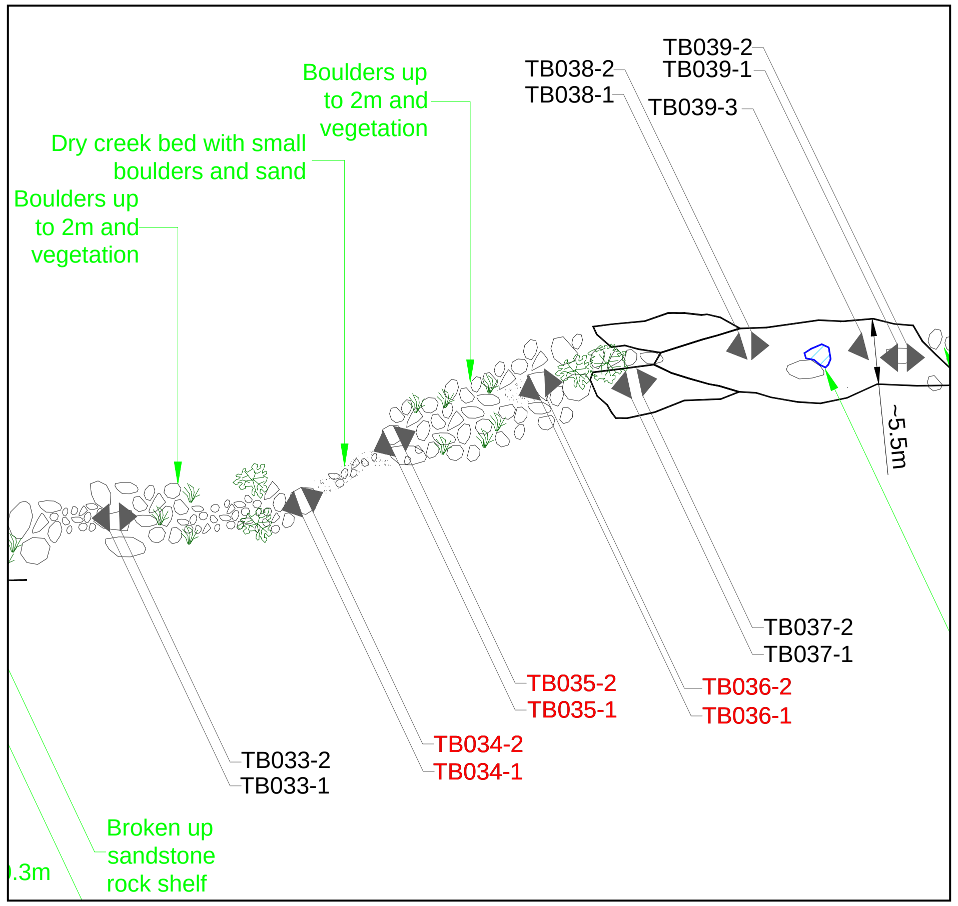
**TB034-1** Boulder field looking Upstream

Notes (as at 22 December 2009)

- Boulders up to 2m and vegetation
- Dry creek bed with small boulders and alluvial deposits
- No flow visible

**TB034-2** Boulder field looking Downstream

**TB035-1** Dry creek bed looking Upstream




**TB035-2** Boulder field looking Downstream

**TB036-1** Boulder field looking Upstream

**TB036-2** Boulder field looking Downstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TB034-1 | 308830 | 6214937 | 250 |
| TB034-2 | 308830 | 6214937 | 50 |
| TB035-1 | 308838 | 6214943 | 245 |
| TB035-2 | 308838 | 6214943 | 65 |
| TB036-1 | 308851 | 6214948 | 245 |
| TB036-2 | 308851 | 6214948 | 85 |

# TRIBUTARY B STREAM MAPPING SUMMARY

**TB037-1** Rockbar looking Upstream

**TB037-2** Rockbar looking Downstream

**TB038-1** Rockbar looking Upstream

Notes (as at 22 December 2009)

- Rockbar at TB038 approximately 25m long and 5.5m wide with minor ponding
- Boulders and vegetation both upstream and downstream of the rockbar

**TB038-2** Rockbar looking Downstream

**TB039-1** Rockbar looking Upstream

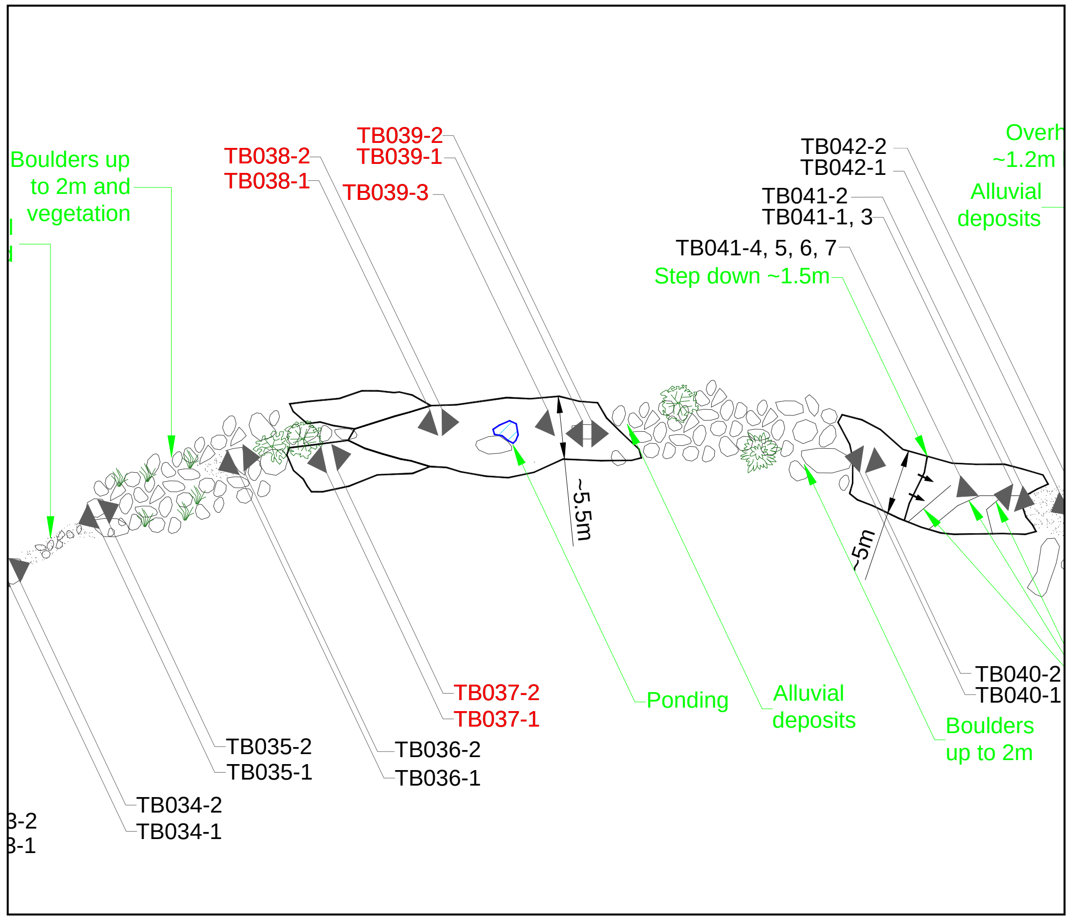



Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TB037-1 | 308857 | 6214947 | 260 |
| TB037-2 | 308857 | 6214947 | 80 |
| TB038-1 | 308870 | 6214952 | 250 |
| TB038-2 | 308870 | 6214952 | 90 |
| TB039-1 | 308884 | 6214949 | 270 |
| TB039-2 | 308884 | 6214949 | 90 |
| TB039-3 | 308884 | 6214949 | 255 |

**TB039-2** Rockbar looking Downstream

**TB039-3** Ponding

# TRIBUTARY B STREAM MAPPING SUMMARY

**TB040-1** Rockbar looking Upstream

**TB040-2** Rockbar looking Downstream

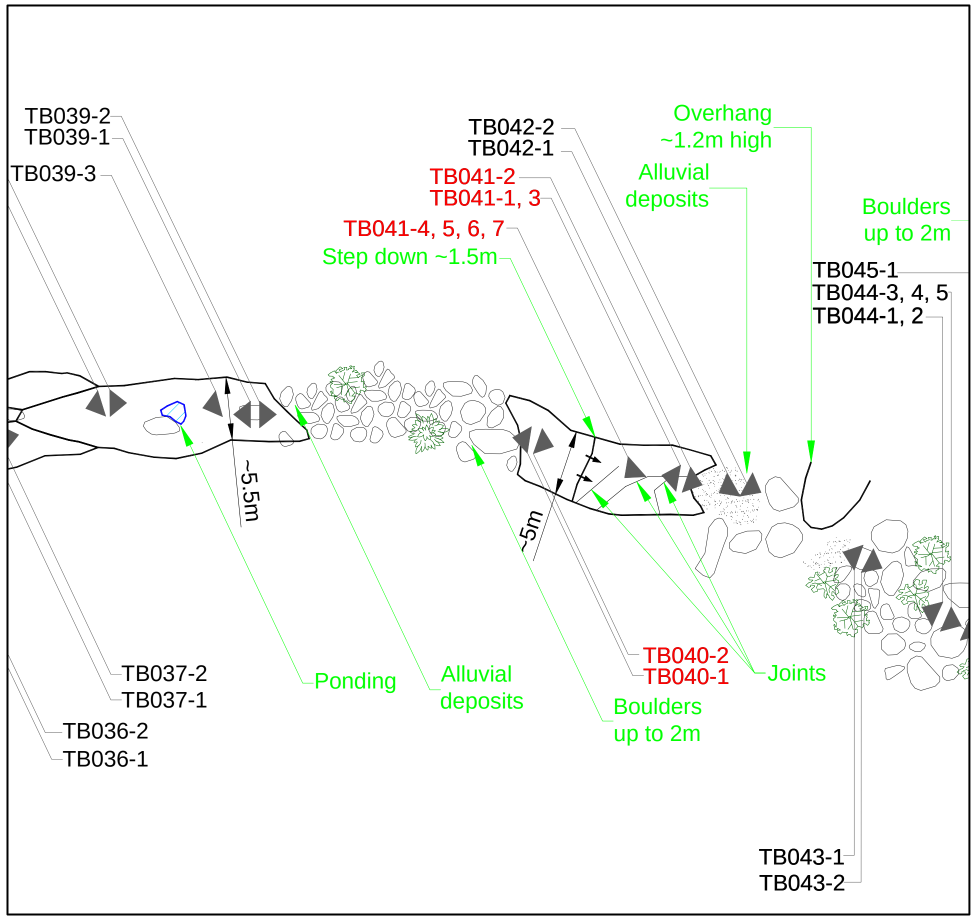
**TB041-1** Rockbar looking Upstream

Notes (as at 22 December 2009)

- Rockbar at TB040 approximately 18m long and 5m wide, with a step down of approximately 1.5m half way along
- Rockbar has many joints
- No visible flow

**TB041-2** Rockbar looking Downstream

**TB041-3** Joints




**TB041-4** Joint

**TB041-5** Joint

**TB041-6** Joint

**TB041-7** Joint

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TB040-1 | 308908 | 6214951 | 275 |
| TB040-2 | 308908 | 6214951 | 105 |
| TB041-1 | 308913 | 6214946 | 280 |
| TB041-2 | 308913 | 6214946 | 110 |
| TB041-3 | 308913 | 6214946 | 280 |
| TB041-4 | 308913 | 6214946 | 230 |
| TB041-5 | 308913 | 6214946 | 230 |
| TB041-6 | 308913 | 6214946 | 230 |
| TB041-7 | 308913 | 6214946 | 230 |

# TRIBUTARY B STREAM MAPPING SUMMARY

**TB042-1** Rockbar looking Upstream

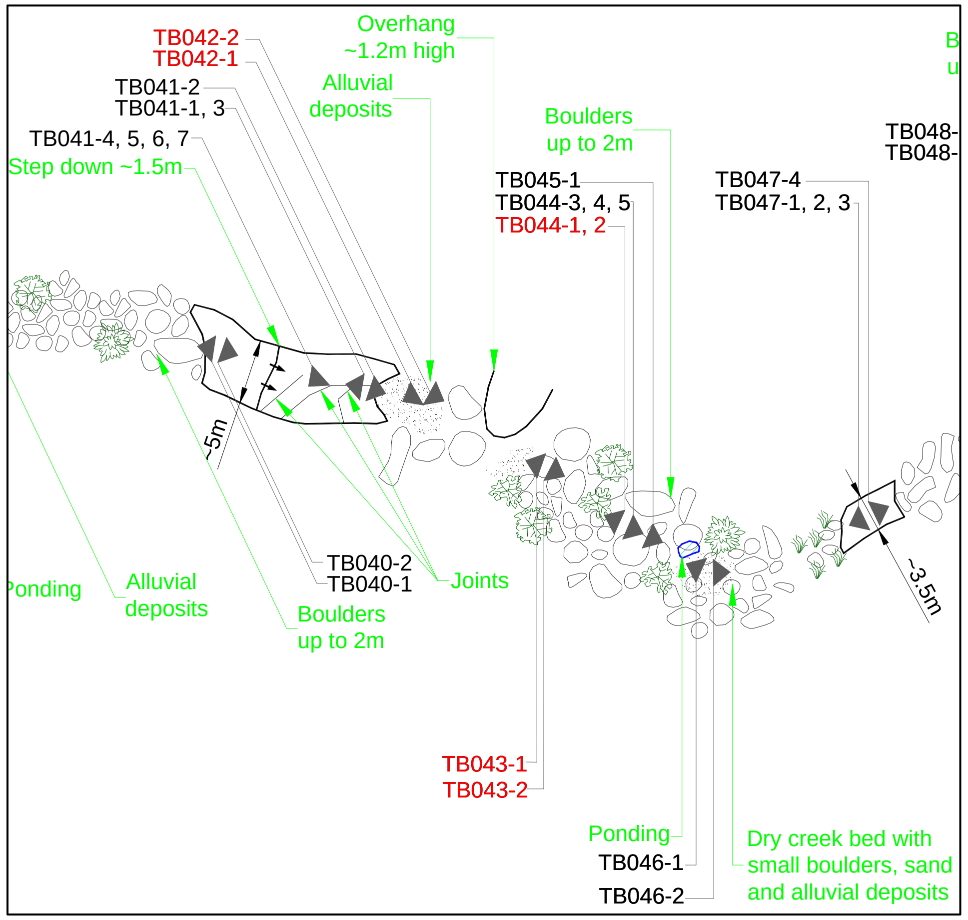
**TB042-2** Rockbar looking Downstream

**TB043-1** Boulder field looking Upstream

Notes (as at 22 December 2009)

- Alluvial depsoits, large boulders and scattered vegetation at TB042 and TB043
- No flow visible
- Overhang on northern bank approximately 1.2m high

**TB043-2** Boulder field looking Downstream




**TB044-1** Boulder field looking Upstream

**TB044-2** Boulder field looking Upstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TB042-1 | 308927 | 6214944 | 240 |
| TB042-2 | 308927 | 6214944 | 120 |
| TB043-1 | 308940 | 6214937 | 285 |
| TB043-2 | 308940 | 6214937 | 115 |
| TB044-1 | 308947 | 6214932 | 295 |
| TB044-2 | 308947 | 6214932 | 295 |

# TRIBUTARY B STREAM MAPPING SUMMARY

**TB044-3** Boulder field looking Downstream

**TB044-** Boulder field looking Downstream

**TB044-5** Boulder field looking Downstream

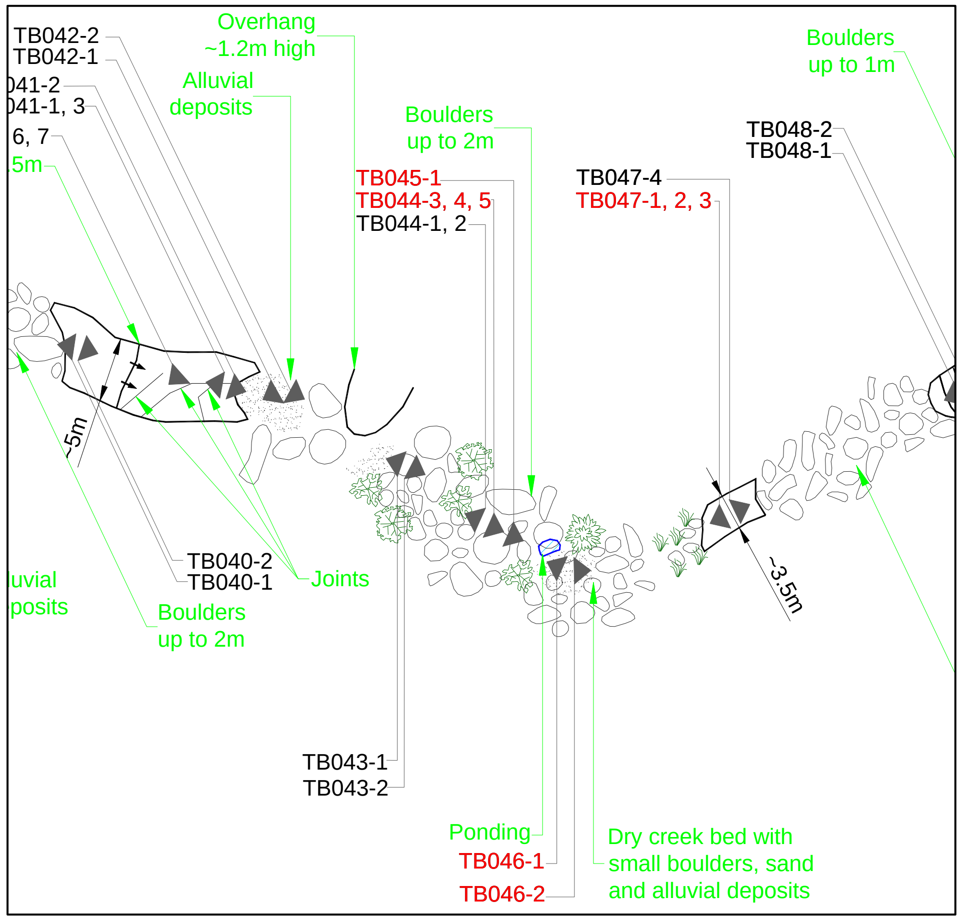
Notes (as at 22 December 2009)

- Minor ponding and alluvial deposits at TB046
- Rockbar at TB047 approximately 6m long and 3.5m wide, with boulders downstream and vegetation upstream

**TB045-1** Dry creek bed looking Upstream

**TB046-1** Boulder field looking Upstream

**TB046-2** Boulder field looking Downstream




**TB047-1** Rockbar looking Upstream

**TB047-2** Rockbar looking Upstream

**TB047-3** Rockbar looking Upstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TB044-3 | 308947 | 6214932 | 115 |
| TB044-4 | 308947 | 6214932 | 115 |
| TB044-5 | 308947 | 6214932 | 115 |
| TB045-1 | 308947 | 6214932 | 115 |
| TB046-1 | 308949 | 6214925 | 295 |
| TB046-2 | 308949 | 6214925 | 90 |
| TB047-1 | 308969 | 6214933 | 245 |
| TB047-2 | 308969 | 6214933 | 245 |
| TB047-3 | 308969 | 6214933 | 245 |

# TRIBUTARY B STREAM MAPPING SUMMARY

**TB047-4** Rockbar looking Downstream

**TB048-1** Rockbar looking Upstream

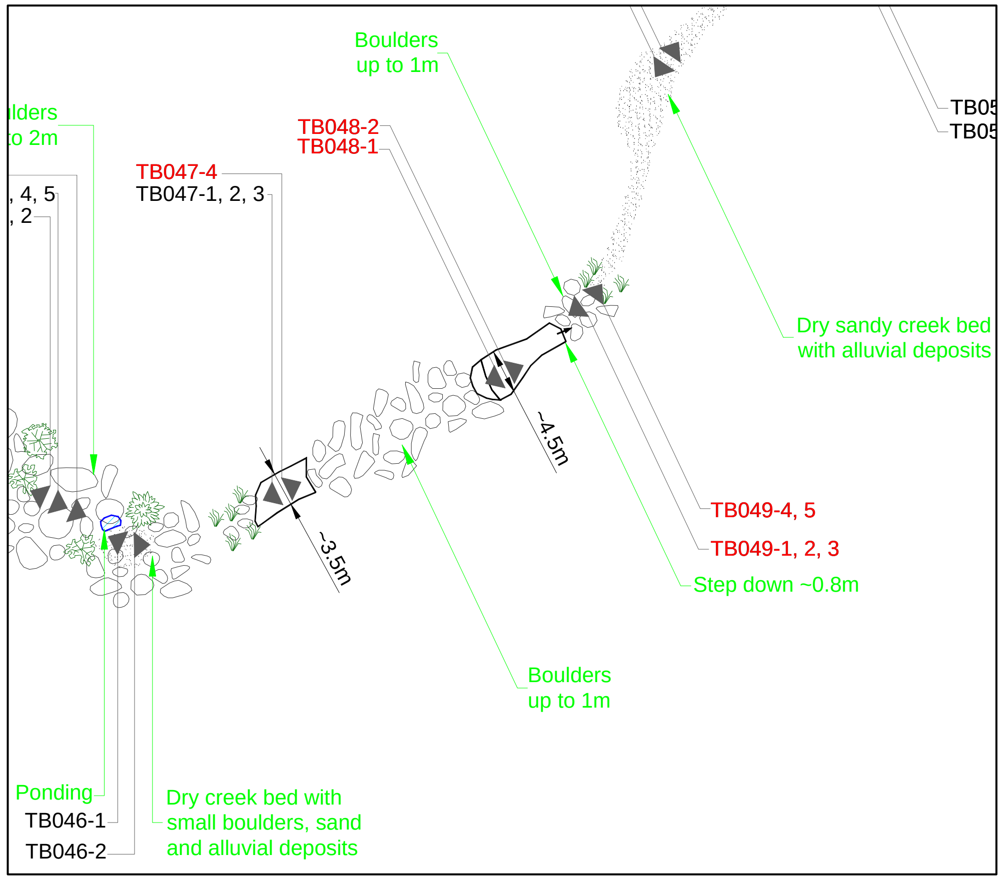
Notes (as at 22 December 2009)

- Rockbar at TB048 approximately 10m long and 4.5m wide
- Rockbar has a step down of approximately 0.4m at the upstream end
- Rockbar has a step down of approximately 0.8m at the downstream end

**TB048-2** Rockbar looking Downstream

**TB049-1** Rockbar looking Upstream

**TB049-2** Rockbar looking Upstream




**TB049-3** Rockbar looking Upstream

**TB049-4** Sandy creek bed looking Downstream

**TB049-5** Sandy creek bed looking Downstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TB047-4 | 308969 | 6214933 | 65 |
| TB048-1 | 308992 | 6214944 | 245 |
| TB048-2 | 308992 | 6214944 | 65 |
| TB049-1 | 309000 | 6214951 | 235 |
| TB049-2 | 309000 | 6214951 | 235 |
| TB049-3 | 309000 | 6214951 | 235 |
| TB049-4 | 309000 | 6214951 | 40 |
| TB049-5 | 309000 | 6214951 | 40 |

# TRIBUTARY B STREAM MAPPING SUMMARY

**TB050-1** Sandy creek bed looking Upstream

**TB050-2** Sandy creek bed looking Downstream

**TB051-1** Sandy creek bed looking Upstream

**TB051-2** Sandy creek bed looking Downstream

**TB052-1** Sandy creek bed looking Upstream

**TB052-2** Sandy creek bed looking Downstream

**TB053-1** Sandy creek bed looking Upstream

**TB053-2** Sandy creek bed looking Downstream

**TB054-1** Dry sandstone creek bed looking Upstream

**TB054-2** Dry sandstone creek bed looking Downstream

Notes (as at 22 December 2009)

- Alluvial deposits extend over approximately 65m downstream between TB049 and TB053
- Alluvial deposits open up to dry sandstone creek bed at TB054

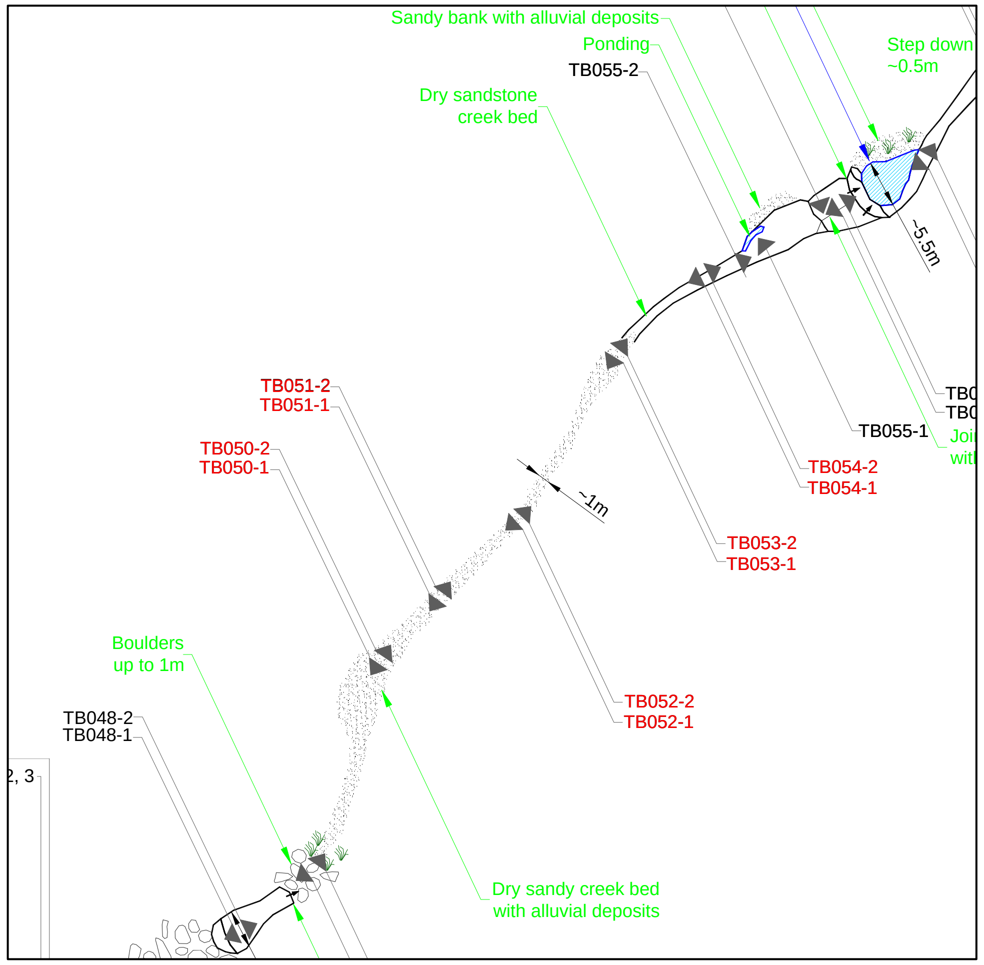



Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TB050-1 | 309008 | 6214975 | 215 |
| TB050-2 | 309008 | 6214975 | 35 |
| TB051-1 | 309010 | 6214986 | 215 |
| TB051-2 | 309010 | 6214986 | 35 |
| TB052-1 | 309026 | 6214988 | 230 |
| TB052-2 | 309026 | 6214988 | 45 |
| TB053-1 | 309035 | 6215010 | 210 |
| TB053-2 | 309035 | 6215010 | 35 |
| TB054-1 | 309045 | 6215019 | 245 |
| TB054-2 | 309045 | 6215019 | 65 |

# TRIBUTARY B STREAM MAPPING SUMMARY

**TB055-1** Upstream from Pool TB-F looking toward northern bank

**TB055-2** Upstream from Pool TB-F looking Downstream

**TB056-1** Upstream end of Pool TB-F looking Upstream

Notes (as at 22 December 2009)

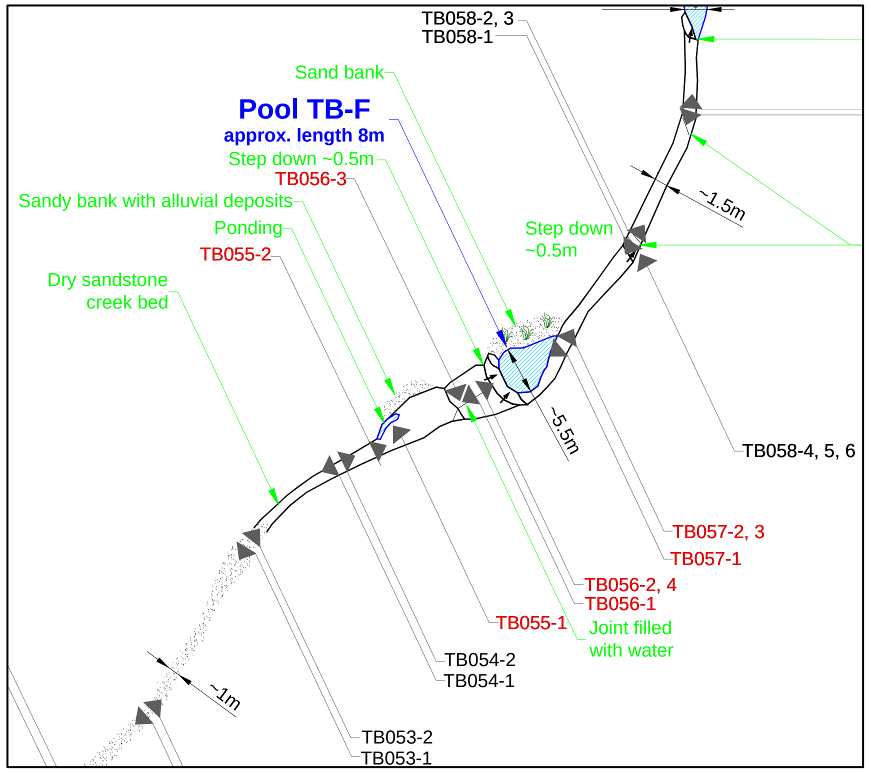
- Minor ponding at TB055 with scattered vegetation debris and alluvial deposits on northern bank
- Joint along centre of rockbar at TB056

- Pool TB-F approximately 8m long, 5.5m wide and 0.5 m deep
- Sand deposit on northern bank
- Rockbar upstream steps down approximately 0.5m to Pool TB-F
- No flow visible downstream of pool

**TB056-2** Upstream end of Pool TB-F looking Downstream

**TB056-3** Joint

**TB056-4** Joint




**TB057-1** Downstream end of Pool TB-F looking Upstream

**TB057-2** Downstream end of Pool TB-F looking Downstream

**TB057-3** Downstream end of Pool TB-F looking Downstream

Photo Details

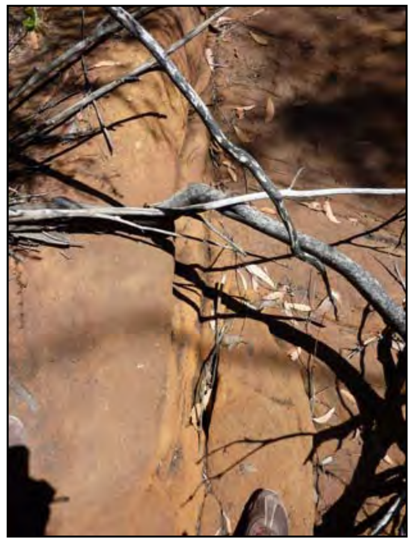
| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TB055-1 | 309052 | 6215022 | 325 |
| TB055-2 | 309052 | 6215022 | 65 |
| TB056-1 | 309057 | 6215026 | 240 |
| TB056-2 | 309057 | 6215026 | 60 |
| TB056-3 | 309057 | 6215026 | 155 |
| TB056-4 | 309057 | 6215026 | 60 |
| TB057-1 | 309070 | 6215032 | 235 |
| TB057-2 | 309070 | 6215032 | 30 |
| TB057-3 | 309070 | 6215032 | 30 |

# TRIBUTARY B STREAM MAPPING SUMMARY

**TB058-1** Downstream from Pool TB-F looking Upstream

**TB058-2** Downstream from Pool TB-F looking Downstream

**TB058-3** Downstream from Pool TB-F looking Downstream



**TB058-4** Joint

**TB058-5** Joint

**TB058-6** Joint

**TB059-1** Upstream from Pool TB-G looking Upstream

**TB059-2** Upstream from Pool TB-G looking Downstream

**TB059-3** Joint

**TB060-1** Downstream end of Pool TB-G looking Upstream

**TB060-2** Downstream end of Pool TB-G looking Downstream

Notes (as at 22 December 2009)

- Rockbar at TB058 approximately 1.5m wide, with a step down of approximately 0.5m
- Water-filled joints across rockbar at TB058 and TB059
- Step down of approximately 0.8m at upstream end of Pool TB-G

- Pool TB-G approximately 5m long, 2m wide and 0.5m deep
- Base of the pool is sandstone
- Exposed sandstone with scattered vegetation debris downstream of the pool

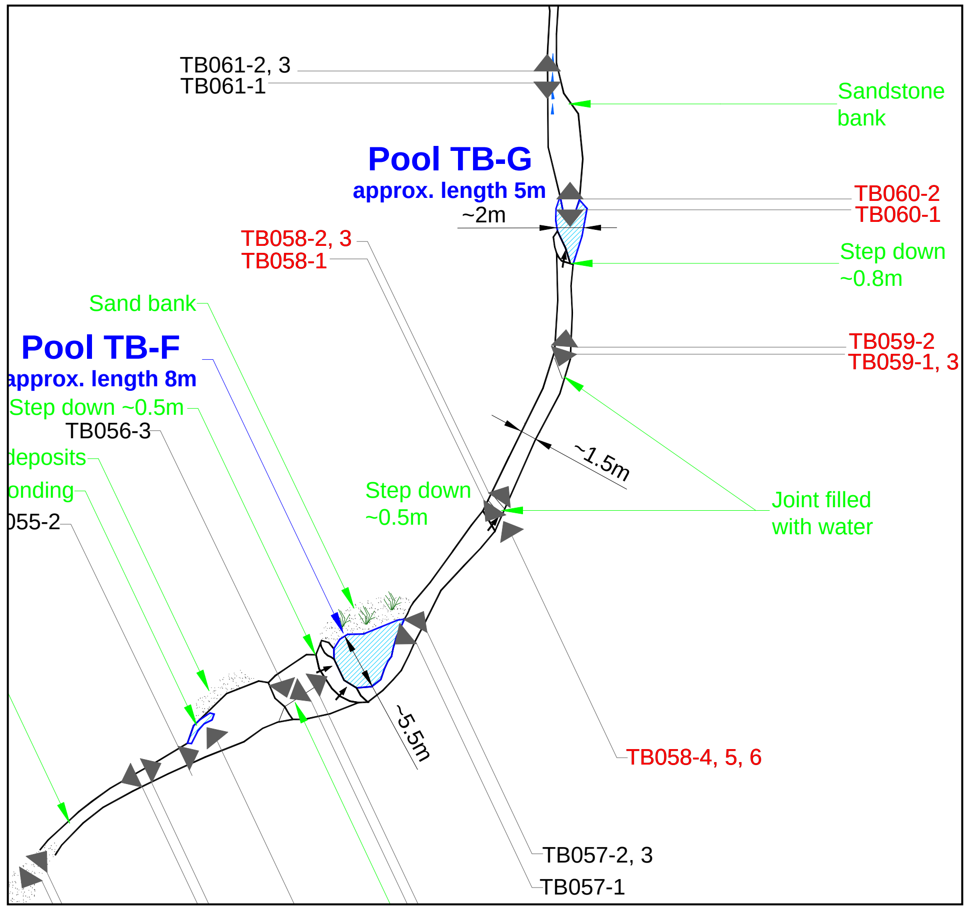


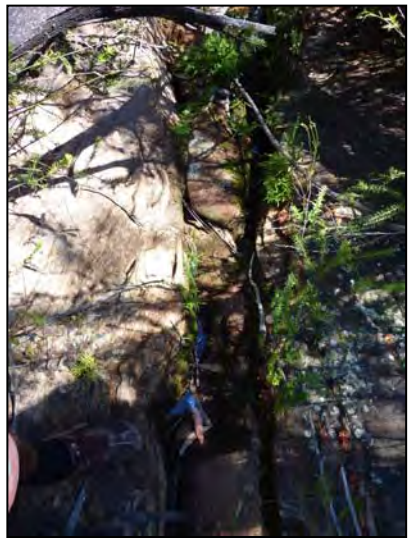

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TB058-1 | 309077 | 6215042 | 215 |
| TB058-2 | 309077 | 6215042 | 30 |
| TB058-3 | 309077 | 6215042 | 30 |
| TB058-4 | 309077 | 6215042 | 330 |
| TB058-5 | 309077 | 6215042 | 330 |
| TB058-6 | 309077 | 6215042 | 330 |
| TB059-1 | 309084 | 6215057 | 195 |
| TB059-2 | 309084 | 6215057 | 10 |
| TB059-3 | 309084 | 6215057 | 195 |
| TB060-1 | 309085 | 6215072 | 180 |
| TB060-2 | 309085 | 6215072 | 0 |

# TRIBUTARY B STREAM MAPPING SUMMARY

**TB061-1** Downstream from Pool TB-G looking Upstream

**TB061-2** Downstream from Pool TB-G looking Downstream

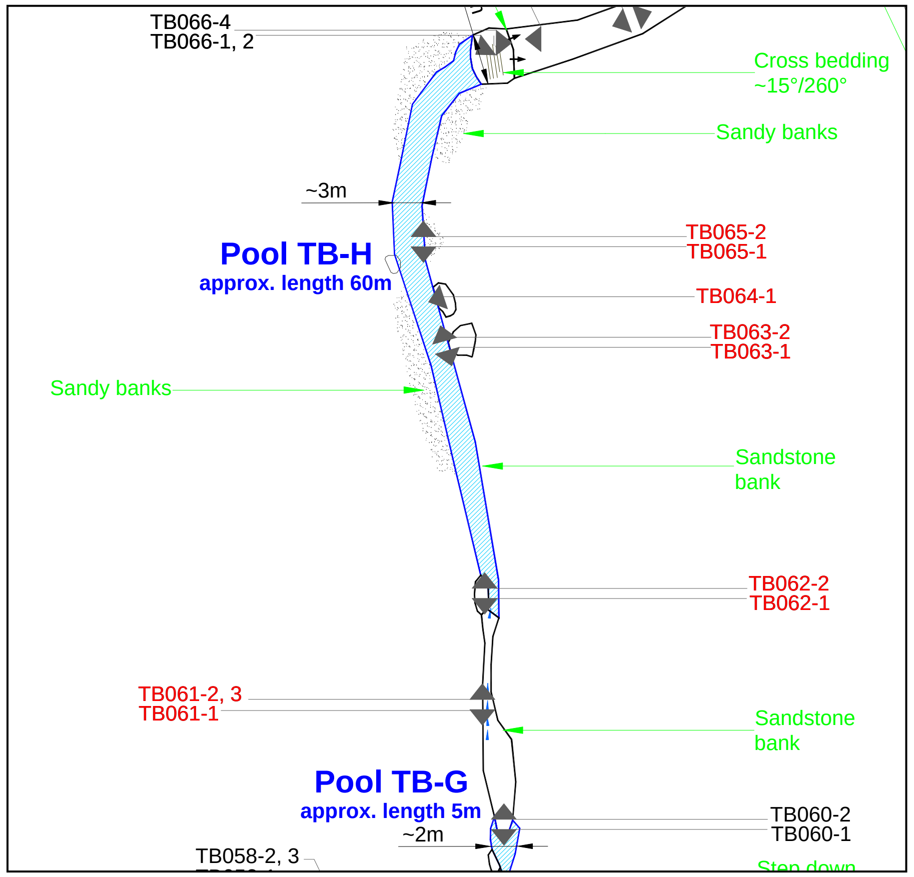


**TB061-3** Joint

Notes (as at 22 December 2009)

- Flow path along western side of rockbar at TB061

- Pool TB-H approximately 60m long, up to 3m wide and up to 0.4m deep
- Base of the pool is sandstone with vegetation encroaching on both sides
- Vegetation debris across pool at many locations
- Alluvial deposits on banks at downstream end of pool




**TB062-1** Upstream end of Pool TB-H looking Upstream

**TB062-2** Upstream end of Pool TB-H looking Downstream

**TB063-1** Midway along Pool TB-H looking Upstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TB061-1 | 309082 | 6215084 | 180 |
| TB061-2 | 309082 | 6215084 | 0 |
| TB061-3 | 309082 | 6215084 | 0 |
| TB062-1 | 309086 | 6215095 | 180 |
| TB062-2 | 309086 | 6215095 | 0 |
| TB063-1 | 309080 | 6215120 | 165 |
| TB063-2 | 309080 | 6215120 | 345 |
| TB064-1 | 309079 | 6215125 | 250 |
| TB065-1 | 309077 | 6215130 | 180 |
| TB065-2 | 309077 | 6215130 | 0 |

**TB063-2** Midway along Pool TB-H looking Downstream

**TB064-1** Midway along Pool TB-H looking toward western bank

**TB065-1** Midway along Pool TB-H looking Upstream

**TB065-2** Midway along Pool TB-H looking Downstream

# TRIBUTARY B STREAM MAPPING SUMMARY

**TB066-1** Downstream end of Pool TB-H looking Upstream

**TB066-2** Downstream end of Pool TB-H looking Upstream

**TB066-3** Downstream end of Pool TB-H looking Upstream

**TB066-4** Downstream end of Pool TB-H looking Downstream

**TB067-1** Downstream of Pool TB-H looking Upstream

**TB067-2** Downstream of Pool TB-H looking Downstream

**TB068-1** Downstream of Pool TB-H looking Upstream

**TB068-2** Downstream of Pool TB-H looking Downstream

Notes (as at 22 December 2009)

- Rockbar at downstream end of Pool TB-H approximately 4m long and 5m wide with cross bedding
- Approximate 1m step down at downstream end of rockbar
- Rockbar approximately 50m long through TB067 and TB068, with much vegetation debris
- No flow visible on rockbar

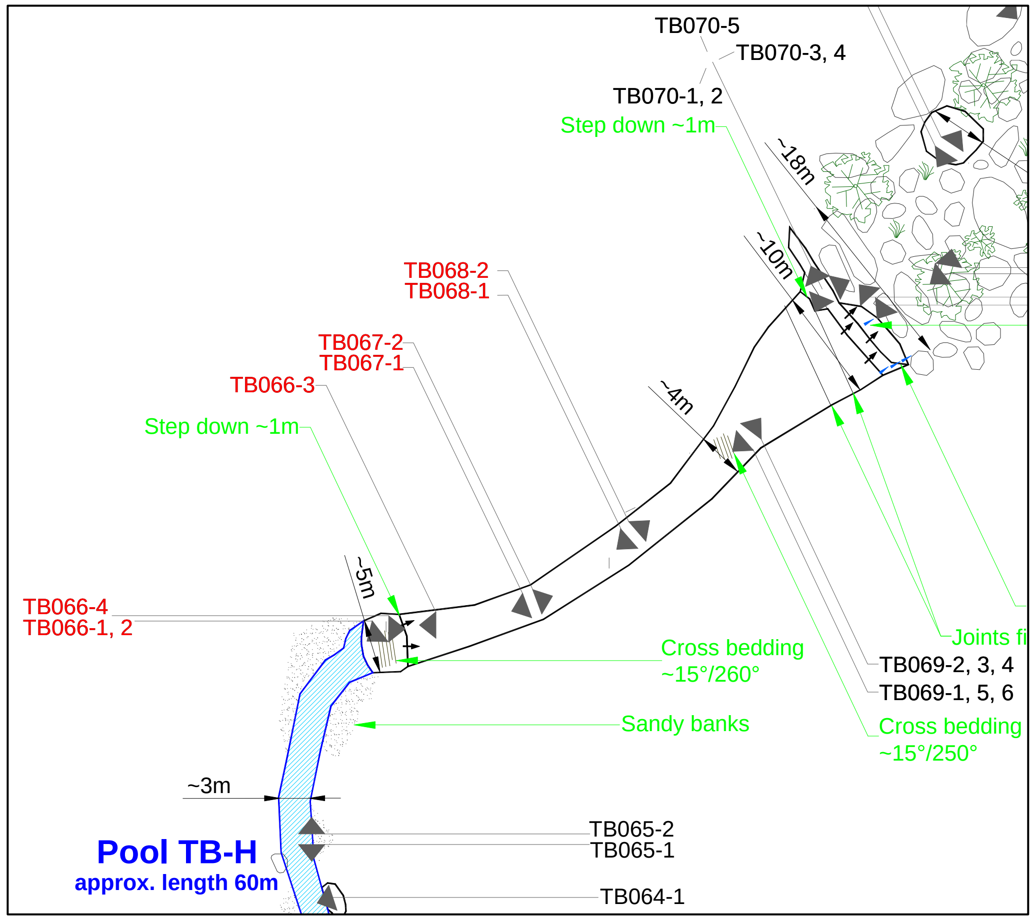



Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TB066-1 | 309084 | 6215150 | 235 |
| TB066-2 | 309084 | 6215150 | 235 |
| TB066-3 | 309084 | 6215150 | 270 |
| TB066-4 | 309084 | 6215150 | 90 |
| TB067-1 | 309098 | 6215151 | 250 |
| TB067-2 | 309098 | 6215151 | 70 |
| TB068-1 | 309104 | 6215156 | 235 |
| TB068-2 | 309104 | 6215156 | 45 |

# TRIBUTARY B STREAM MAPPING SUMMARY

**TB069-1** Rockbar looking Upstream

**TB069-2** Rockbar looking Downstream

**TB069-3** Cross bedding

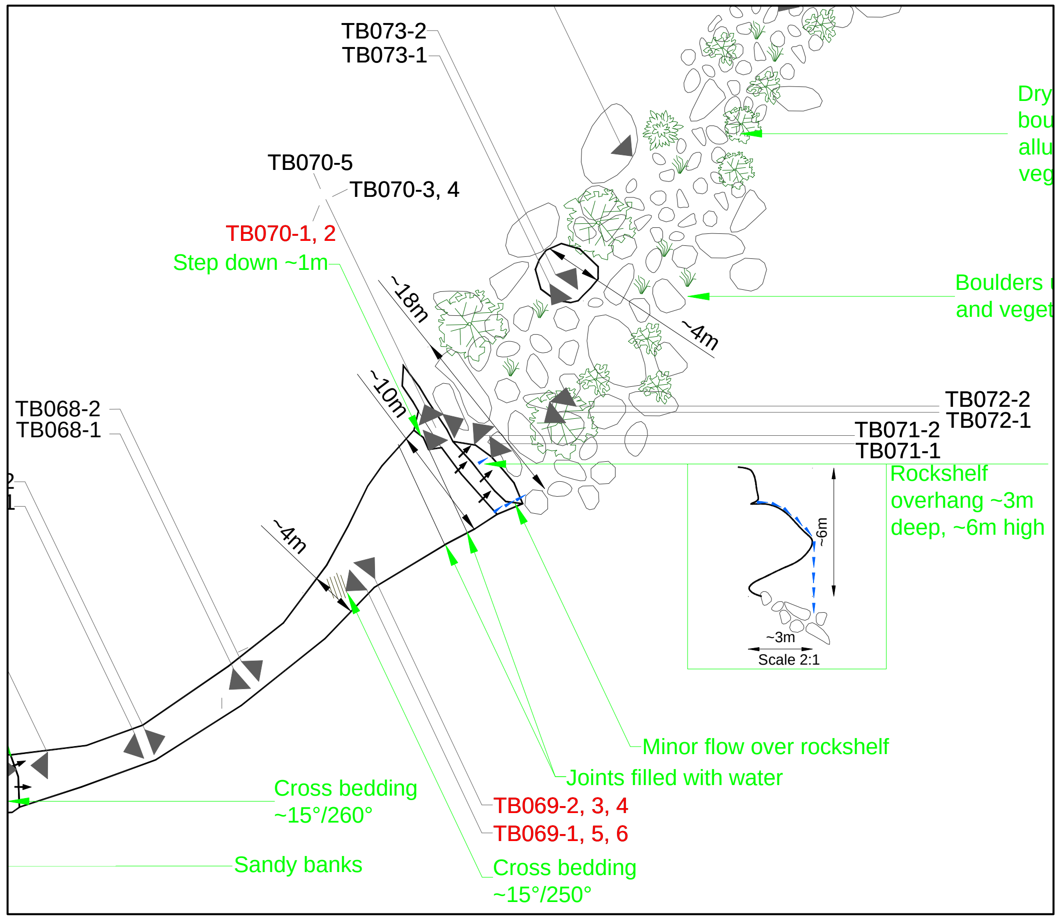
Notes (as at 22 December 2009)

- Rockbar at TB069 approximately 4m wide with cross bedding
- Rockbar widens to approximately 10m at TB070, with a step down of approximately 1m
- Joints across width of rockbar at downstream end

**TB069-4** Cross bedding

**TB069-5** Joint with water

**TB069-6** Joint with water




**TB070-1** Rockshelf looking Upstream

**TB070-2** Rockshelf looking Upstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TB069-1 | 309115 | 6215167 | 225 |
| TB069-2 | 309115 | 6215167 | 35 |
| TB069-3 | 309115 | 6215167 | 35 |
| TB069-4 | 309115 | 6215167 | 35 |
| TB069-5 | 309115 | 6215167 | 225 |
| TB069-6 | 309115 | 6215167 | 225 |
| TB070-1 | 309126 | 6215181 | 200 |
| TB070-2 | 309126 | 6215181 | 200 |

# TRIBUTARY B STREAM MAPPING SUMMARY

**TB070-3** Looking Downstream from high rockshelf

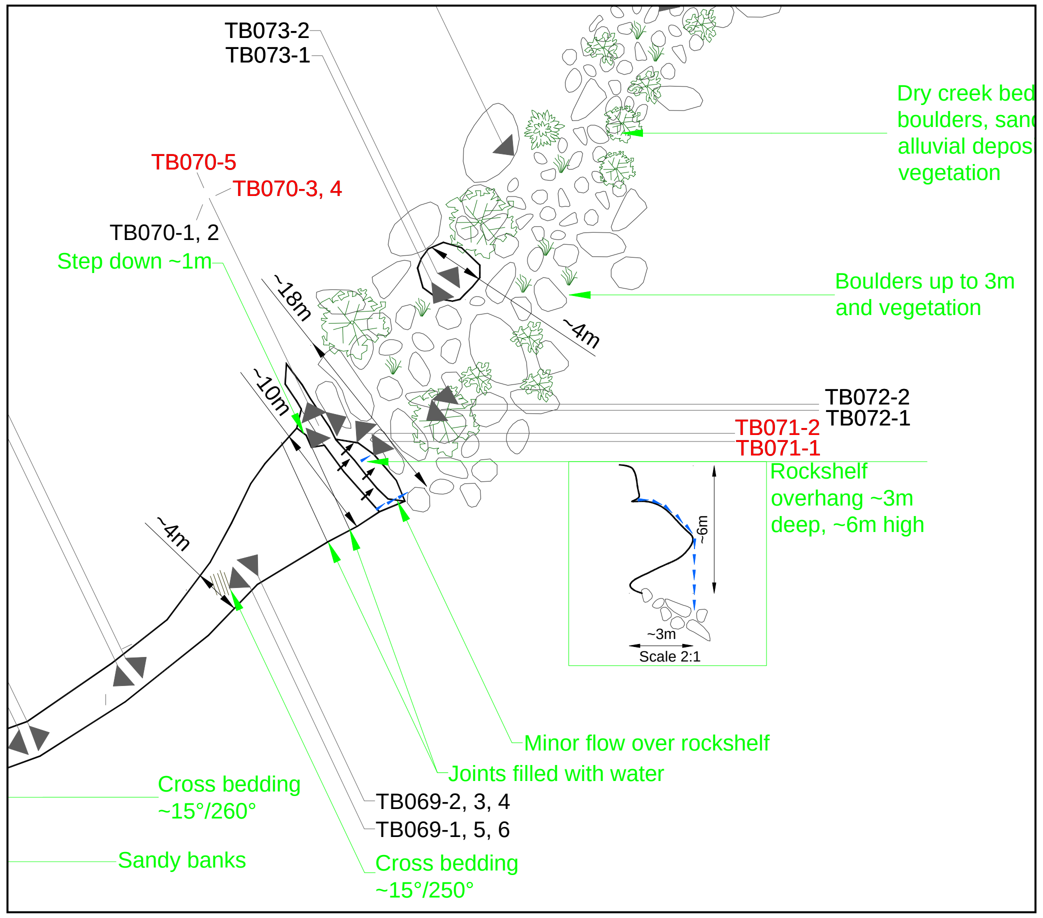
Notes (as at 22 December 2009)

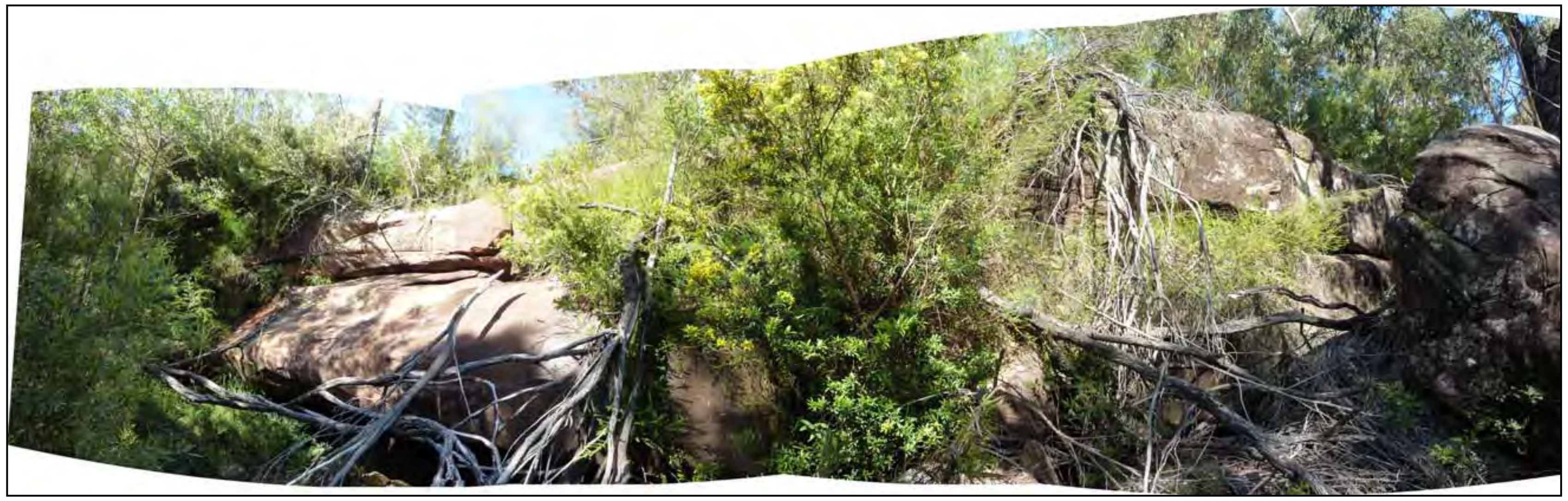
- Rockshelf approximately 6m high and 3m deep at TB071
- Minor flow over rockshelf on southern side
- Boulders and vegetation at base of rockshelf and downstream

**TB070-4** Looking Downstream from top of rockshelf

**TB070-5** Joint

**TB071-2** Looking North West along rockshelf



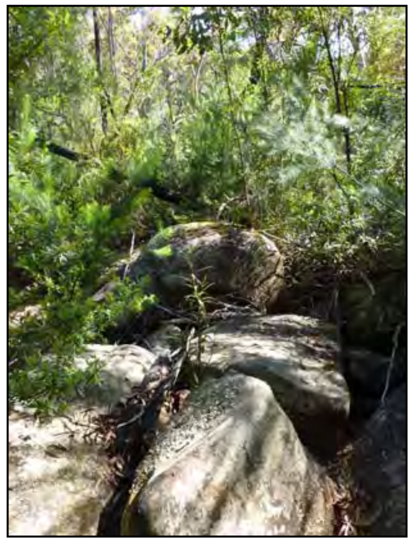
**TB071-1** Looking Upstream to rockshelf

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TB070-3 | 309126 | 6215181 | 70 |
| TB070-4 | 309126 | 6215181 | 70 |
| TB070-5 | 309126 | 6215181 | 335 |
| TB071-1 | 309131 | 6215182 | 205 |
| TB071-2 | 309131 | 6215182 | 215 |

# TRIBUTARY B STREAM MAPPING SUMMARY

**TB072-1** Boulder field looking Upstream



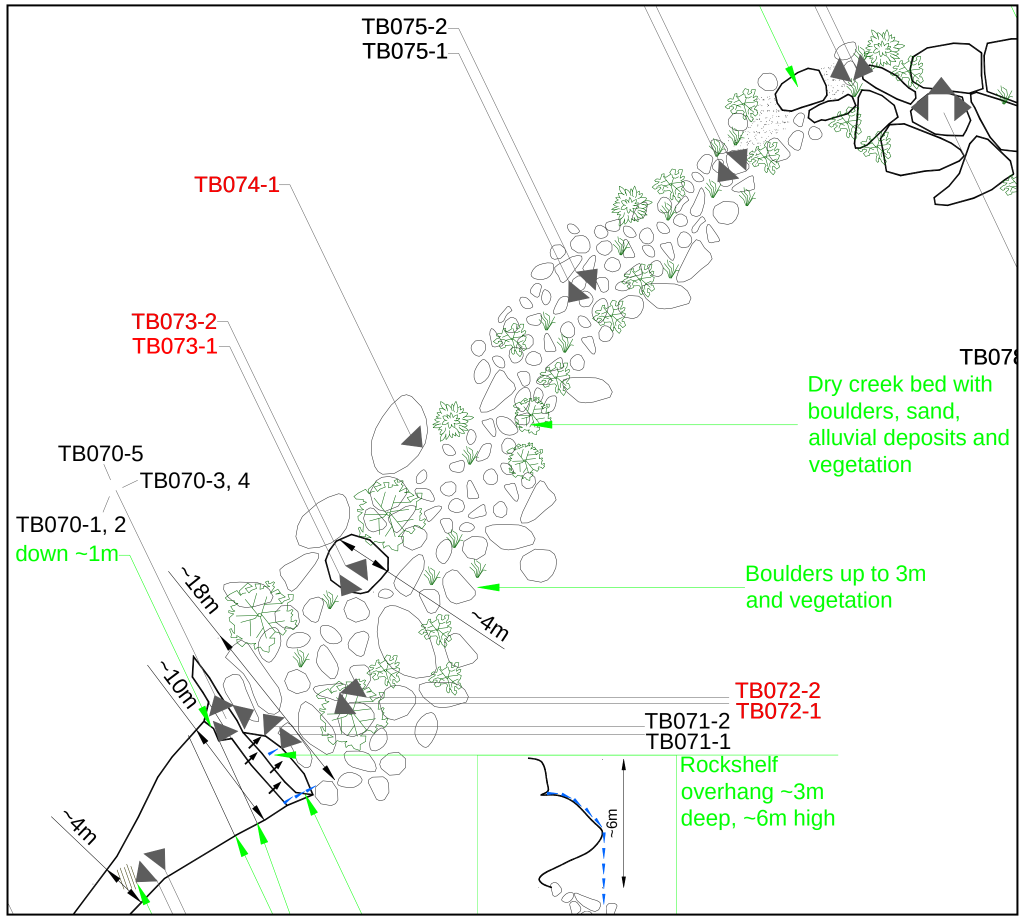
**TB072-2** Boulder field looking Downstream

**TB073-1** Boulder field looking Upstream

Notes (as at 21 & 22 December 2009)

- Boulder field and vegetation through TB072, TB073 and TB074, with boulders up to 3m
- Minor alluvial deposits
- No flow visible

**TB073-2** Boulder field looking Downstream




**TB074-1** Boulder field looking toward eastern bank

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TB072-1 | 309133 | 6215178 | 230 |
| TB072-2 | 309133 | 6215178 | 35 |
| TB073-1 | 309137 | 6215195 | 205 |
| TB073-2 | 309137 | 6215195 | 35 |
| TB074-1 | 309141 | 6215208 | 135 |

# TRIBUTARY B STREAM MAPPING SUMMARY

**TB075-1** Dry creek bed looking Upstream

**TB075-2** Dry creek bed looking Downstream

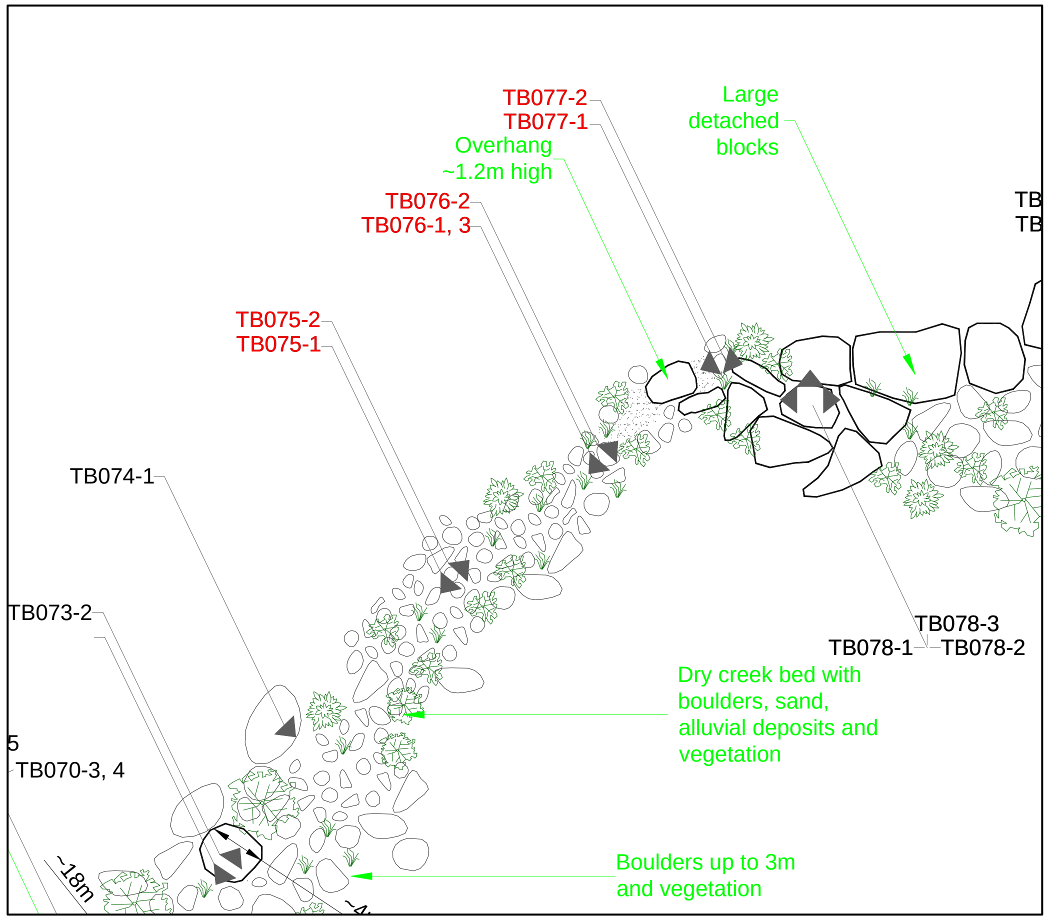
**TB076-1** Dry creek bed looking Upstream

Notes (as at 21 December 2009)

- Boulder field and vegetation through TB075, TB076 and TB077, with minor alluvial deposits
- No flow visible

**TB076-2** Dry creek bed looking Downstream

**TB076-3** Dry creek bed looking Upstream




**TB077-1** Boulder field looking Upstream

**TB077-2** Boulder field looking Downstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TB075-1 | 309157 | 6215224 | 220 |
| TB075-2 | 309157 | 6215224 | 45 |
| TB076-1 | 309173 | 6215234 | 225 |
| TB076-2 | 309173 | 6215234 | 35 |
| TB076-3 | 309173 | 6215234 | 225 |
| TB077-1 | 309183 | 6215242 | 245 |
| TB077-2 | 309183 | 6215242 | 100 |

# TRIBUTARY B STREAM MAPPING SUMMARY

**TB078-1** Large detached blocks looking Upstream

**TB078-2** Large detached blocks looking Downstream

**TB078-3** Large detached blocks looking toward northern bank

Notes (as at 21 December 2009)

- Large detached blocks on northern bank and tributary path
- No flow visible through boulder field

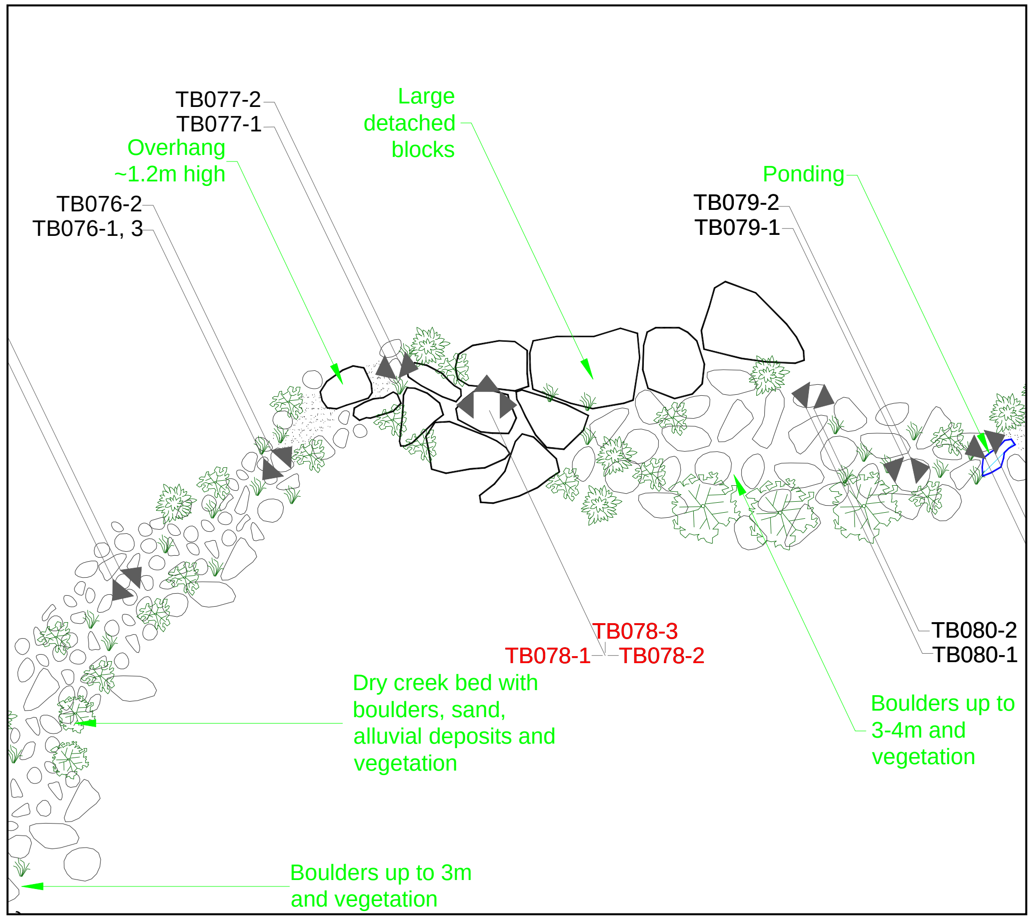



Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TB078-1 | 309192 | 6215239 | 270 |
| TB078-2 | 309192 | 6215239 | 90 |
| TB078-3 | 309192 | 6215239 | 0 |

# TRIBUTARY B STREAM MAPPING SUMMARY

**TA079-1** Boulder field looking Upstream

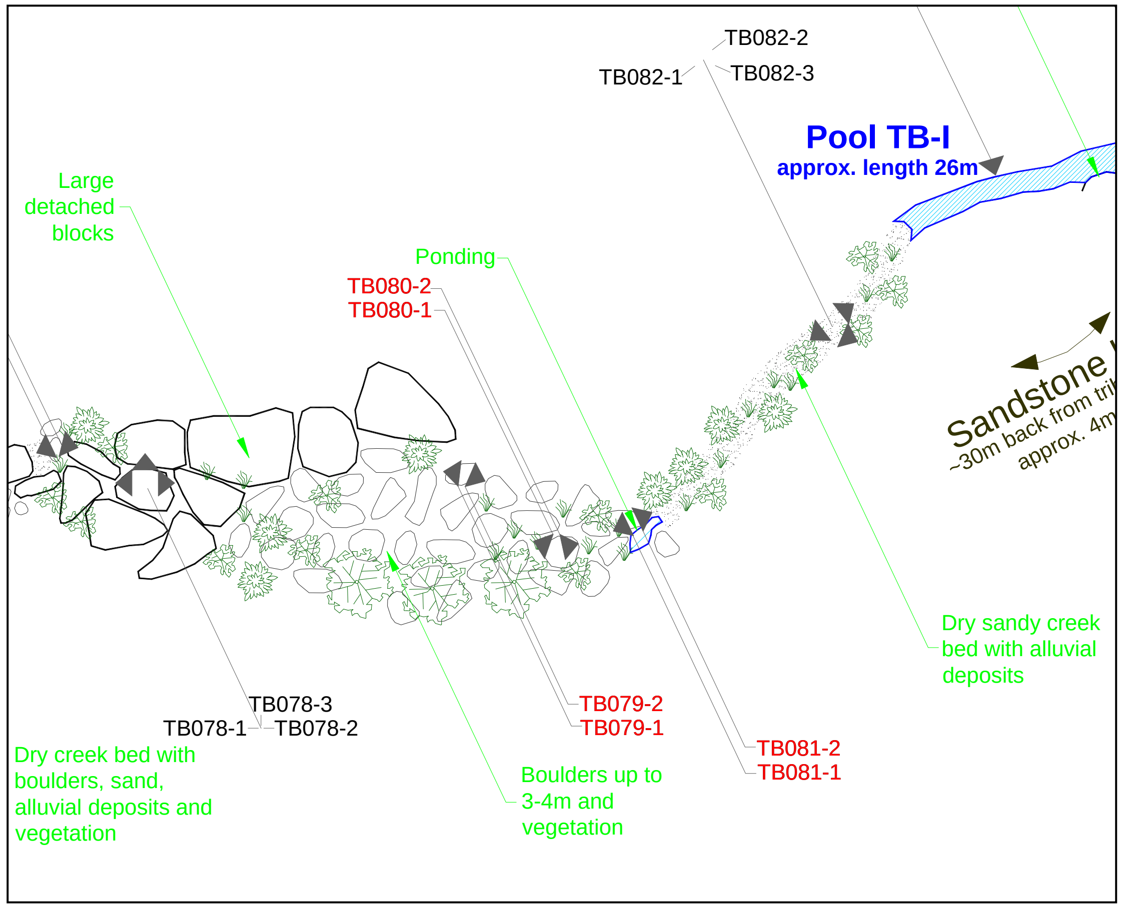
**TA079-2** Boulder field looking Downstream

<u>Notes (as at 21 December 2009)</u>

- Large boulders and vegetation through TB079 and TB080
- No flow visible
- Ponding and alluvial deposits at TB081, with vegetation downstream

**TA080-1** Boulder field looking Upstream

**TA080-2** Boulder field looking Downstream




**TA081-1** Upstream of Pool TB-I looking Upstream

**TA081-2** Upstream of Pool TB-I looking Downstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TB079-1 | 309223 | 6215242 | 290 |
| TB079-2 | 309223 | 6215242 | 75 |
| TB080-1 | 309232 | 6215234 | 275 |
| TB080-2 | 309232 | 6215234 | 115 |
| TB081-1 | 309238 | 6215235 | 245 |
| TB081-2 | 309238 | 6215235 | 65 |

# TRIBUTARY B STREAM MAPPING SUMMARY

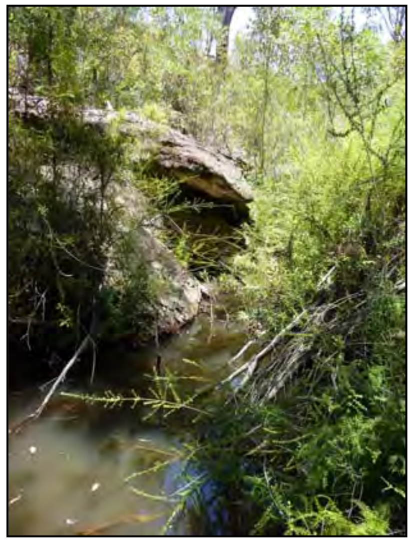
**TB082-1** Upstream of Pool TB-I looking Upstream

**TB082-2** Upstream of Pool TB-I looking Downstream

**TB082-3** Upstream of Pool TB-I looking toward southern bank

**TB083-1** Midway along Pool TB-I looking toward southern bank

**TB084-1** Downstream end of Pool TB-I looking Upstream



**TB084-2** Overhang

Notes (as at 21 December 2009)

- Dry creek bed with alluvial deposits upstream of Pool TB-I

- Pool TB-I approximately 26m long, up to 3.5m wide and 0.5m deep
- Base of the pool is sandstone
- Overhang on southern bank approximately 1.8m high and 1m deep
- Alluvial deposits downstream of pool

- Sandstone ledge up to 4m high on southern side of Pool TB-I at a distance of approximately 30m

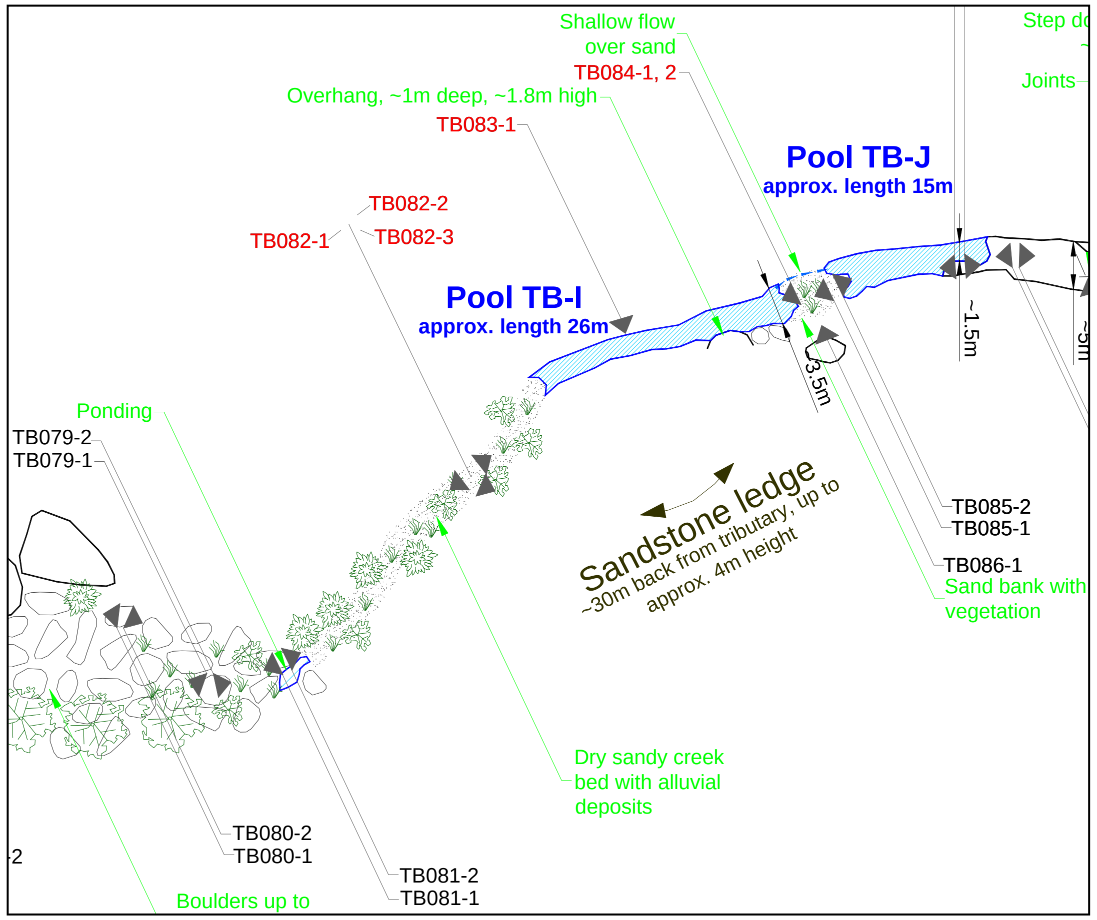



Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TB082-1 | 309256 | 6215256 | 235 |
| TB082-2 | 309256 | 6215256 | 50 |
| TB082-3 | 309256 | 6215256 | 110 |
| TB083-1 | 309273 | 6215270 | 165 |
| TB084-1 | 309290 | 6215270 | 245 |
| TB084-2 | 309290 | 6215270 | 245 |

# TRIBUTARY B STREAM MAPPING SUMMARY

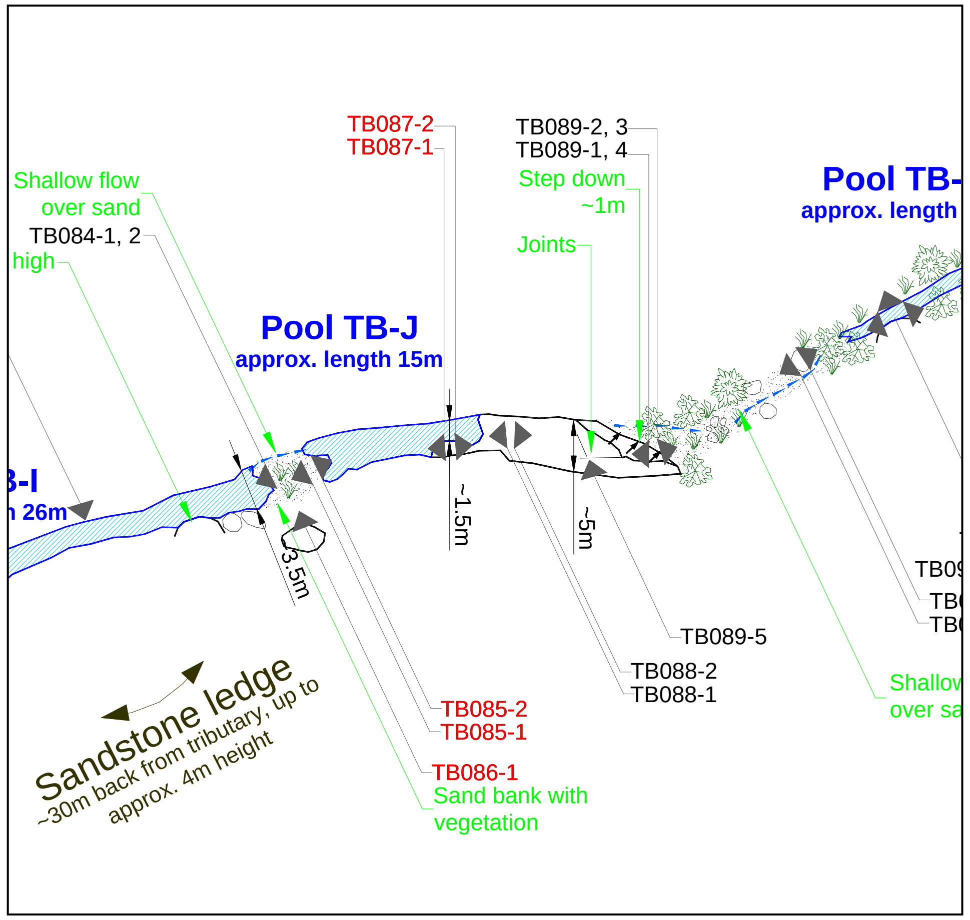
**TB085-1** Upstream end of Pool TB-J looking Upstream

**TB085-2** Upstream end of Pool TB-J looking Downstream

Notes (as at 21 December 2009)

- Pool TB-J approximately 5m long, 1.5m wide and 0.3m deep
- Base of the pool is alluvial at the upstream end and sandstone at the downstream end
- Sand bank with vegetation upstream of the pool
- Shallow flow along northern side of sand bank at upstream end of pool

**TB086-1** Between Pools TB-I and TB-J looking toward northern bank




**TB087-1** Along Pool TB-J looking Upstream

**TB087-2** Along Pool TB-J looking Downstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TB085-1 | 309294 | 6215273 | 245 |
| TB085-2 | 309294 | 6215273 | 65 |
| TB086-1 | 309300 | 6215265 | 340 |
| TB087-1 | 309310 | 6215276 | 265 |
| TB087-2 | 309310 | 6215276 | 85 |

# TRIBUTARY B STREAM MAPPING SUMMARY

**TB088-1** Downstream end of Pool TB-J looking Upstream

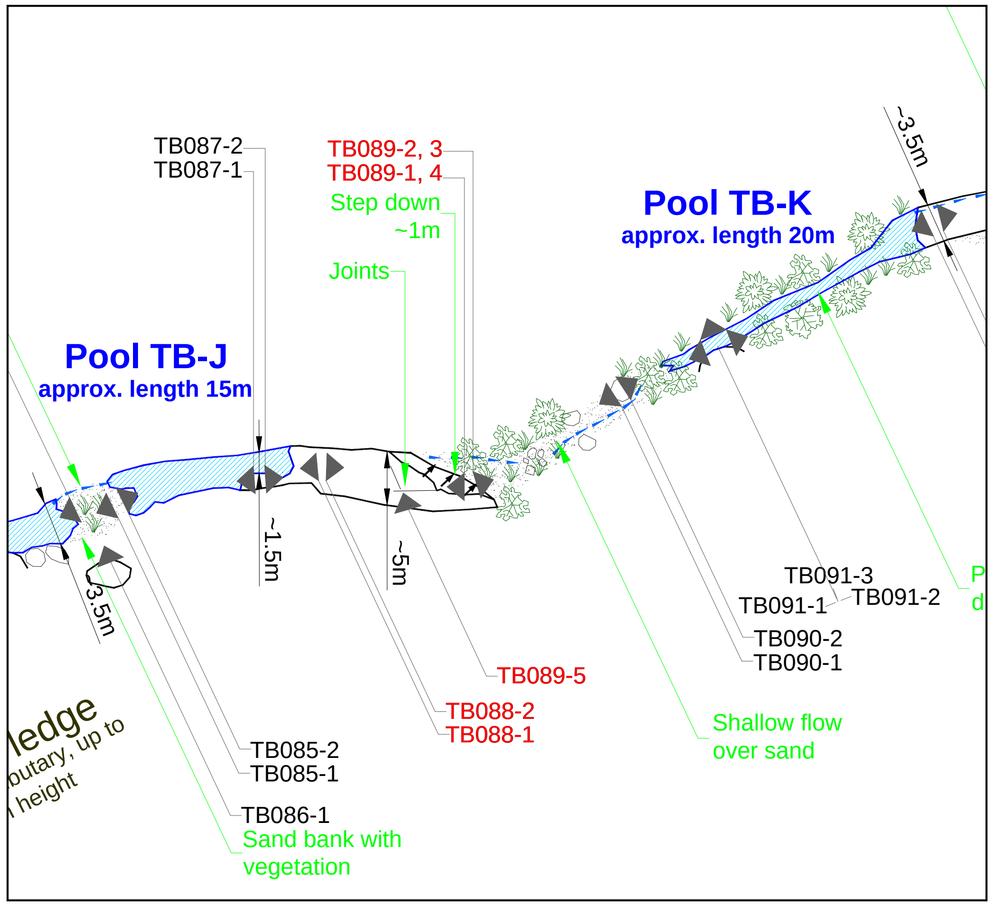
**TB088-2** Downstream end of Pool TB-J looking Downstream

Notes (as at 21 December 2009)

- Rockbar downstream of Pool TB-J approximately 19m long and up to 5m wide
- Joints across rockbar at TB089
- Step down approximately 1m at downstream end of rockbar
- Vegetation and alluvial deposits downstream of rockbar

**TB089-1** Downstream of Pool TB-J looking Upstream

**TB089-2** Downstream of Pool TB-J looking Downstream




**TB089-3** Downstream of Pool TB-J looking Downstream

**TB089-4** Joint

**TB089-5** Joint

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TB088-1 | 309312 | 6215274 | 265 |
| TB088-2 | 309312 | 6215274 | 90 |
| TB089-1 | 309323 | 6215274 | 270 |
| TB089-2 | 309323 | 6215274 | 70 |
| TB089-3 | 309323 | 6215274 | 70 |
| TB089-4 | 309323 | 6215274 | 270 |
| TB089-5 | 309323 | 6215274 | 345 |

# TRIBUTARY B STREAM MAPPING SUMMARY

**TB090-1** Upstream of Pool TB-K looking Upstream

**TB090-2** Upstream of Pool TB-K looking Downstream

**TB091-1** Near upstream end of Pool TB-K looking Upstream

**TB091-2** Near upstream end of Pool TB-K looking Downstream

**TB091-3** Near upstream end of Pool TB-K looking toward northern bank

<u>Notes (as at 21 December 2009)</u>

- Pool TB-K approximately 20m long, up to 3.5m wide at the downstream end, and 0.5m deep
- Base of the pool is sandstone with vegetation encroaching on both sides
- Shallow flow over sand upstream of pool

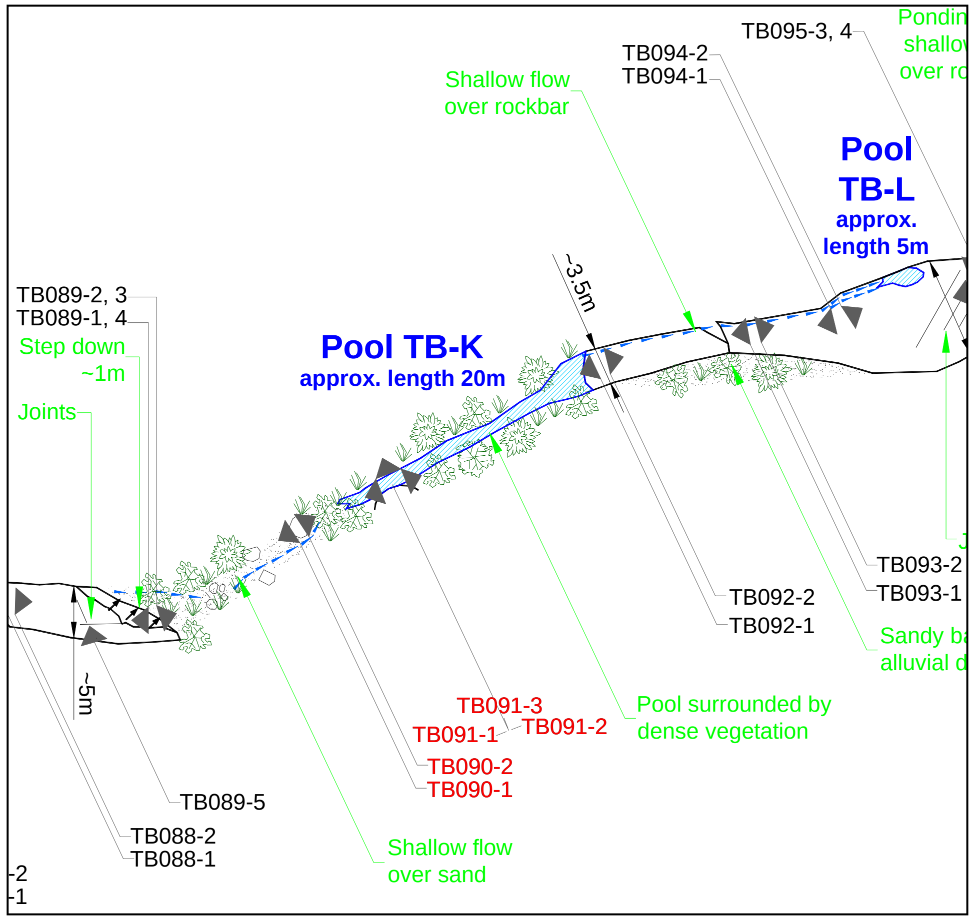



Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TB090-1 | 309339 | 6215283 | 235 |
| TB090-2 | 309339 | 6215283 | 55 |
| TB091-1 | 309348 | 6215287 | 250 |
| TB091-2 | 309348 | 6215287 | 70 |
| TB091-3 | 309348 | 6215287 | 340 |

# TRIBUTARY B STREAM MAPPING SUMMARY

**TB092-1** Downstream end of Pool TB-K looking Upstream

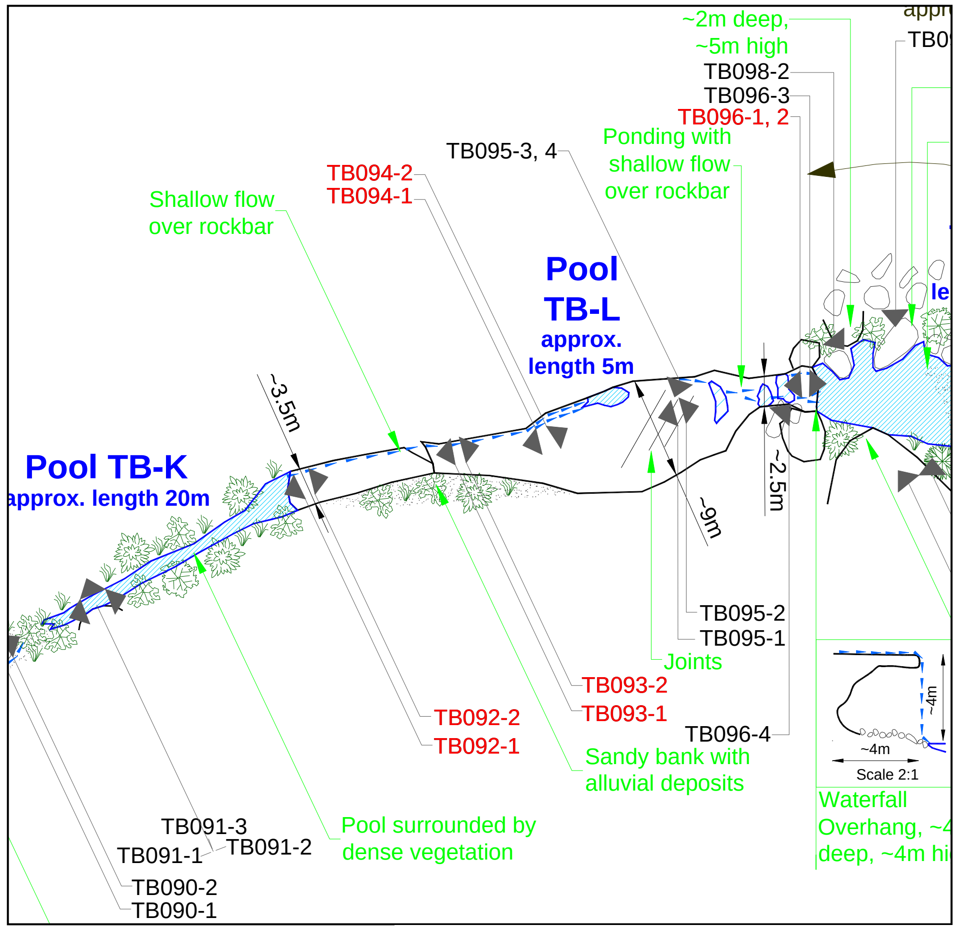
**TB092-2** Downstream end of Pool TB-K looking Downstream

Notes (as at 21 December 2009)

- Rockbar downstream of Pool TB-K approximately 3.5m wide
- Flow path along northern side of rockbar into Pool TB-L
- Pool TB-L approximately 5m long, 1.5m wide and 0.2m deep
- Base of the pool is sandstone

**TB093-1** Upstream of Pool TB-L looking Upstream

**TB094-1** Upstream end of Pool TB-L looking Upstream




**TB093-2** Upstream of Pool TB-L looking Downstream

**TB094-2** Upstream end of Pool TB-L looking Downstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TB092-1 | 309367 | 6215299 | 245 |
| TB092-2 | 309367 | 6215299 | 80 |
| TB093-1 | 309384 | 6215301 | 260 |
| TB093-2 | 309384 | 6215301 | 75 |
| TB094-1 | 309396 | 6215296 | 260 |
| TB094-2 | 309396 | 6215296 | 55 |

# TRIBUTARY B STREAM MAPPING SUMMARY

**TB095-1** Downstream of Pool TB-L looking Upstream

**TB095-2** Downstream of Pool TB-L looking Downstream

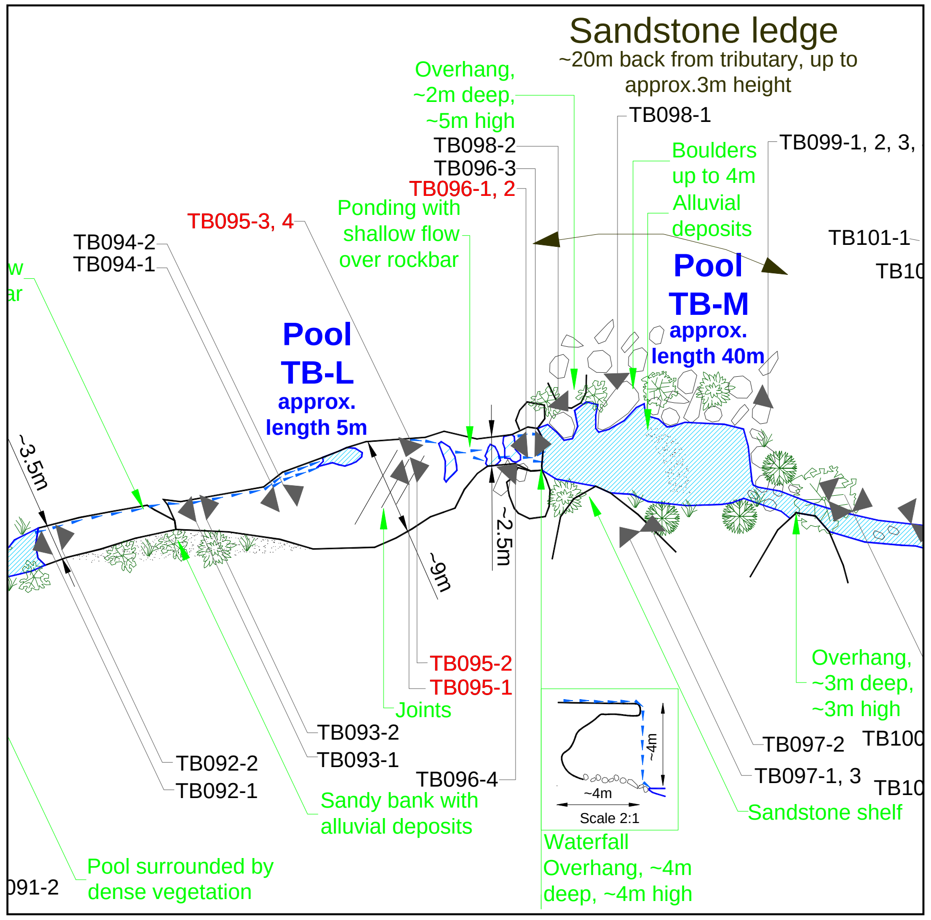
Notes (as at 21 December 2009)

- Rockbar downstream of Pool TB-L approximately 9m wide, with several joints at TB095
- Ponding and shallow flow over rockbar downstream

**TB095-3** Joint

**TB095-4** Joint

**TB096-1** Upstream of Pool TB-M looking Upstream




**TB096-2** Upstream end of Pool TB-M looking Upstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TB095-1 | 309406 | 6215311 | 250 |
| TB095-2 | 309406 | 6215311 | 75 |
| TB095-3 | 309406 | 6215311 | 195 |
| TB095-4 | 309406 | 6215311 | 195 |
| TB096-1 | 309413 | 6215308 | 270 |
| TB096-2 | 309413 | 6215308 | 270 |

# TRIBUTARY B STREAM MAPPING SUMMARY

**TB096-3** Upstream end of Pool TB-M looking Downstream

Notes (as at 21 December 2009)

- Pool TB-M approximately 40m long, up to 7m wide and up to 1m deep at the upstream end
- Base of the pool is sandstone
- Alluvial deposits and vegetation across pool
- Waterfall at upstream end of pool drops approximately 4m, with depth of overhang approximately 4m
- Small boulders at base of waterfall
- Overhang on northern bank approximately 5m high and 2m deep
- Steep slope toward sandstone ledge with large boulders along northern bank of Pool TB-M

**TB096-4** Upstream end of Pool TB-M looking toward overhang on northern bank

**TB097-1** Near upstream end of Pool TB-M looking toward overhang on northern bank

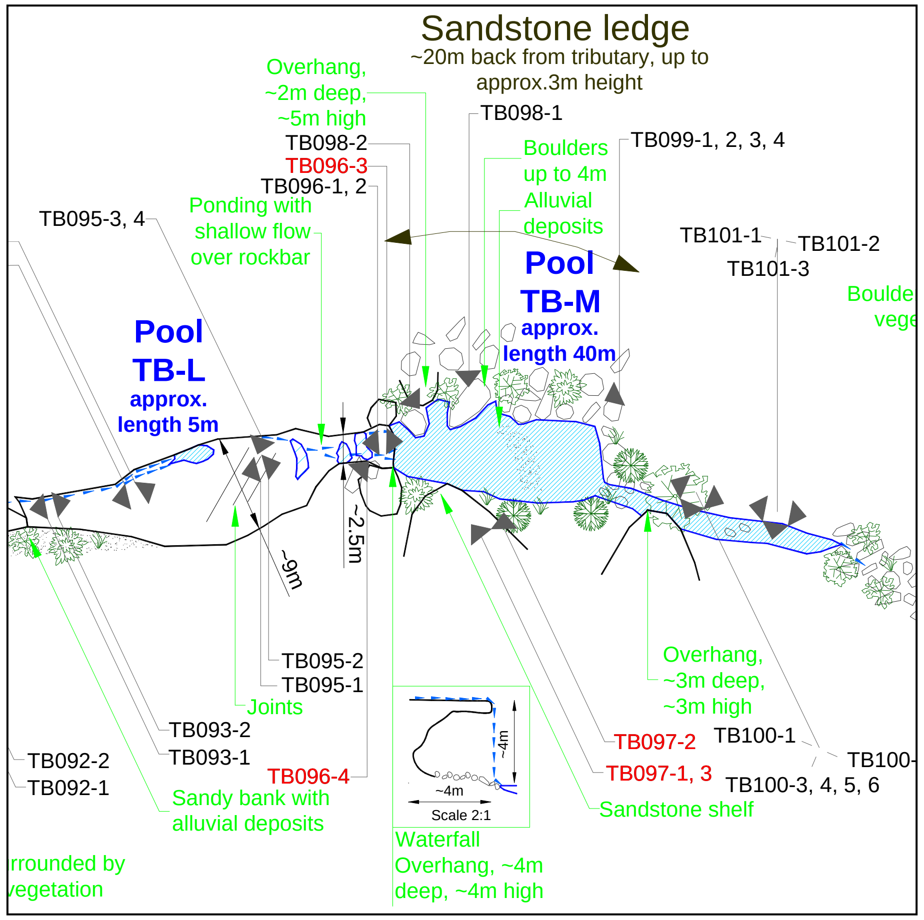



Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TB096-3 | 309416 | 6215311 | 85 |
| TB096-4 | 309416 | 6215311 | 45 |
| TB097-1 | 309439 | 6215295 | 320 |
| TB097-2 | 309439 | 6215295 | 0 |
| TB097-3 | 309439 | 6215295 | 320 |

**TB097-2** Near upstream end of Pool TB-M looking toward northern bank

**TB097-3** Sandstone shelf on southern bank near upstream end of Pool TB-M

# TRIBUTARY B STREAM MAPPING SUMMARY

**TB098-1** Near Upstream end of Pool TB-M looking toward southern bank

**Notes (as at 21 December 2009)**

- Pool TB-M approximately 40m long, up to 7m wide and up to 1m deep at the upstream end
- Base of the pool is sandstone
- Alluvial deposits and vegetation across pool (TB098-2)

**TB098-2** Near Upstream end of Pool TB-M looking toward southern bank

**TB099-1** Midway along Pool TB-M looking toward waterfall at Upstream end of pool

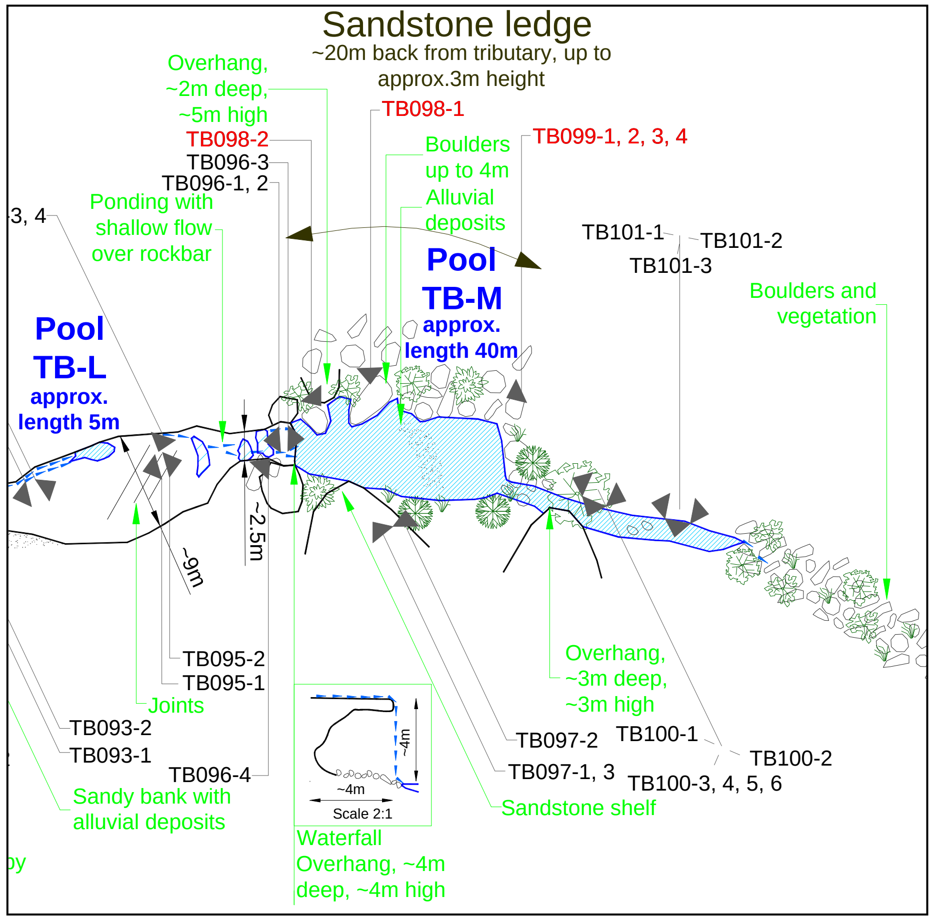



Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TB098-1 | 309416 | 6215311 | 175 |
| TB098-2 | 309416 | 6215311 | 145 |
| TB099-1 | 309444 | 6215304 | 245 |
| TB099-2 | 309444 | 6215304 | 245 |
| TB099-3 | 309444 | 6215304 | 245 |
| TB099-4 | 309444 | 6215304 | 245 |

**TB099-2** Midway along Pool TB-M looking toward waterfall at Upstream end of pool

**TB099-3** Midway along Pool TB-M looking toward southern bank

**TB099-4** Midway along Pool TB-M looking toward southern bank

# TRIBUTARY B STREAM MAPPING SUMMARY

**TB100-1** Near Downstream end of Pool TB-M looking Upstream

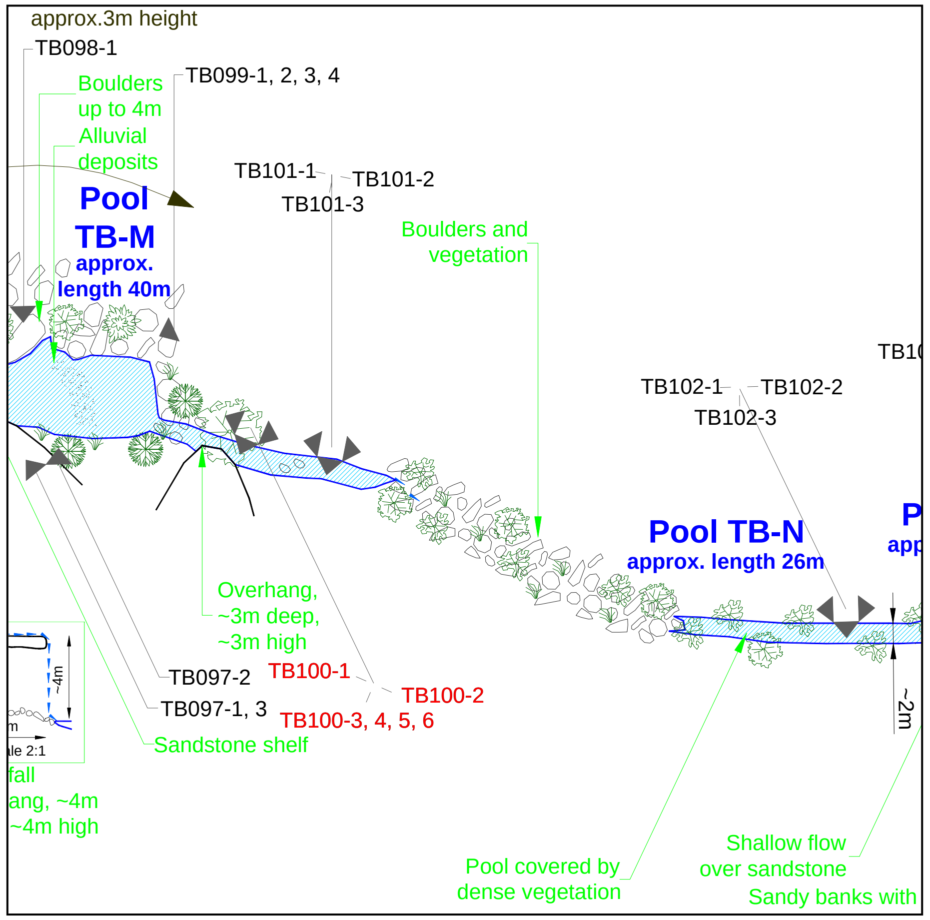
**TB0100-2** Near Downstream end of Pool TB-M looking Downstream

Notes (as at 21 December 2009)

- Pool TB-M approximately 2m wide at downstream end
- Boulders and vegetation downstream of pool
- Overhang on southern bank approximately 3m high and 3m deep
- Alluvial deposits beneath overhang

**TB100-3** Near Downstream end of Pool TB-M looking toward southern bank

**TB100-4** Near Downstream end of Pool TB-M looking toward southern bank




**TB100-5** Overhang on southern bank

**TB100-6** Overhang on southern bank

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TB100-1 | 309454 | 6215304 | 295 |
| TB100-2 | 309454 | 6215304 | 115 |
| TB100-3 | 309454 | 6215304 | 205 |
| TB100-4 | 309454 | 6215304 | 205 |
| TB100-5 | 309454 | 6215304 | 205 |
| TB100-6 | 309454 | 6215304 | 205 |

# TRIBUTARY B STREAM MAPPING SUMMARY

**TB101-1** Downstream end of Pool TB-M looking Upstream

**TB0101-2** Downstream end of Pool TB-M looking Downstream

**TB101-3** Downstream end of Pool TB-M looking toward southern bank

**TB102-1** Midway along Pool TB-N looking Upstream

**TB0102-2** Midway along Pool TB-N looking Downstream

**TB102-3** Midway along Pool TB-N looking toward southern bank

Notes (as at 21 December 2009)

- Pool TB-N approximately 26m long and 2m wide
- Base of the pool not visible
- Vegetation encroaches on both sides of pool
- Shallow flow over sandstone downstream of pool

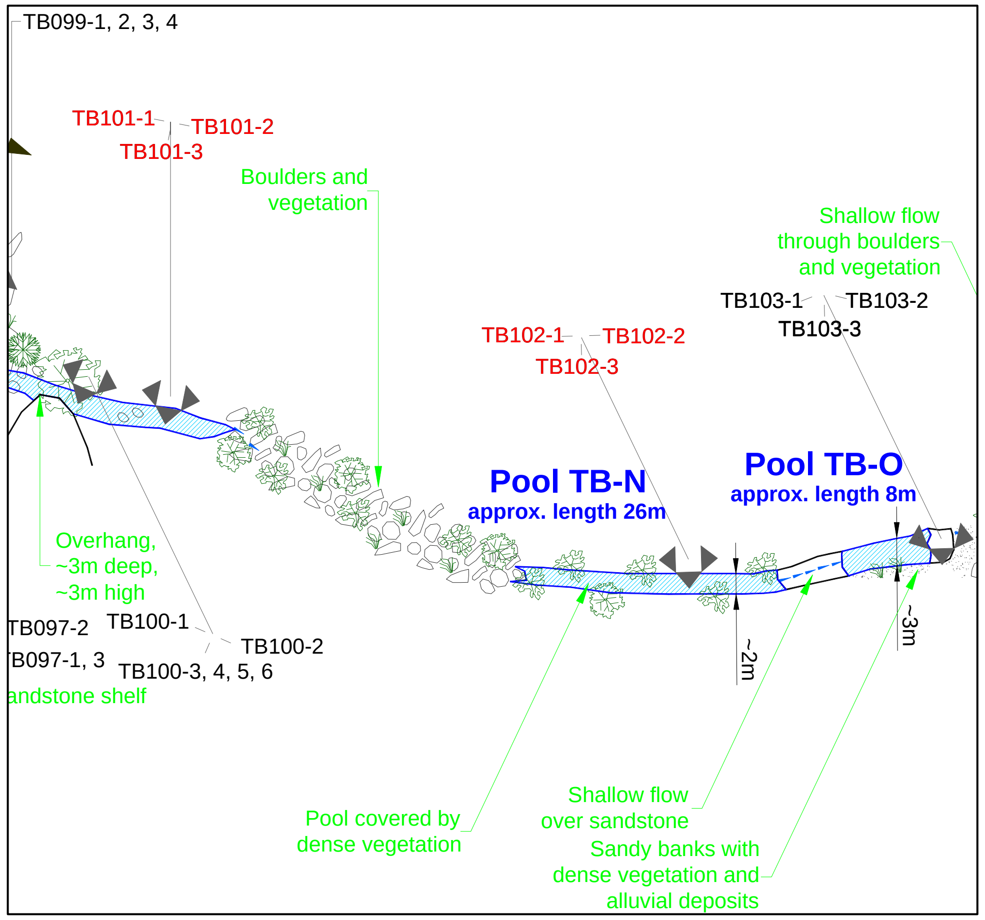



Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TB101-1 | 309456 | 6215296 | 280 |
| TB101-2 | 309456 | 6215296 | 190 |
| TB101-3 | 309456 | 6215296 | 100 |
| TB102-1 | 309502 | 6215284 | 270 |
| TB102-2 | 309502 | 6215284 | 90 |
| TB102-3 | 309502 | 6215284 | 180 |

# TRIBUTARY B STREAM MAPPING SUMMARY

**TB103-1** Downstream end of Pool TB-O looking Upstream

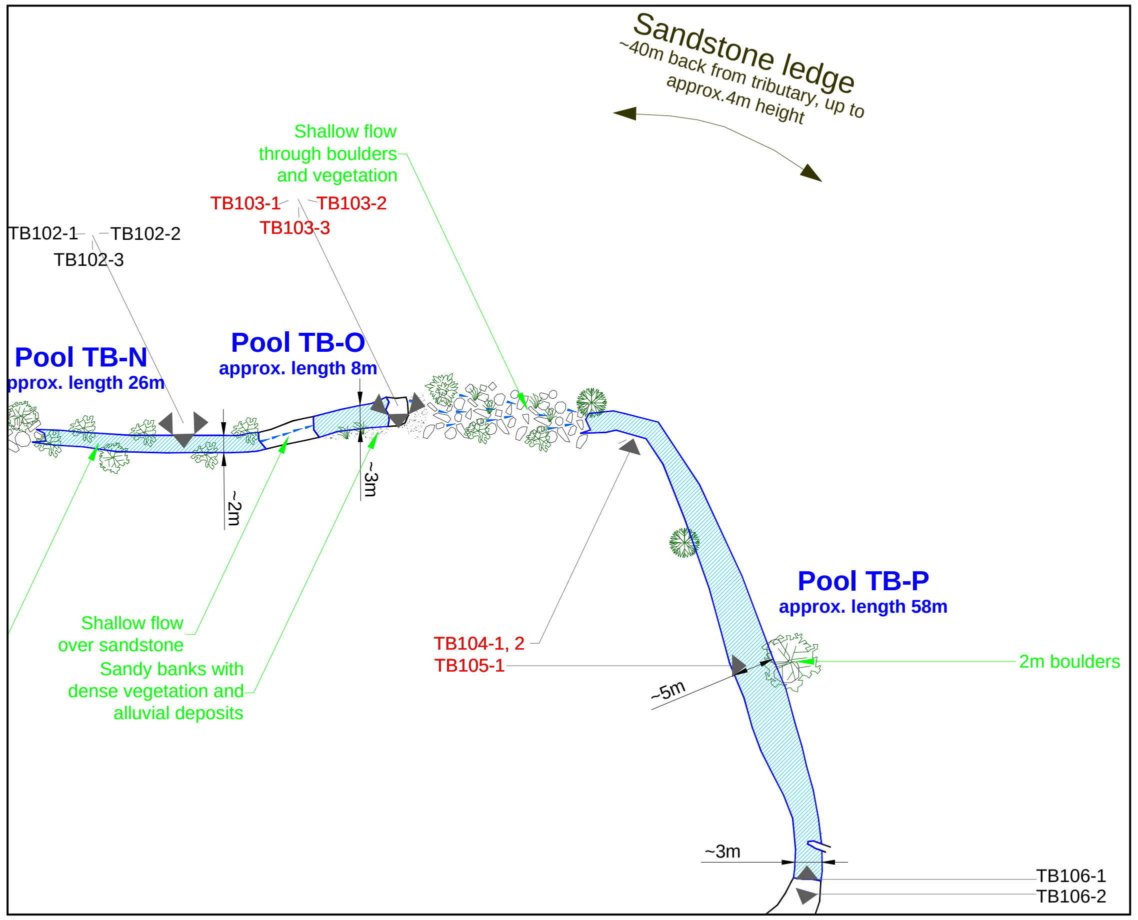
**TB103-2** Downstream end of Pool TB-O looking Downstream

Notes (as at 21 December 2009)

- Pool TB-O approximately 8m long, 3m wide and 0.4m deep
- Base of the pool is sandstone with vegetation debris at the downstream end
- Alluvial deposits on southern bank at downstream end of the pool
- Shallow flow through boulders and vegetation downstream into Pool TB-P
- Sandstone ledge up to 4m high on northern side of Pool TB-P at a distance of approximately 40m (TB104)
- Boulders up to 2m on eastern bank (TB105)

**TB103-3** Downstream end of Pool TB-O looking toward southern bank

**TB104-1** Near upstream end of Pool TB-P looking toward sandstone ledge





**TB104-2** Near upstream end of Pool TB-P looking toward sandstone ledge

**TB105-1** Midway along Pool TB-P looking toward eastern bank

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TB103-1 | 309526 | 6215287 | 250 |
| TB103-2 | 309526 | 6215287 | 100 |
| TB103-3 | 309526 | 6215287 | 180 |
| TB104-1 | 309552 | 6215283 | 25 |
| TB104-2 | 309552 | 6215283 | 25 |
| TB105-1 | 309564 | 6215257 | 90 |

# TRIBUTARY B STREAM MAPPING SUMMARY

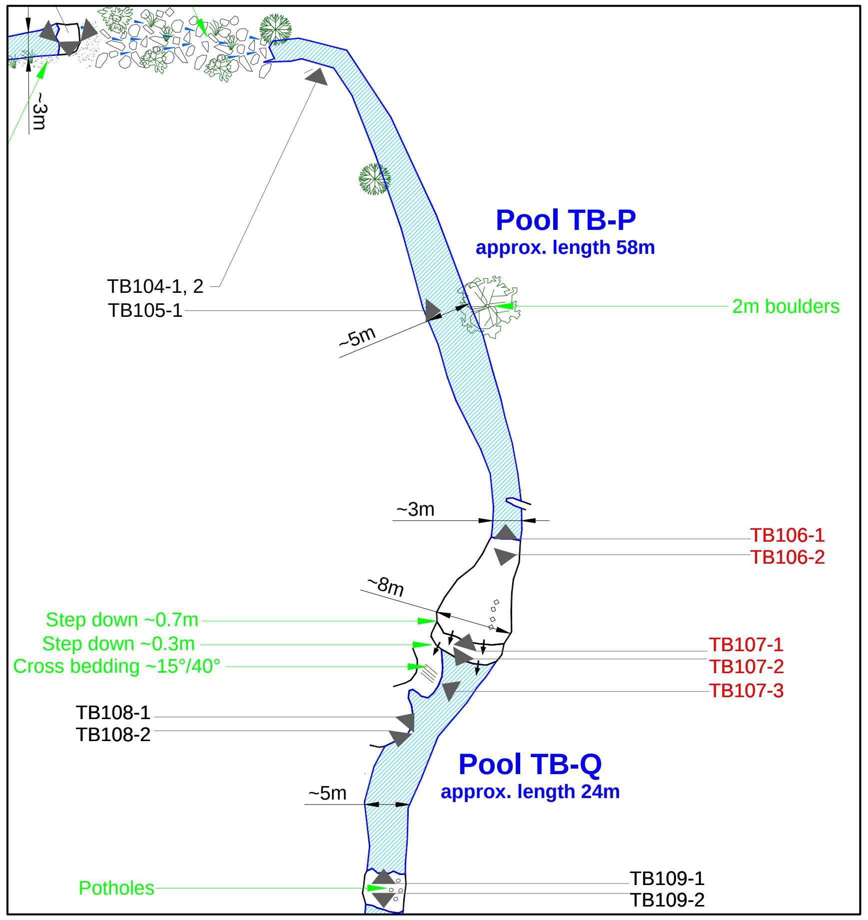
**TB106-1** Downstream end of Pool TB-P looking Upstream

**TB106-2** Downstream end of Pool TB-P looking Downstream

Notes (as at 21 December 2009)

- Pool TB-P approximately 58m long and 3 to 5m wide
- Base of the pool not visible
- Rockbar downstream of Pool TB-P is approximately 12m long and 8m wide
- No flow visible on rockbar, but minor ponding evident
- Approximate 1m change in height along rockbar approaching Pool TB-Q

**TB107-1** Upstream end of Pool TB-Q looking Upstream




**TB107-2** Upstream end of Pool TB-Q looking Downstream

**TB107-3** Upstream end of Pool TB-Q looking toward western bank

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TB106-1 | 309574 | 6215234 | 0 |
| TB106-2 | 309574 | 6215234 | 200 |
| TB107-1 | 309568 | 6215228 | 15 |
| TB107-2 | 309568 | 6215228 | 210 |
| TB107-3 | 309568 | 6215228 | 300 |

# TRIBUTARY B STREAM MAPPING SUMMARY

**TB108-1** Midway along Pool TB-Q looking Upstream

**TB108-2** Midway along Pool TB-Q looking Downstream

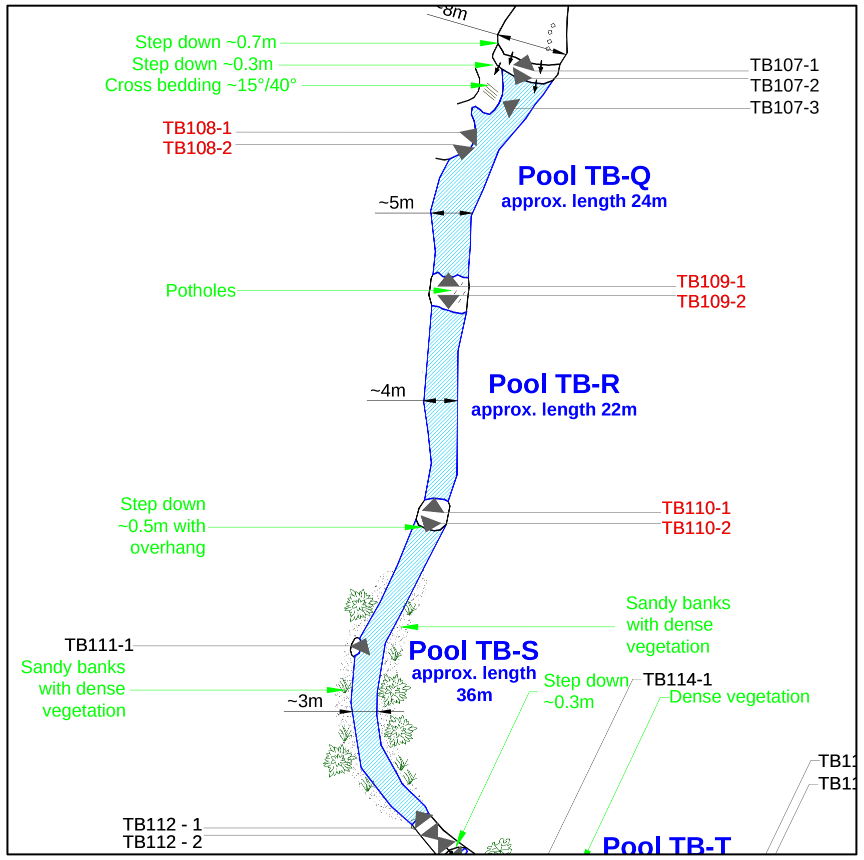
Notes (as at 21 December 2009)

- Pool TB-Q approximately 24m long, 5m wide and 1m deep
- Base of the pool is sandstone
- Rockbar downstream of pool approximately 4m long and 4.5m wide

- Pool TB-R approximately 22m long, 4m wide and 0.5m deep
- Base of the pool is sandstone
- Scattered vegetation debris at downstream end of pool

**TB109-1** Downstream end of Pool TB-Q looking Upstream

**TB109-2** Upstream end of Pool TB-R looking Downstream




**TB110-1** Downstream end of Pool TB-R looking Upstream

**TB110-2** Upstream end of Pool TB-S looking Downstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TB108-1 | 309562 | 6215213 | 40 |
| TB108-2 | 309562 | 6215213 | 190 |
| TB109-1 | 309560 | 6215196 | 0 |
| TB109-2 | 309560 | 6215196 | 180 |
| TB110-1 | 309559 | 6215170 | 5 |
| TB110-2 | 309559 | 6215170 | 205 |

# TRIBUTARY B STREAM MAPPING SUMMARY

**TB111-1** Midway along Pool TB-S looking Upstream

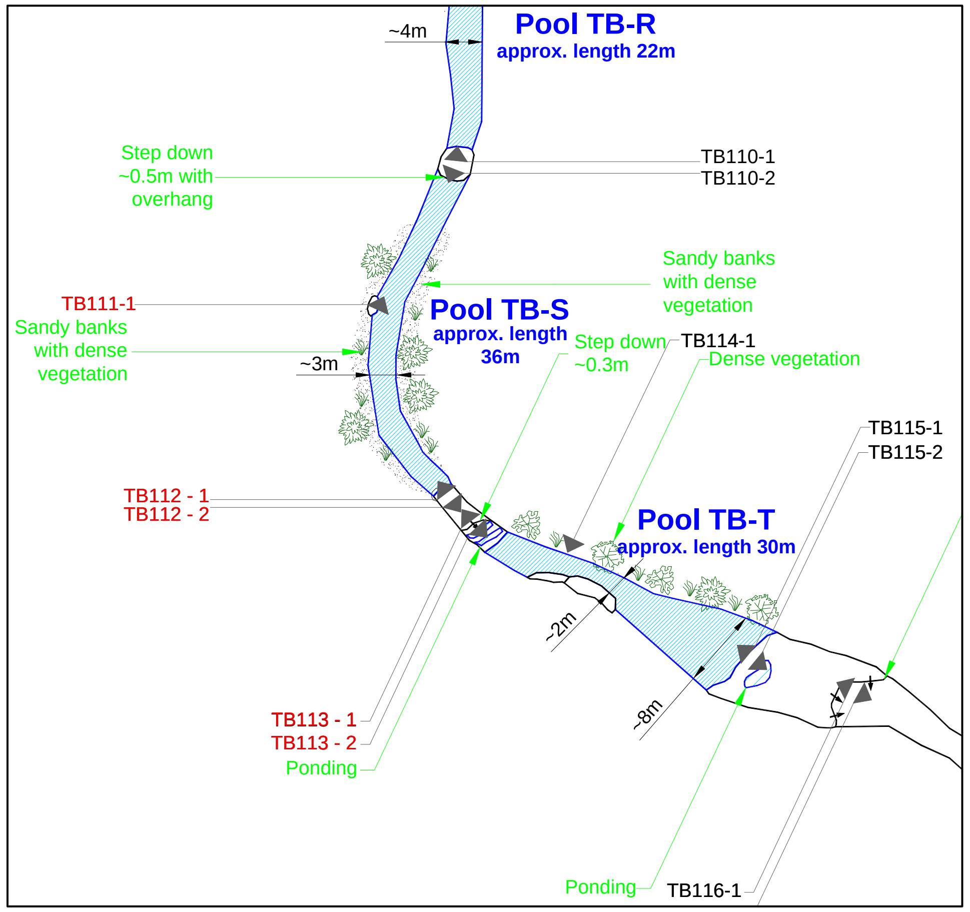
**TB112-1** Downstream end of Pool TB-S looking Upstream

Notes (as at 21 December 2009)

- Pool TB-S approximately 36m long, 3m wide and 0.3m deep
- Base of the pool is sandstone
- Sandy banks and dense vegetation on both sides of pool
- Rockbar downstream of pool approximately 5m long with a step down of approximately 0.3m at the downstream end
- Shallow ponding on rockbar

**TB112-1** Downstream end of Pool TB-S looking Downstream

**TB113-1** Upstream of Pool TB-T looking Upstream




**TB113-2** Upstream of Pool TB-T looking Downstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TB111-1 | 309556 | 6215156 | 25 |
| TB112-1 | 309558 | 6215135 | 325 |
| TB112-2 | 309558 | 6215135 | 145 |
| TB113-1 | 309559 | 6215132 | 325 |
| TB113-2 | 309559 | 6215132 | 135 |

# TRIBUTARY B STREAM MAPPING SUMMARY

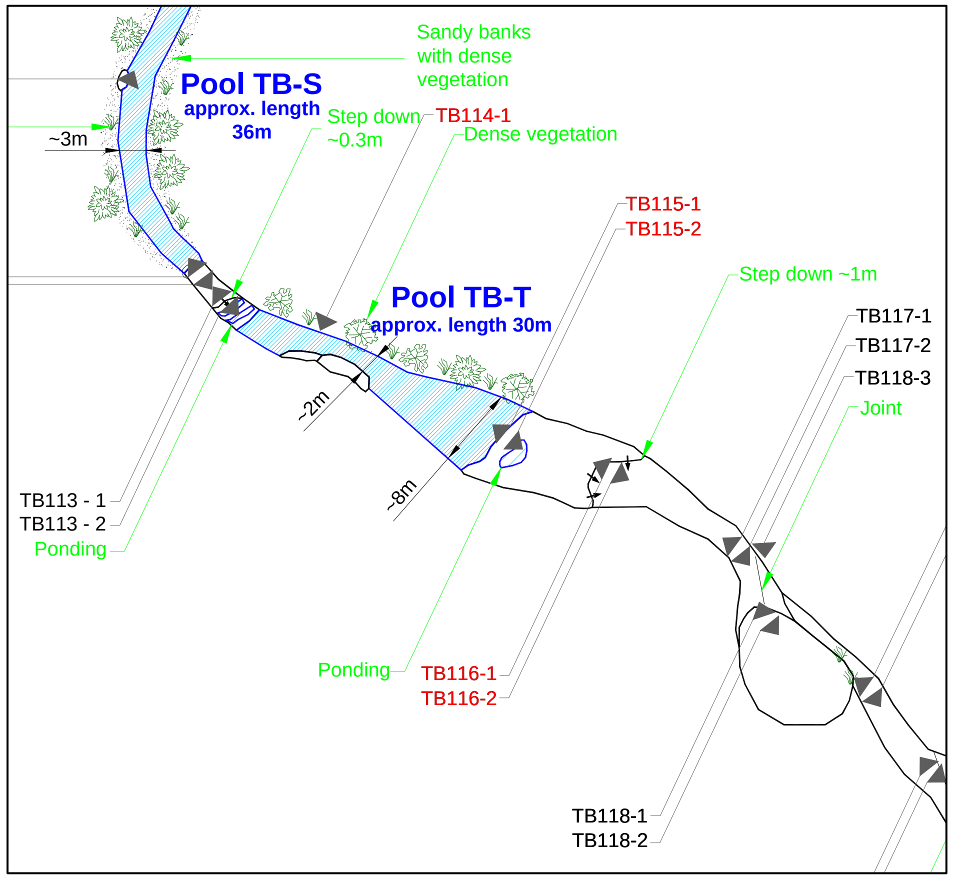
**TB114-1** Midway along Pool TB-T looking toward southern bank

**TB115-1** Downstream end of Pool TB-T looking Upstream

Notes (as at 15 & 21 December 2009)

- Pool TB-T approximately 30m long, 2 to 8m wide and 0.3m deep
- Base of the pool is sandstone with algae
- Sandstone ledge on southern bank and dense vegetation on northern bank
- Ponding and potholes on wide rockbar at downstream end of pool
- Rockbar steps down approximately 1m at TB116

**TB115-2** Downstream end of Pool TB-T looking Downstream




**TB116-1** Downstream of Pool TB-T looking Upstream

**TB116-2** Downstream of Pool TB-T looking Downstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TB114-1 | 309572 | 6215129 | 210 |
| TB115-1 | 309589 | 6215116 | 310 |
| TB115-2 | 309589 | 6215116 | 130 |
| TB116-1 | 309601 | 6215114 | 295 |
| TB116-2 | 309601 | 6215114 | 115 |

# TRIBUTARY B STREAM MAPPING SUMMARY

**TB117-1** Downstream of Pool TB-T looking Upstream

**TB117-2** Downstream of Pool TB-T looking Downstream

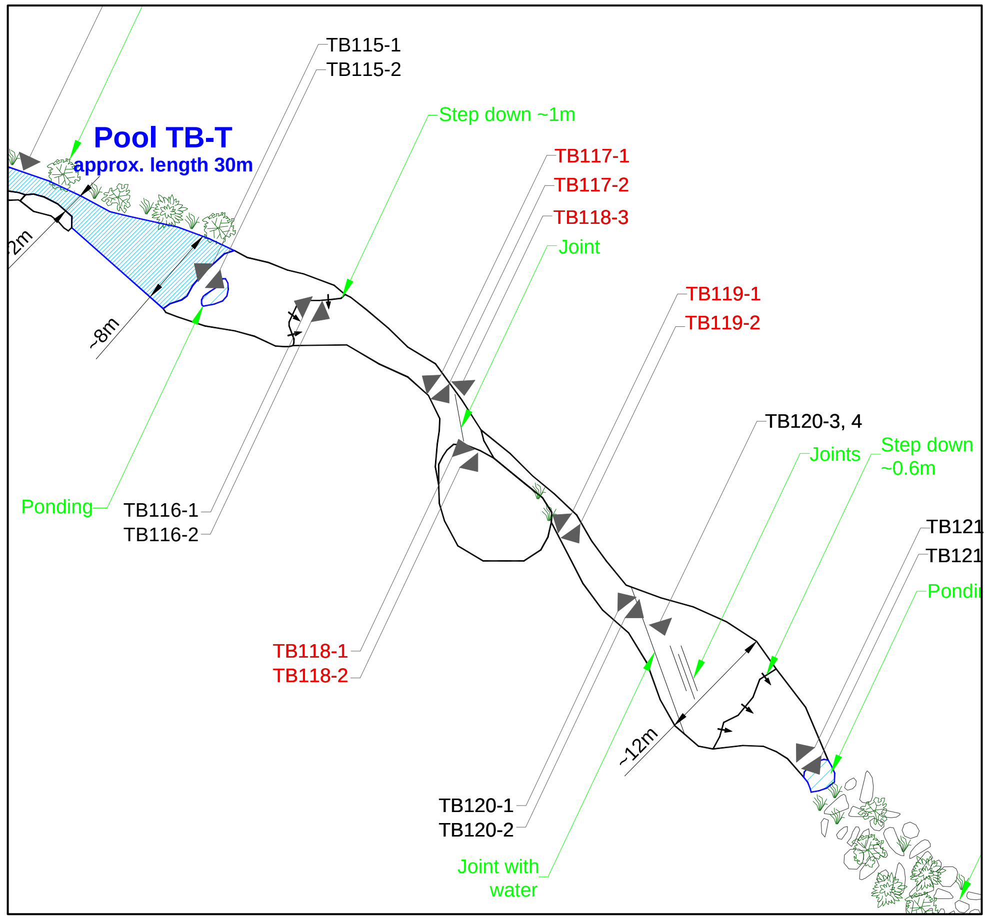
Notes (as at 15 December 2009)

- Rockbar downstream of Pool TB-T extends through TB117, TB118 and TB119
- No flow visible

**TB118-1** Downstream of Pool TB-T looking Upstream

**TB118-2** Downstream of Pool TB-T looking Downstream

**TB118-3** Joint




**TB119-1** Downstream of Pool TB-T looking Upstream

**TB119-2** Downstream of Pool TB-T looking Downstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TB117-1 | 309614 | 6215105 | 305 |
| TB117-2 | 309614 | 6215105 | 145 |
| TB118-1 | 309615 | 6215097 | 340 |
| TB118-2 | 309615 | 6215097 | 145 |
| TB118-3 | 309615 | 6215097 | 175 |
| TB119-1 | 309628 | 6215091 | 305 |
| TB119-2 | 309628 | 6215091 | 145 |

# TRIBUTARY B STREAM MAPPING SUMMARY

**TB120-1** Rockbar looking Upstream

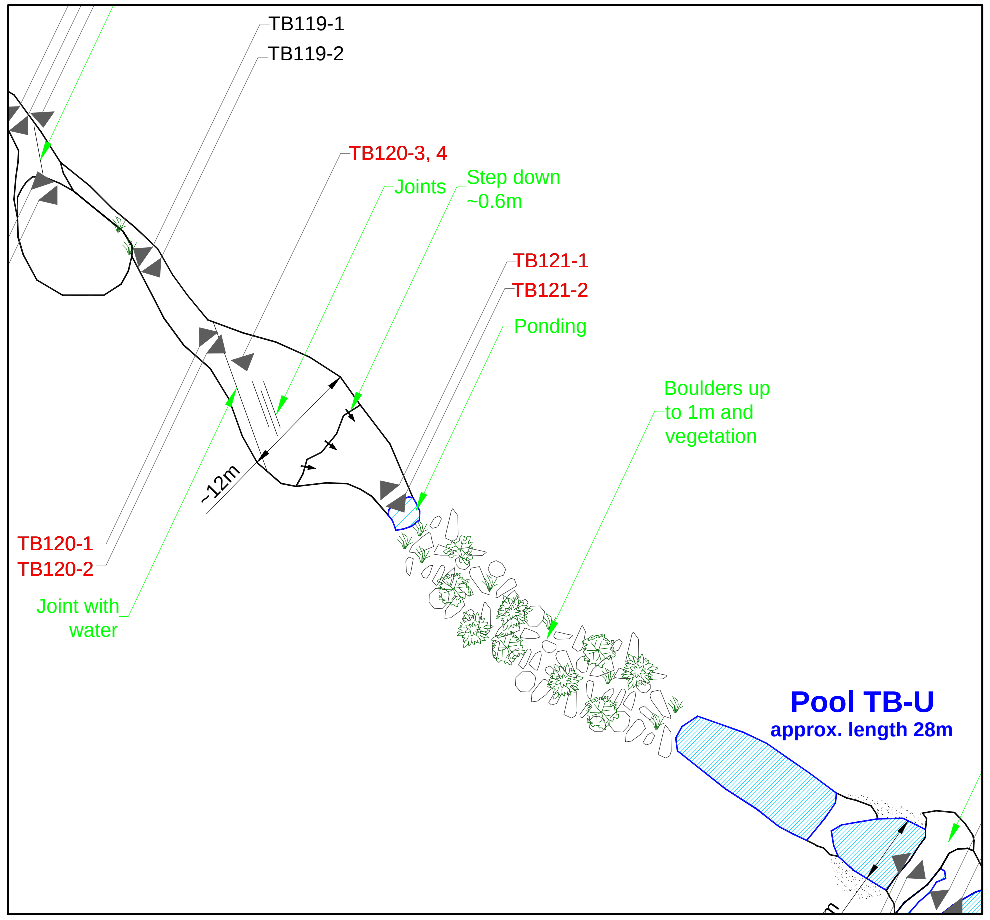
**TB120-3** Joint with water

**TB120-4** Joint

<u>Notes (as at 15 December 2009)</u>

- Rockbar between TB120 and TB121 approximately 12m wide and 24m long, with many joints
- Step down of approximately 0.6m approaching TB121
- Ponding at downstream end of rockbar leading into boulder field

**TB120-2** Rockbar looking Downstream




**TB121-1** Upstream of Pool TB-U looking Upstream

**TB121-2** Upstream of Pool TB-U looking Downstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TB120-1 | 309635 | 6215082 | 320 |
| TB120-2 | 309635 | 6215082 | 125 |
| TB120-3 | 309635 | 6215082 | 160 |
| TB120-4 | 309635 | 6215082 | 160 |
| TB121-1 | 309654 | 6215066 | 320 |
| TB121-2 | 309654 | 6215066 | 150 |

# TRIBUTARY B STREAM MAPPING SUMMARY

**TB122-1** Downstream end of Pool TB-U looking Upstream

**TB122-2** Downstream end of Pool TB-U looking Downstream

Notes (as at 15 December 2009)

- Pool TB-U approximately 28m long, 7m wide and 0.5m deep
- Base of the pool is sandstone with alluvial deposits on the northern and southern banks at the downstream end

- Pool TB-V approximately 30m long, 8m wide at the upstream end, 2m wide at the downstream end, and up to 1m deep
- Base of the pool is sandstone with alluvial deposits

- Rockbar between Pools TB-U and TB-V approximately 6.5m long and 11m wide, with raised sandstone shelf approximately 0.5m high with underflow

**TB123-1** Upstream end of Pool TB-V looking Upstream

**TB123-2** Upstream end of Pool TB-V looking Downstream

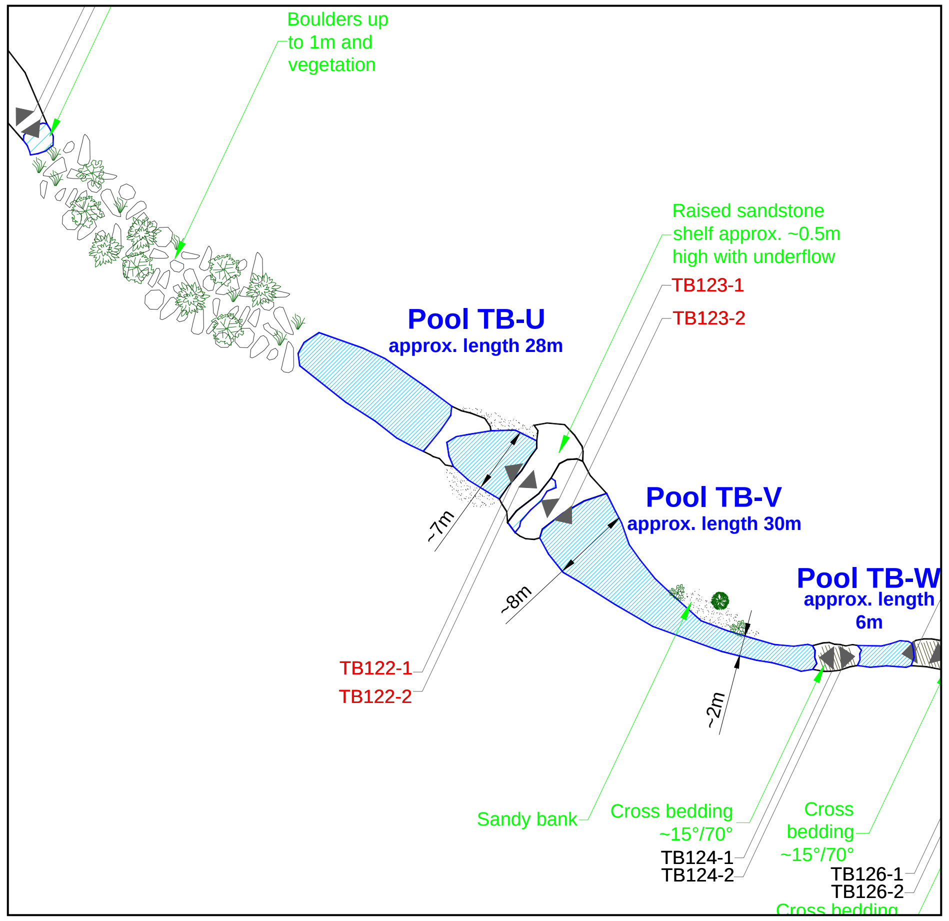



Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TB122-1 | 309707 | 6215027 | 300 |
| TB122-2 | 309707 | 6215027 | 130 |
| TB123-1 | 309711 | 6215024 | 305 |
| TB123-2 | 309711 | 6215024 | 140 |

# TRIBUTARY B STREAM MAPPING SUMMARY

**TB124-1** Downstream end of Pool TB-V looking Upstream

**TB124-2** Upstream end of Pool TB-W looking Downstream

Notes (as at 15 December 2009)

- Rockbar between Pools TB-V and TB-W approximately 5m long and 2m wide with some cross bedding evident

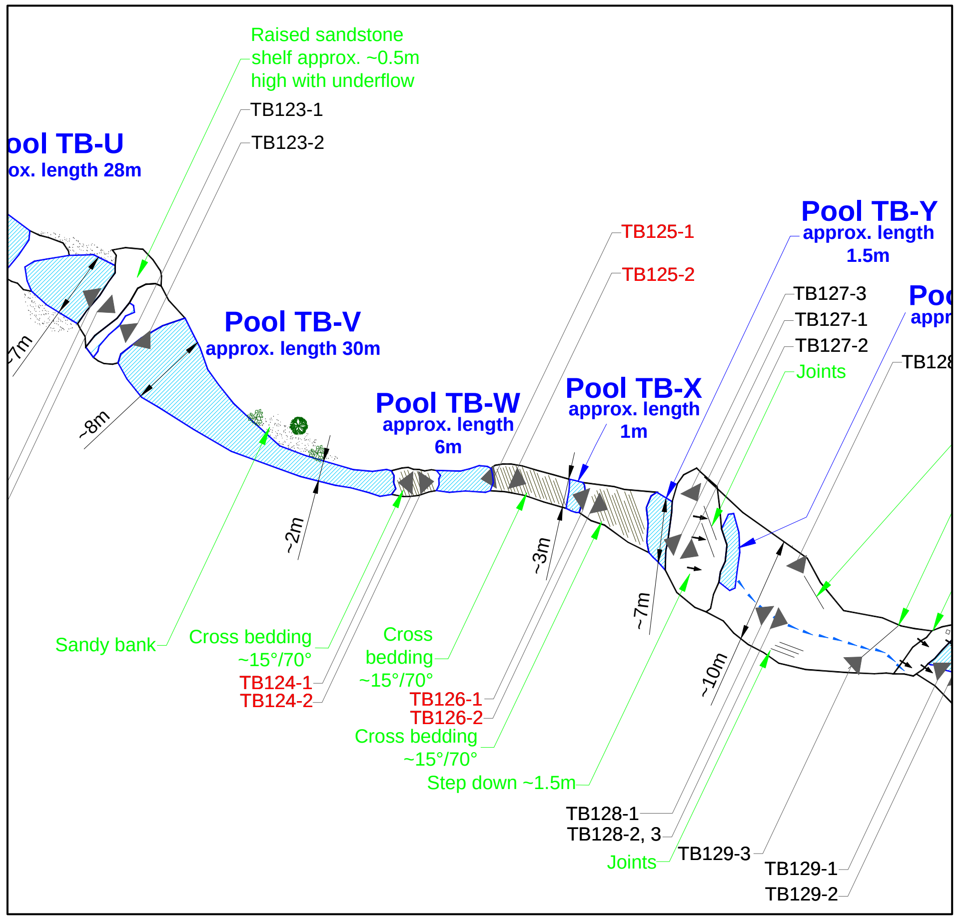
- Pool TB-W approximately 6m long, 2.5m wide and 0.5m deep
- Base of the pool is sandstone with alluvial deposits

- Pool TB-X approximately 1m long, 3m wide and 0.4 m deep
- Base of the pool is sandstone with alluvial deposits

- Rockbar between Pools TB-W and TB-X approximately 8m long and 3m wide, with cross bedding evident along the whole length of the rockbar

**TB125-1** Downstream end of Pool TB-W looking Upstream

**TB125-2** Downstream end of Pool TB-W looking Downstream




**TB126-1** Downstream end of Pool TB-X looking Upstream

**TB126-2** Downstream end of Pool TB-X looking Downstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TB124-1 | 309744 | 6215006 | 275 |
| TB124-2 | 309744 | 6215006 | 85 |
| TB125-1 | 309753 | 6215010 | 265 |
| TB125-2 | 309753 | 6215010 | 115 |
| TB126-1 | 309762 | 6215005 | 285 |
| TB126-2 | 309762 | 6215005 | 115 |

# TRIBUTARY B STREAM MAPPING SUMMARY

**TB127-1** Downstream end of Pool TB-Y looking Upstream

**TB127-2** Downstream end of Pool TB-Y looking Downstream

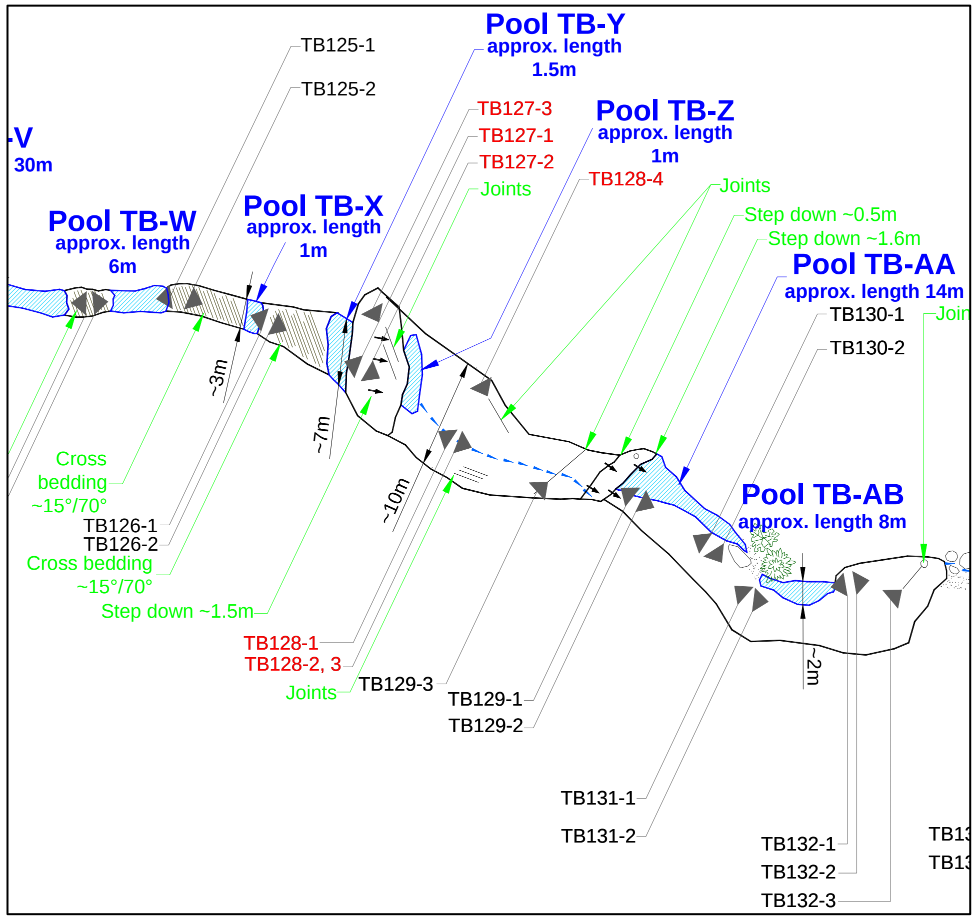
**TB127-3** Joint

<u>Notes (as at 15 December 2009)</u>

- Pool TB-Y approximately 1.5m long, 7m wide and 0.2m deep
- Base of the pool is sandstone

- Pool TB-Z approximately 1m long, 8m wide and 0.2m deep
- Base of the pool is sandstone

- Rockbar between Pools TB-Y and TB-Z approximately 6.5m long and 14m wide, with several joints
- Approximate 1.5m change in height between Pools TB-Y and TB-Z




**TB128-1** Downstream end of Pool TB-Z looking Upstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TB127-1 | 309772 | 6215000 | 290 |
| TB127-2 | 309772 | 6215000 | 120 |
| TB127-3 | 309772 | 6215000 | 155 |
| TB128-1 | 309783 | 6214996 | 305 |
| TB128-2 | 309783 | 6214996 | 110 |
| TB128-3 | 309783 | 6214996 | 110 |
| TB128-4 | 309783 | 6214996 | 155 |

**TB128-2** Downstream end of Pool TB-Z looking Downstream

**TB128-3** Joints

**TB128-4** Joint

# TRIBUTARY B STREAM MAPPING SUMMARY

**TB129-1** Upstream end of Pool TB-AA looking Upstream

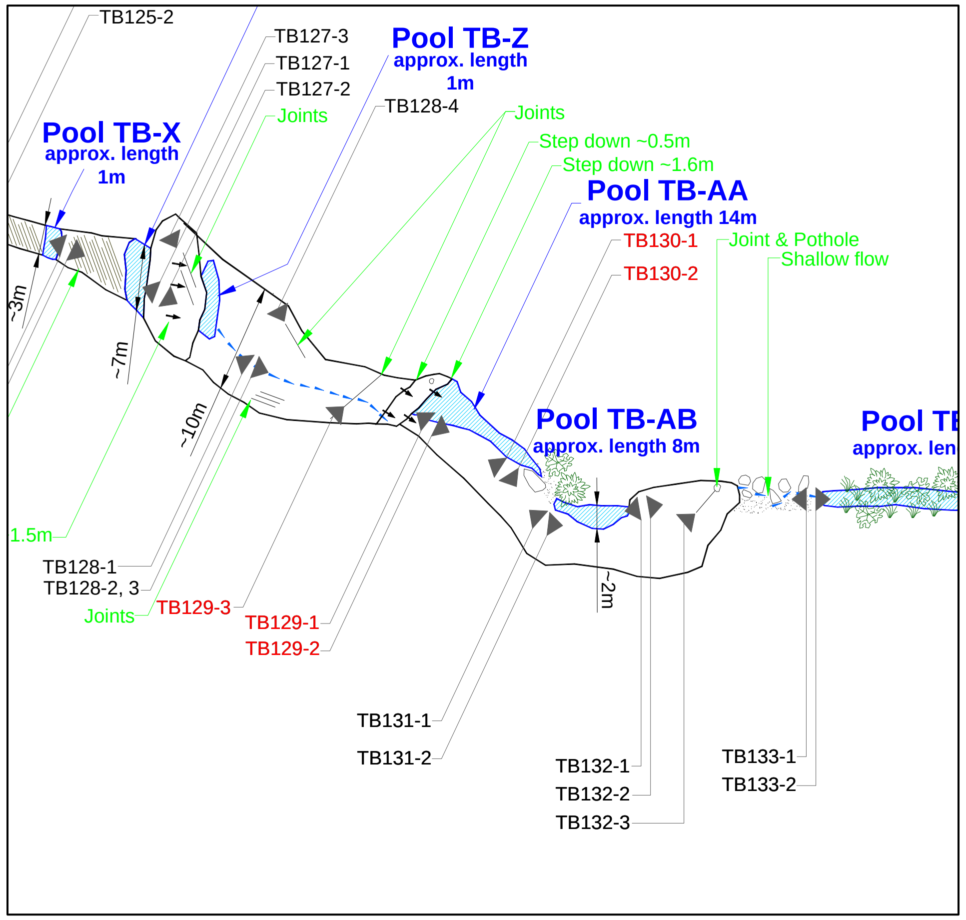
Notes (as at 15 December 2009)

- Pool TB-AA approximately 14m long, 1 to 5.5m wide and 0.5m deep
- Base of the pool is sandstone with alluvial deposits

- Rockbar upstream of Pool TB-AA approximately 23m long and up to 10m wide at the upstream end
- Flow path down centre of rockbar between Pools TB-Z and TB-AA, but no flow visible
- Approximate 2.1m change in height between Pools TB-Z and TB-AA

**TB129-2** Upstream end of Pool TB-AA looking Downstream

**TB129-3** Joint




**TB130-1** Downstream end of Pool TB-AA looking Upstream

**TB130-2** Downstream end of Pool TB-AA looking Downstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TB129-1 | 309800 | 6214988 | 310 |
| TB129-2 | 309800 | 6214988 | 115 |
| TB129-3 | 309800 | 6214988 | 50 |
| TB130-1 | 309809 | 6214979 | 300 |
| TB130-2 | 309809 | 6214979 | 145 |

# TRIBUTARY B STREAM MAPPING SUMMARY

**TB131-1** Upstream end of Pool TB-AB looking Upstream

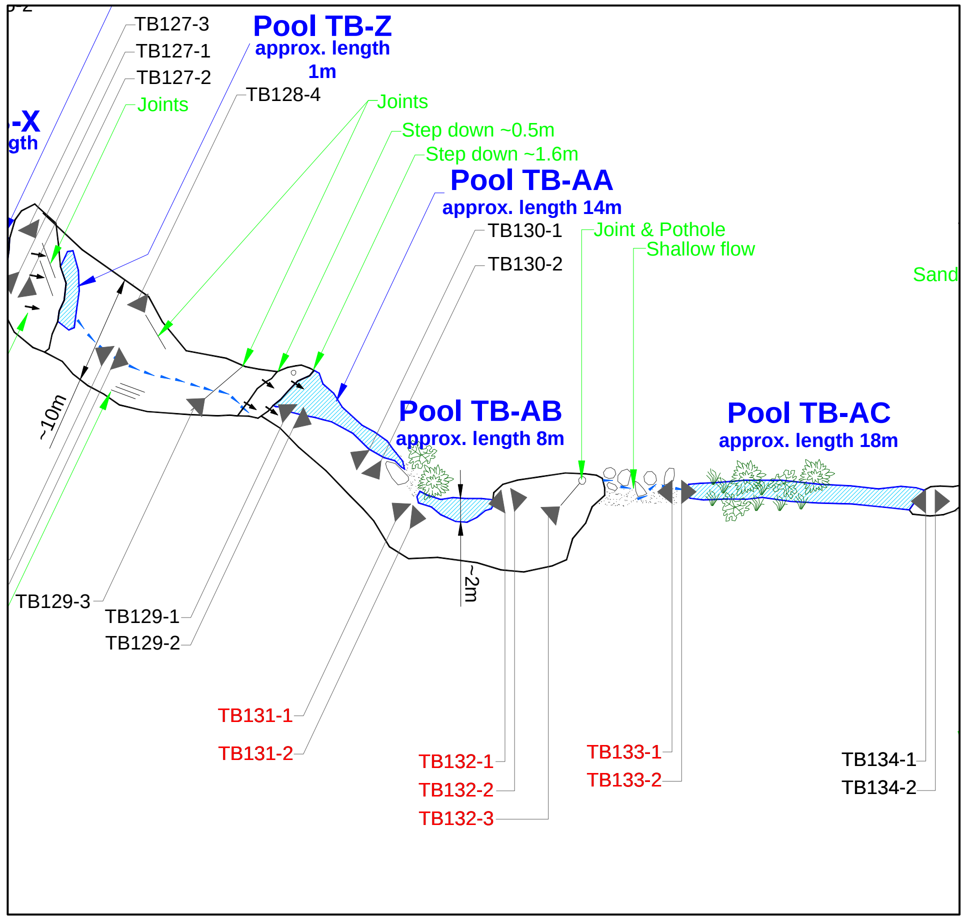
**TB131-2** Upstream end of Pool TB-AB looking Downstream

Notes (as at 15 December 2009)

- Pool TB-AB approximately 8m long, 2m wide and 0.2m deep
- Base of the pool is sandstone with alluvial deposits
- Rockbar downstream of the pool approximately 10m wide with long joint and pothole
- Shallow flow over small boulders and alluvial deposits in to Pool TB-AC

**TB132-1** Downstream end of Pool TB-AB looking Upstream

**TB132-2** Downstream end of Pool TB-AB looking Downstream




**TB132-3** Joint and pothole

**TB133-1** Upstream end of Pool TB-AC looking Upstream

**TB133-2** Upstream end of Pool TB-AC looking Downstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TB131-1 | 309814 | 6214973 | 315 |
| TB131-2 | 309814 | 6214973 | 95 |
| TB132-1 | 309824 | 6214977 | 260 |
| TB132-2 | 309824 | 6214977 | 80 |
| TB132-3 | 309824 | 6214977 | 50 |
| TB133-1 | 309842 | 6214978 | 270 |
| TB133-2 | 309842 | 6214978 | 90 |

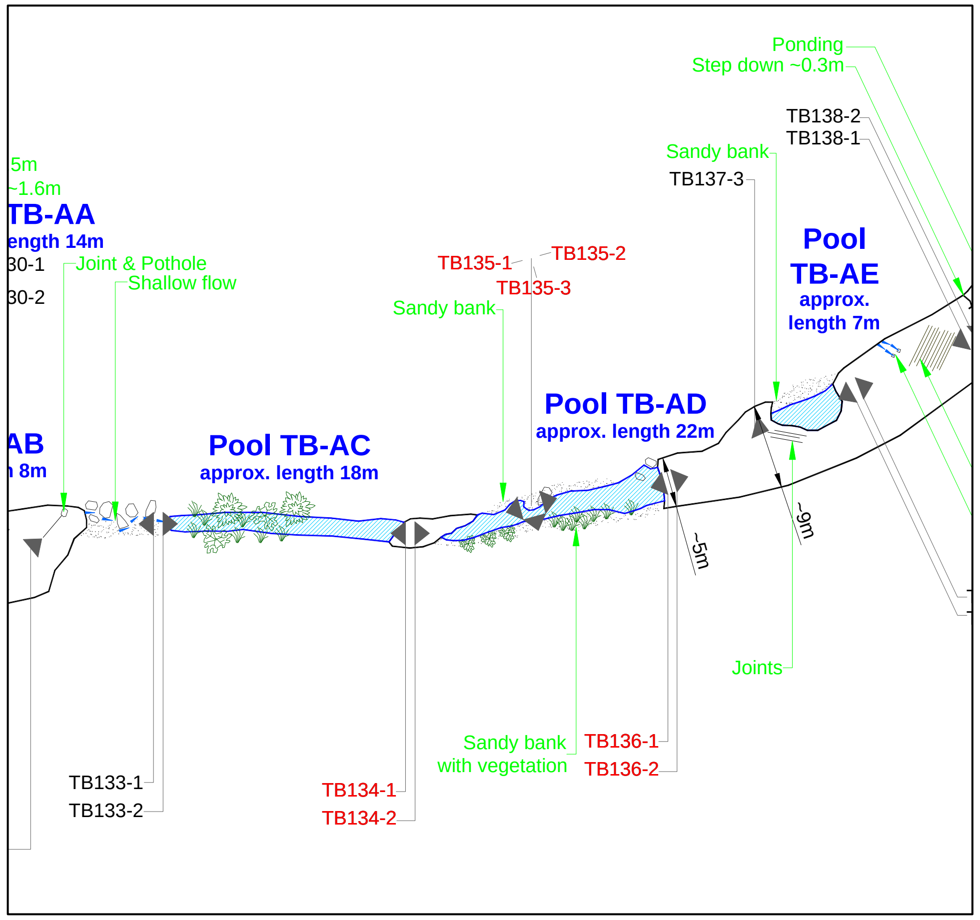
# TRIBUTARY B STREAM MAPPING SUMMARY

**TB134-1** Downstream end of Pool TB-AC looking Upstream

**TB134-2** Upstream end of Pool TB-AD looking Downstream

Notes (as at 15 December 2009)

- Pool TB-AC approximately 18m long, 2m wide and 0.2m deep
- Base of the pool is sandstone with alluvial deposits on southern bank
- Pool TB-AD approximately 22m long, up to 4.5m wide at the downstream end, and 0.5m deep
- Rockbar between Pools TB-AC and TB-AD approximately 7m long




**TB135-1** Midway along Pool TB-AD looking Upstream

**TB135-2** Midway along Pool TB-AD looking Downstream

**TB135-3** Midway along Pool TB-AD looking toward southern bank

**TB136-1** Downstream end of Pool TB-AD looking Upstream

**TB136-2** Downstream end of Pool TB-AD looking Downstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TB134-1 | 309869 | 6214977 | 270 |
| TB134-2 | 309869 | 6214977 | 90 |
| TB135-1 | 309882 | 6214980 | 255 |
| TB135-2 | 309882 | 6214980 | 75 |
| TB135-3 | 309882 | 6214980 | 165 |
| TB136-1 | 309897 | 6214982 | 255 |
| TB136-2 | 309897 | 6214982 | 75 |

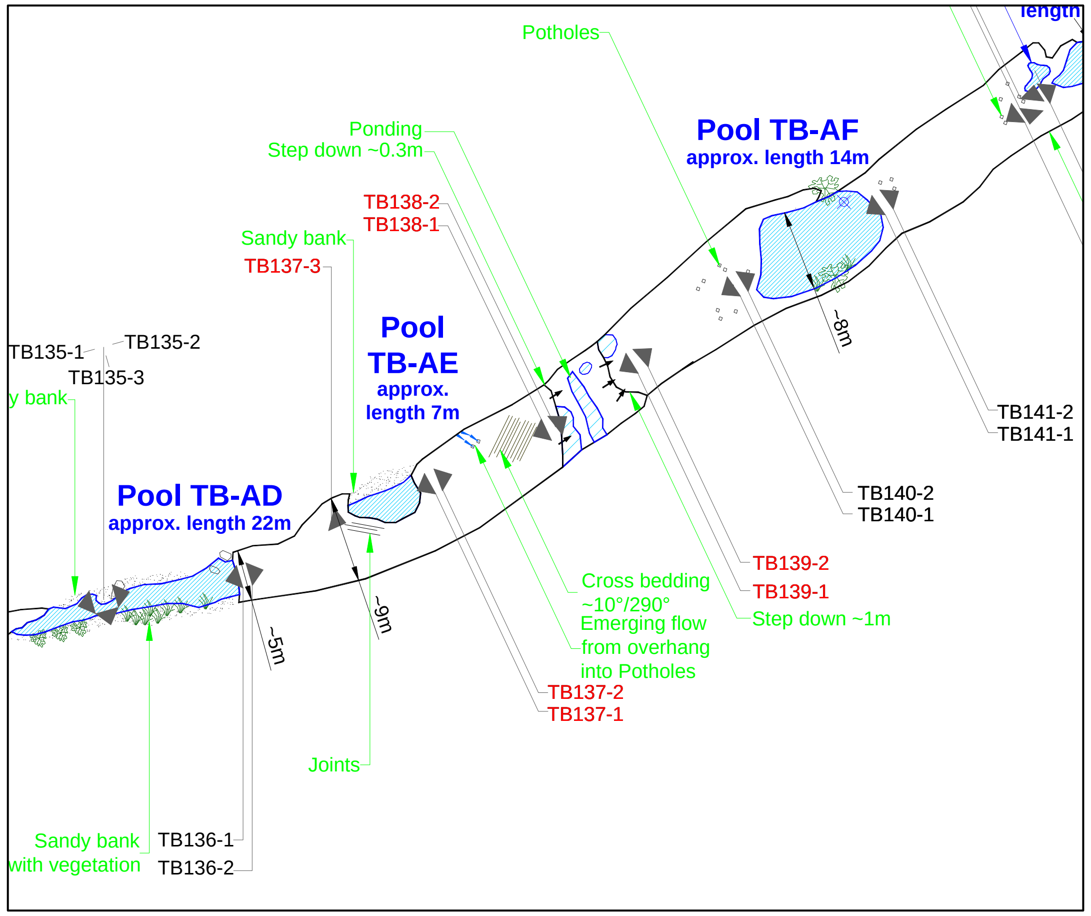
# TRIBUTARY B STREAM MAPPING SUMMARY

**TB137-1** Downstream end of Pool TB-AE looking Upstream

**TB137-2** Downstream end of Pool TB-AE looking Downstream

Notes (as at 15 December 2009)

- Pool TB-AE approximately 7m long, 3.5m wide and 0.5m deep
- Base of the pool is sandstone with alluvial deposits and scattered vegetation debris on the northern bank
- Rockbar downstream of the pool approximately 16m long with cross bedding
- Rockbar steps down approximately 0.3m at TB138, with ponding downstream (TB138-2)
- Rockbar steps down approximately 1m at TB139 (TB139-1)




**TB137-3** Joints

**TB138-1** Downstream of Pool TB-AE looking Upstream

**TB138-2** Downstream of Pool TB-AE looking Downstream

**TB139-1** Upstream of Pool TB-AF looking Upstream

**TB139-2** Upstream of Pool TB-AF looking Downstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TB137-1 | 309916 | 6214992 | 245 |
| TB137-2 | 309916 | 6214992 | 65 |
| TB137-3 | 309916 | 6214992 | 100 |
| TB138-1 | 309929 | 6214998 | 245 |
| TB138-2 | 309929 | 6214998 | 55 |
| TB139-1 | 309938 | 6215005 | 240 |
| TB139-2 | 309938 | 6215005 | 50 |

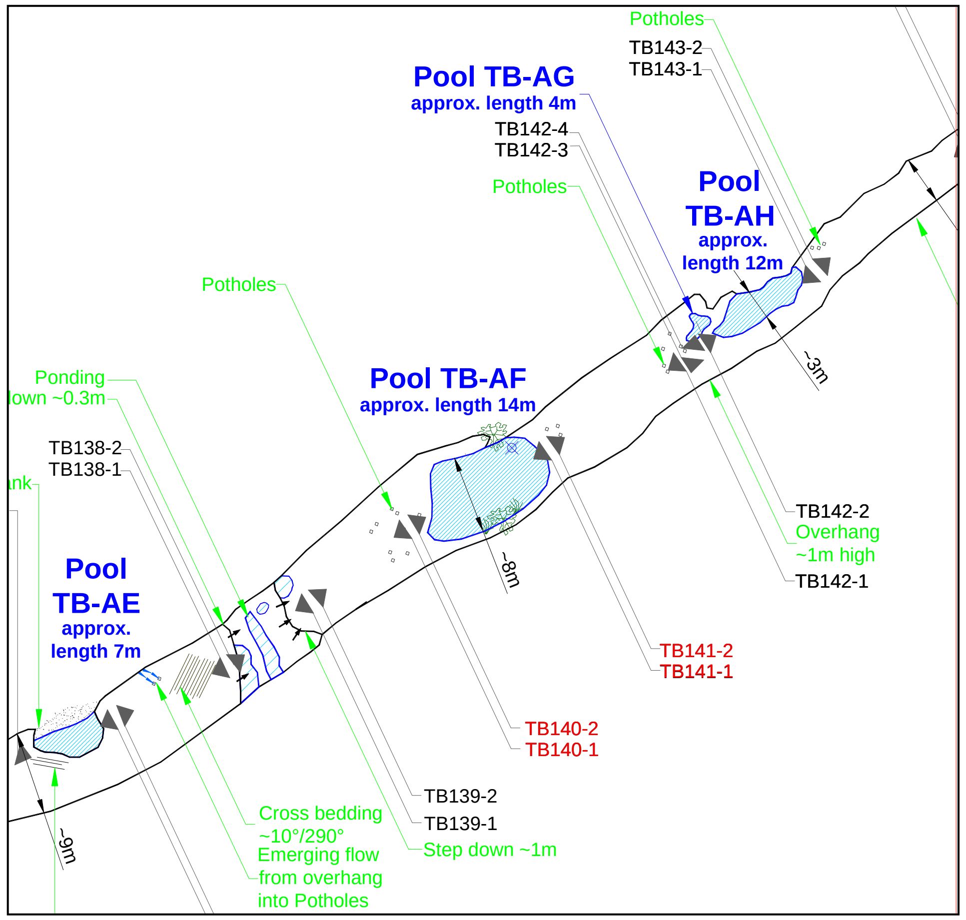
# TRIBUTARY B STREAM MAPPING SUMMARY

**TB140-1** Upstream end of Pool TB-AF looking Upstream

**TB140-2** Upstream end of Pool TB-AF looking Downstream

Notes (as at 15 December 2009)

- Pool TB-AF approximately 14m long, 8m wide and up to 1.5m deep
- Base of the pool is sandstone with alluvial deposits
- Rockbar upstream of the pool has many potholes and no flow visible
- Rockbar downstream of the pool approximately 9m wide with many potholes at the downstream end




**TB141-1** Downstream end of Pool TB-AF looking Upstream

**TB141-2** Downstream end of Pool TB-AF looking Downstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TB140-1 | 309950 | 6215011 | 235 |
| TB140-2 | 309950 | 6215011 | 60 |
| TB141-1 | 309963 | 6215022 | 235 |
| TB141-2 | 309963 | 6215022 | 55 |

# TRIBUTARY B STREAM MAPPING SUMMARY

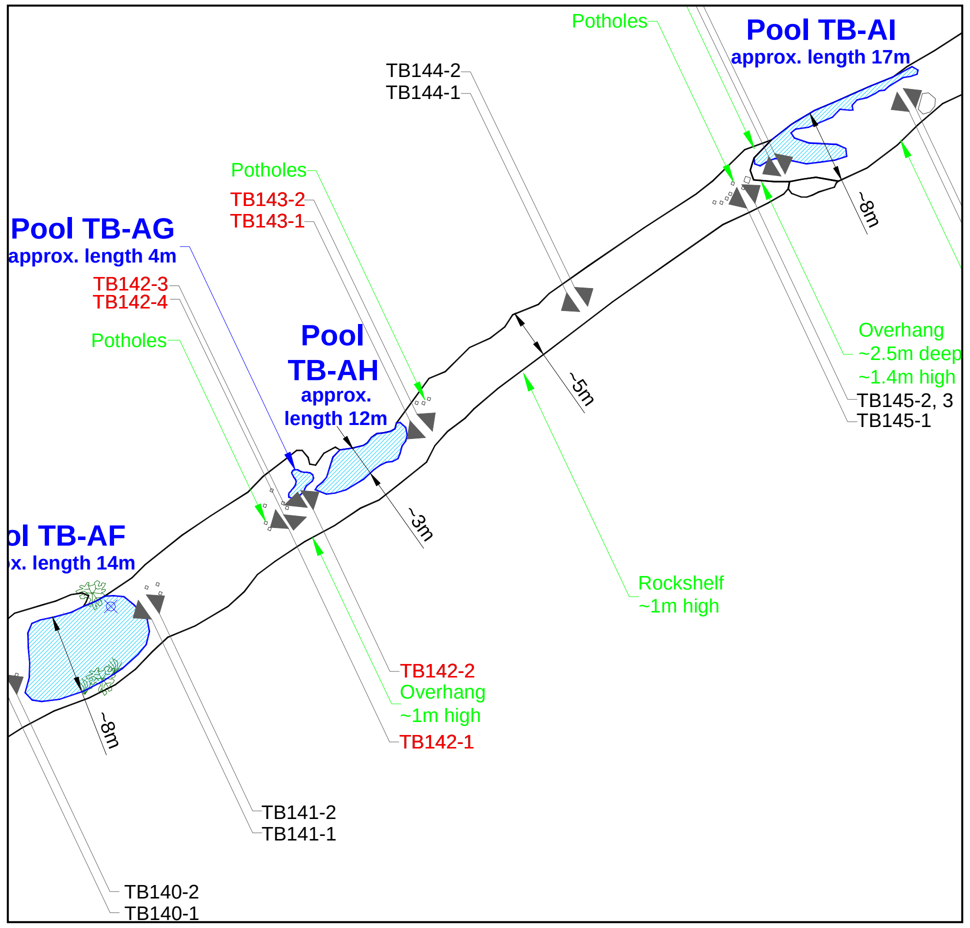
**TB142-1** Upstream end of Pool TB-AG looking Upstream

**TB142-2** Upstream end of Pool TB-AG looking Downstream

Notes (as at 15 December 2009)

- Pool TB-AG approximately 4m long, up to 2m wide and 0.3m deep
- Base of the pool is sandstone with alluvial deposits

- Pool TG-AH approximately 12m long, 3m wide and 0.5m deep
- Base of the pool is sandstone with alluvial deposits
- Overhang on southern bank approximately 1m high




**TB142-3** Pool TB-AG Looking toward northern bank

**TB142-4** Overhang along southern bank Upstream of Pool TB-AG

**TB143-1** Downstream end of Pool TB-AH looking Upstream

**TB143-2** Downstream end of Pool TB-AH looking Downstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TB142-1 | 309977 | 6215032 | 235 |
| TB142-2 | 309977 | 6215032 | 55 |
| TB142-3 | 309977 | 6215032 | 185 |
| TB142-4 | 309977 | 6215032 | 5 |
| TB143-1 | 309993 | 6215041 | 225 |
| TB143-2 | 309993 | 6215041 | 45 |

# TRIBUTARY B STREAM MAPPING SUMMARY

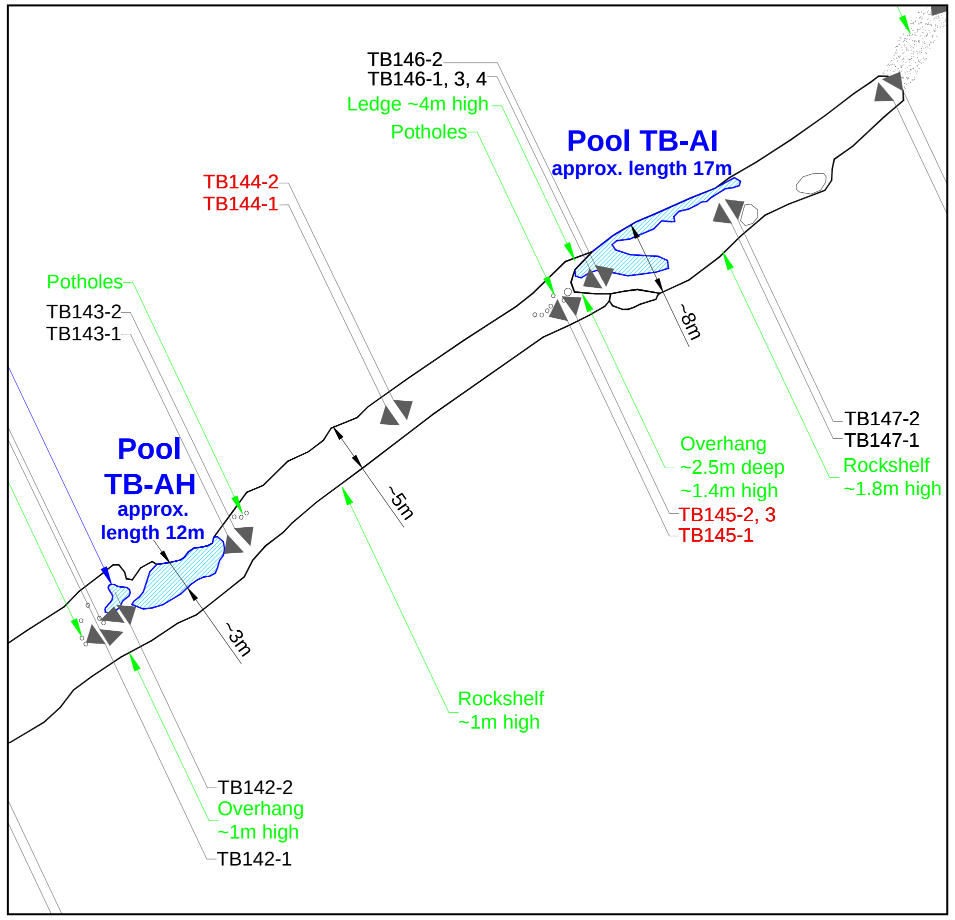
**TB144-1** Downstream of Pool TB-AH looking Upstream

**TB144-2** Downstream of Pool TB-AH looking Downstream

<u>Notes (as at 15 December 2009)</u>

- Rockbar between Pools TB-AH and TB-AI approximately 45m long and 5m wide, with many potholes
- Overhang at downstream end of rockbar approximately 1.4m high and 2.5m deep

**TB145-1** Upstream of Pool TB-AI looking Upstream




**TB145-2** Upstream of Pool TB-AI looking Downstream

**TB145-3** Pothole in overhang

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TB144-1 | 310008 | 6215056 | 235 |
| TB144-2 | 310008 | 6215056 | 55 |
| TB145-1 | 310032 | 6215061 | 245 |
| TB145-2 | 310032 | 6215061 | 55 |
| TB145-3 | 310032 | 6215061 | 55 |

# TRIBUTARY B STREAM MAPPING SUMMARY

**TB146-1** Upstream end of Pool TB-AI looking Upstream

**TB146-2** Upstream end of Pool TB-AI looking Downstream

**TB146-3** Pothole in overhang

**TB146-4** Pothole in overhang

<u>Notes (as at 15 December 2009)</u>

- Pool TB-AI approximately 17m long, up to 4m wide at the upstream end, and 0.3m deep
- Base of the pool is sandstone with alluvial deposits
- Overhang approximately 1.4m high and 2.5m deep, with large potholes

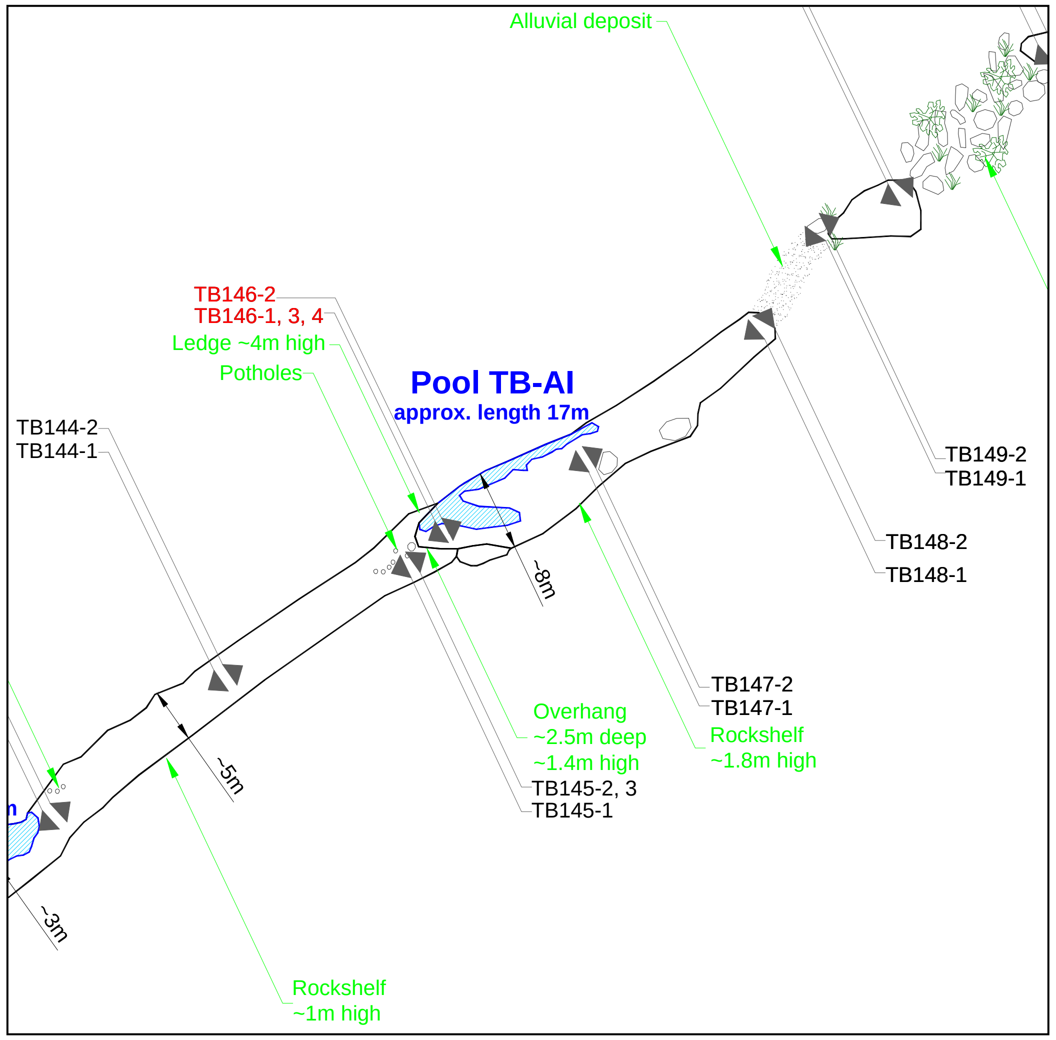



Photo Details

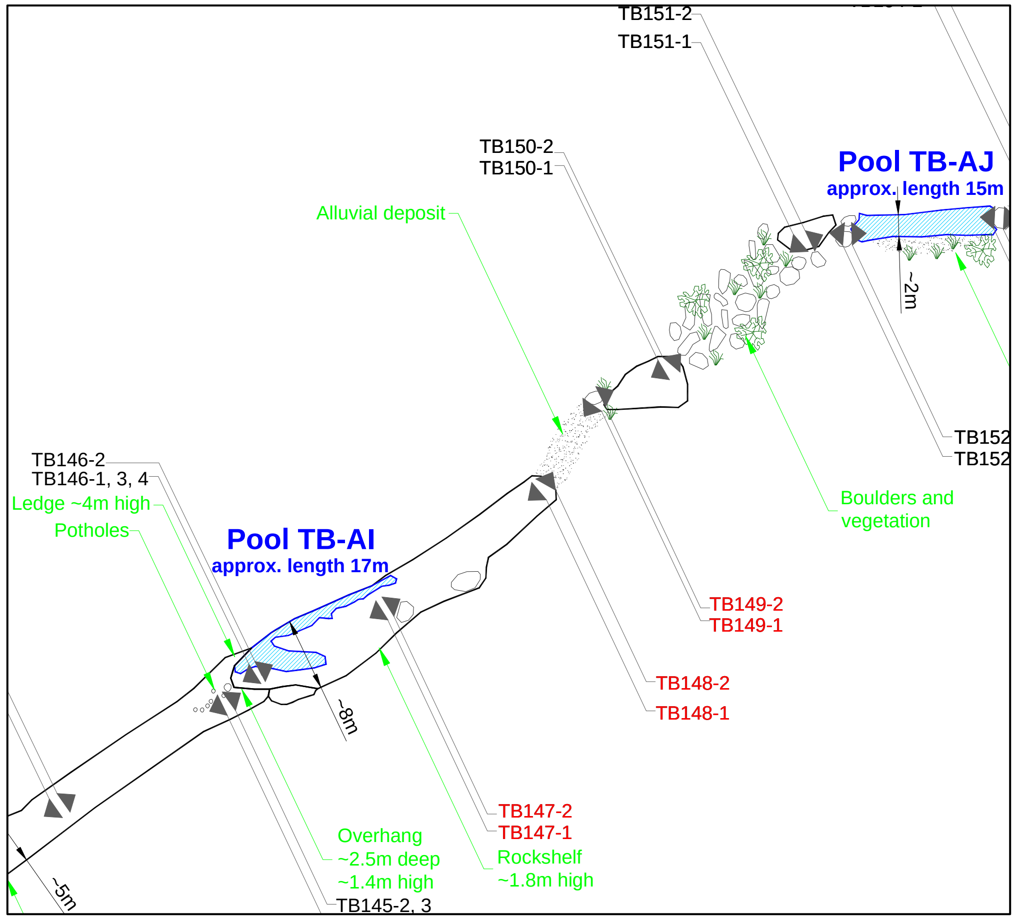
| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TB146-1 | 310046 | 6215079 | 235 |
| TB146-2 | 310046 | 6215079 | 65 |
| TB146-3 | 310046 | 6215079 | 235 |
| TB146-4 | 310046 | 6215079 | 235 |

# TRIBUTARY B STREAM MAPPING SUMMARY

**TB147-1** Downstream end of Pool TB-AI looking Upstream

Notes (as at 15 December 2009)

- Pool TB-AI approximately 17m long, up to 4m wide at the upstream end, and 0.3m deep
- Base of the pool is sandstone with alluvial deposits
- Alluvial deposits and scattered vegetation debris between TB148 and TB149




**TB147-2** Downstream end of Pool TB-AI looking Downstream

**TB148-1** Downstream of Pool TB-AI looking Upstream

**TB148-2** Downstream of Pool TB-AI looking Downstream

**TB149-1** Downstream of Pool TB-AI looking Upstream

**TB149-2** Downstream of Pool TB-AI looking Downstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TB147-1 | 310046 | 6215079 | 240 |
| TB147-2 | 310046 | 6215079 | 60 |
| TB148-1 | 310062 | 6215089 | 235 |
| TB148-2 | 310062 | 6215089 | 30 |
| TB149-1 | 310076 | 6215099 | 215 |
| TB149-2 | 310076 | 6215099 | 65 |

# TRIBUTARY B STREAM MAPPING SUMMARY

**TB150-1** Upstream of Pool TB-AJ looking Upstream

**TB150-2** Upstream of Pool TB-AJ looking Downstream

**TB151-1** Upstream of Pool TB-AJ looking Upstream

**TB151-2** Upstream of Pool TB-AJ looking Downstream

**TB152-1** Upstream end of Pool TB-AJ looking Upstream

**TB152-2** Upstream end of Pool TB-AJ looking Downstream

Notes (as at 15 December 2009)

- Boulder field and vegetation upstream of Pool TB-AJ
- Pool TB-AJ approximately 15m long, 2m wide and 0.3m deep
- Base of the pool is sandstone with alluvial deposits

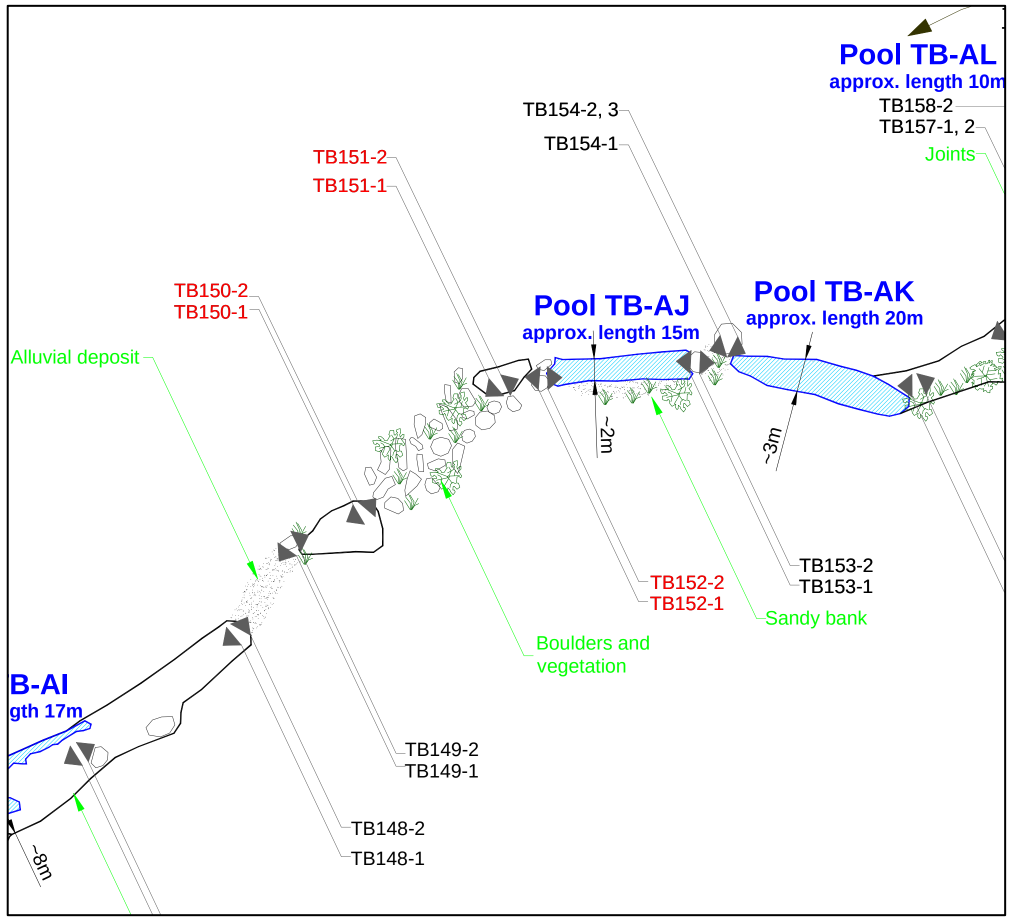



Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TB150-1 | 310076 | 6215099 | 240 |
| TB150-2 | 310076 | 6215099 | 40 |
| TB151-1 | 310090 | 6215117 | 230 |
| TB151-2 | 310090 | 6215117 | 65 |
| TB152-1 | 310095 | 6215116 | 280 |
| TB152-2 | 310095 | 6215116 | 85 |

# TRIBUTARY B STREAM MAPPING SUMMARY

**TB153-1** Downstream end of Pool TB-AJ looking Upstream

**TB153-2** Downstream end of Pool TB-AJ looking Downstream

**TB154-1** Upstream end of Pool TB-AK looking Upstream

Notes (as at 15 December 2009)

- Pool TB-AJ approximately 15m long, 2m wide and 0.3m deep
- Base of the pool is sandstone with alluvial deposits

- Pool TB-AK approximately 20m long, 3m wide and 0.3m deep
- Base of the pool is sandstone with alluvial deposits

- Vegetation and alluvial deposits between Pools TB-AJ and TB-AK
- No flow visible downstream of Pool TB-AK

**TB154-2** Upstream end of Pool TB-AK looking Downstream

**TB154-3** Upstream end of Pool TB-AK looking Downstream

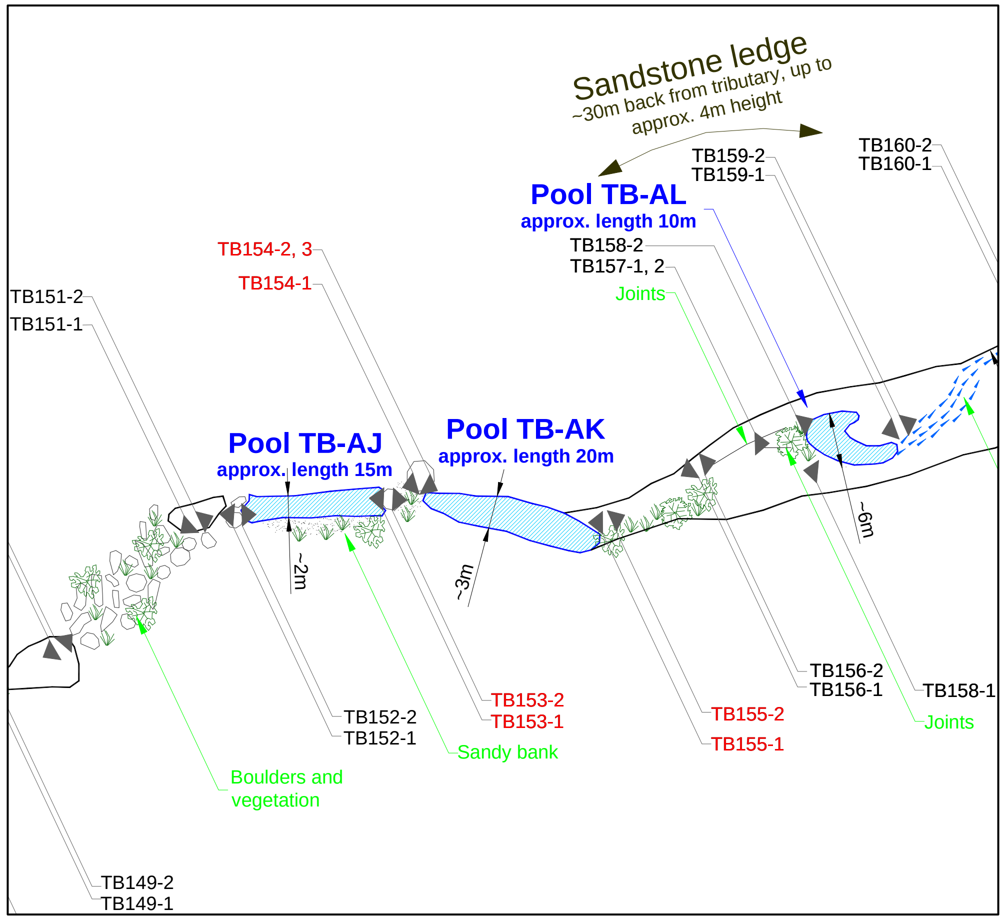



Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TB153-1 | 310111 | 6215118 | 275 |
| TB153-2 | 310111 | 6215118 | 95 |
| TB154-1 | 310115 | 6215120 | 255 |
| TB154-2 | 310115 | 6215120 | 120 |
| TB154-3 | 310115 | 6215120 | 120 |
| TB155-1 | 310135 | 6215117 | 270 |
| TB155-2 | 310135 | 6215117 | 65 |

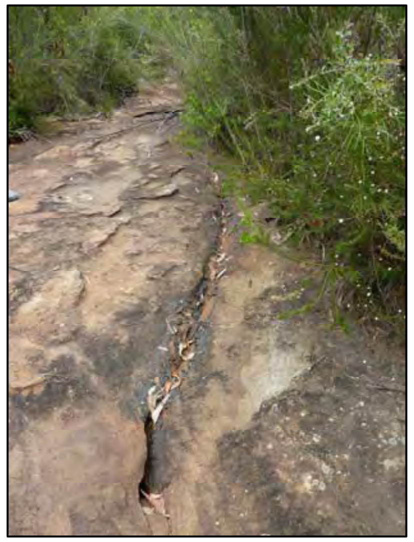
**TB155-1** Downstream end of Pool TB-AK looking Upstream

**TB155-2** Downstream end of Pool TB-AK looking Downstream

# TRIBUTARY B STREAM MAPPING SUMMARY

**TB156-1** Downstream of Pool TB-AK looking Upstream

**TB156-2** Downstream of Pool TB-AK looking Downstream



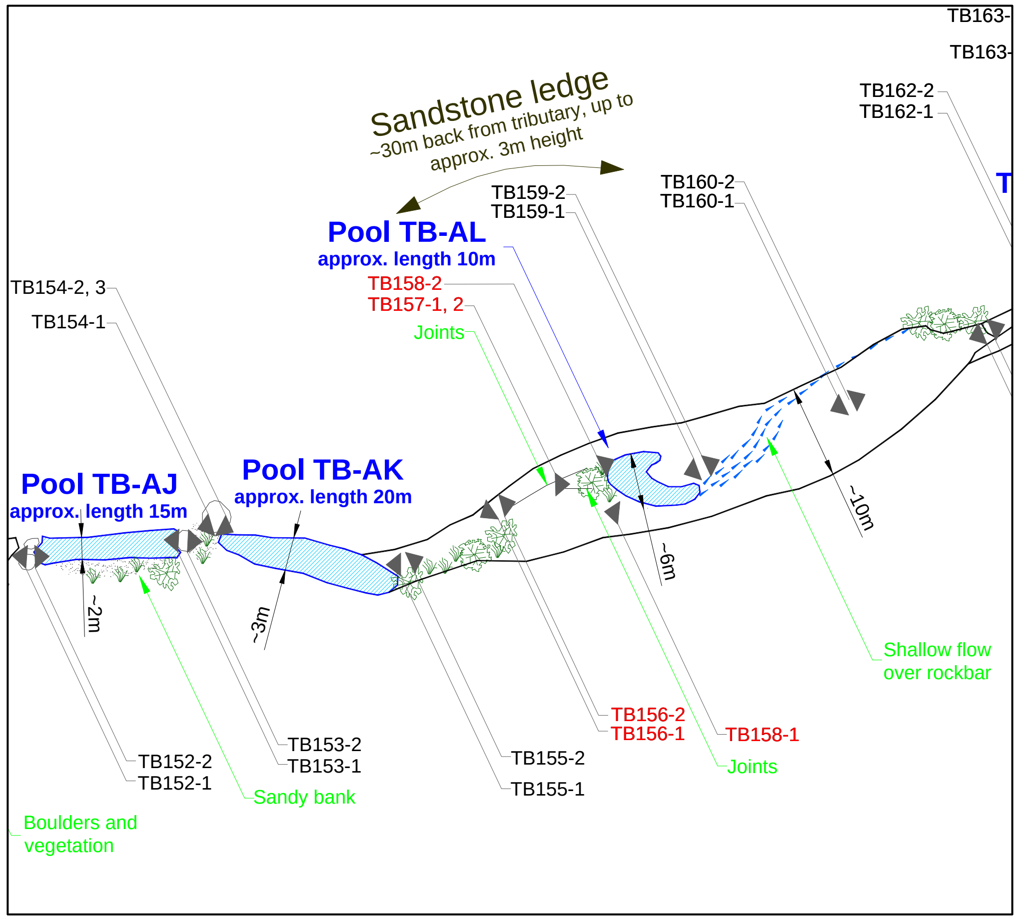
**TB157-1** Joint

Notes (as at 15 December 2009)

- Rockbar upstream of Pool TB-AL approximately 23m long and up to 10m wide, with joints at the downstream end
- Pool TB-AL approximately 10m long, 6m wide and 0.3m deep
- Base of the pool is sandstone with algae at the downstream end
- Sandstone ledge up to 3m high on northern side of Pool TB-AL at a distance of approximately 30m

**TB157-2** Joint

**TB158-1** Upstream end of Pool TB-AL looking Upstream




**TB158-2** Upstream end of Pool TB-AL looking Downstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TB156-1 | 310146 | 6215121 | 235 |
| TB156-2 | 310146 | 6215121 | 75 |
| TB157-1 | 310152 | 6215122 | 85 |
| TB157-2 | 310152 | 6215122 | 85 |
| TB158-1 | 310156 | 6215126 | 275 |
| TB158-2 | 310156 | 6215126 | 65 |

# TRIBUTARY B STREAM MAPPING SUMMARY

**TB159-1** Downstream end of Pool TB-AL looking Upstream

**TB159-2** Downstream end of Pool TB-AL looking Downstream

**TB160-1** Downstream of Pool TB-AL looking Upstream

**TB160-2** Downstream of Pool TB-AL looking Downstream

Notes (as at 15 December 2009)

- Pool TB-AL approximately 10m long, 6m wide and 0.3m deep
- Base of the pool is sandstone with algae at the downstream end
- Shallow flow over 10m wide rockbar downstream of the pool

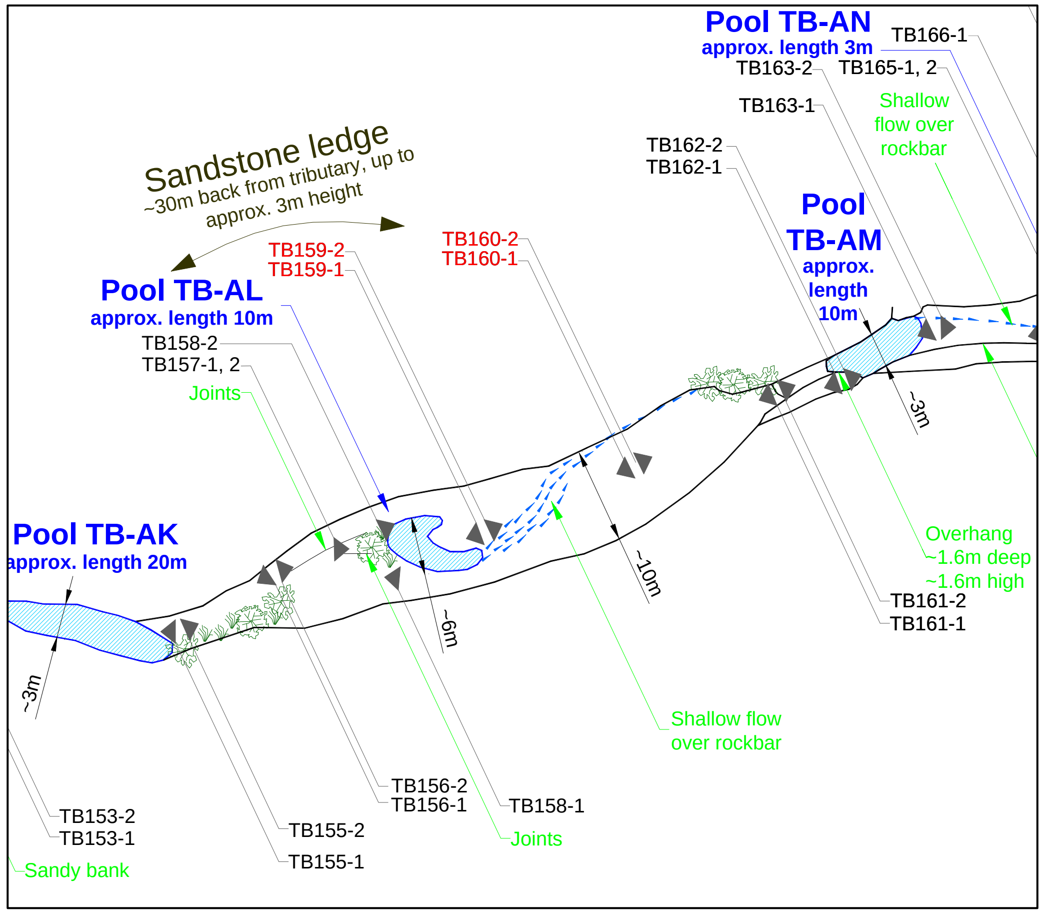



Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TB159-1 | 310168 | 6215124 | 250 |
| TB159-2 | 310168 | 6215124 | 65 |
| TB160-1 | 310183 | 6215133 | 245 |
| TB160-2 | 310183 | 6215133 | 65 |

# TRIBUTARY B STREAM MAPPING SUMMARY

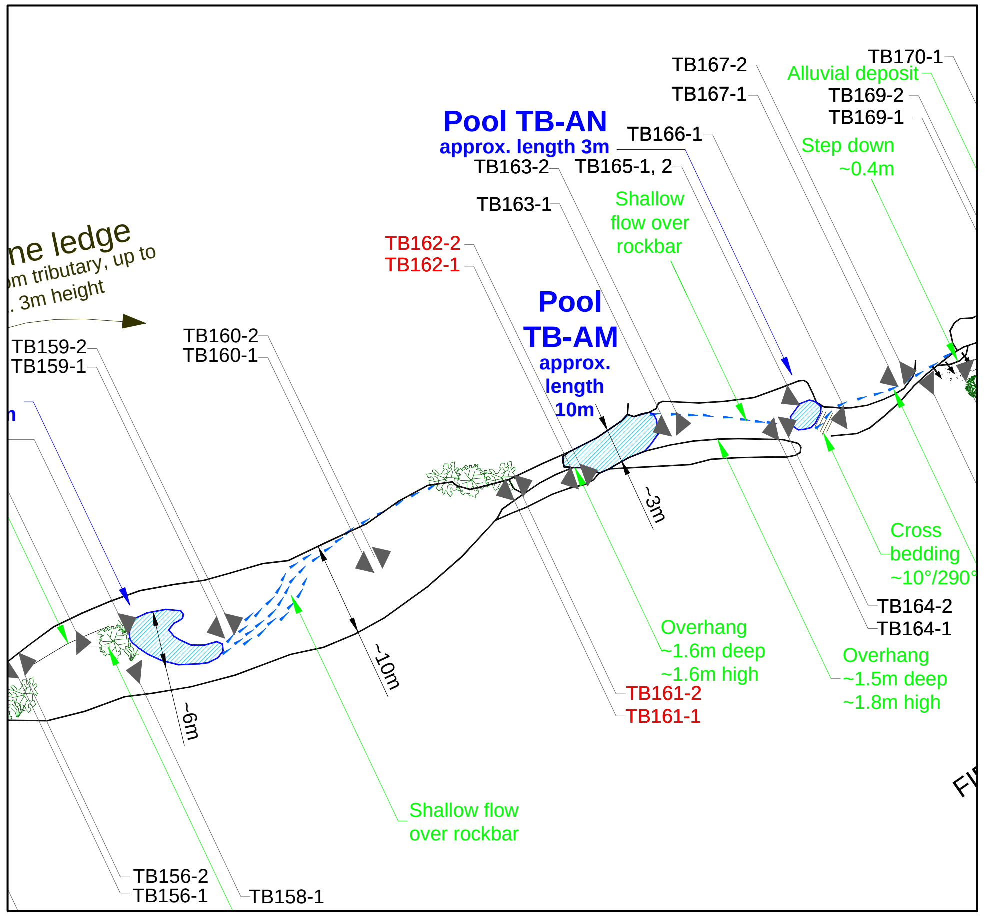
**TB161-1** Upstream of Pool TB-AM looking Upstream

**TB161-2** Upstream of Pool TB-AM looking Downstream

<u>Notes (as at 15 December 2009)</u>

- Pool TB-AM approximately 10m long, 3m wide and 0.3m deep
- Base of the pool is sandstone
- Approximate 1.6m change in height from rockbar at TB162  down to Pool TB-AM

**TB162-1** Upstream end of Pool TB-AM looking Upstream




**TB162-2** Upstream end of Pool TB-AM looking Downstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TB161-1 | 310199 | 6215140 | 245 |
| TB161-2 | 310199 | 6215140 | 65 |
| TB162-1 | 310204 | 6215142 | 250 |
| TB162-2 | 310204 | 6215142 | 70 |

# TRIBUTARY B STREAM MAPPING SUMMARY

**TB163-1** Downstream end of Pool TB-AM looking Upstream

**TB163-2** Downstream end of Pool TB-AM looking Downstream

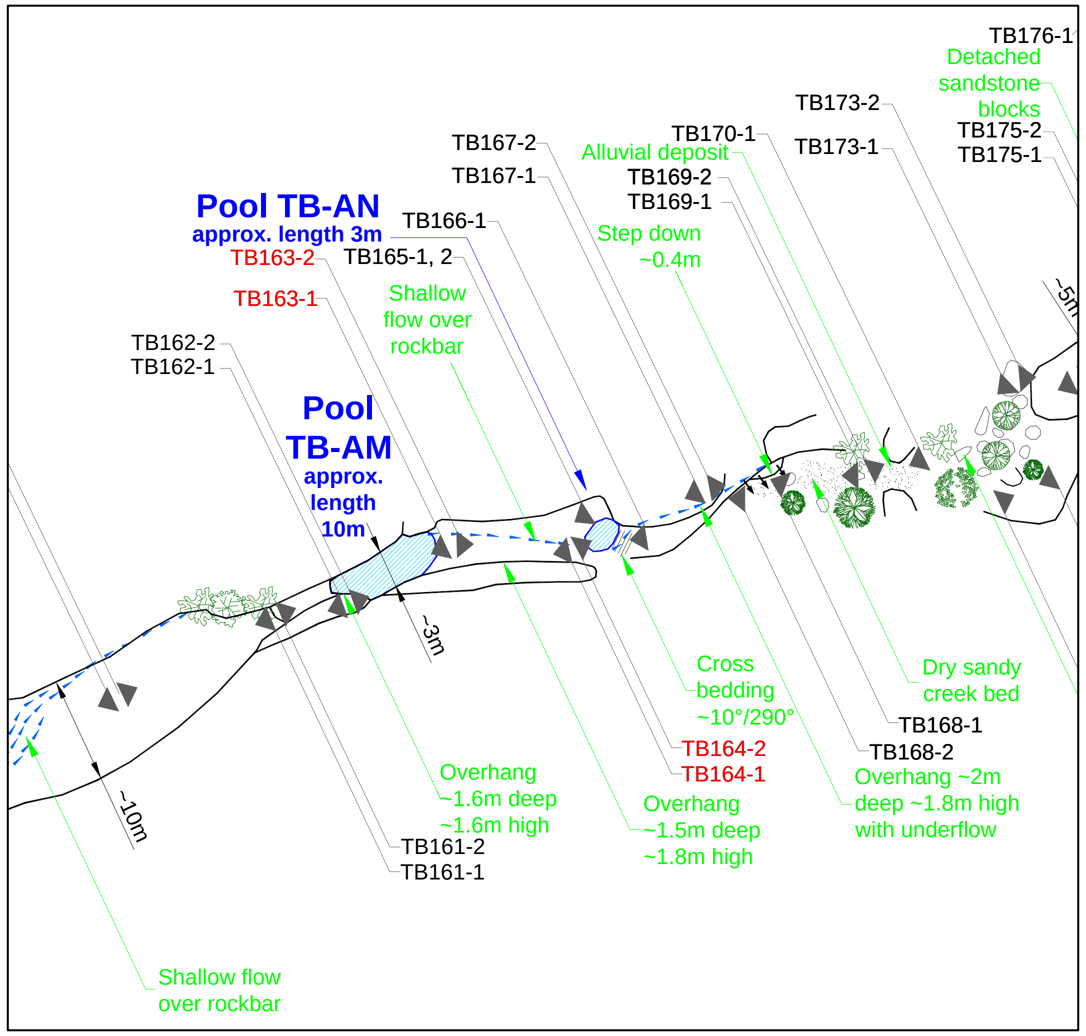
Notes (as at 15 December 2009)

- Pool TB-AM approximately 10m long, 3m wide and 0.3m deep
- Base of the pool is sandstone
- Overhang at upstream end of pool approximately 1.6m high and 1.6m deep

- Pool TB-AN approximately 3m long, 2.5m wide and 0.2m deep
- Base of the pool is sandstone

- Rockbar between Pools TB-AM and TB-AN approximately 16m long and 4m wide, with shallow flow
- Overhang on southern bank approximately 1.8m high and 1.5m deep, and runs along the length of the rockbar

**TB164-1** Upstream end of Pool TB-AN looking Upstream




**TB164-2** Upstream end of Pool TB-AN looking Downstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TB163-1 | 310213 | 6215148 | 245 |
| TB163-2 | 310213 | 6215148 | 90 |
| TB164-1 | 310226 | 6215147 | 255 |
| TB164-2 | 310226 | 6215147 | 65 |

# TRIBUTARY B STREAM MAPPING SUMMARY

**TB165-1** Midway along Pool TB-AN looking Upstream

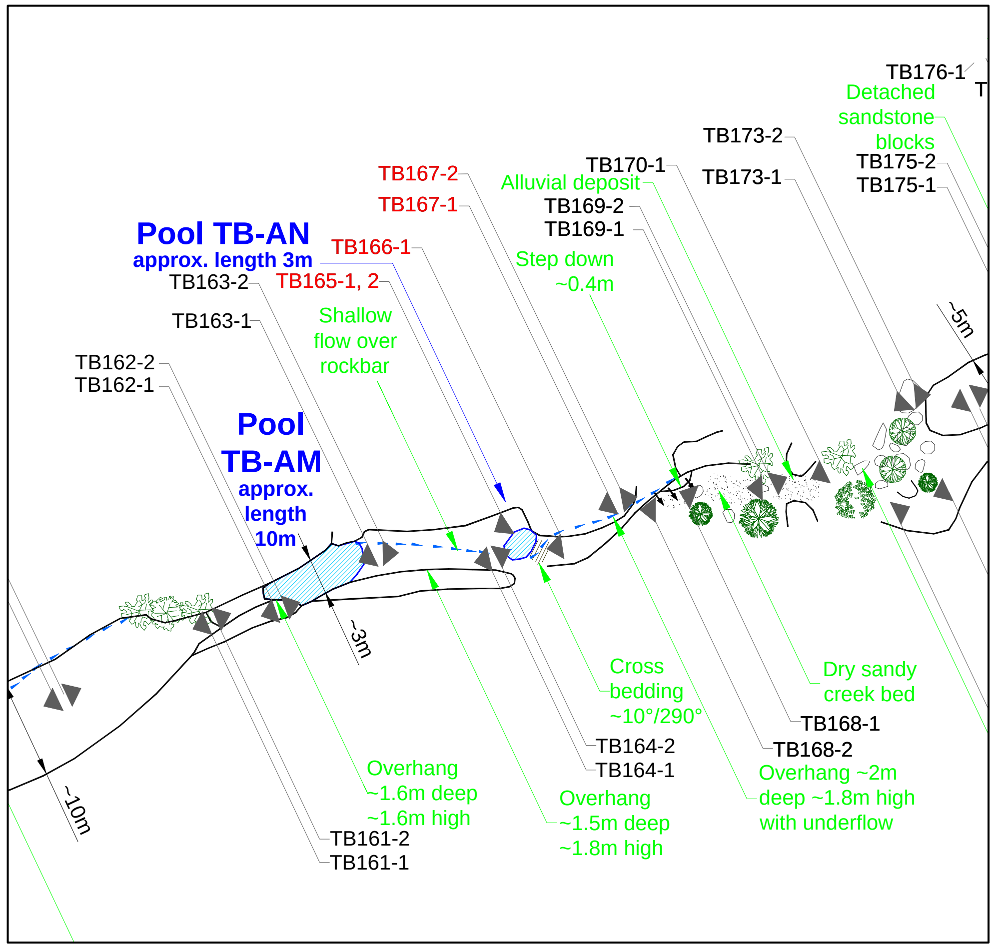
**TB165-2** Overhang at Upstream end of Pool TB-AN

<u>Notes (as at 15 December 2009)</u>

- Pool TB-AN approximately 3m long, 2.5m wide and 0.2m deep
- Base of the pool is sandstone
- Flow over cross bedding planes downstream of the pool, then underflow beneath overhang on northern bank

**TB166-1** Downstream end of Pool TB-AN looking Upstream

**TB167-2** Downstream of Pool TB-AN looking Downstream




**TB167-1** Downstream of Pool TB-AN looking Upstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TB165-1 | 310228 | 6215150 | 235 |
| TB165-2 | 310228 | 6215150 | 235 |
| TB166-1 | 310232 | 6215148 | 260 |
| TB167-1 | 310239 | 6215152 | 245 |
| TB167-2 | 310239 | 6215152 | 75 |

# TRIBUTARY B STREAM MAPPING SUMMARY

**TB168-1** Overhang downstream of Pool TB-AN

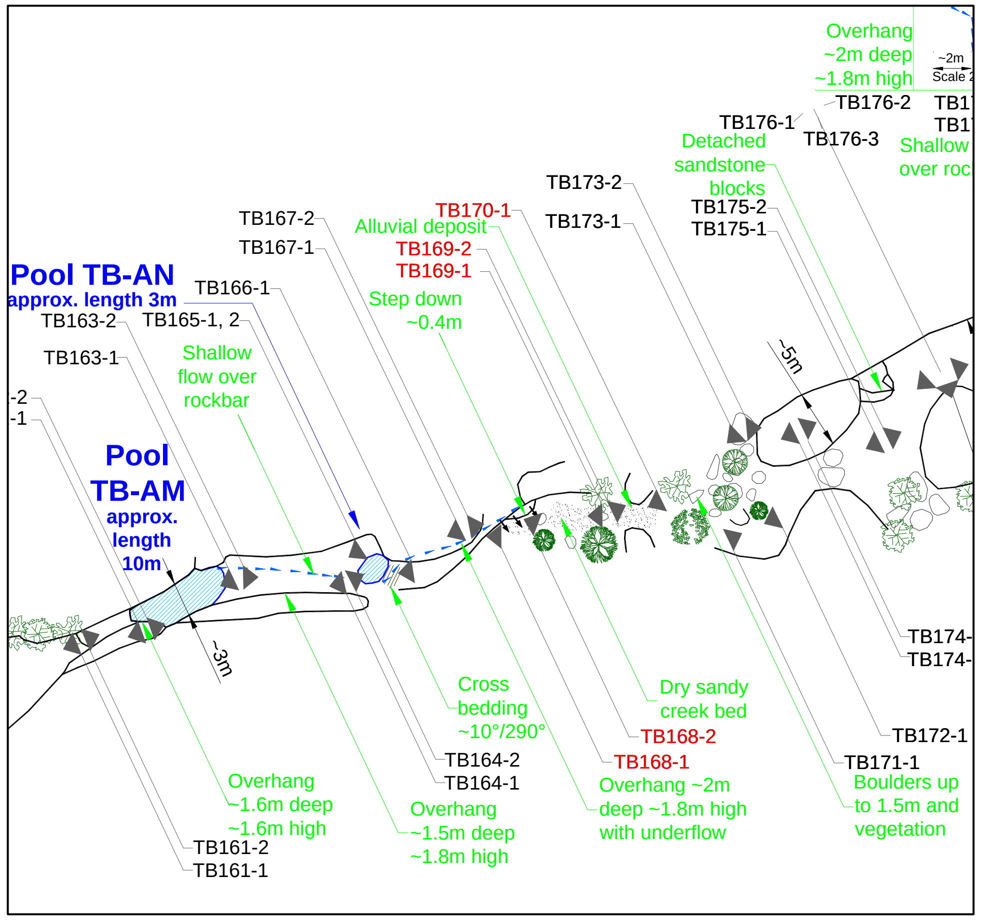
**TB168-2** Downstream of Pool TB-AN looking Upstream

Notes (as at 15 December 2009)

- Overhang downstream of Pool TB-AN approximately 1.8m high and 2m deep with underflow
- Dry sandy creek bed with alluvial deposits downstream

**TB169-1** Downstream of Pool TB-AN looking Upstream

**TB169-2** Downstream of Pool TB-AN looking Downstream




**TB170-1** Downstream of Pool TB-AN looking Upstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TB168-1 | 310242 | 6215152 | 290 |
| TB168-2 | 310242 | 6215152 | 270 |
| TB169-1 | 310257 | 6215154 | 270 |
| TB169-2 | 310257 | 6215154 | 65 |
| TB170-1 | 310255 | 6215154 | 245 |

# TRIBUTARY B STREAM MAPPING SUMMARY

**TB171-1** Upstream of Pool P looking Downstream

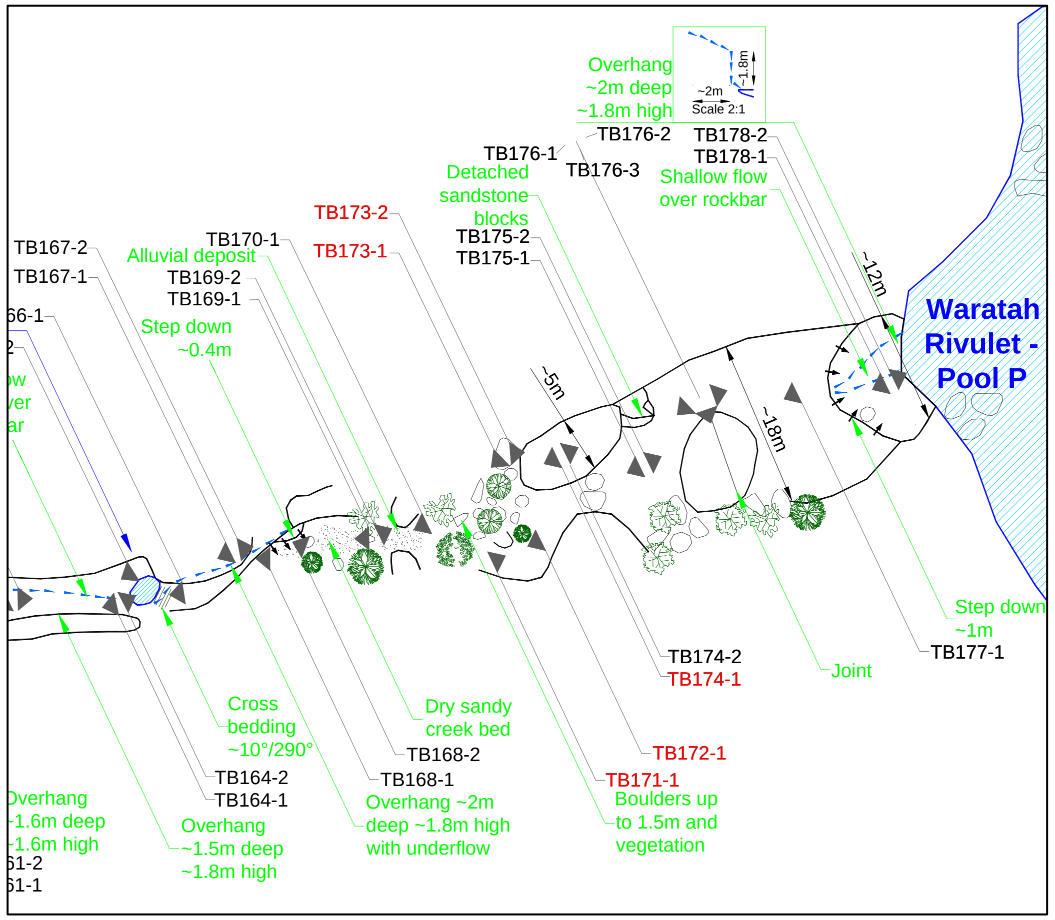
**TB172-1** Upstream of Pool P looking Upstream

**TB173-1** Upstream of Pool P looking Upstream

Notes (as at 15 December 2009)

- Alluvial deposits open to boulder field and vegetation, with boulders up to 1m
- No flow visible through boulder field
- Boulder field opens to wide rockbar at TB173

**TB173-2** Upstream of Pool P looking Downstream




**TB174-1** Upstream of Pool P looking Upstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TB171-1 | 310266 | 6215152 | 65 |
| TB172-1 | 310271 | 6215151 | 245 |
| TB173-1 | 310267 | 6215163 | 225 |
| TB173-2 | 310267 | 6215163 | 85 |
| TB174-1 | 310273 | 6215163 | 245 |

# TRIBUTARY B STREAM MAPPING SUMMARY

**TB174-2** Upstream of Pool P looking Downstream

**TB175-1** Upstream of Pool P looking Upstream

**TB175-2** Upstream of Pool P looking Downstream

Notes (as at 15 December 2009)

- Rockbar at TB175 approximately 12m wide
- No flow visible
- Scattered vegetation debris

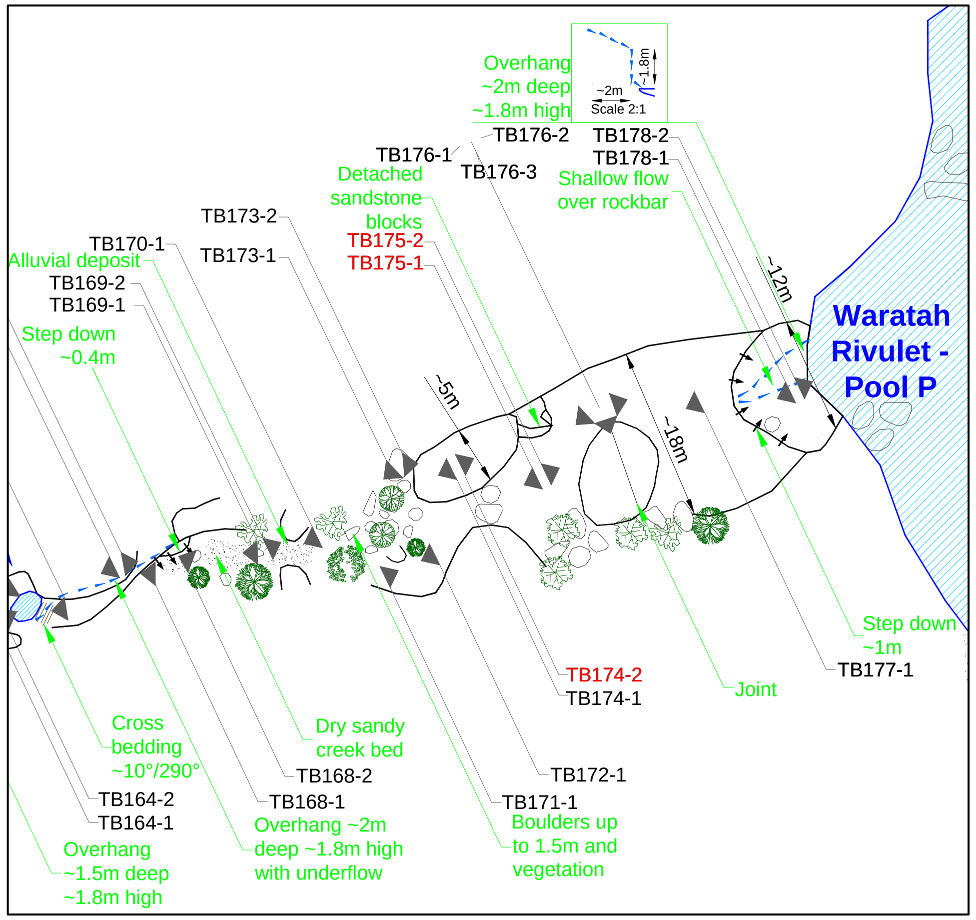



Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TB174-2 | 310273 | 6215163 | 65 |
| TB175-1 | 310283 | 6215162 | 245 |
| TB175-2 | 310283 | 6215162 | 65 |

# TRIBUTARY B STREAM MAPPING SUMMARY

Notes (as at 15 December 2009)

- Rockbar approximately 18m wide at TB176, with large detached sandstone blocks
- Large joint through rockshelf on southern bank

**TB176-1** Upstream of Pool P looking Upstream

**TB176-2** Upstream of Pool P looking Downstream

**TB176-3** Joint

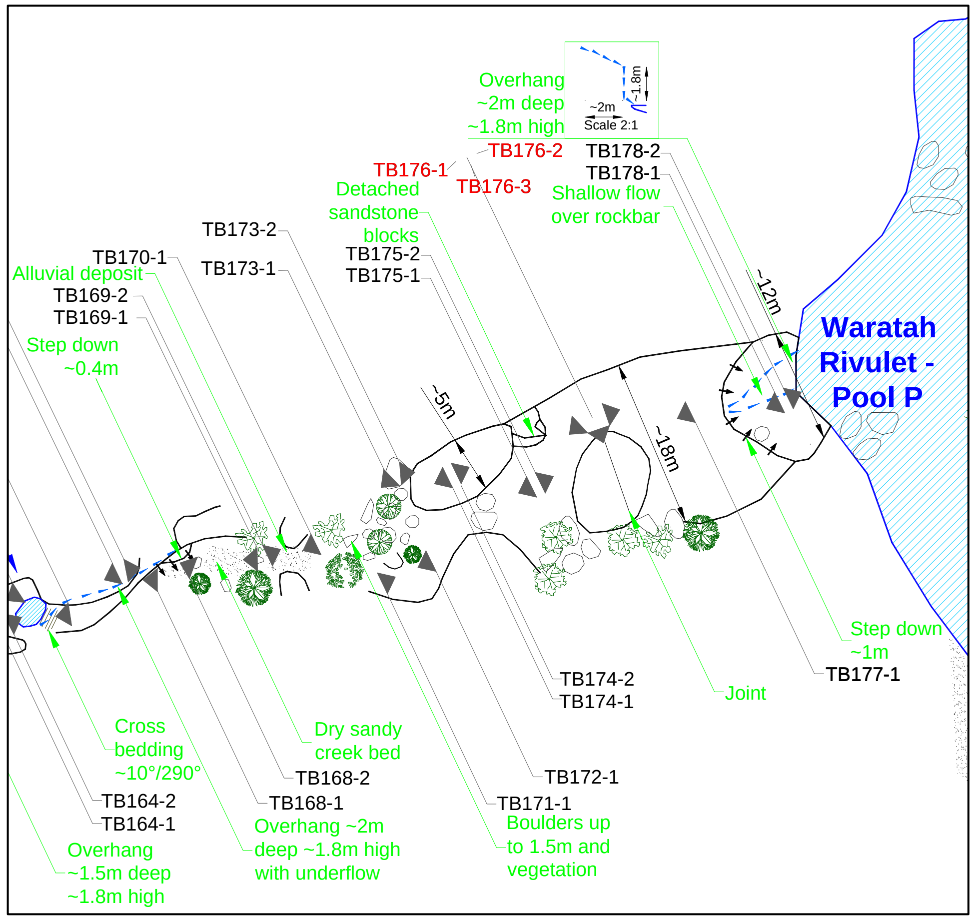



Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TB176-1 | 310290 | 6215168 | 230 |
| TB176-2 | 310290 | 6215168 | 70 |
| TB176-3 | 310290 | 6215167 | 160 |

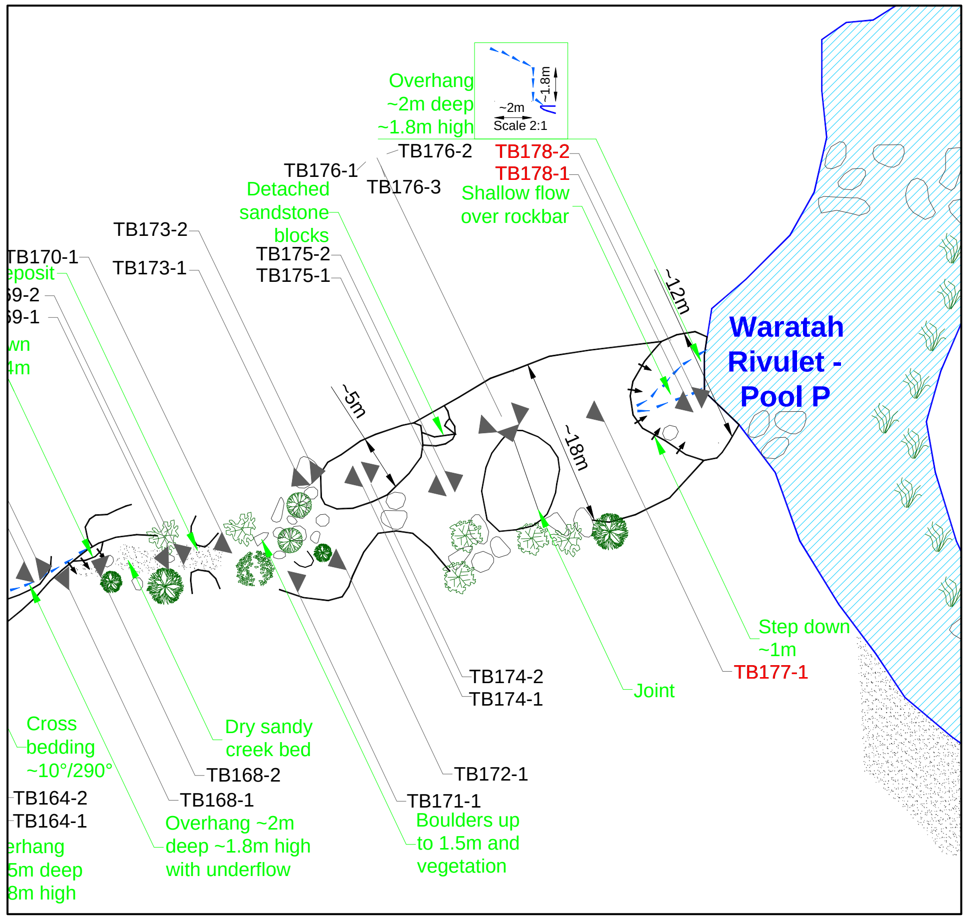
# TRIBUTARY B STREAM MAPPING SUMMARY

**TB177-1** Upstream of Pool P looking Upstream

Notes (as at 15 December 2009)

- Rockbar steps down approximately 1m at TB177 where flow emerges
- Shallow flow over rockbar downstream toward Waratah Rivulet
- Rockbar approximately 12m wide at the downstream end
- Overhang approximately 1.8m high and 2m deep

**TB178-1** Upstream of Pool P looking Upstream




**TB178-2** Upstream of Pool P looking Downstream

Photo Details

| Photo ID | Easting | Northing | Bearing |
|---|---|---|---|
| TB177-1 | 310300 | 6215176 | 245 |
| TB178-1 | 310312 | 6215174 | 245 |
| TB178-2 | 310312 | 6215174 | 65 |

# APPENDIX 5

# VISUAL INSPECTION AND PHOTOGRAPHIC SURVEY OF STREAMS IN THE VICINITY OF LONGWALLS 301 TO 303

HYDRO ENGINEERING & CONSULTING PTY LTD

# Visual Inspection and Photographic Survey of Streams in the Vicinity of Longwalls 301 to 303

## 1. INTRODUCTION

A visual inspection and photographic survey of streams in the vicinity of Longwalls 301-303 was conducted by Gilbert & Associates (now Hydro Engineering & Consulting) in July 2015 to characterise the baseline characteristics/condition of the streams and to investigate whether any surface water quantity, pool water level, or water quality monitoring of the streams would be required.

## 2. DESKTOP ASSESSMENT

### 2.1 Catchments and Streams

An east-west divide runs approximately north to south through the Longwalls 301 to 303 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). Twelve small sub-catchments within 600 metres (m) of Longwalls 301-303 have been identified on the western side of the study area and two on the eastern side of the study area (Figure 1). A summary of the sub-catchments is provided in Table 1.

**Table 1 Sub-catchments and Streams in the Vicinity of Longwalls 301 to 303**

| Sub-catchment Designation | Sub-catchment Area ($km^2$) | Stream Order[1] |
|---|---|---|
| A | 0.24 | 2 |
| B | 0.15 | 2 |
| C | 0.28 | 2 |
| D | 0.04 | 1 |
| E | 0.19 | 2 |
| F | 0.14 | 2 |
| G | 0.04 | 1 |
| H | 0.22 | 2 |
| I | 0.22 | 2 |
| J | 0.38 | 2 |
| K | 0.21 | 2 |
| L | 0.19 | 2 |
| M | 0.79 | 2 |
| N | 0.79 | 3 |

[1] Based on mapping of streams using 1 m contours.

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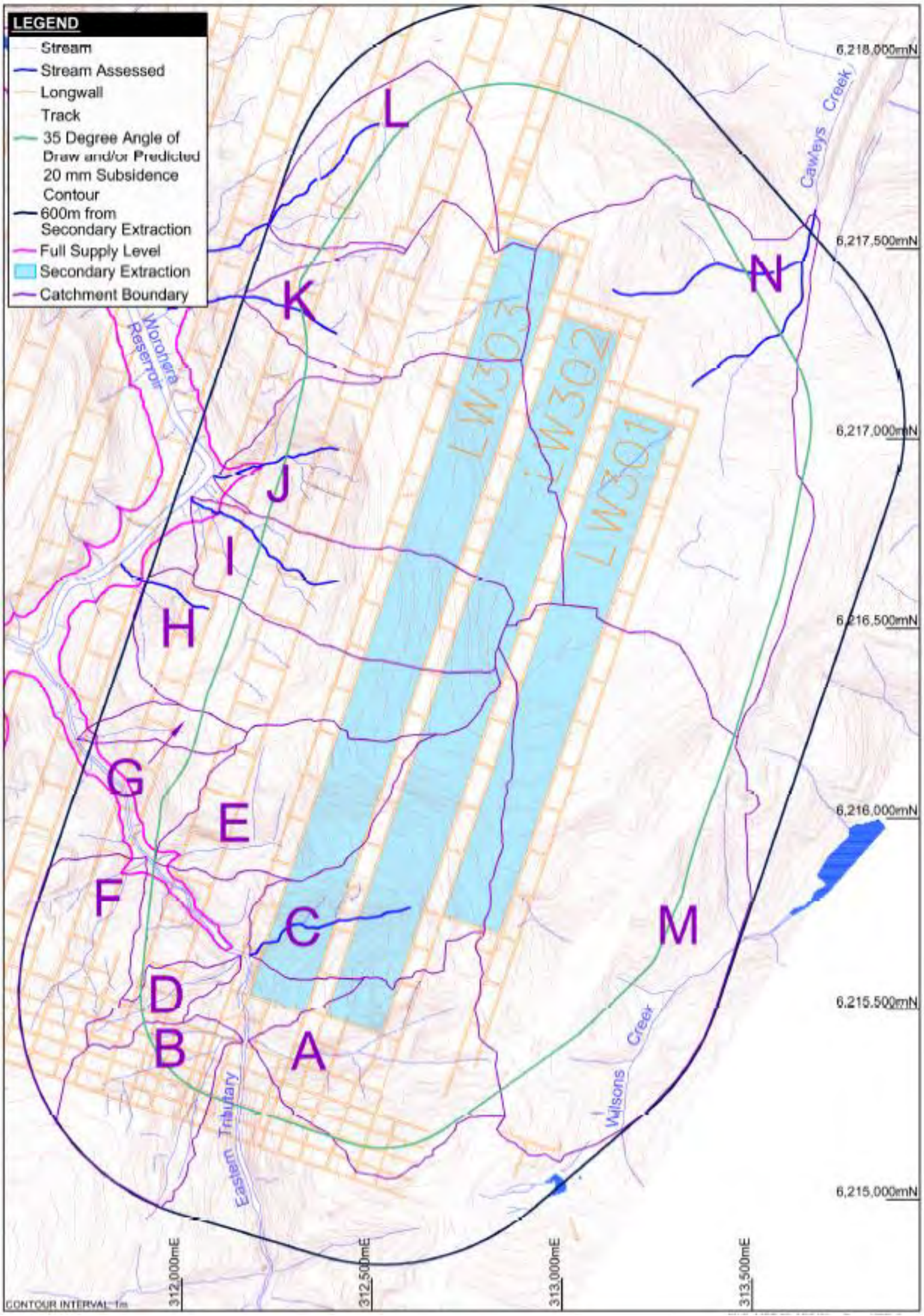


**Figure 1 Sub-catchments in the vicinity of Longwalls 301 to 303**

One metre contours were used to refine the mapping available from the Department of Lands in the vicinity of Longwalls 301-303. The one metre contour mapping generated by

Geo-Spectrum (Australia) Pty Limited[1] was the most detailed mapping available and provided greater accuracy in terms of stream location, alignment and stream network for the field survey. Figure 1 and Figure 2 show the streams mapped by Geo-Spectrum using one metre contours in the vicinity of Longwalls 301-303.

## 2.2 Selection of Streams for Visual Inspection and Photographic Survey

Figure 2 was used to inform the selection of streams for visual inspection, mapping and photographic survey.

The streams in the study area (excluding the Eastern Tributary) comprise relatively shallow drainage lines, generally within valleys which are less than 10 m high[2]. The streams are predicted to experience relatively small magnitudes of upsidence and closure[2] particularly in their headwater reaches. The valley heights increase at the lower reaches of these streams. Of the streams above Longwalls 301-303, the stream with the largest valley height is located near the (southern) end of Longwalls 302 and 303 (i.e. stream 3 within sub-catchment C). This stream has a maximum valley height of approximately 20 m. Of the minor tributaries, this stream is predicted to experience the greatest closure due to Longwalls 301-303 (predicted total closure of 190 millimetres [mm])[2]. Streams 1 and 2 (within sub-catchments A and B) are predicted to experience maximum predicted total closures of 130 mm and 30 mm respectively after the extraction of Longwall 303[2]. As a result, there is a reduced likelihood of valley related impacts to Stream 1 . Valley related impacts to Stream 2 due to the extraction of Longwalls 301 to 303 are considered to be unlikely based on the low value of predicted closure for this stream[2].

The streams selected for inspection (i.e. streams 3, 8, 9, 10 11, 12, 14 and 15 in sub-catchments C, H, I, J, K, L and N respectively) were considered the most significant (based on sub-catchment area, and stream length) and to be representative of the other small tributary streams in the study area.

The streams within sub-catchments A and B were not selected as they are primarily located over the main headings and are considered to be less likely to experience subsidence impacts. Wilsons Creek (sub-catchment M) was not selected for visual inspection and photographic survey as it is located outside of the surface area likely to be affected by Longwalls 301-303 (i.e. outside the 35 degree angle of draw and/or predicted 20 mm subsidence contour).

Visual inspection, mapping and photographic survey of the Eastern Tributary was conducted by Mine Subsidence Engineering Consultants (MSEC) prior to the commencement of Longwall 20 as a component of the Longwalls 20-22 Water Management Plan.

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1 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.

2 Mine Subsidence Engineering Consultants (2016) *Metropolitan Coal – Report on Subsidence Predictions and Impact Assessments in support of a Request for a Revised Longwall 301 to 303 Layout*, April.

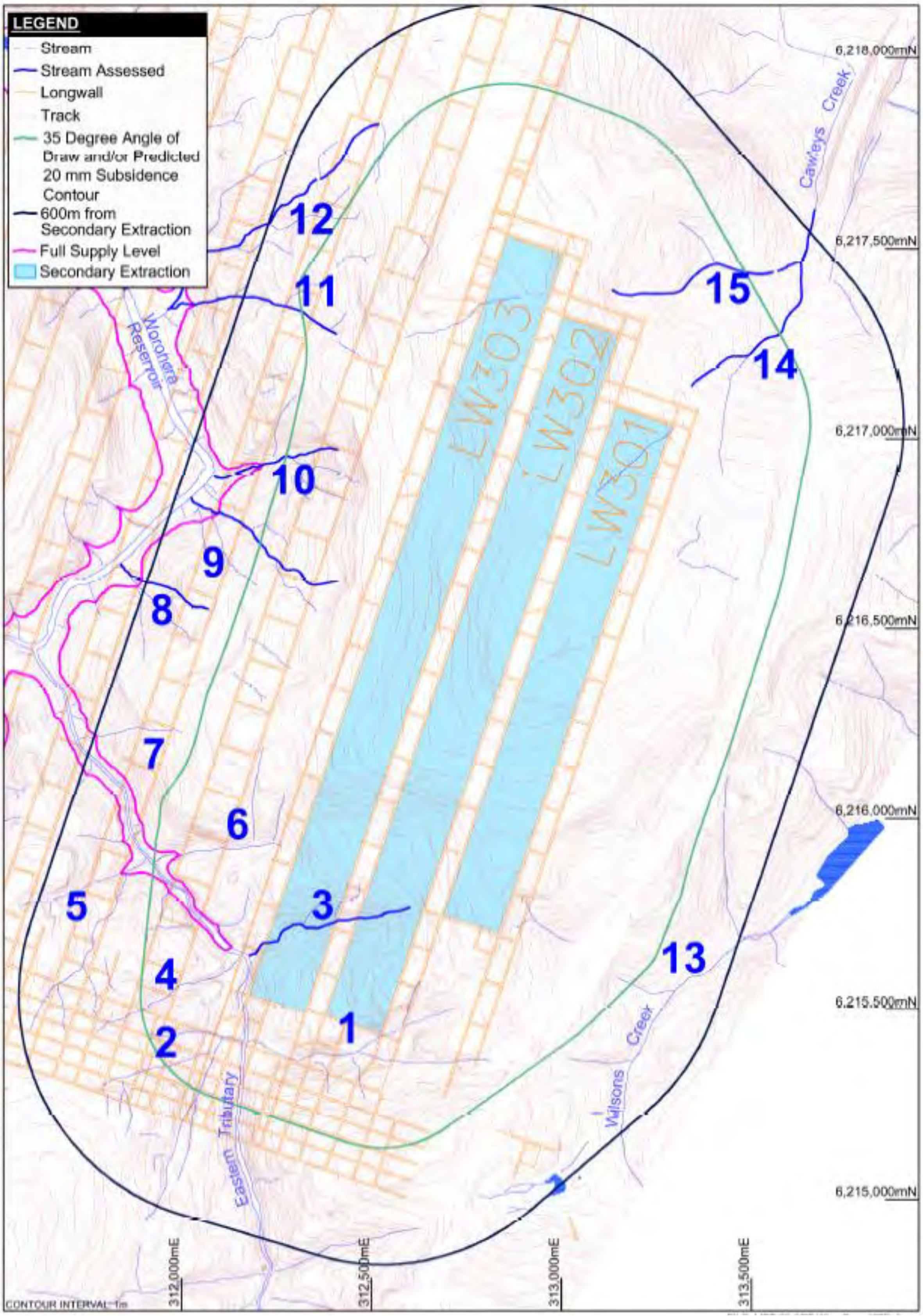


**Figure 2** Streams in the vicinity of Longwalls 301 to 303

## 3. VISUAL INSPECTION AND PHOTOGRAPHIC SURVEY

### 3.1 Inspection and Survey Timing

Visual inspection and photographic survey of the eight streams was undertaken on the 2nd and 3rd of July 2015. Streams 3, 8, 9, 10, 11 and 12 flow into the Eastern Tributary or Woronora Reservoir on the western side of the study area while streams 14 and 15 flow into Cawleys Creek on the eastern side of the study area (Figure 2).

The significance of the rainfall in the period preceding the survey on stream baseflow can be seen on the residual rainfall curve derived from the historical daily rainfall record at the Darkes Forest rainfall station (68024) from 1 January 1900 to 31 December 2015) Chart 1 shows the rainfall residual for the period 1 January 2000 to 31 December 2015. Periods where the residual rainfall curve increases (i.e. has a positive upward sloping gradient), reflect higher than average rainfall and periods where the residual rainfall line decreases (slopes downward), reflect below average rainfall - drying conditions in the catchment. Periods of decreasing rainfall residual tend to be caused by prolonged periods of low or no rainfall and are seen as slow downward sloping trends. In contrast, periods of upward (above average) rainfall are much steeper and occur over shorter time periods because they tend to be caused by isolated high rainfall events.

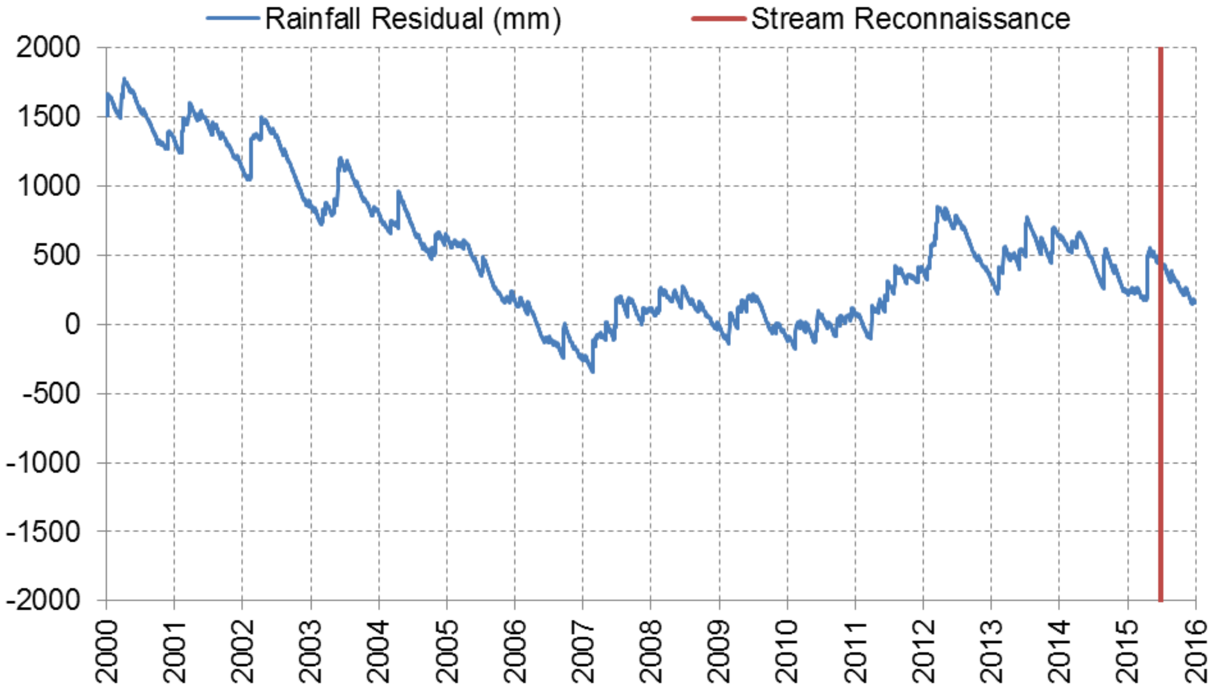


**Chart 1 Darkes Forest Rainfall Residual Plot, January 2000 to 31 December 2015 (Showing Period of Significantly High Rainfall in April 2015)**

Chart 1 shows the overall trend in rainfall from 2000 to 2007 was downward (below average). However this period was also characterised by a series of short significant rainfall events followed by prolonged drying periods. From 2007 to 2011 rainfall trends were near average. There was a significant wet period in early 2012 followed by a dry period into early 2013. Rainfall 2013 and 2014 tended to be near average. The rainfall trend in 2015 prior to the survey was also generally near average but with a significant steep increase in rainfall trend in late April 2015 caused by an intense event which produced over 285 mm of rain in three days in late April. This event would likely have resulted in significant recharge of shallow groundwater. The wetness of the surveyed stream catchments and persistent baseflow observed during the survey reflect these rainfall trends and can be seen to be abnormally wet with comparable conditions being limited to periods in early 2002, 2003, and 2012 since 2000.

### 3.2 Methods and Results

The inspection and survey involved walking along the accessible length of the streams, mapping the geomorphic characteristics and features of the stream, and compiling a photographic record. The mapping provided in Figure 3 to Figure 10 shows the locations where photographs were taken and the location of particular stream features observed along the stream.

Stream features were mapped using the following alphabetic symbols:

(WF) Waterfall of at least 2 m near vertical drop.

(BC) Boulder cascade comprising a very steep chute of boulders. Water would be highly aerated by rapid flow over and through spaces between the boulders.

(RS) Rock shelf comprising a hard and relatively smooth rock outcrop often containing shallow depression(s).

($P_s$) 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.

The streams on the western side (i.e. those flowing into the Eastern Tributary and Woronora Reservoir), were steep, single channel flow paths with sections of very steep boulder cascades and waterfalls. The steeper sections were separated by relatively flatter sections. The distribution and location of flatter and steep sections are apparent on the stream long-sections included in Figure 3 to Figure 8. The photographs taken at the points shown in Figure 3 to Figure 8 are provided in Attachment 1.

Small flows were observed in all western side streams as a result of persistent seepage from the adjacent valley sides and residual baseflow from the recent significant rainfalls experienced in the Woronora Reservoir catchment. Small pools (between 1 m and 3 m long and less than 0.3 m deep) were observed along a 45 m reach on stream 3 and two small pools were observed on stream 12 (Figure 3 and Figure 8). No small pools (between 1 m and 3 m long and less than 0.3 m deep) were observed along streams 8, 9, 10 and 11 (Figure 4 to Figure 7). One medium pool (between 3 m and 5 m long and approximately 0.5 m deep) was recorded on stream 3 and one medium pool (between 3 m and 5 m long and approximately 0.5 m deep) was recorded on stream 9 (Figure 3 and Figure 5). No medium pools were observed along streams 8, 10, 11 and 12 (Figure 4, Figure 6, Figure 7, and Figure 8). The stream beds comprised predominantly rock and boulders with some limited sections of shallow sediment accumulations. There was no iron colouration observed along the stream bed although there were some small iron rich seepages observed emanating from fractures in rock outcrops near the sides of streams and at the sides of waterfalls.

The streams on the eastern side of the study area (streams 14 and 15, Figure 9 and Figure 10) which flow into Cawleys Creek were significantly different in condition and character to those on the western side. They comprise shallow ill-defined channels in an open valley setting. Substantial clearing and weed invasion was observed in parts. The streams followed a moderate grade with predominantly alluvial bed material comprising silts and sand. There were no pools observed. Conditions observed in the streams are shown on the stream condition maps included as Figure 9 and Figure 10). The photographs taken at the points shown on Figure 9 and Figure 10 are provided in Attachment 1.

## 4. CONSIDERATION OF SURFACE WATER MONITORING REQUIREMENTS

The streams which flow to Eastern Tributary and the Woronora Reservoir comprise small (between 0.04 $km^2$ and 0.38 $km^2$) first and second order streams.

Based on the nature and characteristics of the streams and their small and negligible contribution to the Woronora Reservoir (compared to the contributions of Waratah Rivulet and Eastern Tributary which will continue to be monitored), establishment of monitoring sites (for surface water flow, pool water level, or surface water quality) is not, in our opinion, warranted.

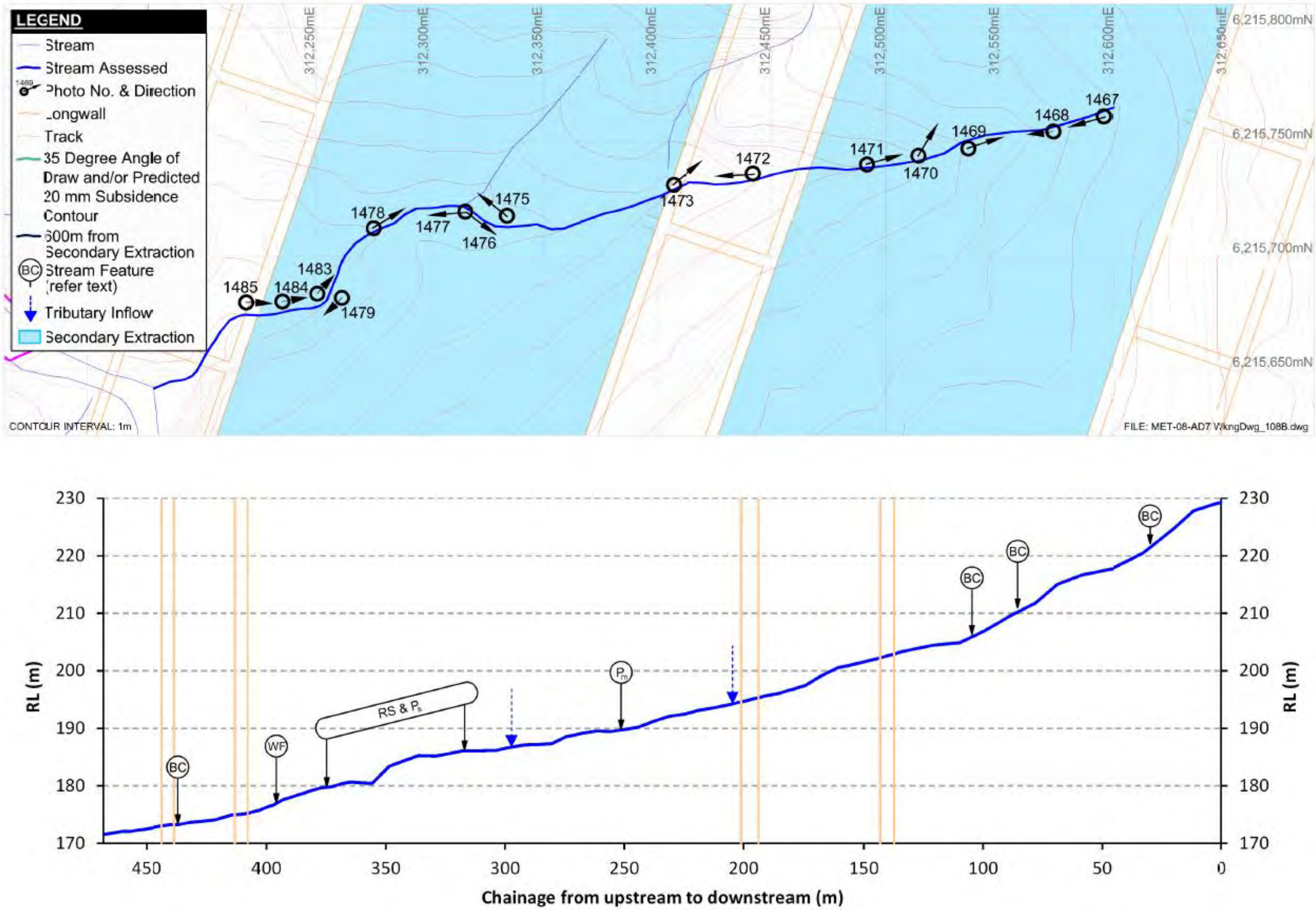


**Figure 3** **Stream 3 Photo Locations and Stream Features**

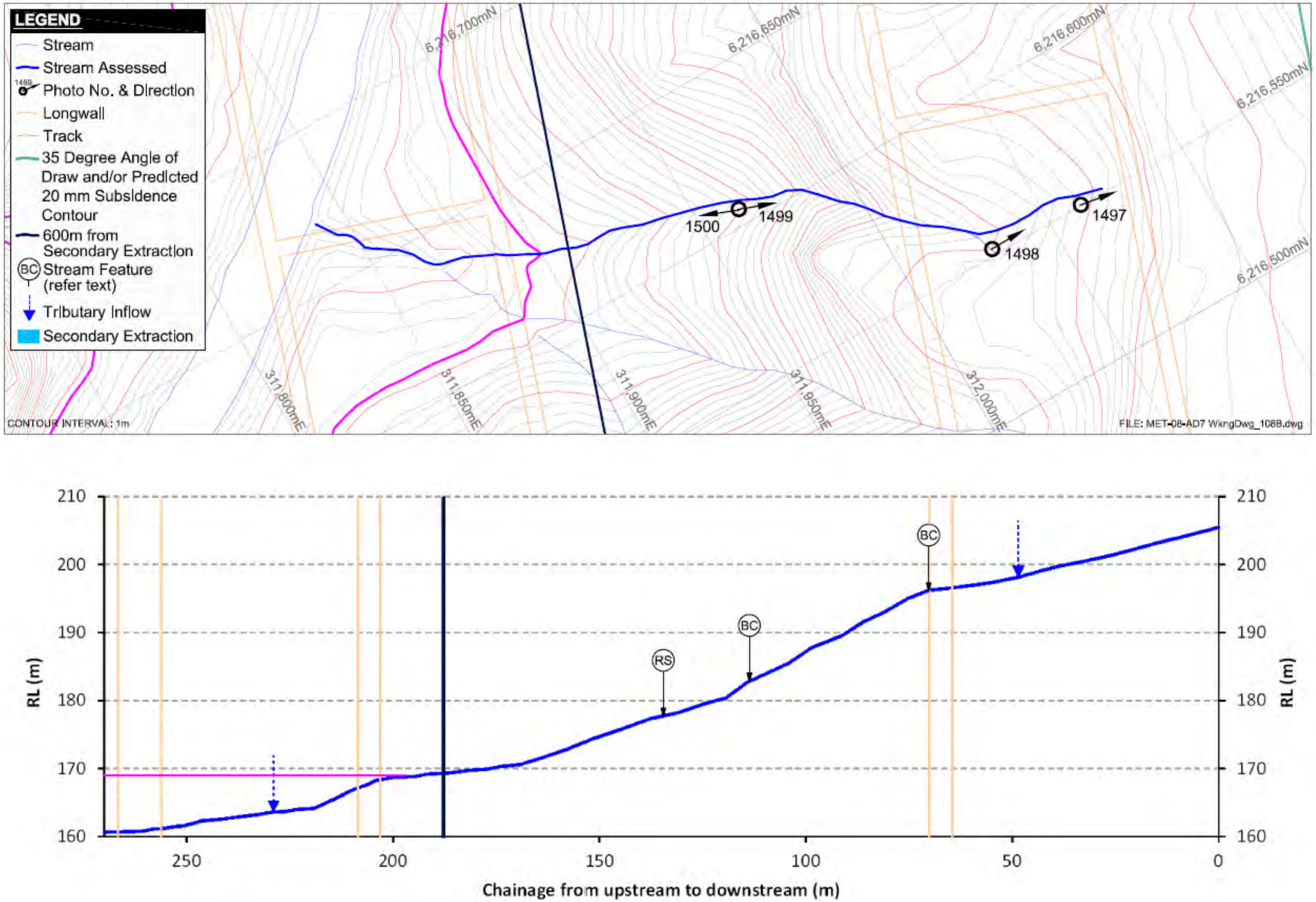


**Figure 4** **Stream 8 Photo Locations and Stream Features**

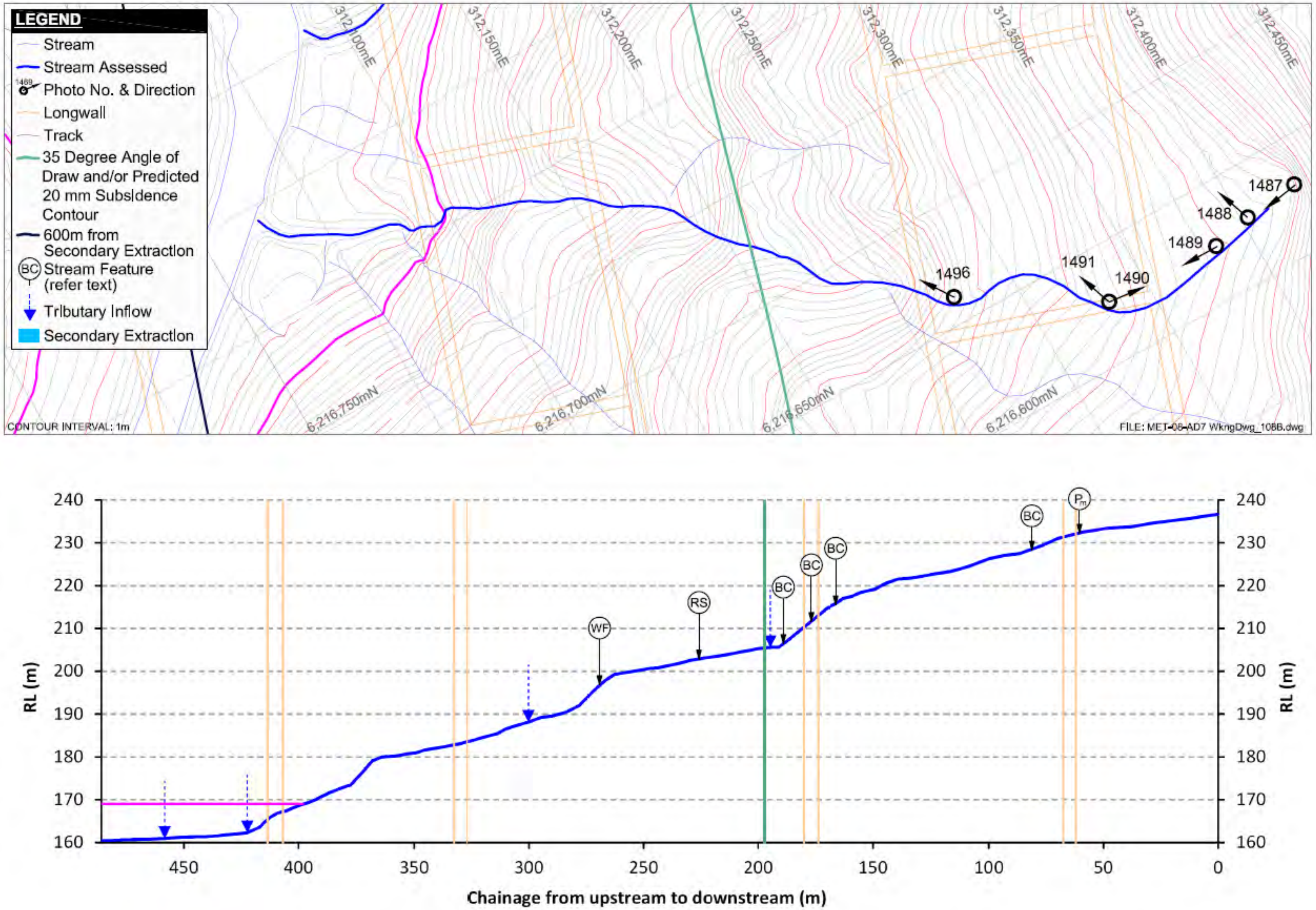


**Figure 5** Stream 9 Photo Locations and Stream Features

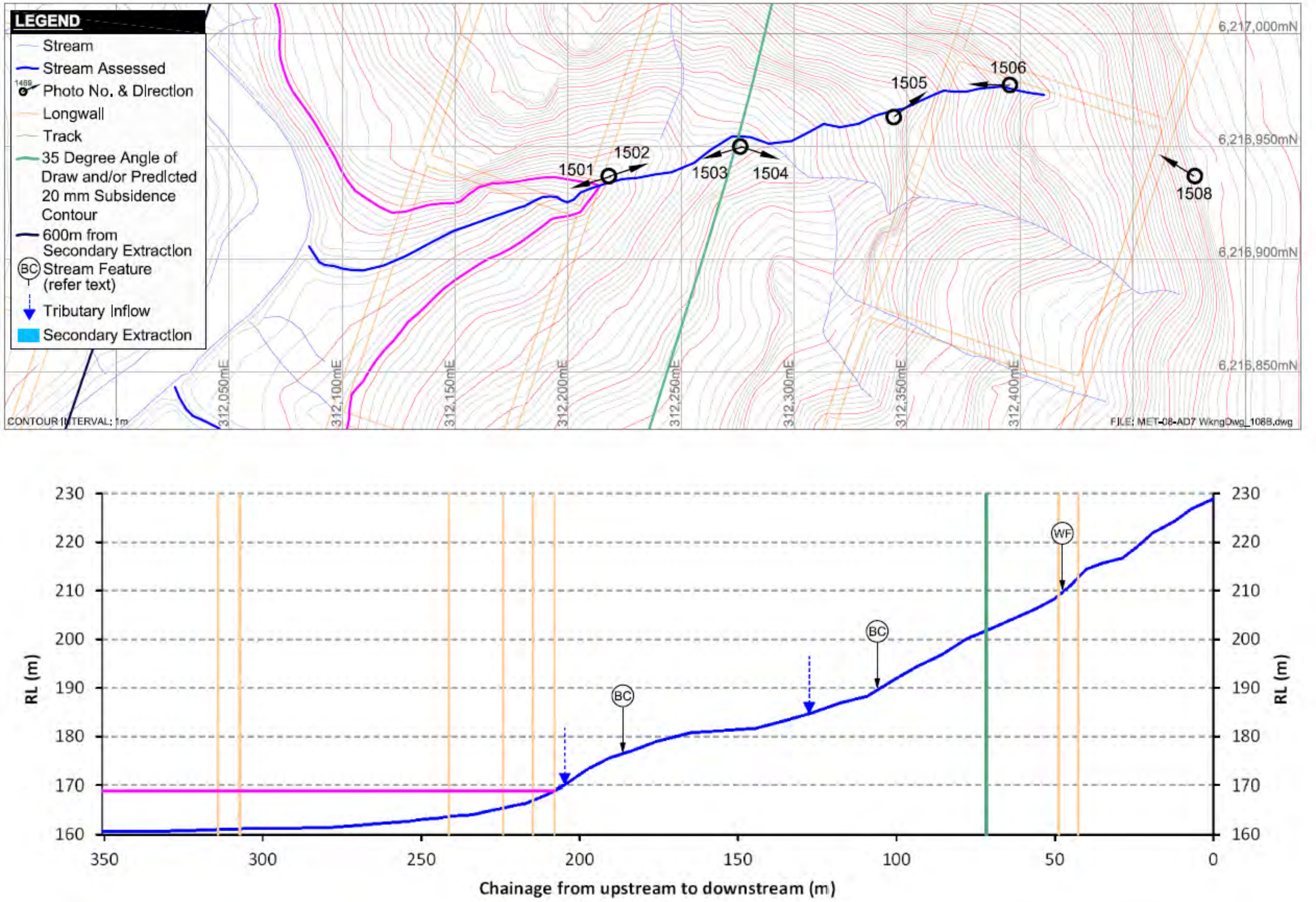


**Figure 6** **Stream 10 Photo Locations and Stream Features**

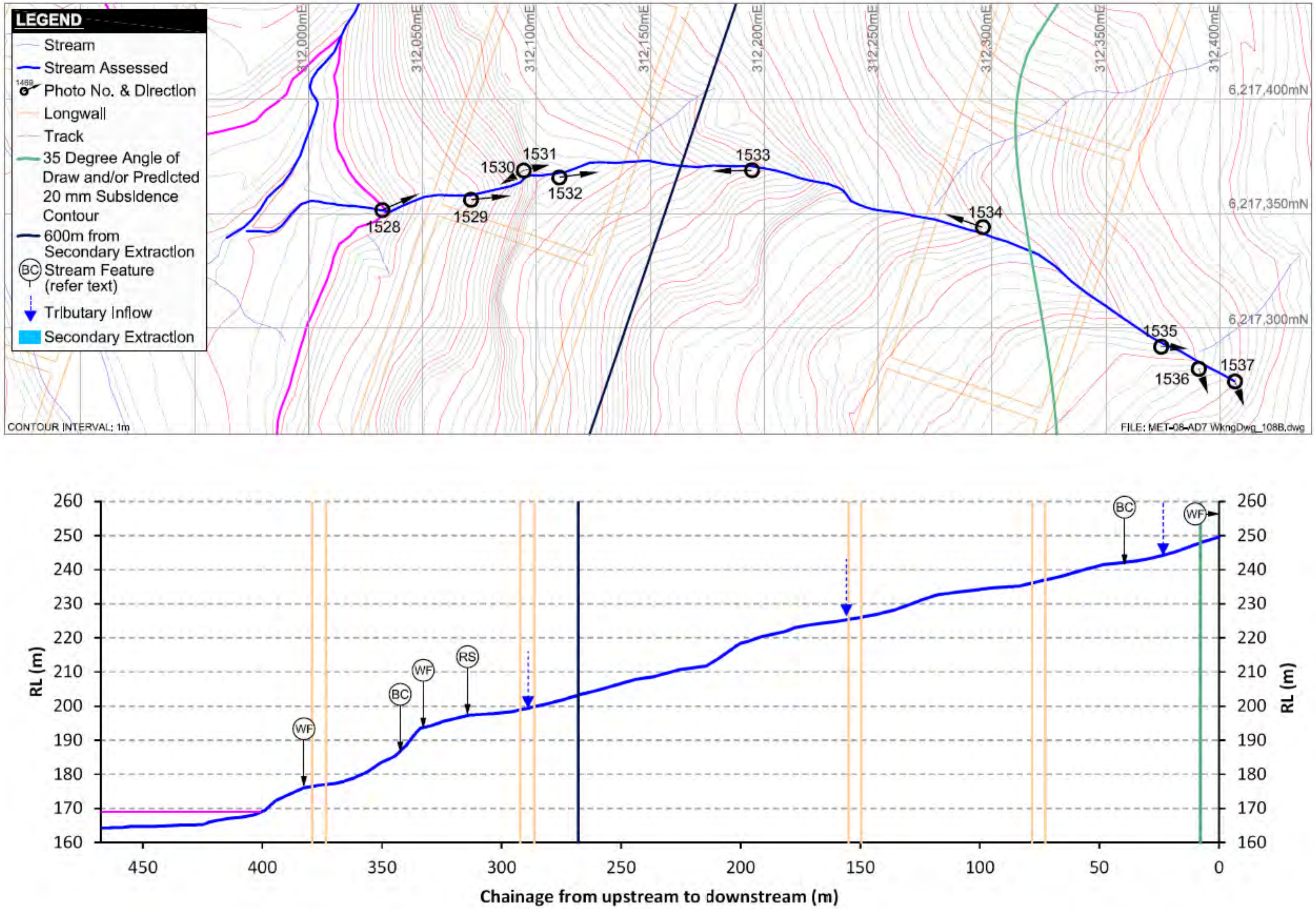


**Figure 7 Stream 11 Photo Locations and Stream Features**

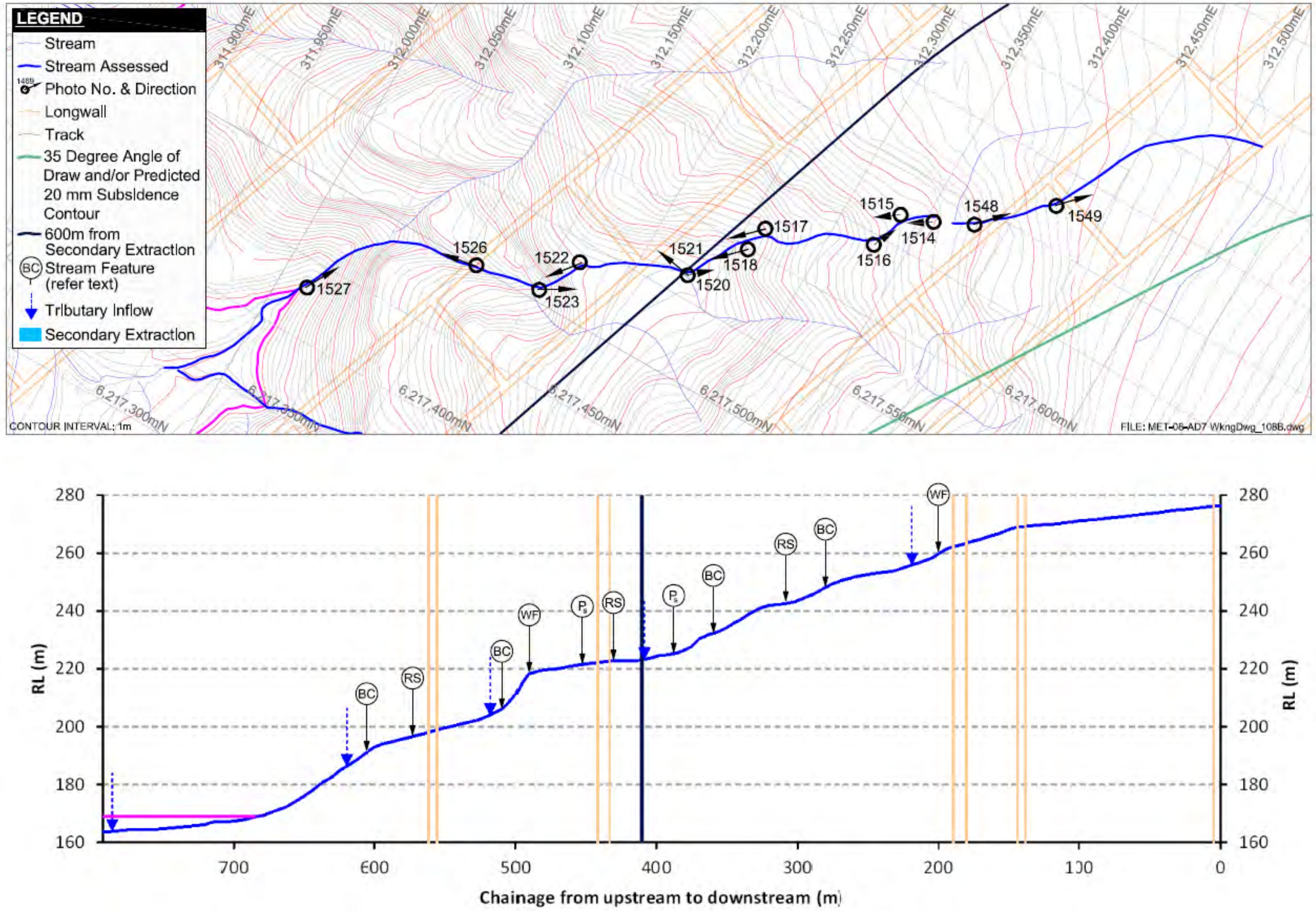


**Figure 8** Stream 12 Photo Locations and Stream Features


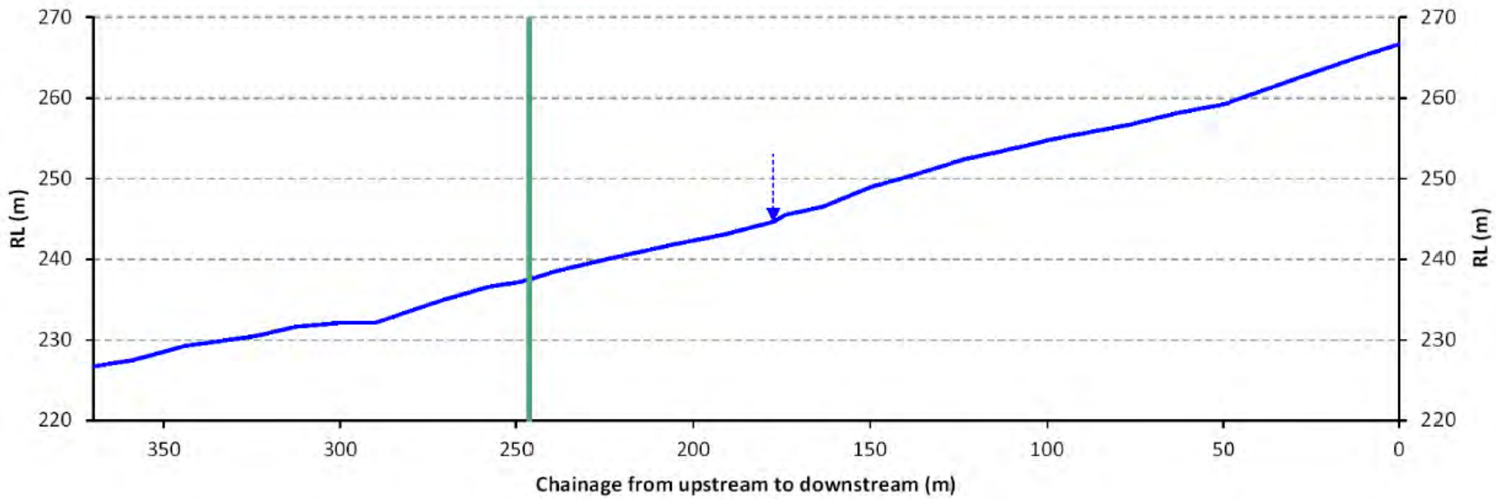


**Figure 9 Stream 14 Photo Locations and Stream Features**

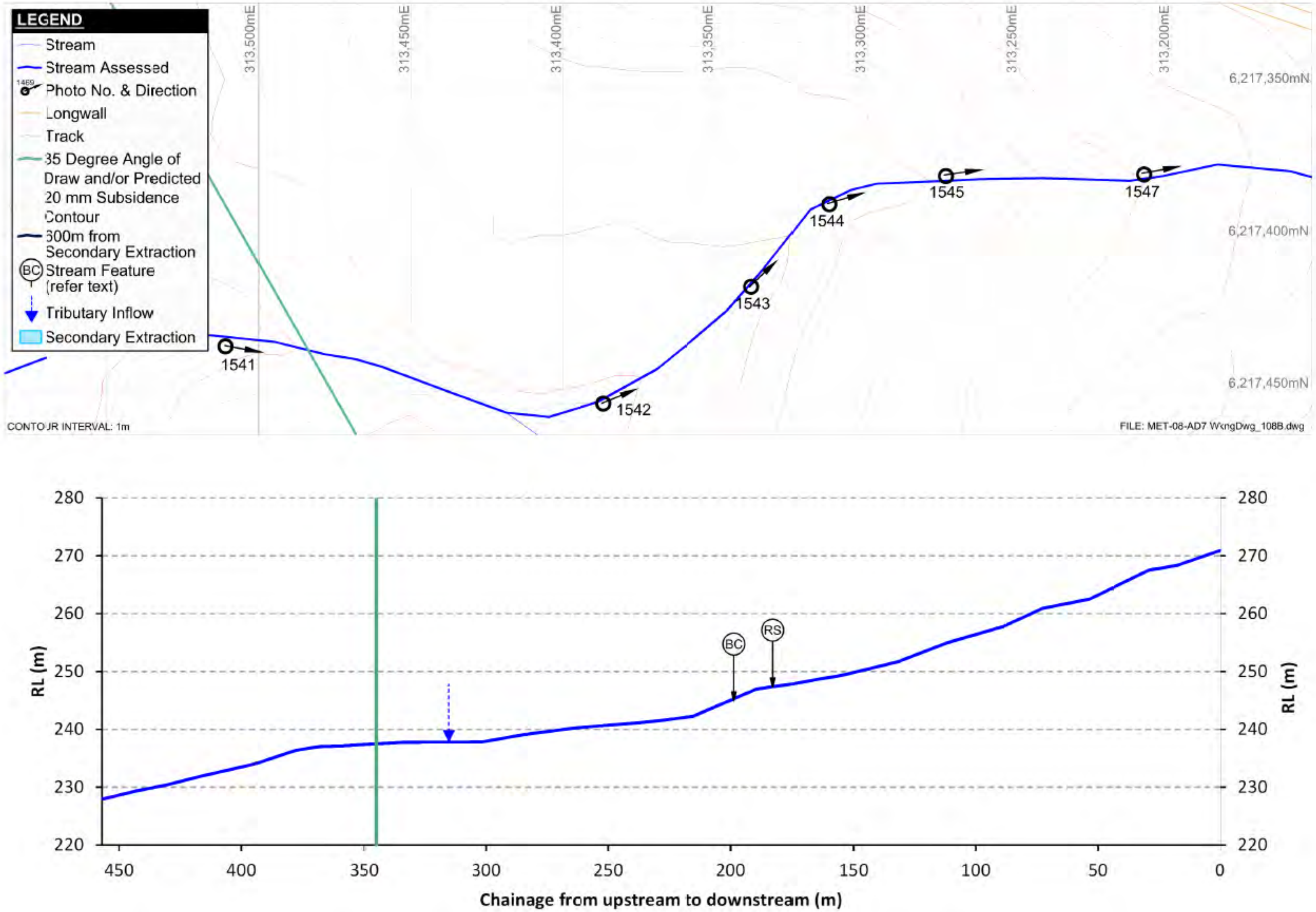


**Figure 10 Stream 15 Photo Locations and Stream Features**

**Attachment 1**

**Stream Reconnaissance Photographs**


Plate 1467

Plate 1468

Plate 1469


Plate 1470

Plate 1471

Plate 1472

**Stream 1 Plates 1467 to 1472**

Plate 1473

Plate 1474

Plate 1475

Plate 1476

Plate 1477


Plate 1478

**Stream 1 Plates 1473 to 1478**


Plate 1479


Plate 1483


Plate 1484


Plate 1485

**Stream 1 Plates 1479 to 1485**

Plate 1497

Plate 1498

Plate 1499

Plate 1500

**Stream 2 Plates 1497 to 1500**


Plate 1487


Plate 1488


Plate 1489


Plate 1490

**Stream 2a      Plates 1487 to 1490**


Plate 1491

Plate 1494

Plate 1495

Plate 1496

**Stream 2A Plates 1491 to 1496**

Plate 1501

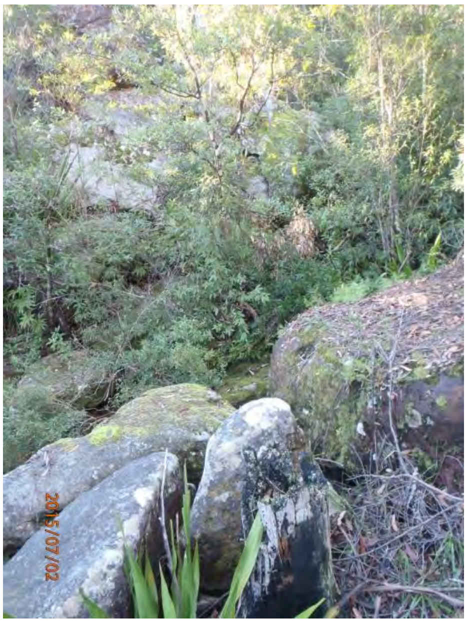

Plate 1502

Plate 1503

Plate 1504

**Stream 3 Plates 1501 to 1504**

Plate 1505

Plate 1506

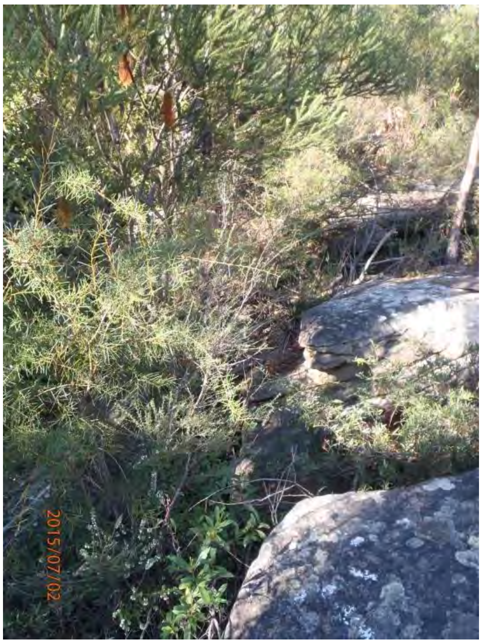

Plate 1508

**Stream 3 Plates 1505 to 1508**

Plate 1528

Plate 1529

Plate 1530

Plate 1531

**Stream 4 Plates 1528 to 1531**

Plate 1532

Plate 1533

Plate 1534

Plate 1535

Plate 1536

Plate 1537

**Stream 4 Plates 1528 to 1538**

Plate 1514

Plate 1515

Plate 1516


Plate 1517

Plate 1518

Plate 1519

**Stream 5 Plates 1514 to 1519**

Plate 1520

Plate 1521

Plate 1522

Plate 1523

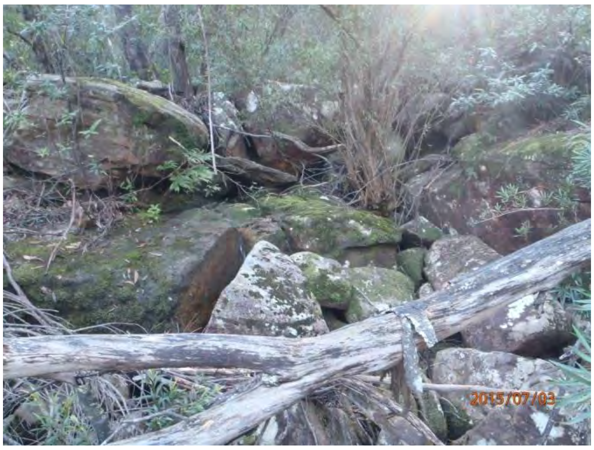

Plate 1526

Plate 1527

**Stream 5 Plates 1523 to 1527**

Plate 1509

Plate 1510

Plate 1512

Plate 1513

**Stream 6 Plates 1509 to 1513**


Plate 1540


Plate 1541


Plate 1542


Plate 1543

Plate 1544

Plate 1545

**Stream 7 Plates 1540 to 1545**

Plate 1547

**Stream 7 Plate 1547**