AQUATIC ECOLOGY MONITORING: METROPOLITAN COAL LONGWALLS 23-27

SPRING 2018 SURVEY

Prepared for

PEABODY ENERGY AUSTRALIA PTY LTD

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1.0 INTRODUCTION

Metropolitan Coal is wholly owned by Peabody Energy Australia Pty Ltd and is located approximately 30 kilometres (km) north of Wollongong in NSW. Metropolitan Coal was granted approval for the Metropolitan Coal Project (the Project) under the NSW *Environmental Planning and Assessment Act, 1979* in June 2009.

The Project comprises the continuation, upgrade and extension of underground coal mining operations and surface facilities at Metropolitan Coal. Longwalls 23-27 define the second secondary extraction mining sub-domain within the Approved Project underground mining area (Figure 1). The schedule of Longwall extraction was as follows:

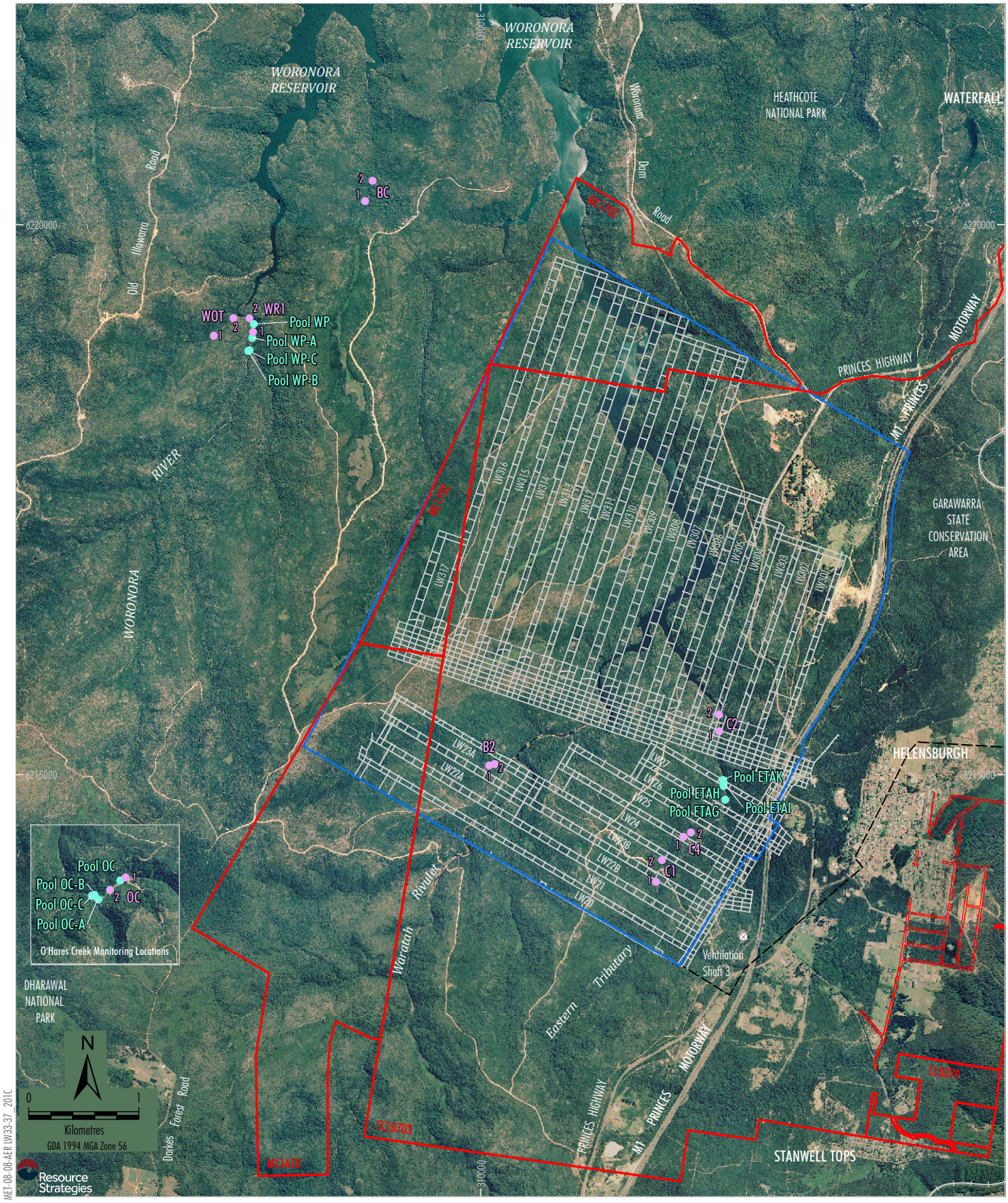
- Longwall 23: May 2014 to March 2015;
- Longwall 24: April 2015 to September 2015;
- Longwall 25: October 2015 to April 2016;
- Longwall 26: May 2016 to August 2016;
- Longwall 27: September 2016 to March 2017.

An aquatic ecology monitoring programme was developed to:

- Monitor subsidence-induced impacts on aquatic ecology (referred to as stream monitoring); and
- Monitor the response of aquatic ecosystems to the implementation of stream remediation works (referred to as pool monitoring).

The design of the monitoring programmes uses the current best practice approach for monitoring impacts on aquatic habitats “Beyond BACI” and focused on representative sampling of selected locations (i.e. stream monitoring) and pools (i.e. pool monitoring) within streams in the Longwalls 23-27 mining area and in suitable control streams (i.e. not subject to mine subsidence).

This report presents the results of the spring 2018 stream monitoring and pool monitoring surveys. This report also presents a temporal analysis of the assemblages of aquatic macrophytes and macroinvertebrates in order to examine patterns in diversity and abundance among sampling events (Section 4 – Temporal Analyses).



LEGEND

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

Monitoring

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

Source: Land and Property Information (2015); Date of Aerial Photography 1998; Department of Industry (2015); Metropolitan Coal (2016); MSEC (2016)

Peabody
METROPOLITAN COAL

Longwalls 23-27
Aquatic Ecology Monitoring Locations

Figure 1

2.0 METHODS

2.1 Study Area

The Project underground mining area and surrounds are located within the Woronora Special Area (WSA) (Figure 1). The WSA is largely undeveloped, covered predominantly by native vegetation and public access is restricted and managed by WaterNSW (previously the Sydney Catchment Authority [SCA]). The WSA drains to the Woronora Reservoir, which supplies water to residents in the areas south of the Georges River including Sutherland, Helensburgh, Stanwell Park, Lucas Heights and Bundeena.

Longwalls 23-27 extend below a tributary of the Woronora Reservoir in the east of the study area (Tributary C/Eastern Tributary) and an un-named tributary of the Waratah Rivulet (Tributary B) (Figure 1).

The headwaters of Tributary C/Eastern Tributary are located in the Darkes Forest area at approximately 300 m AHD. Tributary C/Eastern Tributary flows through a relatively steep valley in a northerly direction into the Woronora Reservoir. The upper reaches of Tributary C/Eastern Tributary traverse the completed Longwalls 1-13 underground mining area (Figure 1).

Tributary B is a relatively small stream (approximately 2.75 km long) that flows through a broad valley into Waratah Rivulet (Figure 1). The upper reach of Tributary B traverses the completed Longwalls 14-17 and Longwalls 18-19a underground mining areas and the completed Longwalls 20-22 underground mining area: mining of Longwall 22B was completed in April 2014 (Figure 1).

Bee Creek, the Woronora Tributary and Woronora River occur within the WSA but lie outside the area potentially affected by past and current mining activities at Metropolitan Coal. As such, these systems in addition to O'Hares Creek, which lies outside the mining area in the Dharawal Nature Conservation Area to the south-west of the WSA, represent the control systems for this study.

2.2 Sampling Design

The current best practice approach for monitoring impacts on aquatic habitats is termed "Beyond BACI" (Underwood, 1992; 1993; 1994) and this approach has been used in order to assess potential impacts on aquatic ecology.

The programmes have been designed to monitor:

(i) subsidence-induced impacts on aquatic ecology; and

(ii) the response of aquatic ecosystems to the implementation of stream restoration works.

These programmes are described in Section 2.2.1 and Section 2.2.2, respectively.

2.2.1 Stream Monitoring

In accordance with the *Metropolitan Coal Longwalls 23-27 Biodiversity Management Plan*[1], the aquatic ecology along Tributary C/Eastern Tributary and Tributary B as well as in appropriate control systems (i.e. Bee Creek, Woronora Tributary, Woronora River and O'Hares Creek) are monitored annually in spring (September 15 to December 15) and autumn (March 15 to June 15), consistent with the timing required by the Australian River Assessment System (AUSRIVAS) protocol. The control systems lie outside the area potentially affected by past and current Metropolitan Coal mining activities (Figure 1).

The spatial design for Longwalls 23-27 includes sampling two random sites (approximately 100 m in length) at the following stream locations (Appendix 1a) [2,3]:

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[1] The *Metropolitan Coal Longwalls 23-27 Biodiversity Management Plan* is superceded by the *Metropolitan Coal Longwalls 301-303 Biodiversity Management Plan*. The stream monitoring program and monitoring methods remain the same as those implemented during the mining of Longwalls 23-27.

[2] Locations C1, C2 and C4 are referred to as ET1, ET2 and ET4 in the *Metropolitan Coal Longwalls 301-303 Biodiversity Management Plan* (and previously in the *Metropolitan Coal Longwalls 20-22 Biodiversity Management Plan)*.

[3] Location C1 on Tributary C/Eastern Tributary is situated over Longwalls 22 and 23 and has also been monitored as a component of the Longwalls 20-22 aquatic ecology monitoring program. Location C4 is situated on Tributary C/Eastern Tributary overlying Longwalls 23-27, downstream of mining activities undertaken within the Longwalls 20-22 mining area. Location C2 on Tributary C/Eastern Tributary is situated downstream of Longwalls 23-27 and has also been monitored as a component of the Longwalls 20-22 aquatic ecology monitoring program. Mining of Longwalls 20-22 commenced in May 2010 and was completed in April 2014.

- Locations C1 and C4 on Tributary C/Eastern Tributary and B2 on Tributary B overlying Longwalls 23-27;
- Location C2 on Tributary C/Eastern Tributary, downstream of Longwalls 23-27;
- Control locations: WR1 on Woronora River; OC on O'Hares Creek; BC on Bee Creek; and WOT on Woronora Tributary.

The approximate locations of the sampling sites are shown on Figure 1.

Location C2 on Tributary C/Eastern Tributary is located downstream of Longwalls 23-27 and will assist in determining the spatial extent of any impacts on aquatic habitat and biota over time as mining progresses.

Information on stream characteristics was recorded at each site in accordance with the Australian River Assessment System (AUSRIVAS) protocol (Turak et al., 2004). Characteristics recorded included a visual assessment of stream width and depth, riparian conditions, signs of disturbance, water quality and percentage cover of the substratum by algae. Samples of assemblages of aquatic macroinvertebrates, aquatic macrophytes and physico-chemical water quality were collected at sites within each of the locations.

2.2.2 Pool Monitoring

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 Tributary C/Eastern Tributary, between the main-gate of Longwall 26 and the full supply level of the Woronora Reservoir.

A number of pools are monitored to allow the response of aquatic ecosystems to the implementation of future stream remediation works to be assessed, namely (Figure 1):

- Larger pool (defined as pools >40 m in length), ETAH on Tributary C/Eastern Tributary overlying Longwalls 23-27.
- Smaller pools (defined as pools <40 m in length) ETAG, ETAK and ETAI on Tributary C/Eastern Tributary overlying Longwalls 23-27.

- One larger control pool on Woronora River (pool WP) and one larger control/ reference pool on O'Hares Creek (pool OC).
- Three smaller control pools on Woronora River (pools WP-A, WP-B and WP-C) and three smaller control/reference pools on O'Hares Creek (pools OC-A, OC-B and OC-C).

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

The design for this component also incorporates a "Beyond BACI" experimental design, with sampling conducted at two random sites within the larger pools and at one site within the smaller pools. Two large and three small control pools (not impacted by mining) of similar size and character to those sampled on Tributary C/Eastern Tributary were also sampled at the same spatial and temporal scales on Woronora River (i.e. WP) and O'Hares Creek (OC) (Appendix 1b).

2.3 Sampling Techniques

2.3.1 Aquatic Macroinvertebrates

Two methods were used to collect aquatic macroinvertebrates at locations sampled as part of the Stream Monitoring Programme: sampling using the AUSRIVAS protocol and quantitative sampling. One method, the quantitative sampling technique, was used to sample assemblages of macroinvertebrates in pools sampled as part of the Pool Monitoring Programme.

AUSRIVAS

To sample assemblages of macroinvertebrates in accordance with the Rapid Assessment Method (RAM), which is based on the AUSRIVAS protocol (Turak et al., 2004), samples of stream edge habitats were collected using a 250 µm mesh dip net. Edge habitat was defined as areas along stream banks with little or no flow, including alcoves and backwaters, with abundant leaf litter, fine sediment deposits, beds of macrophytes, overhanging banks and areas with trailing vegetation (Turak et al., 2004). Riffle habitat was not sampled, because this habitat was not well represented in the stretches of the streams surveyed.

At each site (approximately 100 m long), samples were collected over a total length of 10 m, usually in 1-2 m sections, ensuring all significant edge sub-habitats within a site (i.e. macrophytes, over-hanging bank and vegetation, leaf-litter, pool rocks, logs) were included in the sample (Turak et al., 2004). The contents of each net sample were placed into a white sorting tray and animals were collected for a minimum period of 30 minutes. Thereafter, removals were carried out in 10 minute periods, up to a total of one hour (Turak et al., 2004). If no new taxa were found within a 10 minute period, removals would cease (Turak et al., 2004). The animals collected were placed inside a labelled container and preserved with 70% alcohol.

Samples were identified using an ISSCO M400 stereomicroscope. Taxa were identified to family level with the exception of Acarina (to order), Chironomidae (to sub-family), Nematoda (to phylum), Nemertea (to phylum), Oligochaeta (to class), Ostracoda (to subclass) and Polychaeta (to class). Some families of Anisoptera (dragonfly larvae) were identified to species, because they could potentially include threatened aquatic species.

Quantitative Sampling

Within each site, three replicate macroinvertebrate samples were collected using timed 1-minute sweeps of all habitats (edge, riffle, pools, etc.) using a 250 µm mesh dip net. For each replicate sample, the contents of the net were placed into white plastic trays filled with fresh water and then placed into pre-labelled plastic sample containers filled with 70 % alcohol. In the laboratory, animals were identified to family level with the exception of some families of Anisoptera (dragonfly larvae), which were identified to species, because they could potentially include threatened aquatic species.

2.3.2 Aquatic Macrophytes

The distribution of floating-attached, submerged and emergent (occurring in-stream and in the riparian zone) macrophytes was estimated along each sampling location by assigning a cover class to each species. The cover classes were: (1) one plant or small patch (i.e. few), (2) not common, growing in a few places (i.e. scattered), and (3) widespread (i.e. common). Cover class information was used to help provide a qualitative assessment of the structure of assemblages of plants found at each location (Sections 3.1.1, 3.2.1.1 and 3.2.2.1).

Within each site, an assessment of floating-attached, submerged and emergent macrophytes was undertaken by estimating the relative abundance (i.e. percentage cover) of species within five haphazardly placed 0.25 m^2 quadrats, using a stratified sampling technique. This information provided a quantitative measure of aquatic macrophytes within each site at each location and pool (Sections 3.1.3, 3.2.1.3 and 3.2.2.3). The spatial distribution of floating attached and submerged macrophytes (i.e. *Chara*/*Nitella* spp., *Myriophyllum penduculatum* and *Triglochin procerum*) was also mapped in each pool sampling site (i.e. the pool monitoring program) to provide a visual comparison of their distribution through time.

2.4.3 Water Quality

For the Stream and Pool Monitoring Programmes, a number of water quality variables were measured at each of the sampling sites prior to undertaking the biological sampling. Measurements of physico-chemical water quality were determined using a YEOKAL 611 submersible data logger. Variables included conductivity (µS/cm), dissolved oxygen (% Saturation and mg/L), pH, temperature (ºC), turbidity (NTU) and oxygen reduction potential (mV).

For the Stream Monitoring Programme, two replicate samples of water were also collected to be analysed for alkalinity (mg/L $CaCO_3$), total nitrogen (mg/L) and total phosphorous (mg/L). Alkalinity was determined in the field using a CHEMetrics' total alkalinity field kit.

For analysis of total nitrogen and total phosphorous, samples were sent to the National Measurement Institute (NMI) laboratory (a NATA accredited laboratory). For the purpose of calculating summary statistics (e.g. mean concentration), any results that were recorded less than the detection limit were assigned a concentration value of half the detection limit, except in instances of zero alkalinity. It should be noted that water quality measurements are intended to provide information relevant to the times of sampling only.

2.4 Data Analyses

AUSRIVAS Model Analysis

Data collected using the AUSRIVAS sampling protocol for the Stream Monitoring Programme were analysed using the New South Wales/Spring/Edge model (see Turak et al., 2004). This predictive model was developed from sampling edge habitat at a number of sites across NSW, which had been determined to be unaffected by human disturbances, between 1994 and 1999 (Turak et al., 2004). Physical and chemical data (see Ransom et al., 2004) are used by the model to determine the predicted (i.e. Expected) composition of macroinvertebrate fauna if the site is undisturbed (Turak et al., 2004). Thus, an AUSRIVAS assessment represents a comparison of the macroinvertebrates collected at a site (i.e. Observed) to those predicted to occur (Expected) if the site is in an undisturbed or 'reference' condition.

The principal outputs of the AUSRIVAS model include:

- Observed to Expected ratio (OE50): the ratio of the number of macroinvertebrate families collected at a site which had a predicted probability of occurrence of greater than 50 % (i.e. Observed) to the sum of the probabilities of all of the families predicted with greater than a 50 % chance of occurrence (i.e. Expected) (Ransom et al., 2004).

- BAND: for each model, the OE50 taxa ratios are divided into bands representing different levels of impairment. Band X represents a more diverse assemblage of macroinvertebrates than control sites; Band A is considered equivalent to reference condition; Band B represents sites below reference condition (i.e. significantly impaired); Band C represents sites well below reference condition (i.e. severely impaired); and Band D represents impoverished sites (i.e. extremely impaired) (Ransom et al., 2004).

Quantitative Analyses

Multivariate and univariate statistical procedures were done using Permutational Multivariate Analyses of Variance (PERMANOVA, Anderson 2001; Anderson et al, 2008) and Plymouth Routines in Multivariate Ecological research (PRIMER, Clarke and Warwick, 1994) software packages to examine temporal and spatial patterns in macroinvertebrates and macrophytes sampled within the study area.

Multivariate methods allow comparisons of two (or more) samples based on the degree to which these samples share particular species, at comparable levels of abundance (Clarke and Warwick, 1994). Multivariate analysis was done on Bray Curtis dissimilarities of the macroinvertebrate and macrophyte assemblage (non-transformed) data. A graphical representation of relationships among samples (i.e. the centroids for each location per time) was produced using Principal Coordinates Analyses (PCoA). The amount of variation "explained" by the principle factors is indicated by each axis and the dissimilarity between data points can be determined from their distance apart on the axes (Anderson et al., 2008). Similarity of percentages (SIMPER) was then used to determine those taxa primarily responsible for the observed similarities (or dissimilarities) (Clarke, 1993).

PERMANOVA analyses on selected univariate estimates (e.g. total number of taxa, total abundance and abundances of the most important taxonomic groups identified from the samples) were done on Euclidean Distances. Each analysis was based on 999 permutations of residuals under a reduced model.

Specifically, PERMANOVA were done to test hypotheses related to differential changes occurring in multivariate and univariate estimates for streams or pools subject to mining of Longwalls 23-27 (i.e. potential 'impact' sites) in comparison to independent sites that are not subject to mine subsidence (i.e. control streams and pools).

These analyses were performed separately for the large streams (Eastern Tributary [Locations C1, C2 and C4], Woronora River [Location WR] and O'Hares Creek [Location OC]), small streams (Tributary B [Location B2], Woronora Tributary [Location WOT] and Bee Creek [Location BC]), large pools (Pool ETAH, Pool WP and Pool OC) and small pools (Pool ETAG, Pool ETAK, Pool ETAI, WP-A, WP-B, WP-C, OC-A, OC-B, and OC-C).

To date, for the Longwalls 23-27 aquatic ecology monitoring programme, nine to eleven replicate times (spring 2008 or spring 2009[4] to spring 2013) have been sampled within the 'Before' commencement of Longwall 23 period and ten replicate times (autumn 2014 to spring 2018) have been sampled within the 'After-commencement of mining' period.

A potential impact could be expected to affect the magnitude and/or dispersion of an indicator (e.g. percentage cover). If a statistically significant difference between sample groups is detected that could be attributed to a mining impact, the difference in variance between groups would be explored using the PERMDISP procedure (Anderson et al, 2008). If there is no statistical difference between variances, the statistical difference between groups is most likely due to differences between group means. Pair-wise tests would be used to explore the different possible combinations of the groups of interest, to determine where significant differences occur.

[4] The sampling of Location C4, larger pool ETAH and smaller pools ETAG, ETAI and ETAK on the Eastern Tributary, WP-A to WP-C on Woronora River and OC-A to OC-C on O'Hares Creek commenced in spring 2009. Sampling at all other sites commenced in spring 2008.

3.0 RESULTS

3.1 Stream Monitoring

3.1.1 Stream Characteristics

A summary of findings from surveys of stream characteristics done at stream monitoring locations sampled on Tributary C/Eastern Tributary (Locations C1, C2 and C4), Tributary B (Location B2) and at two control locations (Woronora River, O'Hares Creek) (Figure 1), undertaken between spring 2008 and spring 2018, is presented below.

Tributary C/Eastern Tributary

Tributary C/Eastern Tributary is a third order stream located in the east of the Project area and is approximately 5.4 km in length (Figure 1). The stream is situated in a moderately steep incised valley with numerous in-stream pools. Observations of sections of Tributary C/Eastern Tributary not subject to mine subsidence indicate that stream sections between pools naturally cease to flow during dry periods and pools may dry up.

Location C1

Sampling location C1 is comprised of pools up to approximately 6 m wide and 1.0 m deep connected by sections of shallow flow over bedrock. The dominant riparian vegetation was reported to include *Gleichenia dicarpa, Leptospermum polygalifolium, Acacia binervia, Acacia floribunda, Acacia longifolia, Acacia parramattensis, Banksia marginata, Eucalyptus* sp. and *Grevillea buxifolia* (Bio-Analysis Pty Ltd, 2008).

Pool water at Location C1 has commonly had a green tinge since sampling commenced in spring 2008. Iron staining has commonly been noted at this location since the autumn 2014 survey. Fracturing of the streambed (predominantly bedrock) and a decline in pool water level (by up to 0.8 m) were first noted by the spring 2015 survey, at Site C1-1. Since then, pool water level at Site C1-1 appeared to be below pre-mining levels in autumn 2016, spring 2017 and autumn 2018. At Site C1-2, which has a predominantly sandy substratum, pool water level appeared lower than pre-mining levels at the time of the autumn 2016 survey but not subsequently.

The main findings from the current survey (spring 2018) are summarised below:

- Pool water level at Site C1-1 was similar to pre-mining levels and there was surface flow out of the pool (Plate 1). At Site C1-2, the water level appeared similar to baseline levels (Plate 2);
- A thick iron precipitate/micro-organism complex continues to be observed at both sites (Plate 2);
- The fern, *Gleichenia dicarpa*, appeared desiccated in areas immediately adjacent to the stream, particularly Site C1-1 (Plate 1). Reduced pool water levels at Site C1-1 on several occasions are likely to have contributed to observed declines in riparian health;
- *Empodisma minus*, *Baumea juncea* and *Viminaria juncea* were relatively abundant at the time of this survey (Appendix 2a).
- Submerged aquatic macrophytes have consistently not been recorded at this location (Appendices 2a&b).

Plate 1: Tributary C – Location C1 (C1-1) (sp-18)
Looking upstream

Plate 2: Tributary C – Location C1 (C1-2) (sp-18)
Looking downstream

Location C2

Location C2 is situated downstream of the Longwalls 20-22 and the Longwalls 23-27 underground mining areas (Figure 1). Location C2 has commonly consisted of pools up to approximately 8 m wide and 1.3 m deep with a predominantly bedrock and sand substratum (Plates 3&4).

Previously, riparian vegetation was reported to include *Acacia binervia, Acacia floribunda, Acacia longifolia, Acacia parramattensis, Bauera rubioides, Baumea rubiginosa, Chorizandra cymbaria, Juncus prismatocarpus* and *Lepidosperma filiforme* (Bio-Analysis Pty Ltd, 2008).

Since the autumn 2013 survey, water in pools at Location C2 has occasionally been noted to have a pale-green milky tinge. Iron staining/iron flocculent was first observed at Location C2 in spring 2016[5]. Iron staining was observed to cover the stream substratum from the top of Site C2-1 to the bottom of Site C2-2 in spring 2016[6], autumn 2017, spring 2017 and autumn 2018. In spring 2017, pool water level at Site C2-1 appeared to be ~ 0.5 m below pre-mining levels but were similar to pre-mining levels by the time of the autumn 2018 survey.

The main findings from the current survey (spring 2018) are summarised below:

- Heavy iron staining/iron flocculent was observed at Site C2-1 and Site C2-2 and pool water had a pale-green milky appearance (Plates 3&4);
- Pool water levels appeared to be similar to pre-mining levels (Plate 3);
- *Baumea juncea, Lepidosperma filiforme* and *Lomandra fluviatilis* were relatively abundant at the time of this survey and in good health (Appendix 2a).
- Similar to Location C1, submerged aquatic macrophytes have consistently not been present (Appendices 2a&b).

5 In spring 2016, Location C2 was sampled on 24 October 2016.

6 Pools were impacted by the 'Eastern Tributary Incident' (exceedance of the Eastern Tributary performance measure) in spring 2016.

Plate 3: Tributary C – Location C2 (C2-1) (sp-18)
Looking upstream

Plate 4: Tributary C – Location C2 (C2-2) (sp-18)
Looking upstream

Location C4

Location C4 is situated approximately 500 m downstream of Location C1, above Longwalls 24-25. The study reach was previously comprised by pools (up to approximately 25 m long, 8 m wide and 1.0 m deep) interrupted by runs and steep (up to approximately 10 m) cascades in places.

Mining related disturbances (i.e. iron staining) were first noted at this location in autumn 2014. At the time of the spring 2015 survey, rock fractures, flow diversions and low water levels were noted at the upstream site (i.e. Site C4-1) and within a relatively steep boulder field between sites C4-1 and C4-2. An iron complex covered up to approximately 95% of the remaining submerged substratum. Desiccation of the riparian assemblage was evident in some places. Water reappeared near the top of the reach at Site C4-2, providing some flow to that section of the stream.

Since spring 2015, large proportions of the study reach at Site C4-1 have commonly been dry but there has been some flow along the study reach at Site C4-2.

The main findings from the spring 2018 survey are summarised below:

- Pool water level at Site C4-1 and C4-2 was similar to pre-mining levels and surface flow was apparent although not between sites;
- An iron complex covered up to approximately 95% of the submerged substratum (Plates 5&6);

- Desiccation of emergent macrophytes, particularly *Gleichenia dicarpa* and *Lepidosperma filiformis*, was apparent. *Lomandra fluviatilis* and *Lepidosperma filiformis* were amongst the most common emergent macrophytes (Appendix 2a);
- Submerged aquatic macrophytes have consistently been absent (Appendix 2a&2b).

Plate 5: Tributary C – Location 4 (C4-1) (sp-18)
Looking across-stream

Plate 6: Tributary C – Location 4 (C4-2) (sp-18)
Looking upstream

Tributary B

This tributary is a relatively small stream (approximately 2.75 km long) that flows through a broad valley into Waratah Rivulet. The sampling location (B2) was situated approximately 250 m upstream from the confluence with the Waratah Rivulet.

Prior to the autumn 2016 survey, a series of shallow (i.e. up to approximately 1.0 m deep in places) pools up to approximately 8 m wide, separated by areas of exposed rock (where the stream appeared to run subsurface) mostly comprised the study reach at Location B2. The substratum was predominantly bedrock (up to approximately 90%) with small deposits of sand in areas of low flow.

Mining related disturbances (i.e. iron staining) were first noted at this location at the time of the spring 2014 survey. Fracturing of the stream substratum was first noted at Site B2-1 and Site B2-2 by the autumn 2015 and autumn 2016 surveys, respectively. Flow diversion and reductions in pool water level were noted at both sites by the autumn 2016 survey, in addition to apparent tilting of the rock bar situated at the top of the study reach. Tilting of some sections of the stream substratum were noted at Site B2-1 and Site B2-2 in spring 2016.

Pool water levels appeared to be similar to pre-mining levels at Site B2-1 and Site B2-2 in autumn and spring 2017 but a large proportion of the study reach at Site B2-2 was dry at the time of the autumn 2018 survey.

The spring 2018 survey noted:

- Pool water levels at the upstream site (i.e. B2-1) appeared similar to pre-mining levels but a large proportion of the study reach at Site B2-2 was dry (Plates 7&8);
- An iron precipitate/micro-organism complex covered a large proportion (~ 95 %) of the submerged substratum at Site B2-1 but not Site B2-2 (Plates 7&8). Flow was apparent along the study reach at Site B2-1 but water quality appeared poor (Plate 7);
- The emergent species, *Lepidosperma filiforme*, was common at both sites (Appendix 2a). Whilst the riparian assemblage at Site B2-1 appeared healthy, a considerable proportion (~ 50 %) of the assemblage at Site B2-2 appeared desiccated, most likely due to reduced pool water levels (Plate 8).
- Submerged aquatic macrophytes have consistently not been recorded at sampling sites in this tributary (Appendix 2).

Plate 7. Tributary B (B2-1) (sp-18)
Looking upstream

Plate 8: Tributary B (B2-2) (sp-18)
Looking upstream

Control Locations

Bee Creek

The headwaters of Bee Creek originate in a large upland swamp and the stream runs through a relatively open valley into the Woronora Reservoir. Bee Creek is situated to the north-west of the Longwalls 23-27 mining area (Figure 1). In general, the study reach has been characterised by small to moderate sized (up to approximately 5 m wide), shallow (up to approximately 0.6 m deep) pools and runs interspersed in places by relatively steep (up to approximately 10 m high) cascades. In many places, boulders and dead trees occupy the stream channel. The substratum was predominantly bedrock with occasional small deposits of sand in many of the pools.

Reduced pool water levels and surface flow were noted at Location BC by the autumn and spring 2016 and autumn and spring 2017 surveys. At the time of the autumn 2018 survey, a large proportion (~ 95 %) of the study reach was dry.

At the time of the spring 2018 survey, water was present along the study reach (Plates 9&10). *Gahnia clarkei* was amongst the most common components of the emergent macrophyte assemblage (Appendix 2), which showed signs of desiccation (Plates 9&10). No exotic plants or animals were observed (Appendices 2, 3 and 4).

Plate 9: Bee Creek (BC1) (sp-18)
Looking upstream

Plate 10: Bee Creek (BC2) (sp-18)
Looking downstream

Woronora Tributary

This tributary of the Woronora River is a small stream which runs through a steep valley situated to the north-west of the Longwalls 23-27 mining area. The sampling location consisted of steep, cascading pools (up to approximately 12 m wide and 0.4 m deep) down the reach and dry areas where the stream naturally ran subsurface (Plates 11&12). Steep cascades (up to approximately 10 m) along the study reach are likely to form natural barriers to fish migration. The substratum was predominantly bedrock and boulders with some deposits of sand in larger pools.

In some places, dense vegetation, dominated by *Eucalyptus* sp., *Acacia floribunda, Acacia longifolia, Acacia parramattensis* and *Callistemon citrinus*, has overgrown the stream bed (Bio-Analysis Pty Ltd, 2008). Submerged aquatic macrophytes have not been recorded at sampling sites in this tributary (Appendix 2).

Similar to the autumn 2018 survey, there was no flow along the study reach at Site WOT1 at the time of the spring 2018 survey and a large proportion (~ 50 %) of the study reach at Site WOT2 was dry (Plates 11&12). *Empodisma minus* and *Viminaria juncea* were amongst the most common emergent macrophytes at this location but showed signs of desiccation at Site WOT2 (Plates 11&12, Appendix 2). No exotic plants or animals were observed at the sites (Appendices 2, 3 and 4). Where present, water visibility was clear and free of sediment.

Plate 11: Woronora Tributary (WOT1) (sp-18)
Looking upstream

Plate 12: Woronora Tributary (WOT2) (sp-18)
Looking downstream

Woronora River

Sites were chosen on the Woronora River approximately 7 km from its headwaters (Appendix 1). The river flows through a steep valley into the Woronora Reservoir. The sites sampled were characterised by interconnected pools (up to approximately 1.0 m deep) approximately 1.5 to 11.7 m wide with predominantly sandy bottoms interspersed with large boulders and beds of the native aquatic macrophytes, *Triglochin procerum* and *Myriophyllum pedunculatum* (Plates 13&14) (Appendix 2).

Cummins et al. (2007a) reported that the riparian vegetation was dominated by the species *Acacia parramattensis, Banksia integrifolia, Juncus prismatocarpus* and *Viminaria juncea*. On this sampling occasion, the most common emergent macrophytes included *Gleichenia dicarpa* and *Lepidosperma filiforme* (Appendix 2). No exotic plants or animals have been noted (Appendices 2, 3 and 4). With the exception of the gauging station located approximately 300 m downstream, there was no evidence of de-vegetation or bank degradation associated with human activities. Slumping of the left-bank (looking downstream) has been apparent since the autumn 2017 survey.

Pool water levels were noted to have declined by this and the previous two surveys (i.e. autumn 2018 and spring 2017). Flow along the study reach was not apparent at the time of this or the autumn 2018 survey (Plates 13&14). Visibility of the water was considered fair.

Plate 13: Woronora River (WR1) (sp-18)
Looking upstream

Plate 14: Woronora River (WR2) (sp-18)
Looking downstream

O'Hares Creek

The headwaters of this 4th order stream originate in an upland swamp. The creek is set in a sandstone gorge and natural rock-bars and waterfalls are common along the watercourse. The sandstone bedrock provided for short, infrequent riffles separating long reaching pools. The substratum was predominantly bedrock with some boulders and deposits of sand in areas of low flow. The immediate catchment is the Dharawal National Park.

At the sampling location, the creek consisted of a series of relatively large (approximately 4 to 18 m wide), interconnected pools to a depth of up to approximately 1.2 m (Plates 15&16). The substratum was predominantly bedrock with some boulders and deposits of sand in areas of low flow. With the exception of where Fire Road 10C crosses the creek, there was little evidence of disturbance.

At the time of this survey, dominant riparian vegetation included *Gleichenia dicarpa, Empodisma minus* and *Gahnia clarkei* (Appendix 2a). *Triglochin procerum* and *Chara/Nitella* spp. were common at Site OC1, the most upstream site (Appendix 2a). The exotic macrophyte, *Isolepis prolifera*, was observed at Site OC1 on this and many earlier occasions (Appendix 2a). Stream water visibility was excellent but much of the stream substratum (~95 %) of both sites was covered by diatomaceous/filamentous algal complex.

Plate 15: O'Hares Creek (OC1) (sp-18)
Looking upstream

Plate 16: O'Hares Creek (OC2) (sp-18)
Looking upstream

3.1.2 Aquatic Macroinvertebrates

AUSRIVAS Assessment

A total of 32 taxon were collected from the 15 sites sampled using the AUSRIVAS sampling protocol (Appendix 3). Sampling Site B2-2 was not sampled on this occasion due to insufficient aquatic habitat (Section 3.1.1). No individuals of the threatened dragonfly species, Adams emerald dragonfly (*Archaeophya adamsi*) (NSW Fisheries, 2002) or Sydney hawk dragonfly (*Austrocordulia leonardi*) (NSW Fisheries, 2007), were found. No individuals of the alien fish, *Gambusi*a *holbrooki*, were collected using the AUSRIVAS technique by the spring 2018 survey.

The OE50 scores ranged between 0.10 (C1-1 and C1-2) and 0.86 (WOT1) (Table 1). Of the fifteen sites sampled (not including Site B2-2), two were grouped in Band A (WOT1 and WR1-2), five were grouped in Band B (C2-2, BC2, WOT2, OC1 and OC2), five were grouped into Band C (C2-1, C4-2, B2-1, BC1 and WR1-1) and three were grouped within Band D (C1-1, C1-2 and C4-1) (Table 1). Thus, with the exception of sites WOT1 and WR1-2, fewer families of macroinvertebrates than expected were collected from the sites sampled in spring 2018 compared to reference sites selected by the AUSRIVAS model (Table 1). Similar numbers of families of macroinvertebrates were collected at Sites WOT1 and WR1-2 in spring 2018 compared to reference sites selected by the AUSRIVAS model (Table 1).

Taxon with > 0.85 probability of occurrence but not collected included the water mite family, Acarina, at all sites except WOT1, WOT2, WR11, OC1 and OC2, and the water bug family, Gyrinidae, at C2-1, BC2, WOT1, WR11 and WR12. Also expected but not collected was the water bug family, Hydrophilidae, at sites C1-1, C4-1, WOT1 and WOT2, the mayfly family, Leptophlebiidae, at sites C1-1, C1-2 and C4-1, the aquatic bug family, Veliidae, at all sites and the caddis fly family, Leptoceridae, at C1-1, C1-2, C2-1, C2-2, C4-1, B2-1, BC1 and OC2.

Table 1. AUSRIVAS outputs for sites sampled at each location (spring 2018) (*n* = 1).

System	Location	Site	Site Code	OE50	Band
Tributary C	1	1	C1-1	0.10	D
	1	2	C1-2	0.10	D
	2	1	C2-1	0.48	C
	2	2	C2-2	0.57	B
	4	1	C4-1	0.19	D
	4	2	C4-2	0.48	C
Tributary B	2	1	B2-1	0.29	C
	2	2	B2-2	#	#
Bee Creek	1	1	BC1	0.46	C
	1	2	BC2	0.67	B
Woronora Tributary	1	1	WOT1	0.86	A
	1	2	WOT2	0.67	B
Woronora River	1	1	WR1-1	0.50	C
	1	2	WR1-2	0.84	A
O'Hares Creek	1	1	OC1	0.78	B
	1	2	OC2	0.57	B

[#] Sample not collected due to insufficient aquatic habitat.

Quantitative Assessment

A total of 810 individuals from 40 macroinvertebrate taxon were collected from 16 sites sampled using the quantitative sampling technique (Appendix 4). Two replicate samples were unable to be collected at Site B2-2 and one replicate sample at each of Site BC1 and BC2 by this survey due to insufficient aquatic habitat (Section 3.1.1).

In spring 2018, the most abundant macroinvertebrate taxon was the freshwater shrimp family, Atyidae (134 individuals), followed by the Leptophlebiidae (99 individuals), Chironomidae (94 individuals) and Dytiscidae (72 individuals) (Appendix 4). The native freshwater crayfish (*Euastacus* sp.) was not collected by either the AUSRIVAS or quantitative sampling techniques during the survey period (Appendix 4). *Gambusi*a was not collected using the quantitative technique.

No individuals of the threatened dragonfly species, Adams emerald dragonfly (*Archaeophya adamsi*) (NSW Fisheries, 2002) or Sydney hawk dragonfly (*Austrocordulia leonardi*) (NSW Fisheries, 2007), were found. Confirmation of the presence of the Adams emerald dragonfly or Sydney hawk dragonfly would have triggered a response for further investigations of this species.

Mean abundance and diversity of macroinvertebrates were greatest at the locations sampled along the Woronora River and O'Hares Creek (Figures 2&3).

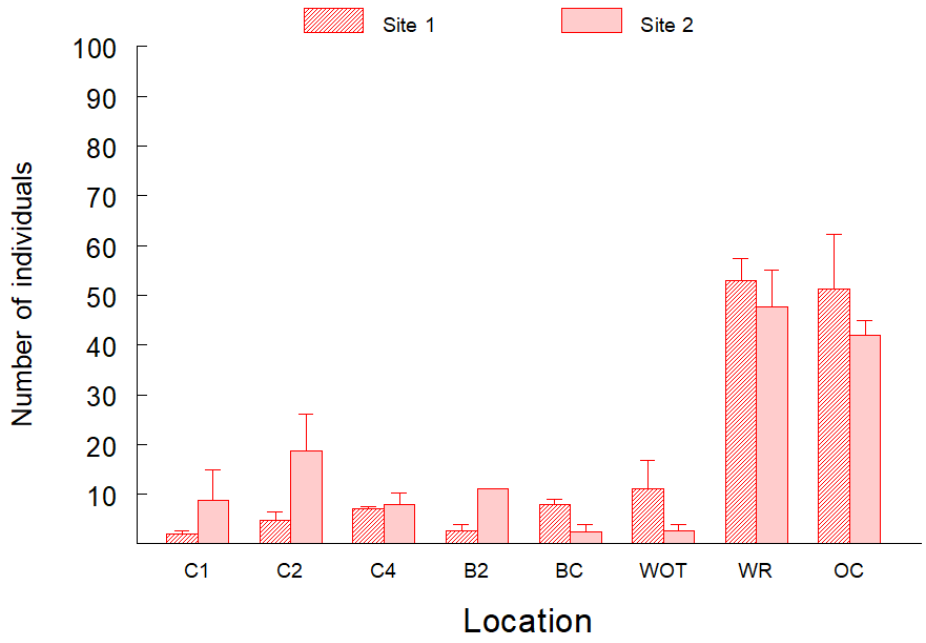


Figure 2. Mean (+SE) abundance of macroinvertebrates at each location (C – Eastern Tributary/Tributary C [C1 – Location 1 etc], B – Tributary B [B2 - Location 2], BC – Bee Creek, WOT – Woronora Tributary, WR – Woronora River, OC – O'Hares Creek).

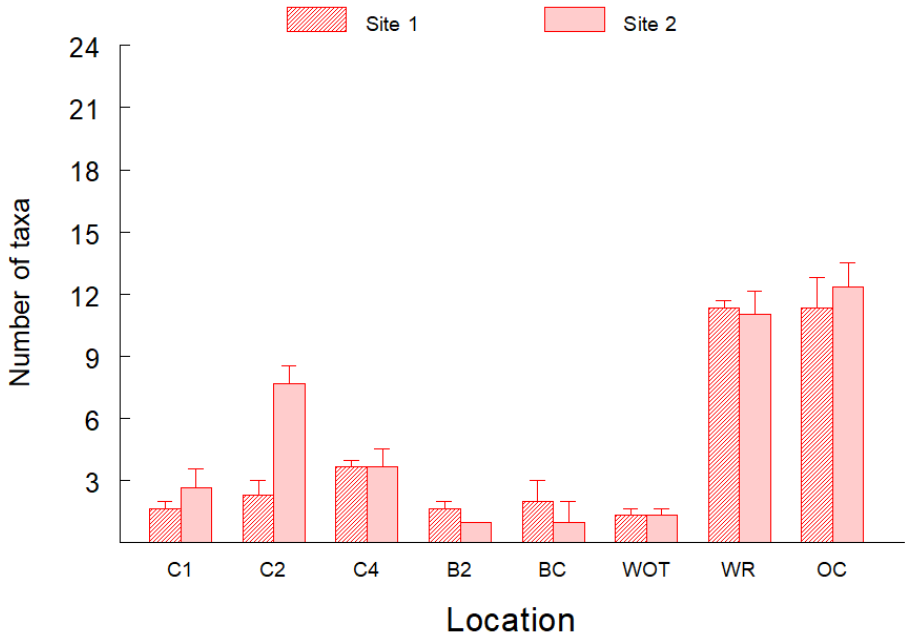


Figure 3. Mean (+SE) diversity of macroinvertebrates at each location (C – Tributary C [C1 – Location 1 etc], B – Tributary B [B2 - Location 2], BC – Bee Creek, WOT – Woronora Tributary, WR – Woronora River, OC – O'Hares Creek).

3.1.3 Aquatic Macrophytes

A total of 23 aquatic macrophyte species were identified in quantitative samples at sites on Tributary C/Eastern Tributary (C1: 7 species, C2: 9 species, C4: 8 species), Tributary B (9 species), Bee Creek (8 species), Woronora Tributary (7 species), Woronora River (9 species) and O'Hares Creek (12 species) (Appendix 2b).

Mean percentage cover of macrophytes was greatest at the location sampled on O'Hares Creek compared to all other locations sampled (Figure 4). Mean diversity of macrophytes recorded in the 0.25 m^2 quadrats at any one location was generally low (i.e. < 4 species) and there were no distinct patterns associated with any location (Figure 5).

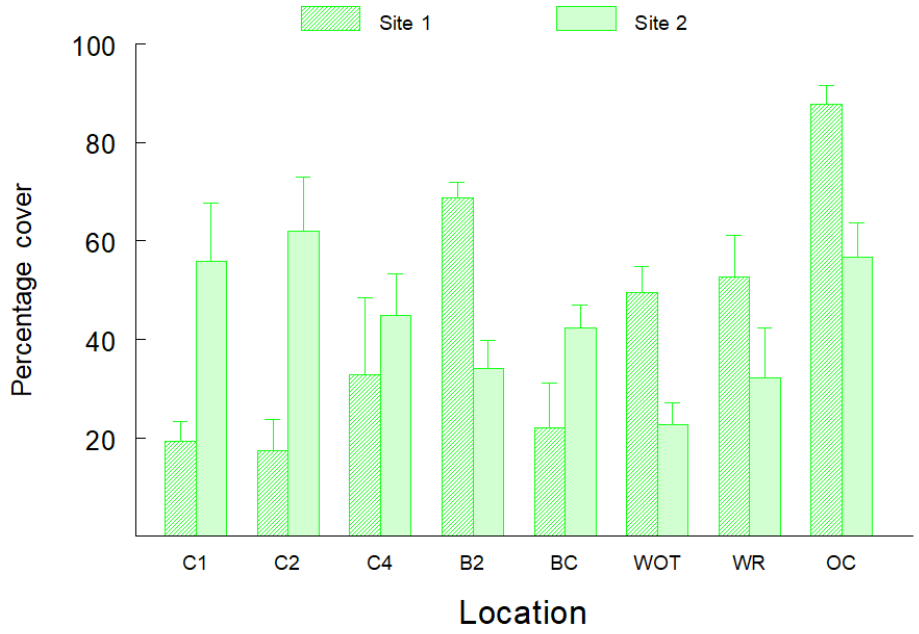


Figure 4. Mean (+SE) percentage cover of macrophytes at each location (C – Tributary C/Eastern Tributary [C1 – Location 1 etc], B – Tributary B [B2 - Location 2], BC – Bee Creek, WOT – Woronora Tributary, WR – Woronora River, OC – O'Hares Creek).

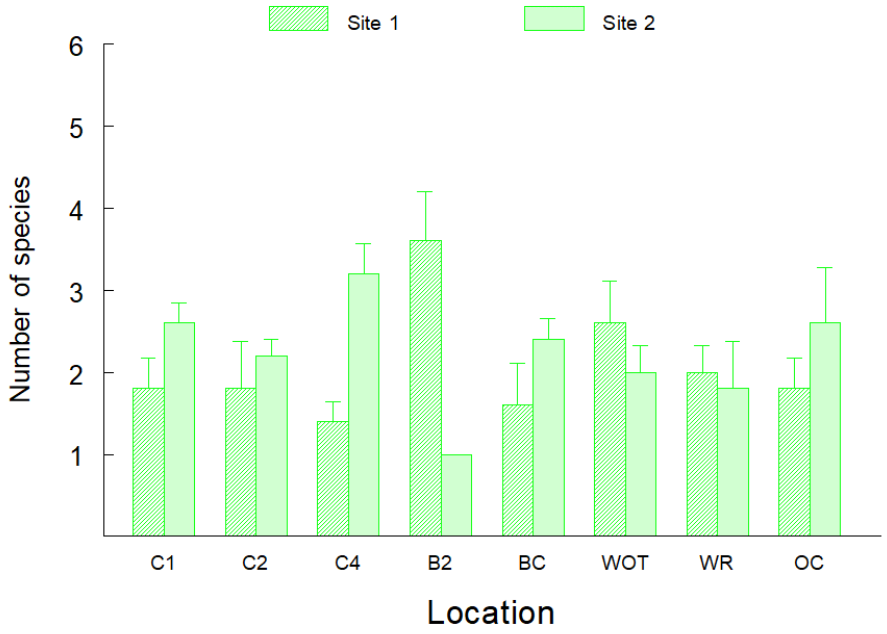


Figure 5. Mean (+SE) diversity of macrophytes at each location (C – Tributary C/Eastern Tributary [C1 – Location 1 etc], B – Tributary B [B2 - Location 2], BC – Bee Creek, WOT – Woronora Tributary, WR – Woronora River, OC – O'Hares Creek).

3.1.4 Water Quality

Mean physico-chemical water quality, alkalinity, total phosphorous and total nitrogen measurements are summarised in Table 2. Values highlighted in bold type indicate where results were outside the default trigger values (DTVs) recommended by ANZECC/ARMCANZ (2000) for protection of aquatic ecosystems in upland rivers (i.e. systems at > 150 m altitude) in southeast Australia.

In general, mean water temperature within the six creeks ranged from 14.6 to 24.6 ° C (Table 2). Mean pH (range = 5.0 – 7.3) was once again below the lower DTV (i.e. pH 6.5-8.0; ANZECC/ARMCANZ, 2000) for upland rivers at several sites including, BC1, BC2, WOT1 and WOT2 (Table 2). Relatively low pH values are common in areas with a sandstone substratum.

Mean conductivity levels (range = 93 – 434 µS/cm) were above the upper DTV at the sites sampled along Tributary B. At the time of the spring 2018 survey, pool water levels at Site B2-1 appeared similar to pre-mining levels but a large proportion of the study reach at Site B2-2 was dry. An iron precipitate/micro-organism complex covered a large proportion (~95%) of the submerged substratum at Site B2-1 but not Site B2-2.

Mean dissolved oxygen levels (range = 12.3 – 102.3 %) were below the lower DTV (range = 90-110% saturation) at Site B2-1 and B2-2, in addition to sites C1-1, C2-1, C2-2, C4-1, C4-2, BC1, BC2, WOT1, WOT2, WR1-1 and WR1-2 (Table 2).

Mean turbidity (range = 4.8 – 70.7 NTU) was above the upper DTV recommended by ANZECC/ARMCANZ (2000) (range = 2 – 25 NTU) at all of the sites sampled except Site C1-2, B2-2, BC1, BC2, OC1 and OC2 (Table 2). Mean oxidation-reduction potential at the sites ranged from 493 to 667 mV (Table 2). Mean alkalinity ranged from 0 to 65 mg/L $CaCO_3$ (Table 2). For nutrients, mean concentrations of total phosphorous (range = < 0.02 to 0.02 mg/L) were within the DTVs but total nitrogen (range = <0.05 to 0.40 mg/L) was above the upper DTV (0.25 mg/L) at Site BC1and WOT2 (Table 2). The raw water quality data are provided in Appendix 5.

Table 2. Mean (± SE) measurements of water quality variables recorded at each site (spring 2018). Values in bold are outside the default trigger values recommended by ANZECC/ARMCANZ (2000).

Watercourse	**Tributary C**		**Tributary C**		**Tributary C**		**Tributary B**	
Location/Site	**C1-1**	**C1-2**	**C2-1**	**C2-2**	**C4-1**	**C4-2**	**B2-1**	**B2-2**
Temperature °C (*n* =3)	19.1 (0.0)	24.6 (0.0)	19.1 (0.0)	16.9 (0.0)	15.9 (0.0)	17.5 (0.0)	16.5 (0.0)	18.4 (0.0)
pH (*n* =3)	6.9 (0.0)	7.0 (0.0)	6.7 (0.0)	7.0 (0.0)	7.1 (0.0)	6.8 (0.0)	6.6 (0.0)	7.3 (0.0)
Conductivity (µS/cm) (*n* = 3)	146.0 (0.0)	151.0 (0.0)	212.0 (0.0)	232.0 (0.0)	197.0 (0.0)	201.7 (1.7)	**434.0** (0.6)	**415.7** (0.3)
DO (% Saturation) (*n* = 3)	**76.8** (0.7)	96.4 (1.1)	**59.6** (0.2)	**48.6** (0.7)	**72.8** (3.5)	**37.6** (0.6)	**42.4** (0.2)	**79.3** (0.2)
Turbidity (NTU) (*n* = 3)	**37.6** (0.5)	19.8 (0.3)	**57.6** (0.4)	**62.8** (0.2)	**57.2** (0.5)	**54.2** (0.4)	**35.3** (0.3)	10.3 (0.0)
ORP (mV) (*n* = 3)	493.3 (0.7)	504.0 (0.6)	655.0 (10.0)	605.7 (1.8)	617.7 (0.3)	514.0 (1.0)	574.0 (0.6)	574.0 (1.5)
Alkalinity (mg/L $CaCO_3$) (*n* = 2)	18	18	17	25	25	25	60	65
Total phosphorous (mg/L) (*n* = 2)*	<0.02 (0.0)	<0.02 (0.0)	<0.02 (0.0)	<0.02 (0.0)	<0.02 (0.0)	<0.02 (0.0)	<0.02 (0.0)	0.02 (0.01)
Total nitrogen (mg/L) (*n* = 2)*	0.13 (0.04)	0.08 (0.03)	<0.05 (0.0)	<0.05 (0.0)	0.04* (0.02)	0.04* (0.02)	0.10 (0.04)	0.09 (0.01)
Watercourse	**Bee Creek**		**Woronora Tributary**		**Woronora River**		**O'Hares Creek**	
Location/Site	**BC1**	**BC2**	**WOT1**	**WOT2**	**WR1-1**	**WR1-2**	**OC1**	**OC2**
Temperature °C (*n* =3)	15.0 (0.0)	15.4 (0.0)	17.2 (0.0)	14.6 (0.0)	17.1 (0.0)	18.4 (0.0)	22.4 (0.0)	24.6 (0.0)
pH (*n* =3)	**5.0** (0.0)	**5.6** (0.0)	**5.9** (0.0)	**6.0** (0.0)	6.9 (0.0)	6.7 (0.0)	6.7 (0.0)	7.0 (0.0)
Conductivity (µS/cm) (*n* =3)	230.0 (0.0)	204.0 (0.0)	93.0 (0.0)	104.0 (0.0)	125.7 (1.3)	119.0 (0.0)	108.0 (0.0)	114.0 (0.0)
DO (% Saturation) (*n* =3)	**12.3** (1.4)	**40.2** (0.0)	**68.0** (0.2)	**45.6** (0.2)	**55.5** (0.1)	**63.6** (0.3)	97.2 (0.2)	102.3 (0.1)
Turbidity (NTU) (*n* =3)	4.8 (0.3)	9.0 (0.2)	**69.9** (0.8)	**67.4** (0.0)	**68.0** (0.0)	**70.7** (0.1)	21.8 (0.1)	22.9 (0.1)
ORP (mV) (*n* = 3)	531.3 (0.3)	534.0 (1.7)	625.0 (0.6)	601.3 (0.9)	662.0 (0.0)	667.0 (0.0)	597.7 (0.3)	575.0 (0.0)
Alkalinity (mg/L $CaCO_3$) (*n* = 2)	5	5	0	0	5	5	5	5
Total phosphorous (mg/L) (*n* = 2)*	0.02 (0.0)	<0.02 (0.0)	<0.02 (0.0)	<0.02 (0.0)	0.02 (0.0)	<0.02 (0.0)	<0.02 (0.0)	<0.02 (0.0)
Total nitrogen (mg/L) (*n* = 2)*	**0.40** (0.04)	0.10 (0.01)	0.24 (0.01)	0.34 (0.07)	0.19 (0.03)	0.15 (0.00)	0.17 (0.01)	0.23 (0.04)

NB: Default trigger values recommended by ANZECC/ARMCANZ (2000) for upland streams: pH (6.5 – 8.0); Conductivity (30 – 350 µS/cm); Turbidity (2 – 25 NTU); Dissolved Oxygen (90–110 % Saturation); Total phosphorous (0.02 mg/L); Total nitrogen (0.25 mg/L). There are no ANZECC/ARMCANZ (2000) guideline values for Temperature, ORP or Alkalinity. *For any site where a value has been recorded as less than the detection limit, a value of half the detection limit was assigned in order to calculate the mean (e.g. <0.02 taken as 0.01). N/R = Not Recorded.

3.2 Pool Monitoring

3.2.1 Large Pools

3.2.1.1 Pool Characteristics

Pool ETAH

One large pool (defined as pools > 40 m in length) is sampled on Tributary C: Pool ETAH, which occurs approximately 1100 m downstream of the crossing with Fireroad 9J. Generally, the pool is approximately 54 m long and from 3 to 5.5 m wide. The base of the pool is sandstone with alluvial deposits. Prior to subsidence related impacts along this section of Tributary C, Pool ETAH was observed to be up to ~2.2 m deep and was fringed by dense riparian vegetation. No submerged or floating-attached macrophytes have been recorded.

Pool water at Pool ETAH has commonly had a milky-green tinge since sampling commenced in spring 2009. Iron staining was first noted by the spring 2016 survey, when it covered up to approximately 90% of the stream substratum in shallow areas at the top of the pool. A considerable lowering of water level within Pool ETAH (up to ~ 1.5 m) was noted by the autumn 2017 survey. Pool ETAH was dry at the time of the spring 2017 and autumn 2018 surveys and there was no surface flow for a considerable distance upstream or downstream.

The spring 2018 survey noted:

- there was no surface flow for a considerable distance upstream or downstream of the pool however, a small inflow of water was observed near the base of the upstream end of Pool ETAH (Plate 17);
- pool water level was up to ~10 cm deep in places (Plates 17&18); and
- a large proportion of previously (up until the spring 2017 survey) dominant emergent macrophyte species, *Gleichenia dicarpa* and *Empodisma minus,* appeared desiccated (Plate 18).

Plate 17: Pool ETAH (ETAH) (sp-18)
Water entering near the base of the upstream end

Plate 18: Pool ETAH (ETAH) (sp-18)
Downstream end looking upstream

Control Pools

Control pools were chosen within the Woronora River (WP) and O'Hares Creek (OP). The Woronora pool was approximately 1.35 m deep at its deepest, 55 m long and up to 15 m wide (Plates 19&20). The pool bed was predominantly sand interspersed with large boulders. Patches of the submerged macrophytes, *Triglochin procerum* and *Myriophyllum pedunculatum*, were common. Dense vegetation surrounded the pool, comprised mostly of the emergent species *Gleichenia dicarpa* and *Lepidosperma filiforme* (Appendix 6). At the time of sampling, there were no obvious signs of disturbance. Flow along the study reach was not apparent at the time of the autumn and spring 2018 surveys and visibility of the water was only considered fair.

Plate 19: Woronora pool (WP) (sp-18)
Upstream end looking downstream

Plate 20: Woronora pool (WP) (sp-18)
Downstream end looking upstream

The control pool on O'Hares Creek was approximately 0.9 m deep at its deepest, 110 m long and up to 22 m wide (Plates 21&22). The pool bed was predominantly sandstone interspersed with deposits of sand and boulders. Patches of the submerged macrophyte, *Triglochin procerum*, were common and there were small patches of *Chara*/*Nitella* spp. dispersed throughout the pool. Dense vegetation surrounded the pool, comprised mostly of the emergent species, *Gleichenia dicarpa*, *Empodisma minus* and *Sticherus flabellatus* (Appendix 6). The introduced aquatic weed, *Isolepis prolifera*, was once again recorded, growing adjacent to the left bank (looking downstream) at the downstream end of the pool. Stream water visibility was good but much of the stream substratum (~95 %) was covered by a diatomaceous/filamentous algal complex.

Plate 21: O'Hares pool (OP) (sp-18)
Downstream end looking upstream

Plate 22: O'Hares pool (OP) (sp-18)
Upstream end looking across-stream

3.2.1.2 Aquatic Macroinvertebrates

At the time of the spring 2018 survey, only two samples of aquatic macroinvertebrates were able to be collected in Pool ETAH (Appendix 7). In total, 531 individuals from 31 macroinvertebrate taxon were collected from the pools sampled using the quantitative sampling technique (Appendix 7).

The most abundant macroinvertebrate taxon was the Atyidae (146 individuals), Leptophlebiidae (61 individuals) and the Chironomidae (50 individuals) (Appendix 7). Similar to the findings of the previous survey, mean abundance and diversity of macroinvertebrates were greatest in the Woronora River pool compared to the O'Hares pool and Pool ETAH in spring 2018 (Figures 6&7).

*Gambusi*a were not collected at any of the pools sampled. No individuals of the threatened dragonfly species, Adams emerald dragonfly (*Archaeophya adamsi*) (NSW Fisheries, 2002) or Sydney hawk dragonfly (*Austrocordulia leonardi*) (NSW Fisheries, 2007) or the native freshwater crayfish (*Euastacus* sp.) were collected (Appendix 7).

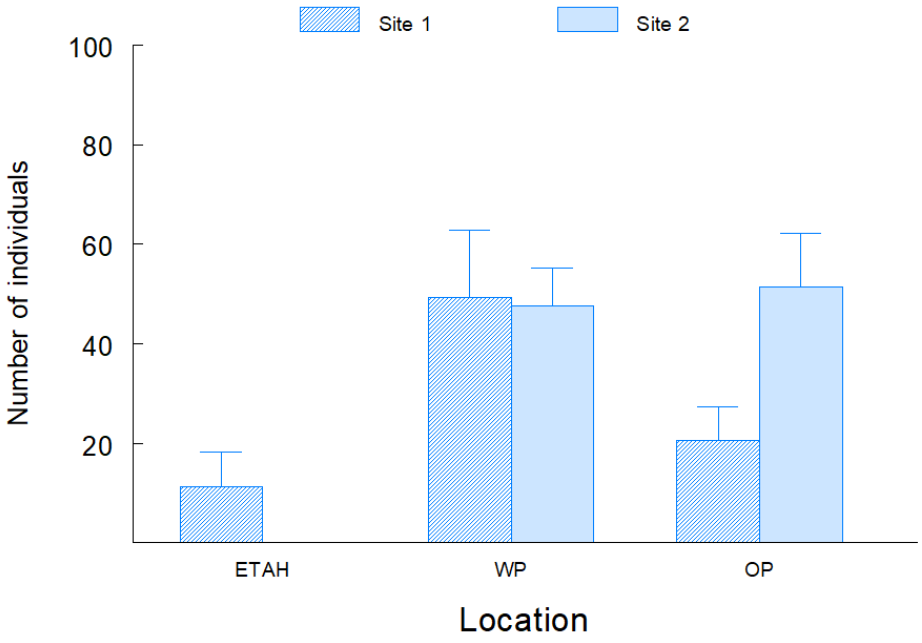


Figure 6. Mean (+SE) abundance of macroinvertebrates at each pool (ETAH – Tributary C/Eastern Tributary Pool, WP – Woronora Pool, OP - O'Hares Pool) (*n* = 3). NB Pool ETAH was dry at the time of sampling.

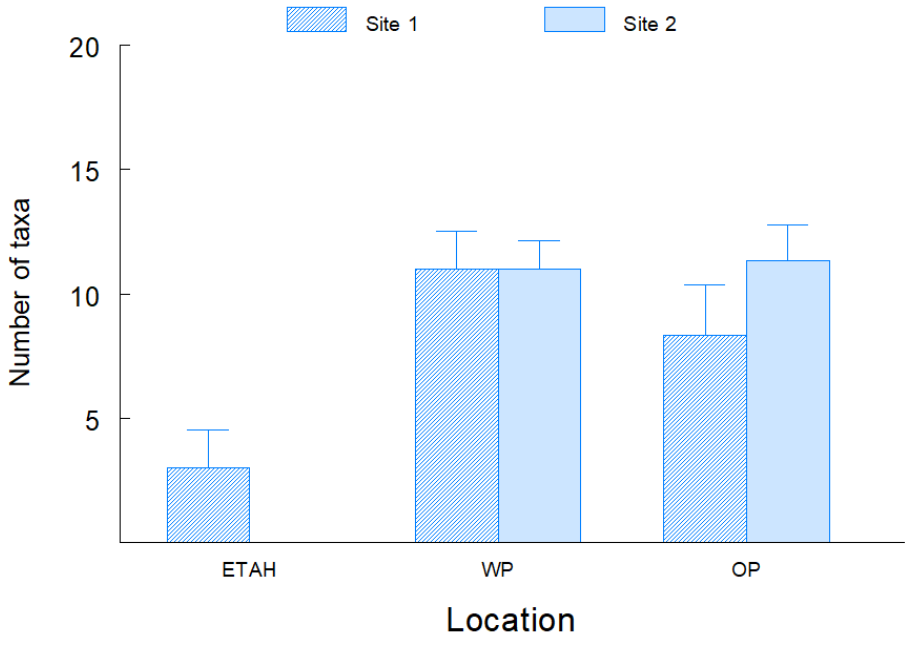


Figure 7. Mean (+SE) diversity of macroinvertebrates at each pool (ETAH – Tributary C/Eastern Tributary Pool, WP – Woronora Pool, OP - O'Hares Pool) (*n* = 3). NB Pool ETAH was dry at the time of sampling.

3.2.1.3 Aquatic Macrophytes

A total of 16 aquatic macrophyte species were found in quantitative samples at the pools sampled: Pool ETAH (6 species), Woronora pool (10 species) and O'Hares pool (8 species) (Appendix 6). Similar to the findings of the previous survey, mean percentage cover of aquatic macrophytes was greatest at the O'Hares Pool in spring 2018, followed by the Woronora Pool and Pool ETAH (Figure 8). Mean diversity of macrophytes recorded in the 0.25 m^2 quadrats at sites within any one pool was generally low (i.e. < 5 species) and there were no distinct patterns associated with any location (Figure 9).

Submerged or floating-attached species of macrophytes have consistently not been recorded in Pool ETAH (Figure 10). The largest area of submerged or floating-attached macrophytes has consistently occurred at the control pool on the Woronora River, where approximately 25 % of the pool bed was covered, mostly by *Triglochin procerum* (Figures 10-12). Patches of *Triglochin procerum* were also common in the O'Hares pool (Figure 12). *Myriophyllum pedunculatum* was only observed in the Woronora pool (Figures 10-12). Small patches of *Chara/Nitella* spp. were recorded in O'Hares pool on this sampling occasion (Figure 12).

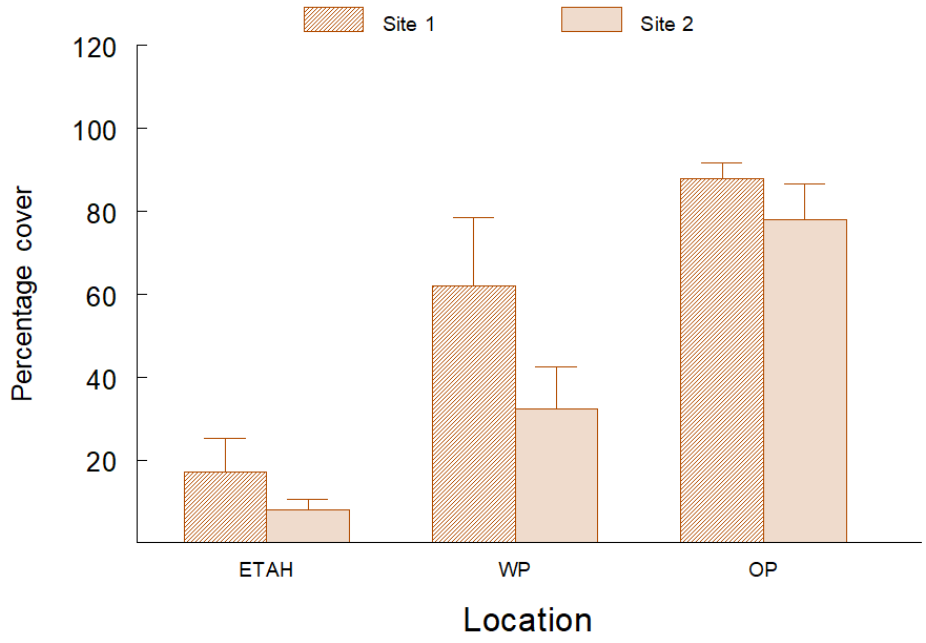


Figure 8. Mean (+SE) percentage cover of macrophytes at each pool (ETAH – Tributary C/Eastern Tributary Pool, WP – Woronora Pool, OP - O'Hares Pool) (*n* = 5).

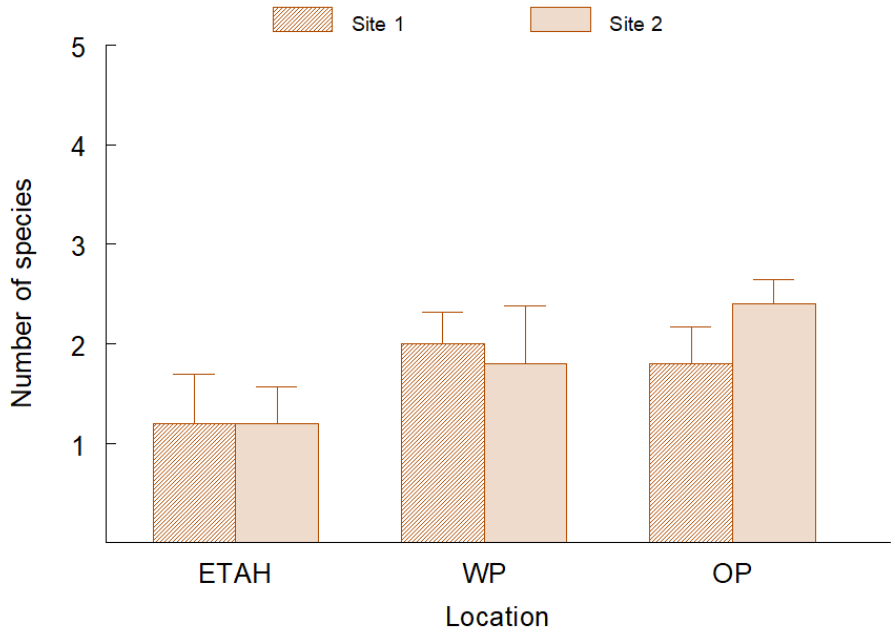
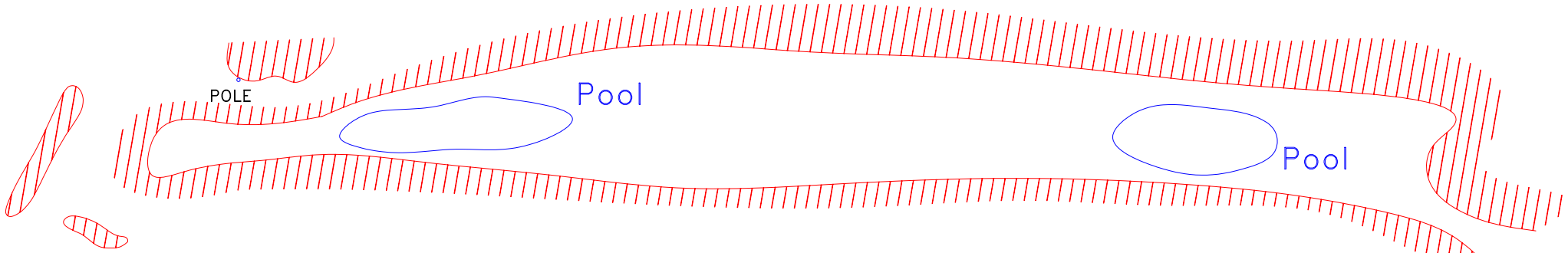


Figure 9. Mean (+SE) diversity of macrophytes at each pool (ETAH – Tributary C/Eastern Tributary Pool, WP – Woronora Pool, OP - O'Hares Pool) (*n* = 5).

FIGURE 10



56H 0312243
6214812

LEGEND

Exposed Rock

0 5 10 20M

SCALE

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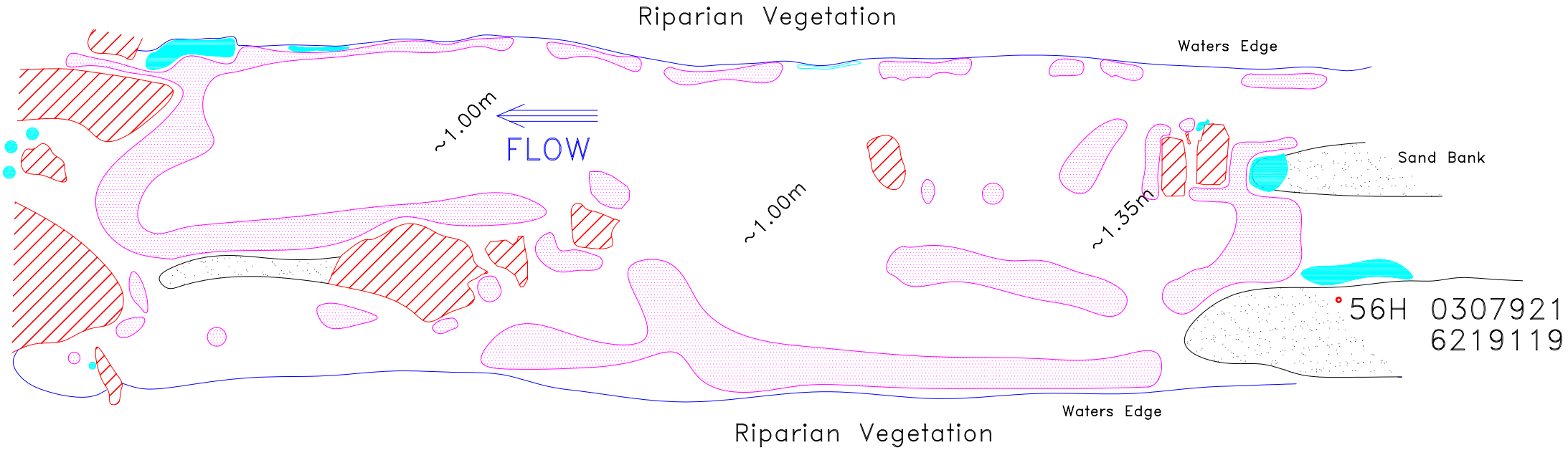
POOL ETAH
SPRING SURVEY 2018

DATE:	SCALE:
01/11/2018	BAR SCALE
No OF SHEETS:	SHEET No:
1	1

FIGURE 11



LEGEND

Exposed Rock

Triglochin procerum

Myriophyllum pedunculatum

0 2.5 5 10M

SCALE

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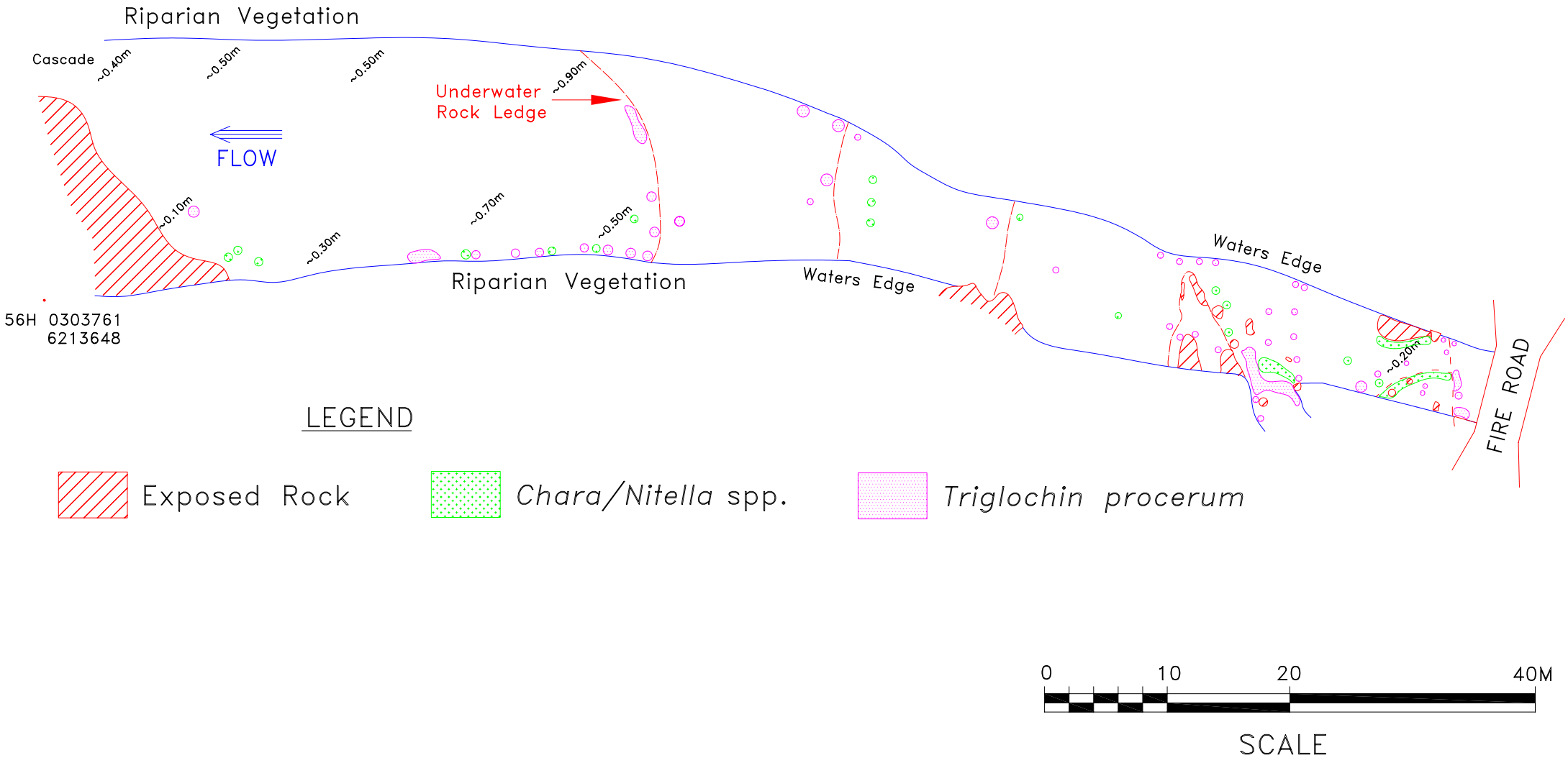
WORONORA POOL WP
SPRING SURVEY 2018

DATE:	SCALE:
19/11/2018	BAR SCALE
No OF SHEETS:	SHEET No:
1	1

FIGURE 12



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O'HARES POOL
SPRING SURVEY 2018

DATE:	SCALE:
03/12/2018	BAR SCALE
No OF SHEETS:	SHEET No:
1	1

3.2.1.4 Water Quality

Physico-chemical water quality measurements are summarised in Table 3, with values highlighted in bold type indicating where mean values were outside the Default Trigger Values (DTVs) recommended by ANZECC/ARMCANZ (2000).

In general, mean water temperature within the control pools ranged from 17.5 to 22.4 ° C (Table 3). The level of pH (range = 4.5 – 6.8) was below the lower DTV recommended for upland rivers (i.e. systems at > 150 m altitude) (ANZECC/ARMCANZ, 2000) (range = 6.5 – 8.0) at Pool ETAH (Table 5). Mean conductivity was within the DTVs (range = 30 -350 µS/cm) and ranged between 108 and 250 µS/cm, while turbidity (range = 21.8 – 70.7 NTU) was above the upper DTV (ANZECC/ARMCANZ, 2000) (range = 2 – 25 NTU) in Pool ETAH and in the Woronora River pool (Table 5). Mean oxidation-reduction potential ranged from 597 – 703 (Table 3). The raw water quality data are provided in Appendix 8.

Table 3. Mean (± SE) measurements of water quality variables recorded at each site (spring 2018).

	Pool ETAH		**Woronora Pool**	
Site	**ETAH1**	**ETAH2**	**WP1**	**WP2**
Temperature °C (*n* =3)	18.1 (0.0)	17.8 (0.0)	17.5 (0.2)	18.4 (0.0)
pH (*n* =3)	**4.5** (0.0)	**4.7** (0.0)	6.8 (0.0)	6.7 (0.0)
Conductivity (µS/cm) (*n* = 3)	250.0 (0.0)	238.7 (1.7)	121.0 (0.0)	119.0 (0.0)
DO (% Saturation) (*n* = 3)	**51.9** (3.1)	**54.7** (1.5)	**62.1** (0.1)	**63.6** (0.3)
Turbidity (NTU) (*n* = 3)	**57.2** (0.2)	**59.1** (0.1)	**68.9** (0.2)	**70.7** (0.1)
ORP (mV) (*n* = 3)	697.3 (0.9)	702.7 (0.3)	669.7 (0.3)	667.0 (0.0)
Site	**OP1**	**OP2**		
Temperature °C (*n* =3)	22.4 (0.0)	22.0 (0.0)		
pH (*n* =3)	6.7 (0.0)	6.5 (0.0)		
Conductivity (µS/cm) (*n* = 3)	108.0 (0.0)	109.0 (0.0)		
DO (% Saturation) (*n* = 3)	97.2 (0.2)	93.6 (0.6)		
Turbidity (NTU) (*n* = 3)	21.8 (0.1)	24.4 (0.5)		
ORP (mV) (*n* = 3)	597.7 (0.3)	615.3 (2.7)		

NB: Guideline values recommended by the ANZECC (2000) guidelines for upland streams: pH (6.5 – 8.0); Conductivity (30 – 350 µS/cm); Turbidity (2 – 25 NTU); Dissolved Oxygen (90–110 % Saturation). There are no ANZECC (2000) guideline values for Temperature, ORP or Alkalinity. I/A = Insufficient Aquatic Habitat. I/M = Instrument Malfunction.

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3.2.2 Small Pools

3.2.2.1 Pool Characteristics

Tributary C/Eastern Tributary Pools

Three small pools (defined as pools < 40 m in length) along Tributary C/Eastern Tributary are sampled as part of the Pool Monitoring Programme: Pools ETAG, ETAI and ETAK.

Any pool water in Pools ETAG, ETAI and ETAK has commonly had a milky-green tinge since sampling commenced in spring 2009. Iron staining was first observed within the Eastern Tributary pools sampled by the aquatic ecology surveys during the spring 2016 survey.

Pool ETAG

Pool ETAG occurs approximately 1 km downstream of the crossing with Fireroad 9J. In general, dimensions of the pool have been approximately 20 m long and up to 8.5 m wide (Plate 23). Prior to the autumn 2017 survey, water depth varied from approximately 0.2 m to 0.8 m deep. The base of the pool was sandstone with alluvial deposits, mostly on the western side. Large amounts of sand had accumulated over time at the upstream end of the pool. Water flowed from the pool into a boulder field.

In January 2017, Metropolitan Coal recorded subsidence impacts to water levels in Pool ETAG (Metropolitan Coal, 2017). At the time of the autumn 2017 survey, a considerable reduction (up to ~ 0.3 m) of the water level within Pool ETAG was noted. Remaining water within the pool had a milky-green tinge and iron floc completely covered the substratum. The pool was completely dry at the time of the spring 2017 and autumn 2018 surveys.

At the time of the spring 2018 survey, flow was apparent in and out of the pool and water level was similar to pre-mining levels (up to ~0.8 m deep) (Plate 23). *Lomandra fluviatilis* was the most abundant component of the aquatic macrophyte assemblage (Appendix 9).

Pool ETAI

Pool ETAI occurs approximately 40 m downstream of the large pool, Pool ETAH. Only small rock-bars separate Pool ETAI and the next 2 pools (i.e. Pool ETAJ and ETAK). In general, pool length has been approximately 30 m and width varies from approximately 2 m to 8 m wide (Plate 24). Prior to the autumn 2017 survey, water depth was up to approximately 1.8 m deep. The pool bed was sandstone with alluvial deposits and scattered boulders. A large sandbank was present on the western side of the pool (Plate 24).

Metropolitan Coal recorded subsidence impacts to water levels in Pool ETAI in late 2016 (Metropolitan Coal, 2017). At the time of the autumn 2017 survey, cracking of the stream substratum was noted at the upstream end of the pool and there had been a considerable reduction in pool water level (up to ~ 1.7 m) compared to pre-mining levels. There was insufficient aquatic habitat to collect samples of aquatic macroinvertebrates. The pool was completely dry at the time of the spring 2017 and autumn 2018 surveys.

At the time of the spring 2018 survey, Pool ETAI was dry (Plate 24). *Baumea juncea* and *Lomandra fluviatilis* were common components of the riparian assemblage (Appendix 9).

Plate 23: Pool ETAG (sp-18)
Downstream end looking upstream

Plate 24: Pool ETAI (sp-18)
Downstream end looking upstream

Pool ETAK

Pool ETAK occurs approximately 25 m downstream of Pool ETAI. Generally, pool length has been approximately 25 m long and width up to 9 m wide (Plate 25). Prior to autumn 2017, pool depth was up to approximately 0.5 m deep. The substratum of the pool was predominantly sandstone covered with alluvial deposits in places of low flow.

Metropolitan Coal recorded subsidence impacts to water levels in Pool ETAK in late 2016 (Metropolitan Coal, 2017). At the time of the autumn 2017 survey, the pool was noted to have completely drained of water. There was no apparent surface flow upstream or downstream of the pool and a considerable proportion of the riparian assemblage, particularly *Gleichenia dicarpa*, appeared desiccated. The pool was completely dry at the time of the spring 2017 and autumn 2018 surveys.

At the time of the spring 2018 survey, Pool ETAK was dry (Plate 25). *Lepidosperma filiforme* was the most common riparian species (Appendix 9). Desiccation of *Gleichenia dicarpa* was apparent.

Small Control Pools

Three small control pools are sampled on each of the Woronora River (i.e. Pools WP-A, WP-B and WP-C) and O'Hares Creek (i.e. Pools OP-A, OP-B and OP-C).

Pool WP-A is the most downstream of the small pools sampled on the Woronora River, situated approximately 165 m upstream from the gauging station. Pool dimensions were approximately 10.5 m long and up to 6 m wide. At the time of the spring 2018 survey, pool depth was up to approximately 0.2 m deep (Plate 26). Boulders to about 1 m in size were located at the upstream and downstream ends of the pool (Plate 26). The substratum of the pool was predominantly sandstone covered with sediment and sand deposits.

Dense vegetation surrounded the pool. Of the emergent species present, *Gleichenia dicarpa* and *Lepidosperma filiforme* were amongst the most common riparian emergent macrophyte species (Appendix 9). The submerged macrophytes, *Triglochin procerum* and *Myriophyllum pedunculatum*, were common (Appendix 9). At the time of sampling, there were no obvious signs of disturbance. Visibility of the water was good.

Plate 25: Pool ETAK (aut-18)
Looking upstream

Plate 26: Woronora Pool A (WPA) (sp-18)
Upstream end looking across-stream

Pool WP-B is the most upstream pool sampled, situated approximately 325 m upstream from the gauging station. Dimensions of the pool were approximately 28 m long and up to 6.7 m wide. Pool depth was up to approximately 1.3 m deep. Boulders to about 2 m in size were located at the upstream and downstream ends of the pool. The substratum of the pool was predominantly sandstone covered with sediment and sand deposits (Plate 27). Dense vegetation surrounded the pool.

Of the emergent species present, *Sticherus flabellatus*, *Eurychorda complanata* and *Lepidosperma filiforme* were amongst the most abundant (Appendix 9). Large patches of the submerged macrophyte, *Triglochin procerum*, were recorded. *Chara/Nitella* and *Myriophyllum pedunculatum* were also present. At the time of sampling, there were no obvious signs of human disturbance. Visibility of the water was good.

Pool WP-C is situated between Pools WP-B and WP-A. Dimensions of the pool were approximately 9 m long and up to 3.5 m wide (Plate 28). Pool depth was up to approximately 0.3 m deep. Boulders were located at the upstream end of the pool. The substratum of the pool was predominantly sandstone, boulders and some deposits of sand. Dense vegetation surrounded the pool. Of the macrophyte species present, *Lomandra fluviatilis* and *Lepidosperma filiforme* were the most abundant (Appendix 9). At the time of this survey, one small patch of *Triglochin procerum* was present (Appendix 9). There were no obvious signs of disturbance and visibility of the water was good.

Plate 27: Woronora Pool B (WP-B) (sp-18)
Downstream end looking upstream

Plate 28: Woronora Pool C (WP-C) (sp-18)
Downstream end looking upstream

Small control pools on O'Hares Creek are all situated downstream of the crossing at Fire Road 10C. Dimensions of Pool OP-A were approximately 40 m long and up to 12 m wide (Plate 29). Pool depth was up to 0.5 m deep. Boulders were located at the upstream and downstream ends of the pool. Of the emergent species present, *Empodisma minus* and *Lomandra fluviatilis* were among the most abundant (Appendix 9). At the time of the survey, *Triglochin procerum* was not present but small patches of *Chara/Nitella* spp. were observed growing amongst boulders situated near the top of the pool (Figure 23). There were no obvious signs of disturbance. Visibility of the water was excellent.

Dimensions of Pool OP-B were approximately 20 m long and up to 10 m wide (Plate 30). Pool depth was up to 0.9 m deep. The substratum of the pool was predominantly sandstone with some boulders, mostly located at the upstream end of the pool. Of the emergent species present, *Empodisma minus* and *Gleichenia dicarpa* were amongst the most abundant (Appendix 9). *Chara/Nitella* spp. was also present (Figure 24). Visibility of the water was excellent.

Plate 29: O'Hares Pool A (OP-A) (sp-18)
Upstream end looking downstream

Plate 30: O'Hares Pool B (OP-B) (sp-18)
Downstream end looking upstream

Dimensions of Pool OP-C were approximately 37 m long and up to 12.5 m wide (Plate 31). Pool depth was up to 1.15 m deep. The substratum of the pool was predominantly sandstone with some boulders at the upstream and downstream ends of the pool. Of the emergent species present, *Gleichenia dicarpa*, *Empodisma minus* and *Eurychorda complanata* were amongst the most abundant (Appendix 9). *Chara/Nitella* spp. was also present (Figure 25). Visibility of the water was excellent.

Plate 31: O'Hares Pool C (OP-C) (aut-18)

Upstream end looking downstream

3.2.2.2 Aquatic Macroinvertebrates

A total of 570 individuals from 36 macroinvertebrate taxon were collected from the six small pools sampled using the quantitative sampling technique (Appendix 10). There was insufficient aquatic habitat in Pools ETAI and ETAK to collect samples of aquatic macroinvertebrates (Figures 13&14). In addition, only one sample was able to be collected in Pool WP-B sampled on the Woronora River due to the water level being relatively low (Appendix 10).

The most abundant macroinvertebrate taxon was the Atyidae (163 individuals) and Leptophlebiidae (93 individuals) followed by the Chironomidae (52 individuals) and the Dytiscidae (40 individuals) (Appendix 10). Overall, mean abundance was greatest at the Woronora River compared to O'Hares Creek pools whilst diversity was greatest at the pools sampled along O'Hares Creek (Figures 13&14).

No individuals of the threatened dragonfly species, Adams emerald dragonfly (*Archaeophya adamsi*) (NSW Fisheries, 2002) or Sydney hawk dragonfly (*Austrocordulia leonardi*) (NSW Fisheries, 2007) or the native freshwater crayfish (*Euastacus* sp.) were collected (Appendix 10).

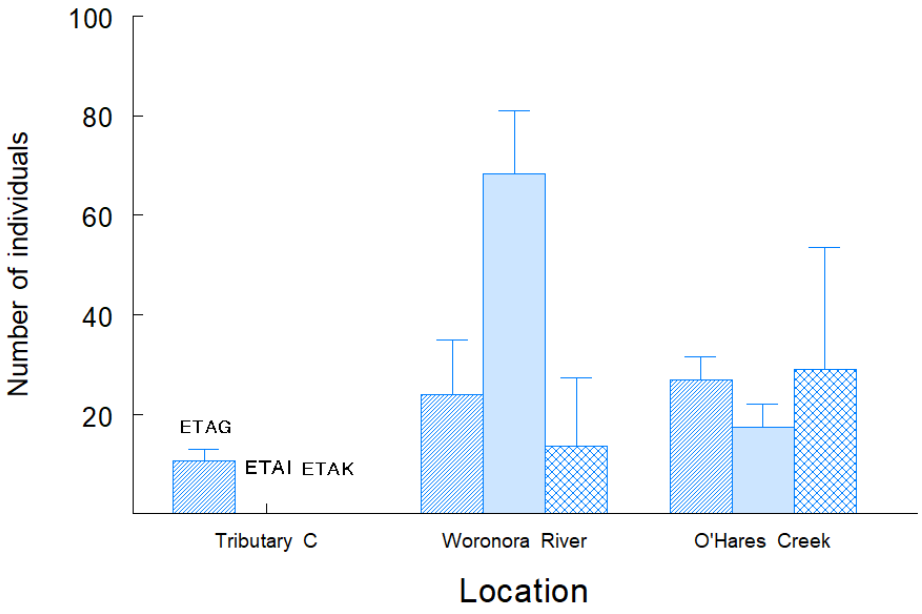


Figure 13. Mean (+SE) abundance of macroinvertebrates at small pools (*n* = 3). NB Pools ETAG, ETAI and ETAK were dry and not sampled.

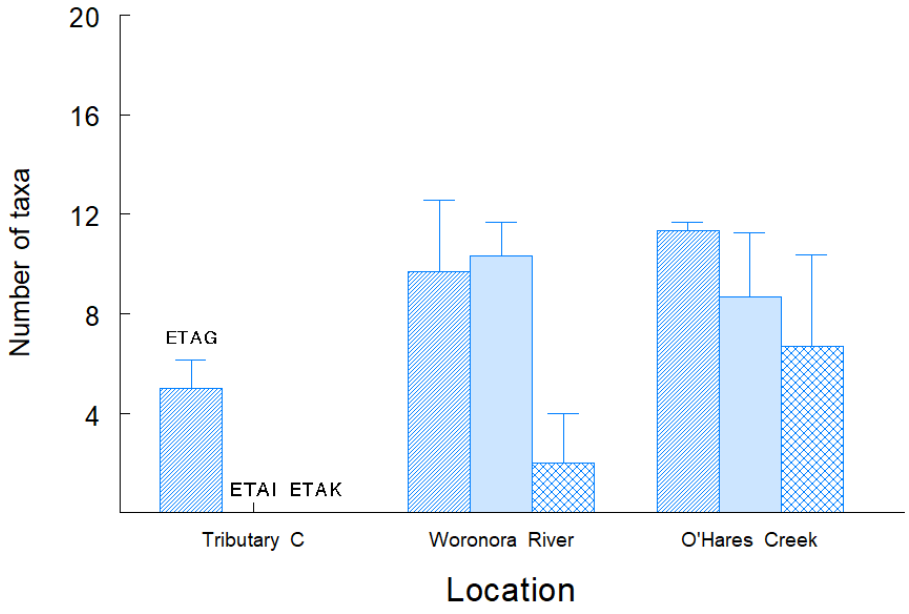


Figure 14. Mean (+SE) diversity of macroinvertebrates at small pools (*n* = 3). NB Pools ETAG, ETAI and ETAK were dry and not sampled.

3.2.2.3 Aquatic Macrophytes

A total of 16 aquatic macrophyte species were found in quantitative samples at replicate pools sampled on Tributary C (8 species), Woronora River (10 species) and O'Hares Creek (10 species) (Appendix 9). Overall, mean percentage cover of aquatic macrophytes was greatest at pools sampled at O'Hares Creek (Figure 15). Similar numbers of taxa were recorded at pools sampled on each of the three creeks (Figure 16).

Pools ETAI and ETAK were dry at the time of the spring 2018 survey and the water level within Pool WP-C was very low (Figures 18, 19&22). Three species of submerged macrophyte were mapped within the small reference pools sampled in spring 2018: *Triglochin procerum*, *Myriophyllum pedunculatum* and *Chara*/*Nitella* spp. (Figures 17-25). On this sampling occasion, *Chara/Nitella* spp. was present in Pool B on the Woronora River and in Pools A, B and C on O'Hares Creek (Figures 17-22). The largest area of macrophytes occurred at Woronora Pool B, where approximately 15 % of the pool bed was covered by patches of *Triglochin procerum*, *Myriophyllum pedunculatum* and *Chara*/*Nitella* spp. (Figure 21).

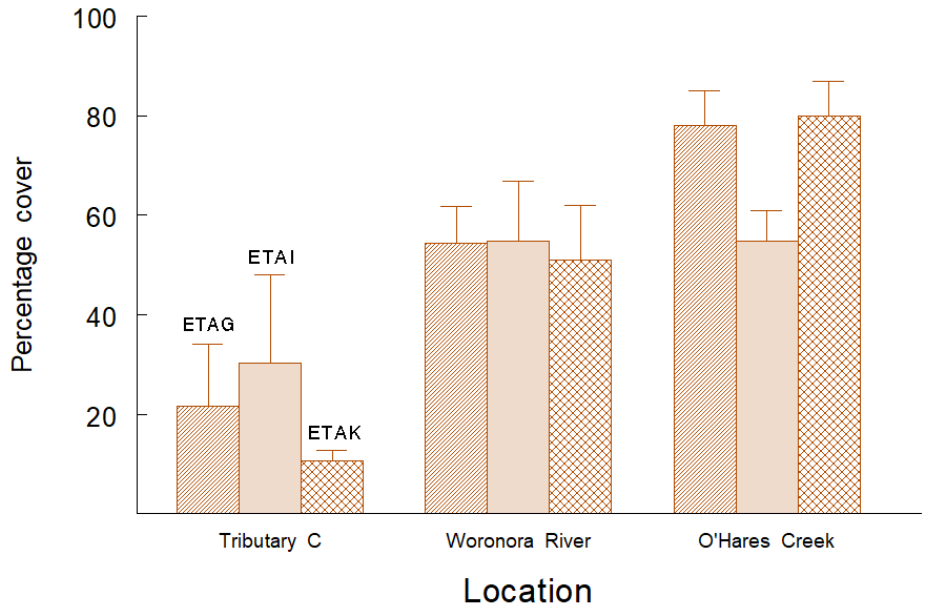


Figure 15. Mean (+SE) percentage cover of macrophytes at small pools (*n* = 5).

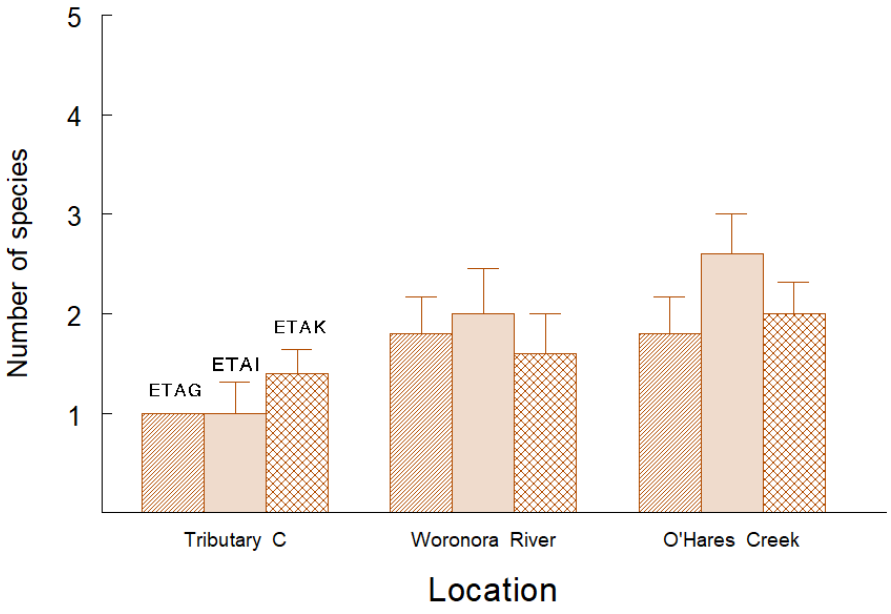
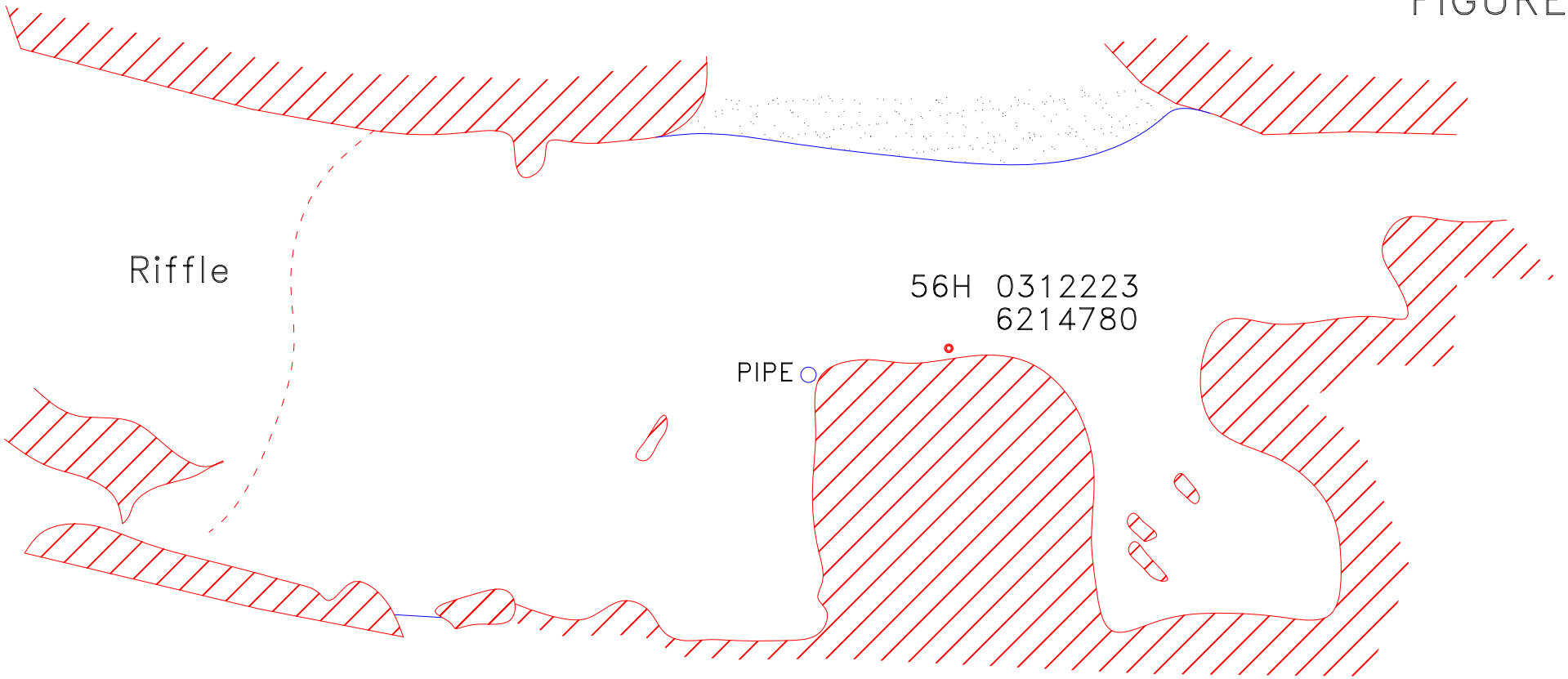


Figure 16. Mean (+SE) diversity of macrophytes at small pools (*n* = 5).

FIGURE 17



LEGEND

Exposed Rock

Sand

0 2.5 5 10M

SCALE

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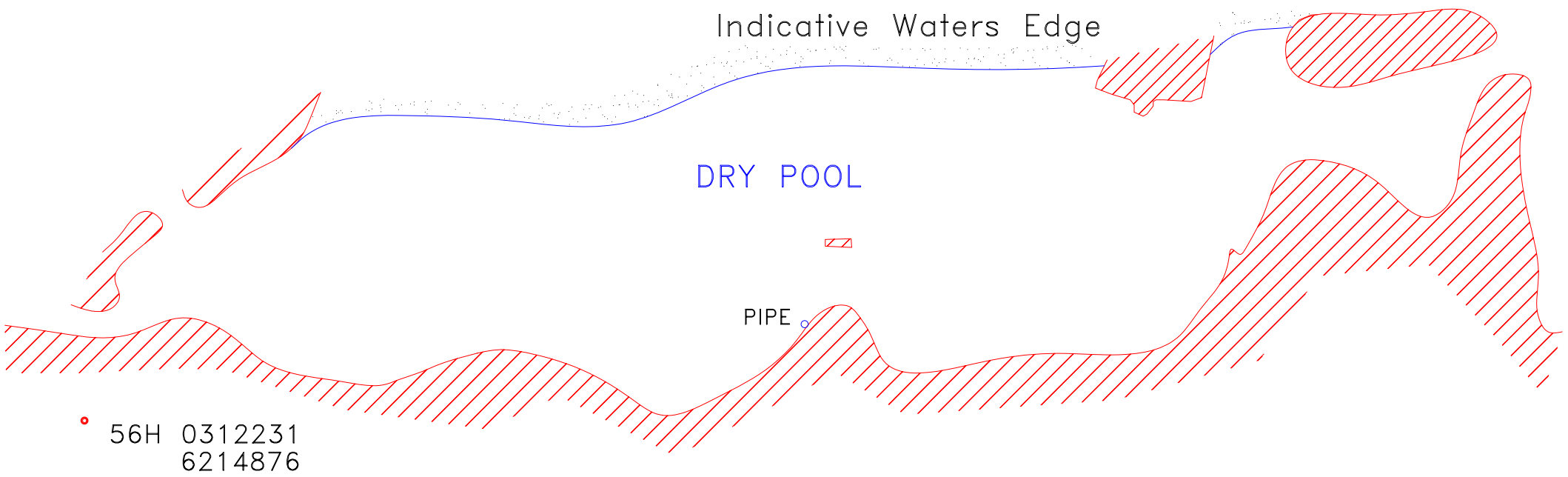
POOL ETAG
SPRING SURVEY 2018

DATE: 01/11/2018	SCALE: BAR SCALE
No OF SHEETS: 1	SHEET No: 1

FIGURE 18



LEGEND

Exposed Rock

Sand

0 2.5 5 10M

SCALE

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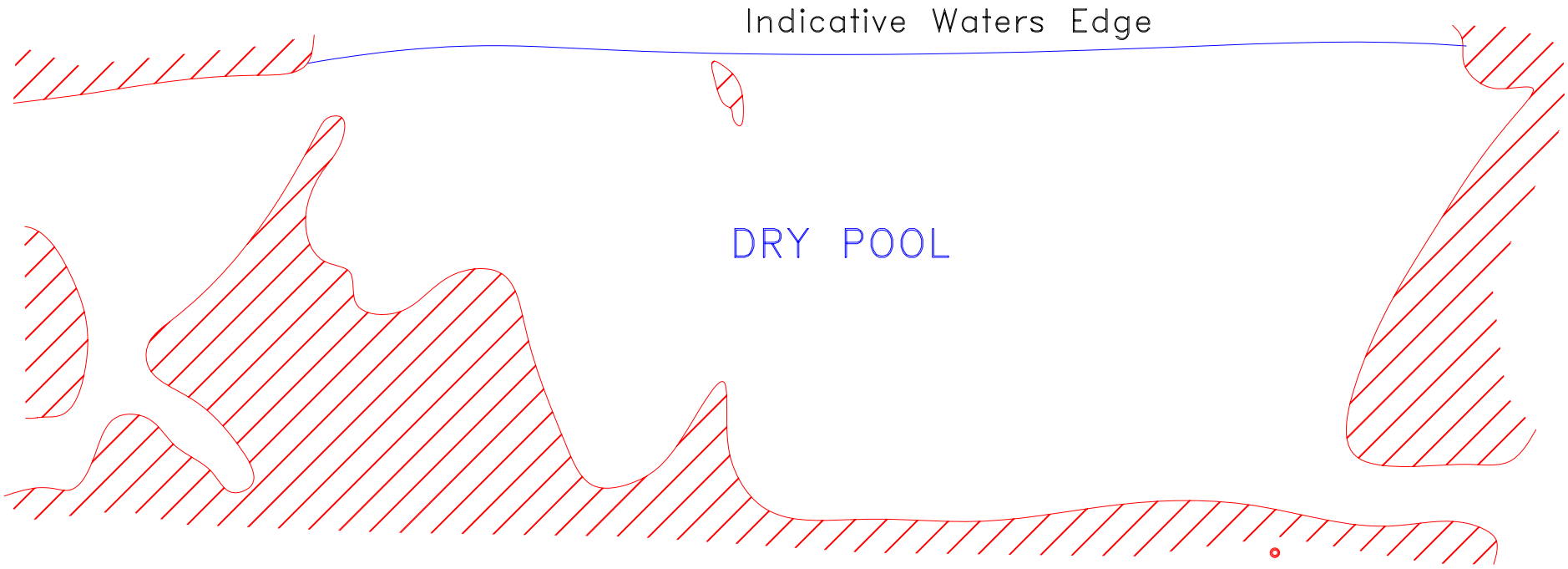
POOL ETAI
SPRING SURVEY 2018

DATE: 01/11/2018	SCALE: BAR SCALE
No OF SHEETS: 1	SHEET No: 1

FIGURE 19



LEGEND

Exposed Rock

0 2.5 5 10M

SCALE

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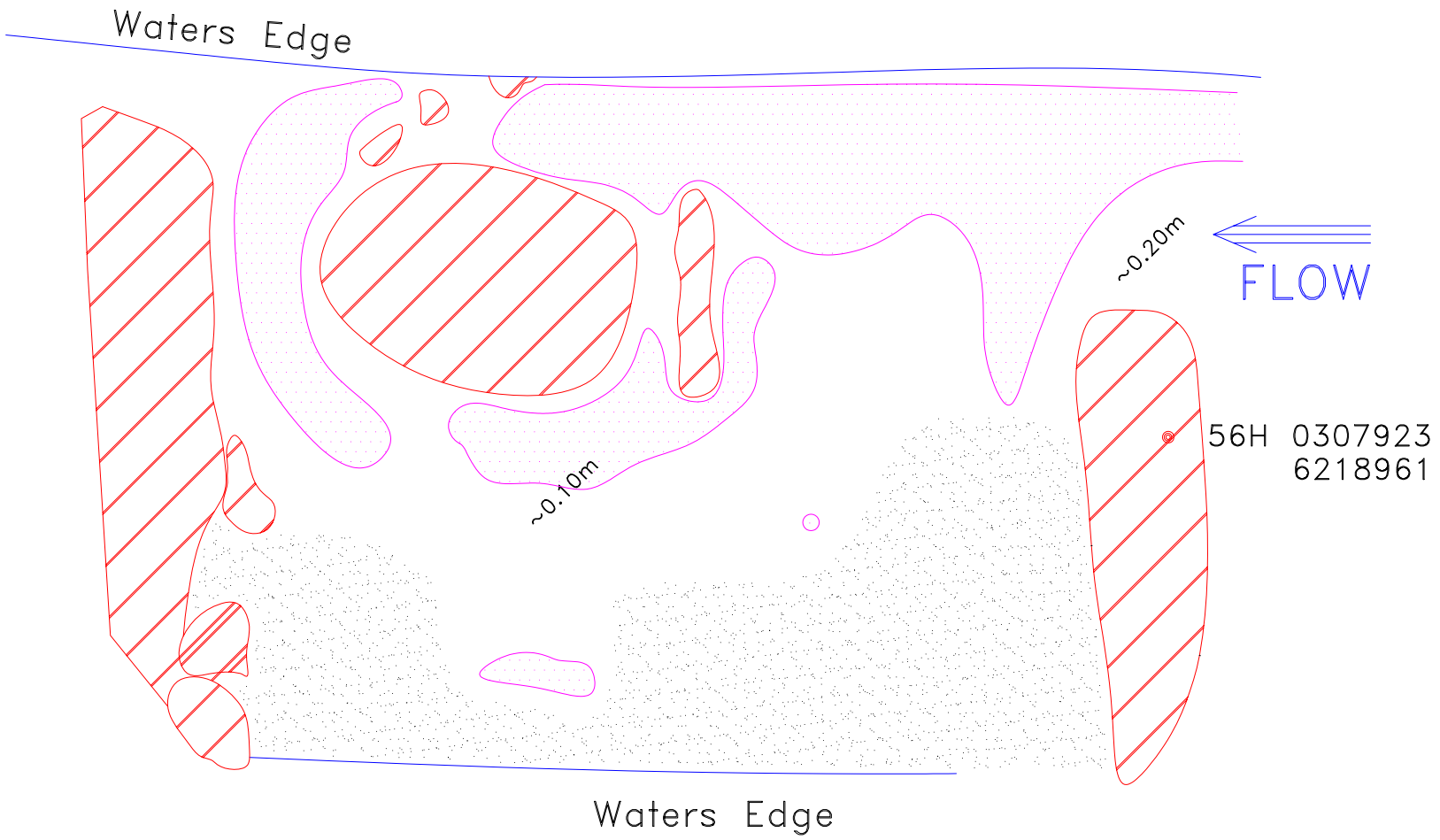
POOL ETAK
SPRING SURVEY 2018

DATE: 01/11/2018	SCALE: BAR SCALE
No OF SHEETS: 1	SHEET No: 1

FIGURE 20



LEGEND

Exposed rock

Sand

Triglochin procerum

0 0.5 1 2 3M

SCALE

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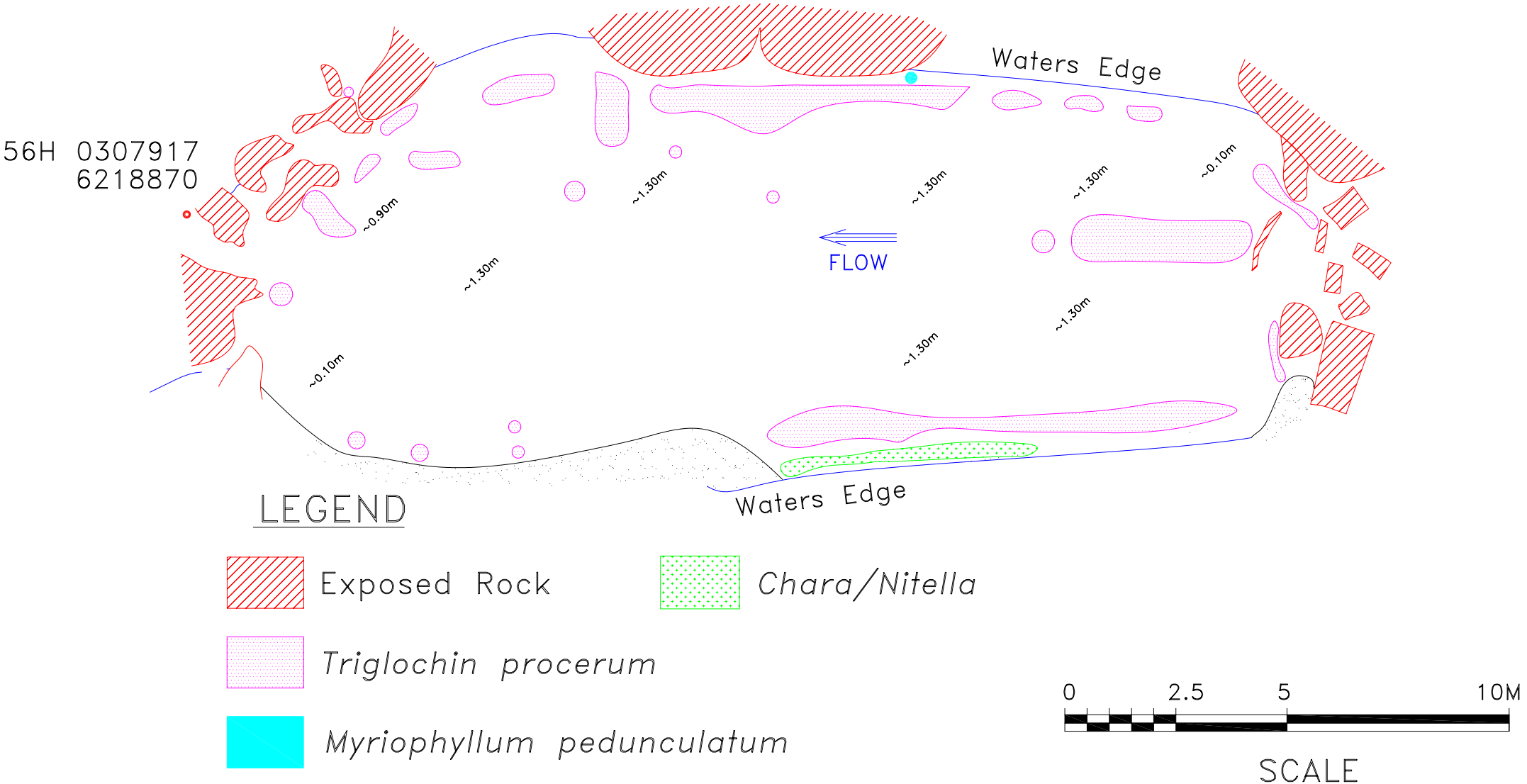
WORONORA POOL A
SPRING SURVEY 2018

DATE:	SCALE:
19/11/2018	BAR SCALE
No OF SHEETS:	SHEET No:
1	1

FIGURE 21



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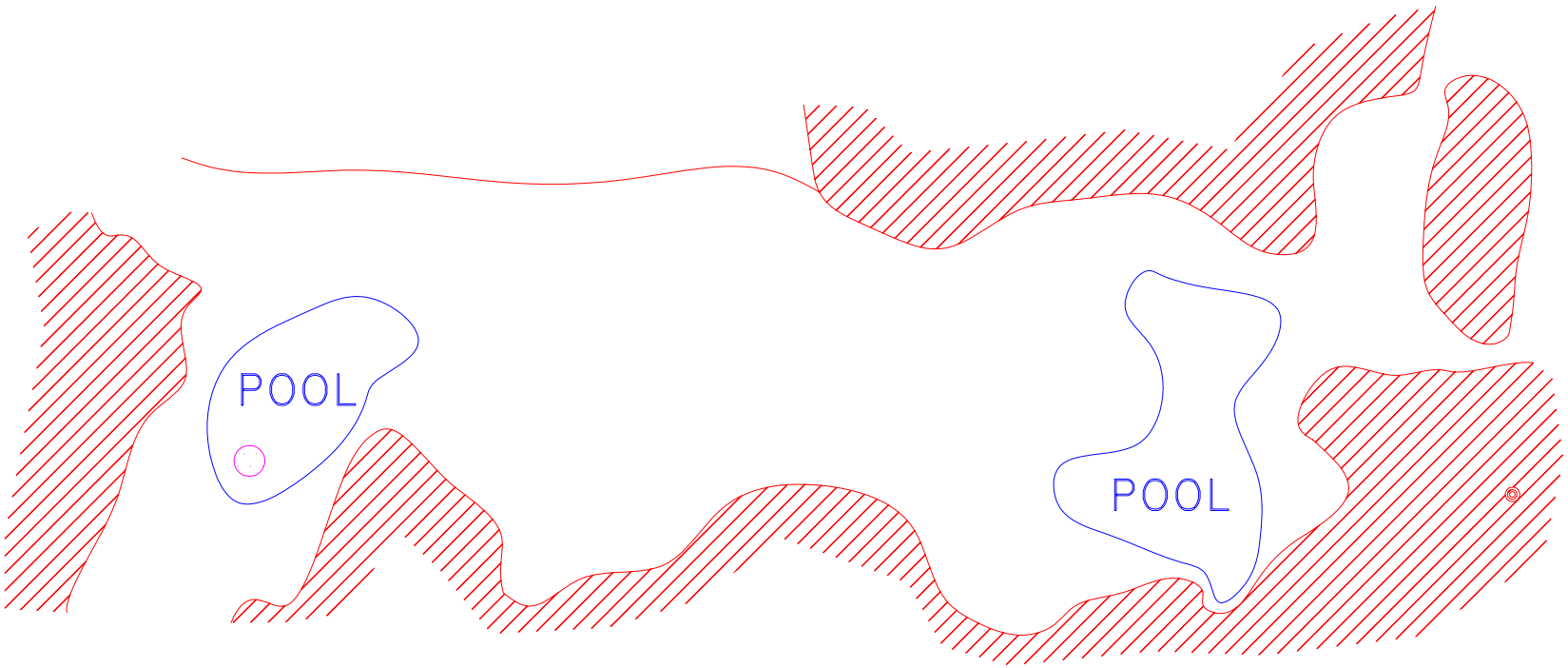
WORONORA POOL B
SPRING SURVEY 2018

DATE: 19/11/2018	SCALE: BAR SCALE
No OF SHEETS: 1	SHEET No: 1

FIGURE 22



56H 0307891
6218889

LEGEND

Exposed rock

Triglochin procerum

0 0.5 1 2 3M

SCALE

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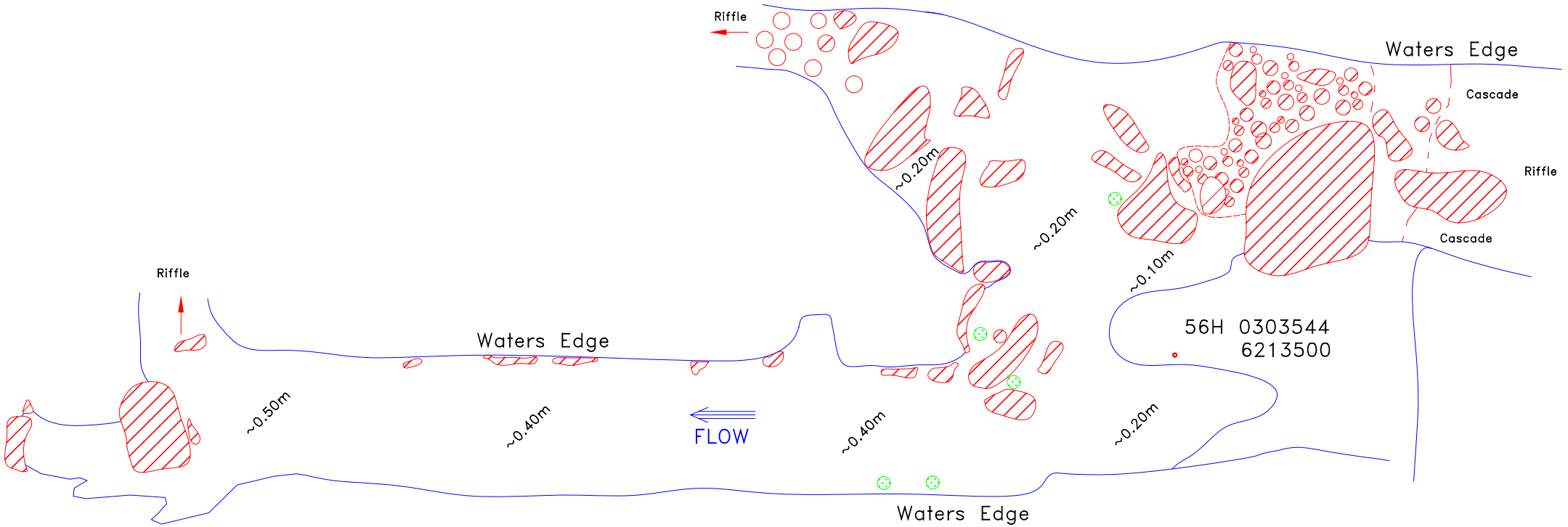
WORONORA POOL C
SPRING SURVEY 2018

DATE: 19/11/2018	SCALE: BAR SCALE
No OF SHEETS: 1	SHEET No: 1

FIGURE 23



LEGEND

Exposed Rock

Chara/Nitella

0 5 10 20M

SCALE

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O'HARES POOL A
SPRING SURVEY 2018

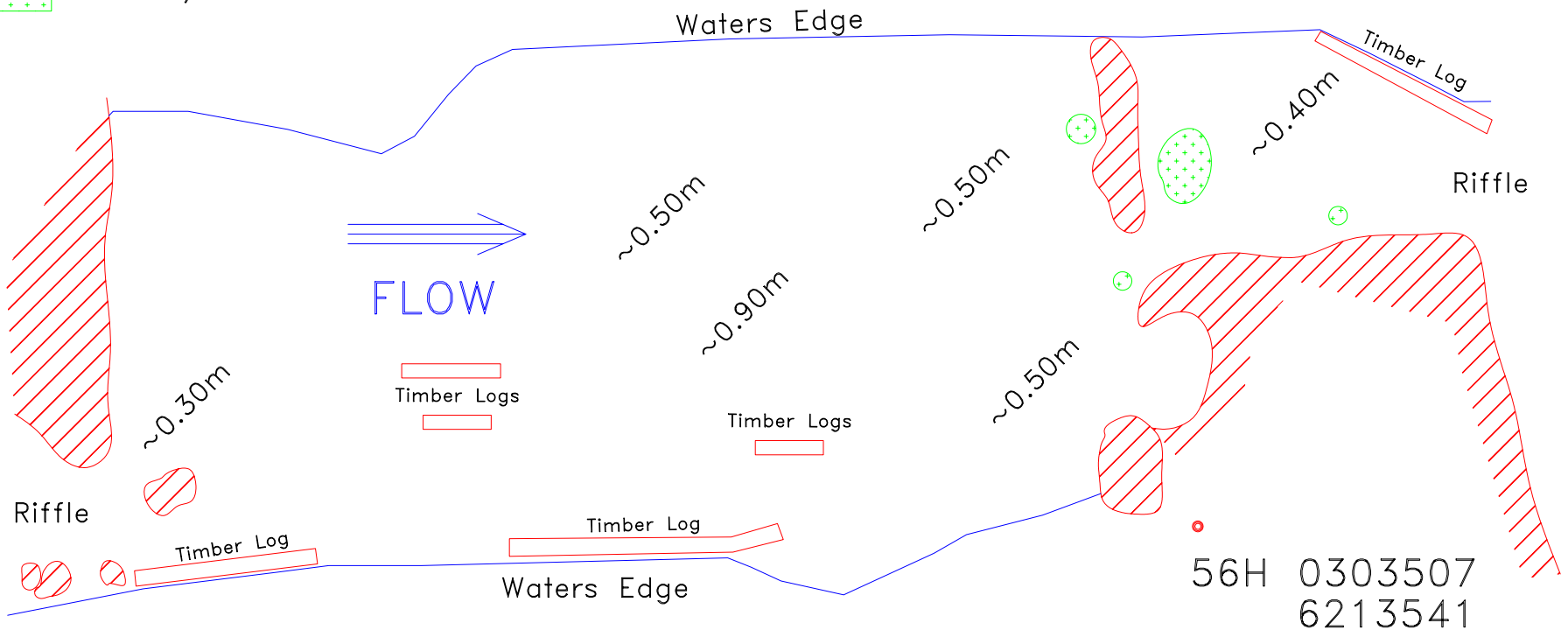
DATE: 03/12/2018	SCALE: BAR SCALE
No OF SHEETS: 1	SHEET No: 1

FIGURE 24

LEGEND

Exposed Rock

Chara/Nitella



SCALE

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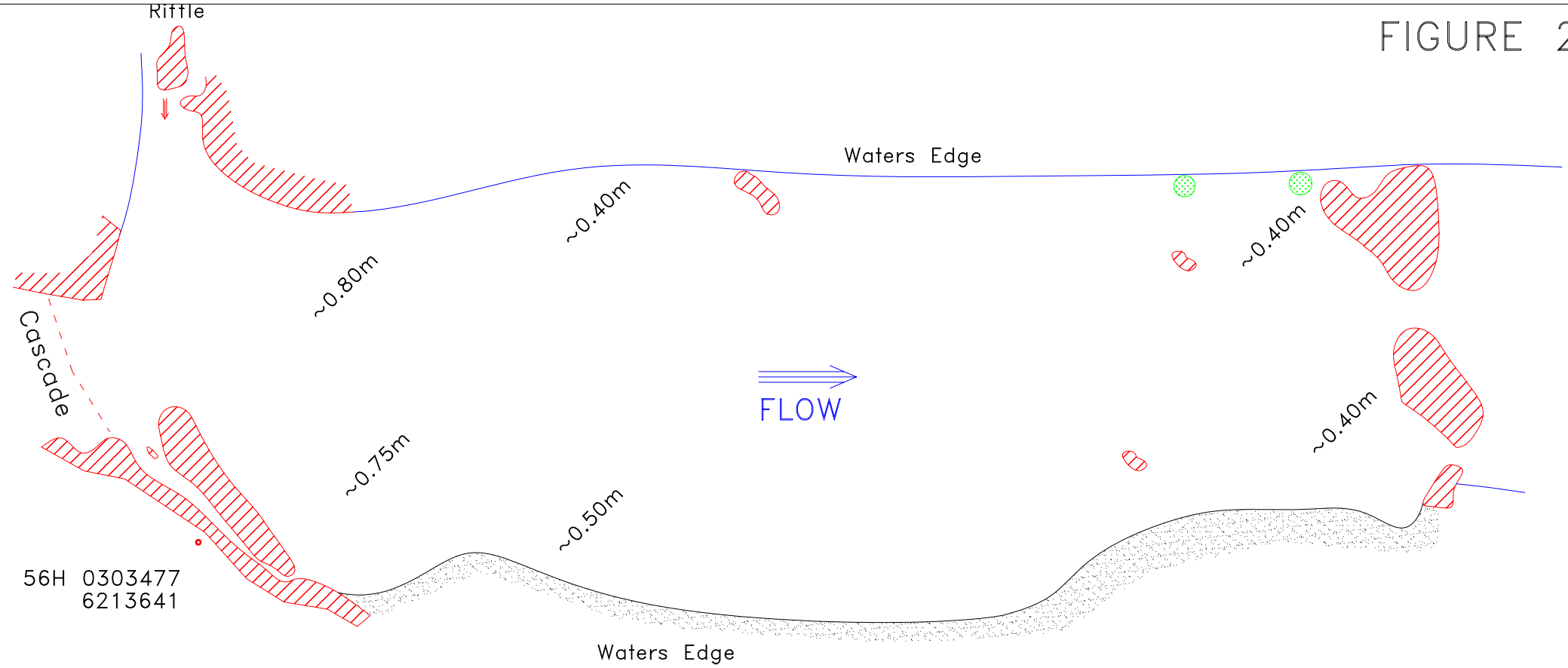
O'HARES POOL B
SPRING SURVEY 2018

DATE:	SCALE:
03/12/2018	BAR SCALE
No OF SHEETS:	SHEET No:
1	1

FIGURE 25



LEGEND

Exposed Rock

Chara/Nitella

0 2.5 5 10M

SCALE

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O'HARES POOL C
SPRING SURVEY 2018

DATE:	SCALE:
03/12/2018	BAR SCALE
No OF SHEETS:	SHEET No:
1	1

3.2.2.4 Water Quality

Physico-chemical water quality measurements are summarised in Table 5, with values highlighted in bold type indicating where mean values were outside the Default Trigger Values (DTVs) recommended by ANZECC/ARMCANZ (2000). At the time of the spring 2018 survey, there was insufficient water within Pools ETAI and ETAK to collect water quality measurements (Table 5).

In general, the mean water temperature within the control pools ranged from 16.6 to 24.9 °C (Table 5). Mean pH (range = 6.6 – 7.6) and conductivity (range = 112 – 174 µS/cm) were within the DTVs recommended by ANZECC/ARMCANZ (2000) (Table 5).

Turbidity (range = 19 – 70.3 NTU) was above the upper DTV in Pool ETAG and the Woronora River pools while oxidation-reduction potential in the pools sampled ranged from 504 – 654 mV (Table 5). The raw water quality data are provided in Appendix 11.

Table 5. Mean (± SE) measurements of water quality variables recorded at each site (spring 2018).

Pool	**ETAG**	**ETAI**	**ETAK**
Temperature °C (*n* =3)	16.6 (0.0)	I/A	I/A
pH (*n* =3)	7.3 (0.0)	I/A	I/A
Conductivity (µS/cm) (*n* = 3)	174.0 (0.0)	I/A	I/A
Dissolved Oxygen (% Saturation) (*n* = 3)	85.6 (0.3)	I/A	I/A
Turbidity (NTU) (*n* = 3)	**52.1** (1.2)	I/A	I/A
ORP (mV) (*n* = 3)	583.3 (0.7)	I/A	I/A
Pool	**WPA**	**WPB**	**WPC**
Temperature °C (*n* =3)	16.8 (0.0)	18.1 (0.2)	17.3 (0.0)
pH (*n* =3)	7.0 (0.0)	6.6 (0.0)	6.6 (0.0)
Conductivity (µS/cm) (*n* = 3)	128.0 (0.0)	114.3 (0.9)	122.0 (0.0)
Dissolved Oxygen (% Saturation) (*n* = 3)	**72.9** (0.5)	**62.1** (0.4)	**69.9** (0.2)
Turbidity (NTU) (*n* = 3)	**69.3** (0.1)	**70.3** (1.3)	**66.4** (0.1)
ORP (mV) (*n* = 3)	654.0 (0.0)	635.0 (0.0)	643.7 (0.7)
Pool	**OCA**	**OCB**	**OCC**
Temperature °C (*n* =3)	24.9 (0.0)	24.2 (0.0)	23.1 (0.0)
pH (*n* =3)	7.2 (0.1)	7.6 (0.0)	7.6 (0.1)
Conductivity (µS/cm) (*n* = 3)	113.0 (0.0)	113.3 (1.7)	112.0 (0.0)
Dissolved Oxygen (% Saturation) (*n* = 3)	102.0 (0.5)	102.1 (0.2)	107.9 (1.1)
Turbidity (NTU) (*n* = 3)	19.0 (0.1)	23.4 (0.1)	24.1 (0.0)
ORP (mV) (*n* = 3)	551.3 (3.7)	523.3 (0.3)	504.3 (0.7)

NB: Guideline values recommended by the ANZECC (2000) guidelines for upland streams: pH (6.5 – 8.0); Conductivity (30 – 350 µS/cm); Turbidity (2 – 25 NTU); Dissolved Oxygen (90–110 % Saturation). There are no ANZECC (2000) guideline values for Temperature, ORP or Alkalinity. I/A: Insufficient Aquatic Habitat.

4.0 TEMPORAL ANALYSES

A temporal comparison of the aquatic macroinvertebrate and macrophyte data was carried out for the Stream Monitoring (Section 4.1) and Pool Monitoring (Section 4.2) components of the Longwalls 23-27 Aquatic Ecology Monitoring Programme. The quantitative data from the surveys done between spring 2008[7], and spring 2018 were analysed using both multivariate and univariate techniques. AUSRIVAS data collected from the stream monitoring locations are also presented (Section 4.1).

4.1 Stream Monitoring

The objective of the following comparisons of aquatic macroinvertebrates and macrophytes was to determine whether any changes may have occurred at sampling locations in Tributary C/Eastern Tributary (Section 4.1.1) and Tributary B (Section 4.1.2) following the commencement of mining of the Longwalls 23-27 mining area, in relation to Control locations.

4.1.1 Tributary C/Eastern Tributary

PERMANOVA was used to test the null hypothesis of no significant change in aquatic macroinvertebrate and macrophyte indicators at Tributary C/Eastern Tributary locations (Locations C1, C2 and C4) Before- vs After- commencement of mining in relation to Control locations (Woronora River and O'Hares Creek). Mining of the Longwalls 23-27 mining area commenced in May 2014 and was completed in March 2017.

Significant differences between groups (e.g. impact versus control) may arise due to differences between group means, differences in dispersion (variance) among groups or a combination of both.

[7] Previously, temporal analyses for the Longwalls 23-27 monitoring report examined data for Locations C1 and C2 from spring 2009, to coincide with the commencement of sampling of Locations C4, B2 and Pools ETAH, ETAG, ETAK and ETAI (BIOANALYSIS, 2018). Here, data collected at Locations C1 and C2 in spring 2008 and autumn 2009 were also examined to assist in interpretation of results for the Longwalls 20-22 mining area reports and to increase the power of analyses. Similar results were obtained. Henceforth, analyses will include the spring 2008 and autumn 2009 data.

Significant main effects (e.g. Period or Impact) are not indicative of a mining-related impact, and, as such, are not described in detail. The Period x Impact interaction is the scale that would indicate that differences or changes could be attributable to mining.

4.1.1.1 Aquatic Macroinvertebrates

Quantitative Assessment

Location C1 v Controls

Prior Surveys (Spring 2008 – Autumn 2018)

Multivariate analyses detected a significant before-to-after change in the structure of the assemblage of aquatic macroinvertebrates at Location C1 in relation to the control locations in spring 2016 (T17) but not for subsequent surveys (i.e. autumn and spring 2017 and autumn 2018). SIMPER analyses indicated that mayflies (Leptophlebiidae) and freshwater shrimp (Atyidae) have consistently contributed most to the structure of assemblages of macroinvertebrates at Location C1 and the control locations.

Univariate analyses found mean numbers of Leptophlebiidae at Location C1 have differed significantly before- vs after-commencement of mining in relation to the control locations on the past six sampling occasions (i.e. since autumn 2015) (Figure 27c). There have been considerable spikes in abundance of Leptophlebiidae at Location C1 within the 'after' period, particularly in spring 2015 (T15), spring 2016 (T17) and spring 2017 (T19), but not at the control locations (Figure 27c). When PERMDISP was used to formally compare the apparent variability (dispersion), a highly significant result was obtained ($P = 0.001$). Pairwise tests show that there was no significant difference in variability between the 'before' and 'after' control surveys ($t = 0.61$; $P = 0.66$), but that numbers of Leptophlebiidae collected from Location C1 were significantly less variable amongst the 'before' compared to 'after' samples ($t = 5.75$, $P = 0.00$) (Figure 27c).

Analyses have consistently found no significant difference to mean total diversity, total abundance or numbers of Atyidae at Location C1 that would indicate an impact from mining (Figures 27a,b&d).

Current Survey (Spring 2018)

Multivariate analyses did not detect a significant before-to-after difference in the structure of the assemblage of aquatic macroinvertebrates at Location C1 in relation to the control locations although the *P*-value obtained for the Period x Impact interaction was borderline (i.e. $P = 0.06$) (Table 6, Figure 26a).

Visual examination of the Principle Co-ordinate Analysis (PCoA) found that there was greater dispersion among centroids representing the assemblage at Location C1 within the 'after' period than for each of the control locations, which could have contributed to the relatively low *P*-value (Figure 26a).

Greater dispersion among the C1 centroids coincides with considerable spikes in mean abundance of Leptophlebiidae at Location C1 within the 'after' period. Univariate analyses have detected a significant Period x Impact interaction for this (spring 2018) and the past six sampling occasions (i.e. since autumn 2015) (Table 7, Figure 27c). Temporal variation (i.e. among surveys) in Leptophlebiidae at Location C1 was significantly more variable within the 'Before' (2.8 ±0.37) compared to 'After' (24.3 ±4.1) period at Location C1 (PERMDISP: $P = 0.001$) but changed little between periods at the control locations (Before: 6.9 ±0.71; After: 7.5 ±0.37) ($P = 0.662$) (Figure 27c).

SIMPER indicates that the contribution that Leptophlebiidae has made to assemblages at Location C1 has increased considerably between Periods (Before: 21.7 %; After: 57.9 %) but changed little at the control locations (Before: 27.6 %; After: 29.0%). These results are indicative of a mining related impact to an indicator species at Location C1 since autumn 2015.

Of the other key variables examined, univariate analyses have consistently found no significant difference in mean total diversity and abundance of macroinvertebrates or mean numbers of Atyidae at Location C1 compared to the control locations that would indicate an impact from mining (Table 7, Figures 27a,b&d).

In general, macroinvertebrate diversity appears to have declined at Location C1 since the autumn 2018 (T20) survey but increased at both control locations (Figure 27a). Similarly, mean abundance appears to have decreased considerably at C1 since autumn 2018 but not at the control locations (Figure 27b). Atyidae were not collected at Location C1 in spring 2018 (Figure 27d). Whilst not significant, SIMPER indicates that Atyid shrimps made a larger contribution to the structure of assemblages at Location C1 within the Before- compared to After-commencement of mining period (Before: 44.0 %; After: 5.3 %) but changed little at the control locations (Before: 40.8 %; After: 35.7 %).

Location C2 v Controls

Prior Surveys (Spring 2008 – Autumn 2018)

Multivariate analysis of the aquatic macroinvertebrate data have consistently found no significant difference between the structure of assemblages at Location C2 and the control locations that would indicate an impact from mining of Longwalls 23-27 (Figure 26b).

Univariate analyses have indicated that mean numbers of Atyidae at Location C2 have differed significantly before- to after- the commencement of mining in relation to the control locations since autumn 2016 (T16) (i.e. autumn and spring 2016, autumn and spring 2017 and autumn 2018) (Figure 27d).

Analyses have consistently found no significant difference to total diversity or abundance of macroinvertebrates or numbers of Leptophlebiidae at Location C2 compared to the controls (Figures 27a-c).

Current Survey (Spring 2018)

Multivariate analysis of the aquatic macroinvertebrate data found no significant difference between the structure of assemblages at Location C2 and the control locations that would indicate an impact from mining of Longwalls 23-27 (Table 6, Figure 26b). With the exception of the factor 'Impact', each of the main factors appeared to have significant effects ($P < 0.05$), particularly 'Location', which contributed 20 % to the components of variation (Table 6).

These results are reflected in the patterns seen in the PCoA, which shows that there is a tendency for samples from the Woronora River location to occur in the upper left of the diagram, compared to those from O'Hares Creek, which occur more in the upper right (Figure 26c). Assemblages differed significantly between Periods and among Times but there appears to be greater variability in the structure of assemblages at Location C2 than at the control locations (Figure 26b).

In spring 2018, SIMPER indicated that Dytiscidae contributed most to the structure of assemblages at Location C2 (36.8 %), followed by Chironomidae (20.9 %) and the Notonectidae (13.6 %).

Similar to previous surveys, univariate analyses found no significant difference to total diversity or mean numbers of Leptophlebiidae at Location C2 in relation to the control locations that would indicate an impact from mining of the Longwalls 23-27 area (Table 7, Figure 27a&c).

However, univariate analyses have detected a significant change in mean numbers of Atyidae at Location C2 that would indicate an effect of mining since autumn 2016 (T16), including spring 2018 (T21) (Table 7, Figure 27d). Results from *Post-hoc* tests indicate that this result was mostly due to differences in the magnitude and direction of change in mean numbers of Atyidae at Location C2 'before' (10.9 ± 1.6) compared to 'after' (5.5 ± 1.2) commencement of mining of the Longwalls 23-27 area in relation to the control locations (Before: 10.6 ± 1.4; After: 12.5 ± 1.5) (Figure 27d). Atyidae were not collected at Location C2 in spring 2018 (T21) or autumn 2018 (T20) (Figure 27d).

For the first time since sampling commenced in spring 2008, univariate analyses detected a significant Period x Impact change in mean abundance at Location C2 in relation to the control locations (Table 7, Figure 27b). *Post-hoc* tests indicated that this result was mostly due to a combination of differences in dispersion ($P = 0.02$) and among group means. In particular, abundance increased significantly between periods at the control locations ($t = 2.06$, $P = 0.03$) but not at Location C2 ($t = 0.69$, $P = 0.82$) (Figure 27b). This result is indicative of an effect of mining.

Location C4 v Controls

Prior Surveys (Spring 2009 – Autumn 2018)

Multivariate analyses have consistently found no evidence of significant change in the structure of the assemblage of macroinvertebrates or in key indicator variables at Location C4 that would indicate an impact from mining of Longwalls 23-27 (Figure 26c).

Analyses have consistently found no significant difference to total abundance of macroinvertebrates or numbers of Leptophlebiidae at Location C4 compared to the control sites.

However, for the first time since sampling commenced in spring 2009, analyses detected a significant 'before' to 'after' change in mean diversity at Location C4 in relation to the control locations in autumn 2018.

Patterns of change in Atyidae at Location C4 differed significantly before- to after-mining in relation to the control locations in autumn 2016 (T14) but not subsequently (i.e. spring 2016, spring and autumn 2017 or autumn 2018).

Current Survey (Spring 2018)

The results indicate that there is no statistically significant interaction in the effects of the Period x Impact interaction on variability in assemblages of aquatic macroinvertebrates (Table 6). With the exception of 'Impact', each of the main factors appear to have strong effects ($P \leq 0.01$), particularly 'Location', which contributed 20 % to the components of variation (Table 6).

These results are reflected in the patterns seen in the PCoA, which shows that there is a tendency for samples from the Woronora River location to occur in the upper left of the diagram, compared to those from O'Hares Creek, which occur more in the upper right (Figure 26c). There is apparent separation of samples from Location C4 into two groups, with spring 2008 to autumn 2012 and spring 2013 to spring 2014 (i.e. Time 1, 2, 3, 4, 5, 6, 7, 8, 11, 12 and 13) tending to group near the bottom left of the PCoA and all other times (i.e. Time 9, 10, 14, 15, 16, 17, 18 and 19) at the top right (Figure 26c). SIMPER analysis indicated that differences between the two groups were primarily due to Atyidae, which contributed 19-54 % to samples near the bottom left of the diagram but < 4 % to samples at the top right (SIMPER, Figure 26c).

In spring 2018, Chironomidae (74.6 %) contributed most to the structure of the assemblage at C4, followed by the Dytiscidae (10.4 %) and Gyrinidae (7.6 %) (SIMPER). Dytiscidae (24.9 %) and Chironomidae (23.1 %) also contributed greatly to assemblages at the O'Hares Creek location, whilst Atyidae (52.9 %), Leptoceridae (12.5 %) and Leptophlebiidae (8.5 %) ranked highest at the Woronora River.

There has consistently been no evidence of a significant change in mean abundance of macroinvertebrates or mean numbers of Leptophlebiidae at Location C4 that would indicate an impact from mining of the Longwalls 23-27 area (Table 7, Figure 27a-c). Nevertheless, mean numbers of macroinvertebrates at Location C4 appear more variable since spring 2015 (T15), mostly due to changes in abundance of Leptophlebiidae (Figures 27b&c).

A significant 'before' to 'after' change in mean diversity has been detected at Location C4 by this (i.e. spring 2018) and the previous survey (autumn 2018) in relation to the control locations (Table 7, Figure 27a). *Post-hoc* tests indicated that this result was mostly due to a combination of differences in dispersion ($P = 0.001$) and among group means. In particular, abundance increased significantly between periods at the control locations ($t = 3.12$, $P = 0.01$) but not at Location C4 ($t = 0.59$, $P = 0.90$) (Figure 27b).

A significant 'before' to 'after' change in mean numbers of Atyidae was detected at Location C4 by this survey (spring 2018) and in autumn 2016 (T16) (Table 7, Figure 27d). Atyidae were not collected at Location C4 in autumn 2017 or spring 2018 (Figure 27d).

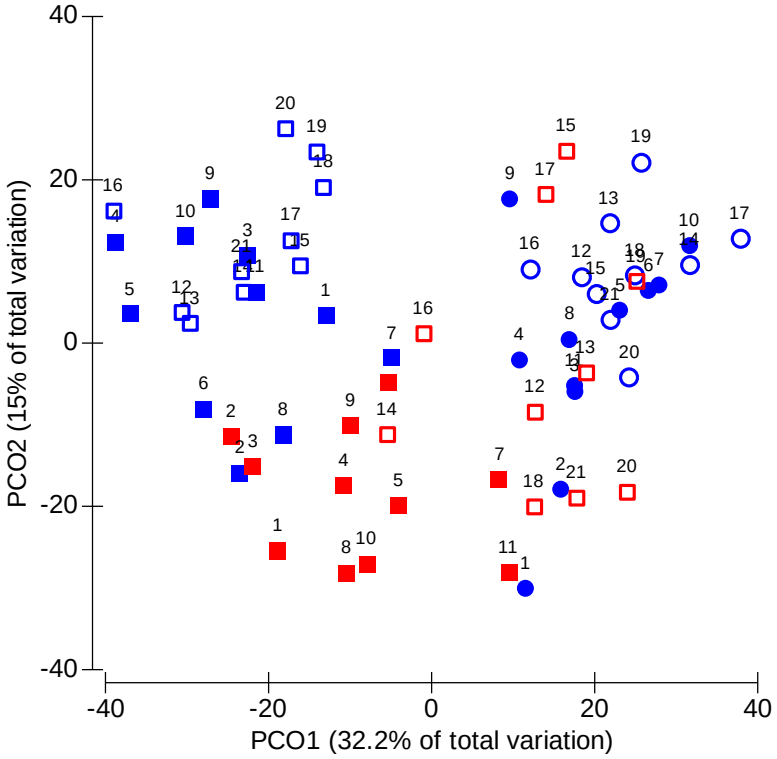
Table 6. PERMANOVA on Bray Curtis dissimilarities of macroinvertebrate assemblage data (non-transformed) to compare locations C1, C2 and C4 sampled on Tributary C/Eastern Tributary with control locations (Woronora River and O'Hares Creek) Before- vs After-commencement of mining. Percentages of Components of Variation (% CV) are shown. Bold numbers indicate significant results at *P* < 0.05.

C1					
Source	**df**	**MS**	***Pseudo-F***	***P***	**% CV**
Period = Pe	**1**	**34925**	**2.72**	**0.01**	**7.06**
Impact = Im	1	39399	0.32	1.00	0.00
Time (Pe) = Ti(Pe)	**19**	**6992**	**1.61**	**0.00**	**7.44**
Location (Im) = Lo(Im)	**1**	**132220**	**11.70**	**0.00**	**18.17**
Pe x Im	1	16783	1.67	0.06	5.83
Site (Lo(Im)) = Si(Lo(Im))	**3**	**7195**	**2.49**	**0.00**	**4.80**
Pe x Lo(Im)	1	7426	1.35	0.09	3.77
Ti(Pe) x Im	19	5233	1.20	0.08	6.07
Pe x Si(Lo(Im))	3	3304	1.14	0.26	2.09
Ti(Pe) x Lo(Im)	**19**	**4356**	**1.51**	**0.00**	**9.05**
Ti(Pe) x Si(Lo(Im))	**57**	**2894**	**1.57**	**0.00**	**10.87**
Residual	252	1839			24.85
C2					
Source	**df**	**MS**	***Pseudo-F***	***P***	**% CV**
Period = Pe	**1**	**23870**	**1.95**	**0.03**	**5.76**
Impact = Im	1	27334	0.23	1.00	0.00
Time (Pe) = Ti(Pe)	**19**	**7059**	**1.62**	**0.00**	**8.28**
Location (Im) = Lo(Im)	**1**	**132220**	**13.06**	**0.00**	**20.03**
Pe x Im	1	14742	1.64	0.06	6.01
Site (Lo(Im)) = Si(Lo(Im))	**3**	**5959**	**2.40**	**0.00**	**4.73**
Pe x Lo(Im)	1	7433	1.24	0.17	3.53
Ti(Pe) x Im	19	4204	0.97	0.59	0.00
Pe x Si(Lo(Im))	3	3629	1.46	0.05	3.84
Ti(Pe) x Lo(Im)	**19**	**4356**	**1.75**	**0.00**	**11.24**
Ti(Pe) x Si(Lo(Im))	**57**	**2485**	**1.43**	**0.00**	**10.08**
Residual	252	1733			26.50
C4					
Source	**df**	**MS**	***Pseudo-F***	***P***	**% CV**
Period = Pe	**1**	**26893**	**2.42**	**0.01**	**6.44**
Impact = Im	1	41586	0.35	0.99	0.00
Time (Pe) = Ti(Pe)	**17**	**6831**	**1.75**	**0.00**	**7.99**
Location (Im) = Lo(Im)	**1**	**125340**	**11.54**	**0.00**	**18.91**
Pe x Im	1	14150	1.69	0.06	5.82
Site (Lo(Im)) = Si(Lo(Im))	**3**	**7190**	**2.75**	**0.00**	**5.29**
Pe x Lo(Im)	1	5891	1.13	0.28	2.41
Ti(Pe) x Im	17	4764	1.22	0.07	6.15
Pe x Si(Lo(Im))	3	3664	1.40	0.06	3.58
Ti(Pe) x Lo(Im)	**17**	**3895**	**1.49**	**0.00**	**8.61**
Ti(Pe) x Si(Lo(Im))	**51**	**2618**	**1.42**	**0.00**	**9.47**
Residual	228	1844			25.33

Table 7. PERMANOVA analysis on Euclidean Distances of four univariate estimates (i.e. non-transformed) (total diversity and abundance and abundances of Leptophlebiidae and Atyidae) of the macroinvertebrate data collected to compare three locations within Tributary C with two control locations Before- vs After-commencement of mining. Bold numbers indicate significant results at $P < 0.05$.

C1		**Diversity**		**Abundance**		**Leptophlebiidae**		**Atyidae**	
Source	***df***	**MS**	***Ps-F***	**MS**	***Ps-F***	**MS**	***Ps-F***	**MS**	***Ps-F***
Period = Pe	1	**341.75**	**9.81**	**34986**	**5.98**	**8749**	**4.84**	28	0.85
Impact = Im	1	823.42	0.85	25654	1.52	923	0.59	3651	0.23
Time (Pe) = Ti(Pe)	19	34.62	1.60	5721	2.83	**1764**	**10.27**	363	0.96
Location (Im) = Lo(Im)	1	**982.61**	**19.40**	**15929**	**5.30**	613	1.90	**17100**	**16.88**
Pe x Im	1	27.60	2.50	1861	1.42	**5374**	**4.22**	134	1.41
Site (Lo(Im)) = Si(Lo(Im))	3	29.67	2.48	1304	0.78	376	0.87	645	3.06
Pe x Lo(Im)	1	2.42	0.60	463	0.65	77	0.72	118	0.82
Ti(Pe) x Im	19	17.24	0.80	2265	1.12	**1236**	**7.20**	246	0.65
Pe x Si(Lo(Im))	3	2.53	0.21	1292	0.77	534	1.24	19	0.09
Ti(Pe) x Lo(Im)	19	**21.60**	**1.81**	2019	1.20	172	0.40	380	1.80
Ti(Pe) x Si(Lo(Im))	57	11.96	1.33	**1677**	**2.48**	**431**	**2.25**	**211**	**1.53**
Residual	252	8.96		676		192		138	
C2		**Diversity**		**Abundance**		**Leptophlebiidae**		**Atyidae**	
Source	***df***	**MS**	***Ps-F***	**MS**	***Ps-F***	**MS**	***Ps-F***	**MS**	***Ps-F***
Period = Pe	1	**311.42**	**7.03**	6636	2.73	471.98	2.33	262	1.03
Impact = Im	1	784.49	0.81	43807	2.73	628.41	1.07	970	0.08
Time (Pe) = Ti(Pe)	19	44.95	2.08	2704	1.34	199.05	1.16	506	1.33
Location (Im) = Lo(Im)	1	**982.61**	**16.80**	**15929**	**5.16**	612.65	2.35	**17100**	**17.39**
Pe x Im	1	37.12	3.18	**3899**	**4.38**	2.23	0.83	**1095**	**6.15**
Site (Lo(Im)) = Si(Lo(Im))	3	**37.41**	**4.26**	1266	1.25	137.84	1.20	**613**	**3.53**
Pe x Lo(Im)	1	2.42	0.25	463	0.54	76.79	0.71	118	0.73
Ti(Pe) x Im	19	16.07	0.74	887	0.44	132.02	0.77	121	0.32
Pe x Si(Lo(Im))	3	24.07	2.74	745	0.73	99.55	0.87	22	0.13
Ti(Pe) x Lo(Im)	19	**21.60**	**2.46**	**2019**	**1.99**	171.76	1.50	**380**	**2.19**
Ti(Pe) x Si(Lo(Im))	57	8.78	1.03	**1017**	**1.86**	**114.72**	**1.52**	**174**	**1.44**
Residual	252	8.51		546		75.48		120	
C4		**Diversity**		**Abundance**		**Leptophlebiidae**		**Atyidae**	
Source	***df***	**MS**	***Ps-F***	**MS**	***Ps-F***	**MS**	***Ps-F***	**MS**	***Ps-F***
Period = Pe	1	90.7	3.55	18199	3.56	1488	1.40	98	1.24
Impact = Im	1	1025.9	1.07	28019	1.67	5	0.11	4276	0.27
Time (Pe) = Ti(Pe)	17	32.0	1.34	5571	2.52	**968**	**5.95**	383	0.95
Location (Im) = Lo(Im)	1	**960.3**	**14.84**	**16422**	**5.22**	884	1.86	**16929**	**15.50**
Pe x Im	1	**137.3**	**9.44**	753	1.62	779	1.05	**220**	**4.43**
Site (Lo(Im)) = Si(Lo(Im))	3	**41.3**	**5.01**	1191	0.89	441	1.83	**701**	**3.61**
Pe x Lo(Im)	1	0.3	0.29	168	0.52	211	0.73	21	0.44
Ti(Pe) x Im	17	16.8	0.70	1655	0.75	**685**	**4.21**	120	0.30
Pe x Si(Lo(Im))	3	5.1	0.62	675	0.50	455	1.88	80	0.41
Ti(Pe) x Lo(Im)	17	**23.9**	**2.90**	2210	1.64	163	0.67	**404**	**2.08**
Ti(Pe) x Si(Lo(Im))	51	8.3	0.97	**1344**	**1.54**	241	0.88	**194**	**1.48**
Residual	228	8.5		875		276		131	

A. C1 v Controls



B. C2 v Controls

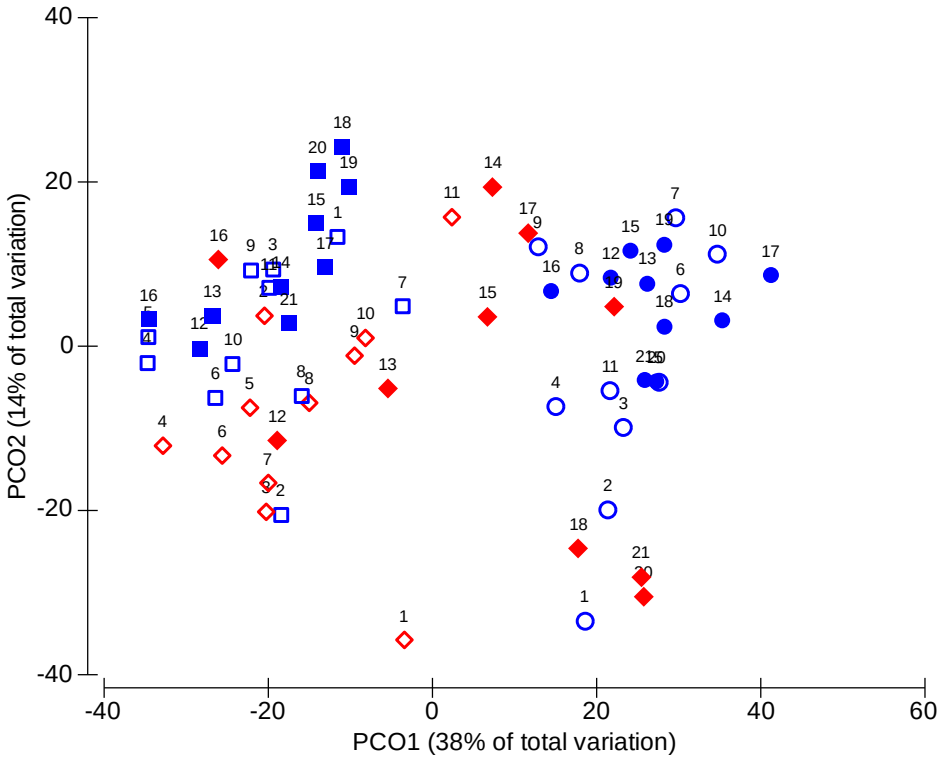


Figure 26. Principle Coordinates ordination (PCoA) of centroids for assemblages of aquatic macroinvertebrates sampled at locations a) C1 (red squares), b) C2 (red diamonds) and two control locations (Woronora River: blue squares; O'Hares Creek (blue circles)) from spring 2008 (T1) to spring 2018 (T21). Empty symbols: 'Before'; Filled symbols: 'After' commencement of mining Longwalls 23-27.

C. C4 v Controls

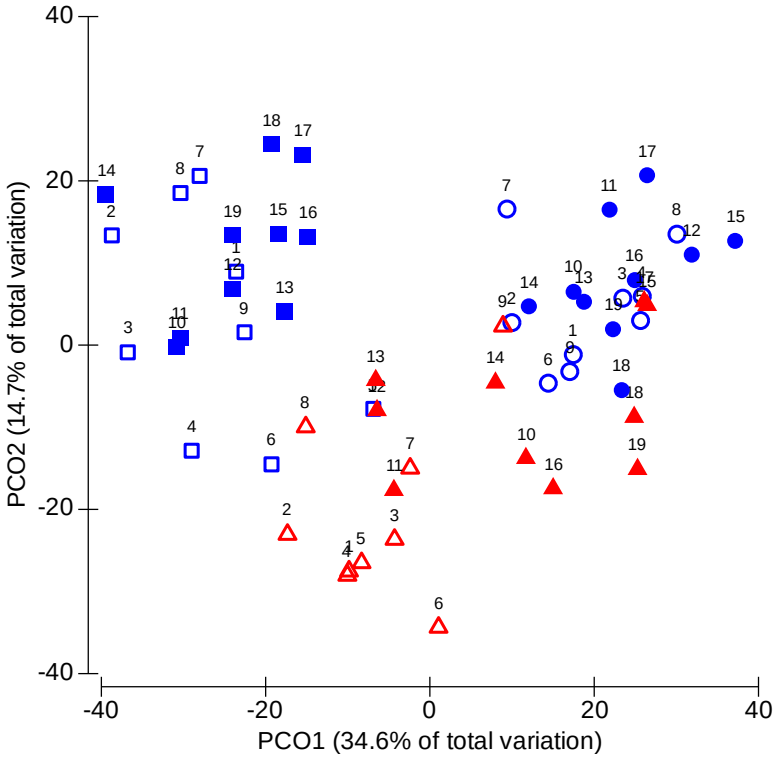


Figure 26 (Cont'd). PCoA of centroids for assemblages of aquatic macroinvertebrates sampled at location c) C4 (red symbols) and two control locations (Woronora River: blue squares; O'Hares Creek (blue circles) between spring 2009 (T1) and spring 2018 (T19). Empty symbols: 'Before-mining'; Filled symbols: 'After-mining Longwalls 23-27'.

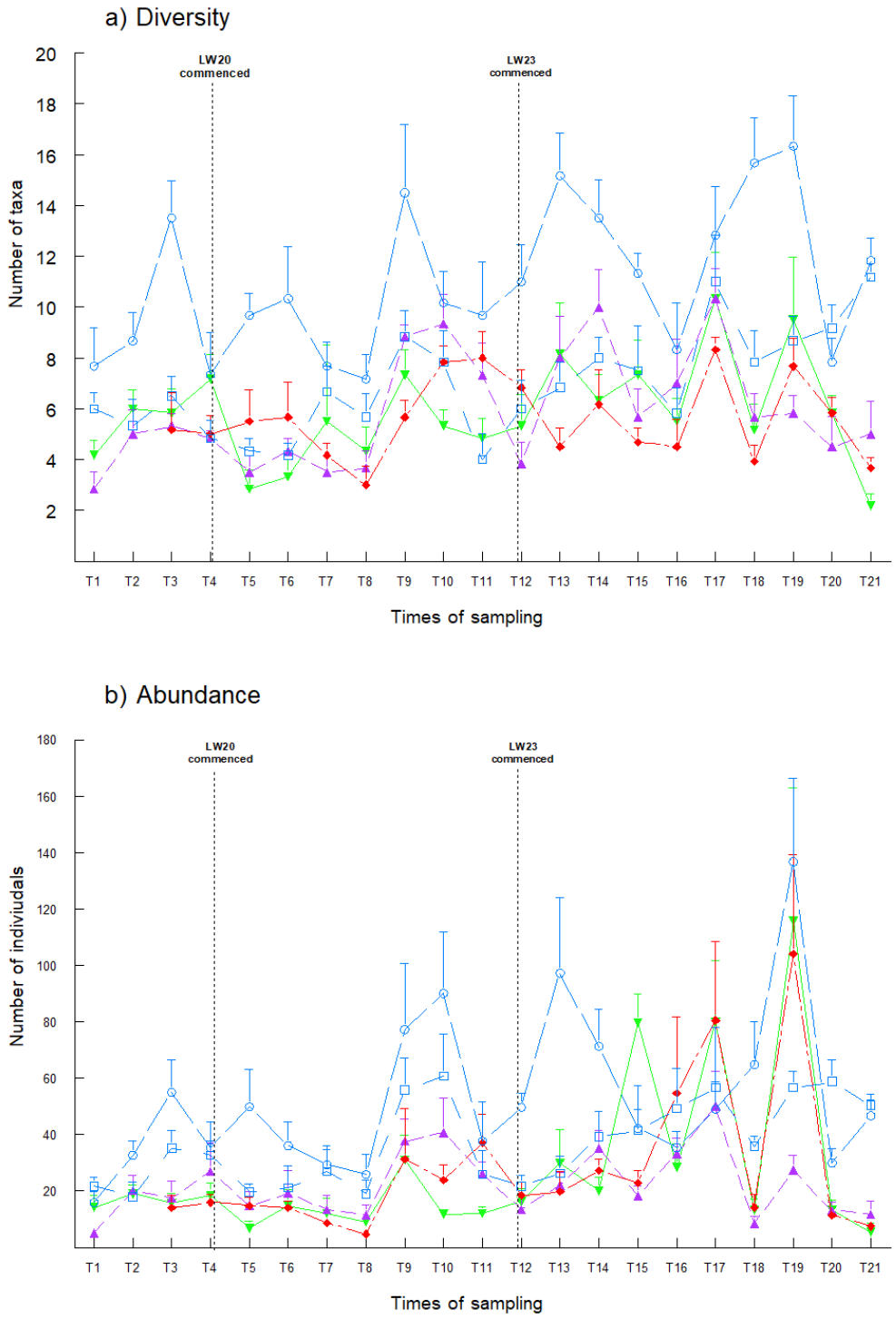


Figure 27. Mean number (+SE) of a) Taxa and b) Individuals of aquatic macroinvertebrates at locations on Tributary C/Eastern Tributary (C1: inverted triangles; C2: triangles; C4: diamonds) and the control locations (Woronora River: squares; O'Hares Creek: circles), between spring 2008 (T1) and spring 2018 (T21) (*n* = 6).

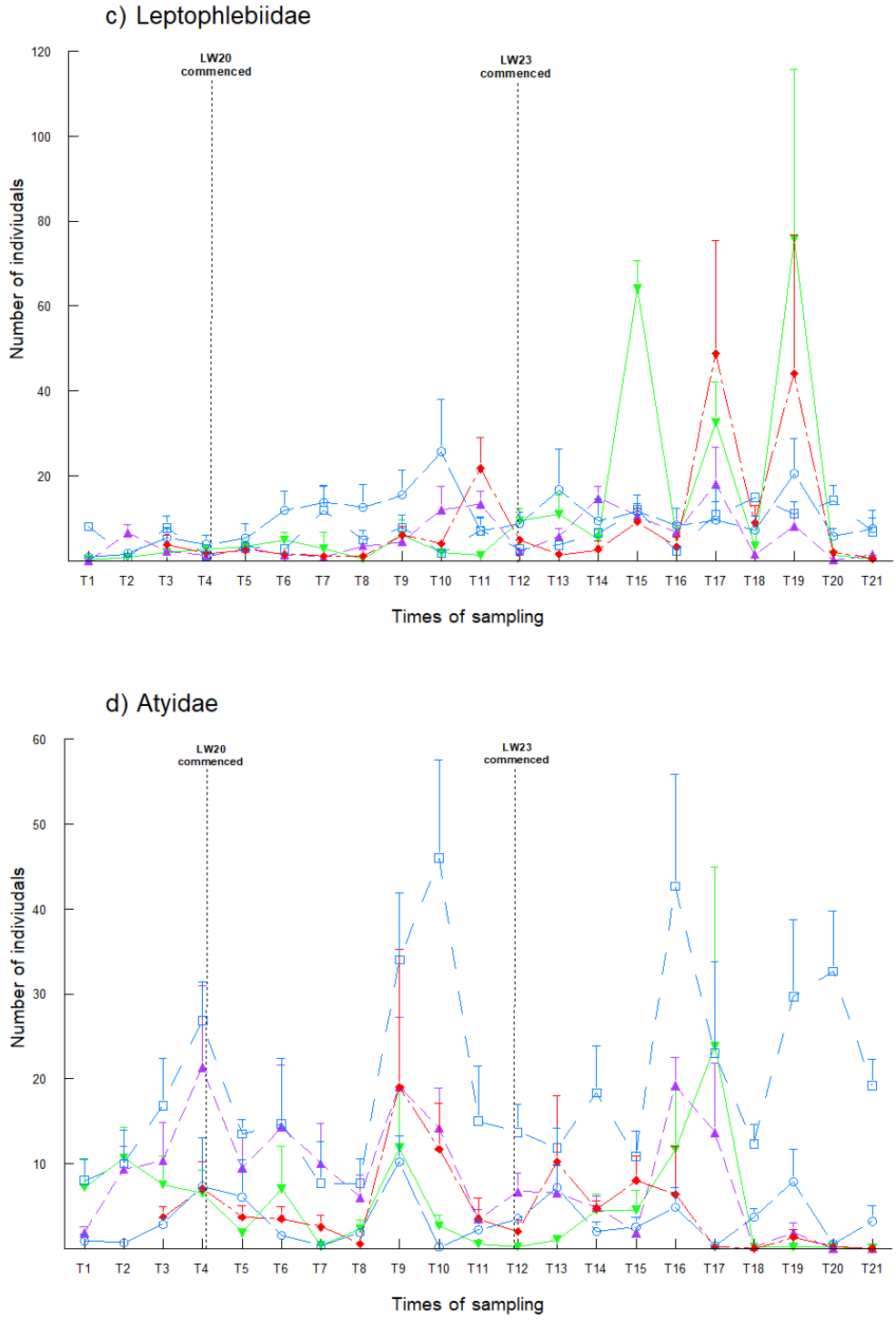


Figure 27 cont'd. Mean number (+SE) of c) Leptophlebiidae and d) Atyidae at locations on Tributary C/Eastern Tributary (C1: inverted triangles; C2: triangles; C4: diamonds) and the control locations (Woronora River: squares; O'Hares Creek: circles) between spring 2008 (T1) and spring 2018 (T21) (*n* = 6).

AUSRIVAS Analyses

For AUSRIVAS surveys done in spring, OE50 scores ranged between 0.10 (C1 in spring 2018) and 0.97 (OC in spring 2014) (Figure 28a). OE50 Taxa Scores for samples collected in autumn ranged from 0.09 (Site C4 in autumn 2016) to 0.88 (Site OC in autumn 2017) (Figure 28b). All of the OE50 Taxa scores were below 1.00 (Figure 28a&b), indicating that the number of taxa observed was less on all occasions than would be expected relative to the AUSRIVAS reference watercourses.

Only one location achieved a Band A score (equivalent to AUSRIVAS reference condition) in autumn (OC in autumn 2017) and two locations in spring (WR in spring 2014 and OC in spring 2014 and spring 2017) (Figure 13a&b). Notably, locations that achieved a Band A score were sampled on control streams (i.e. Woronora River and O'Hares Creek).

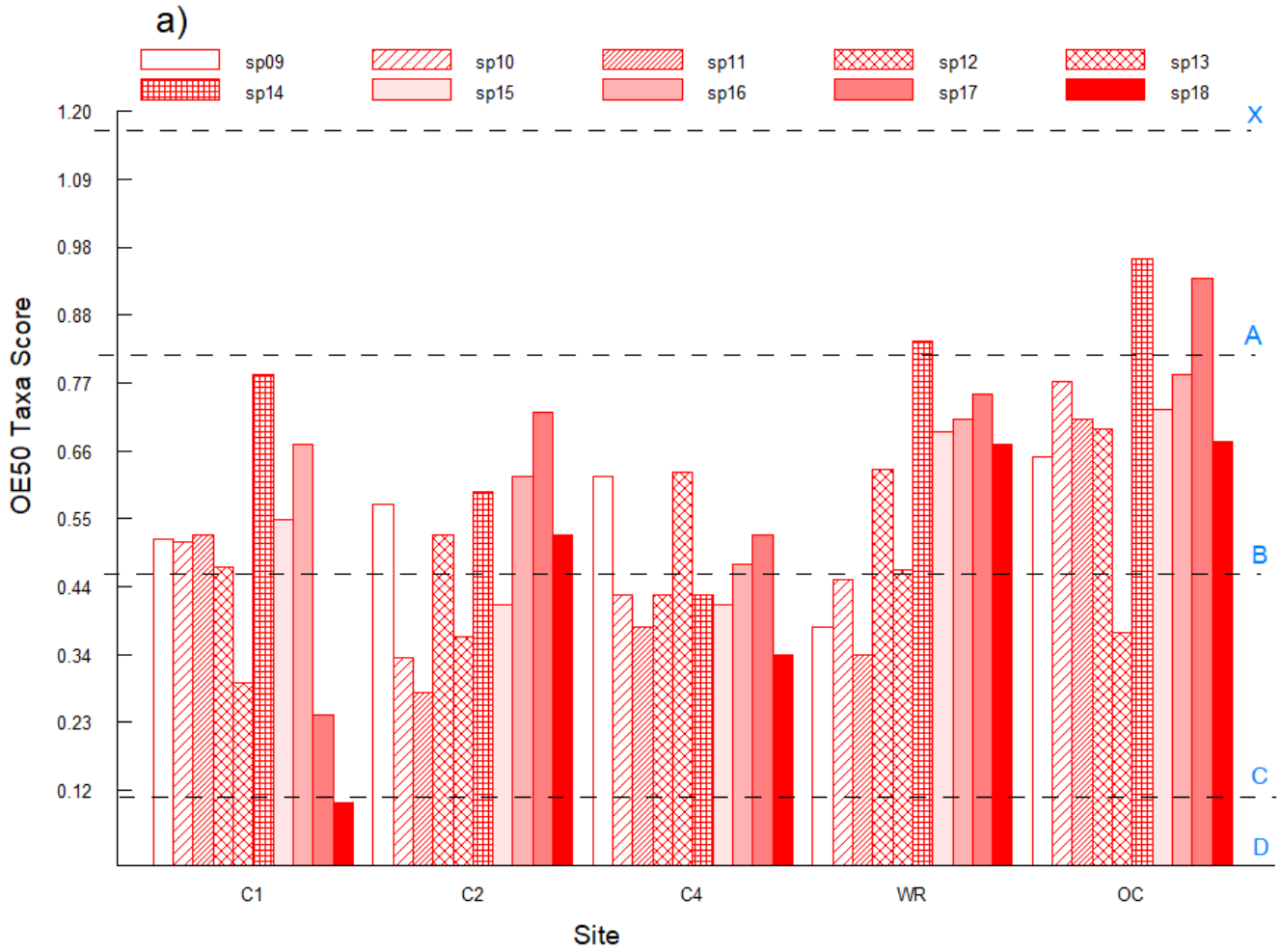


Figure 28a. Mean OE50 Taxa Scores and their respective Band Scores (X-D) from AUSRIVAS samples collected from edge habitat at each site in spring between 2009 and 2018 (*n* = 2).

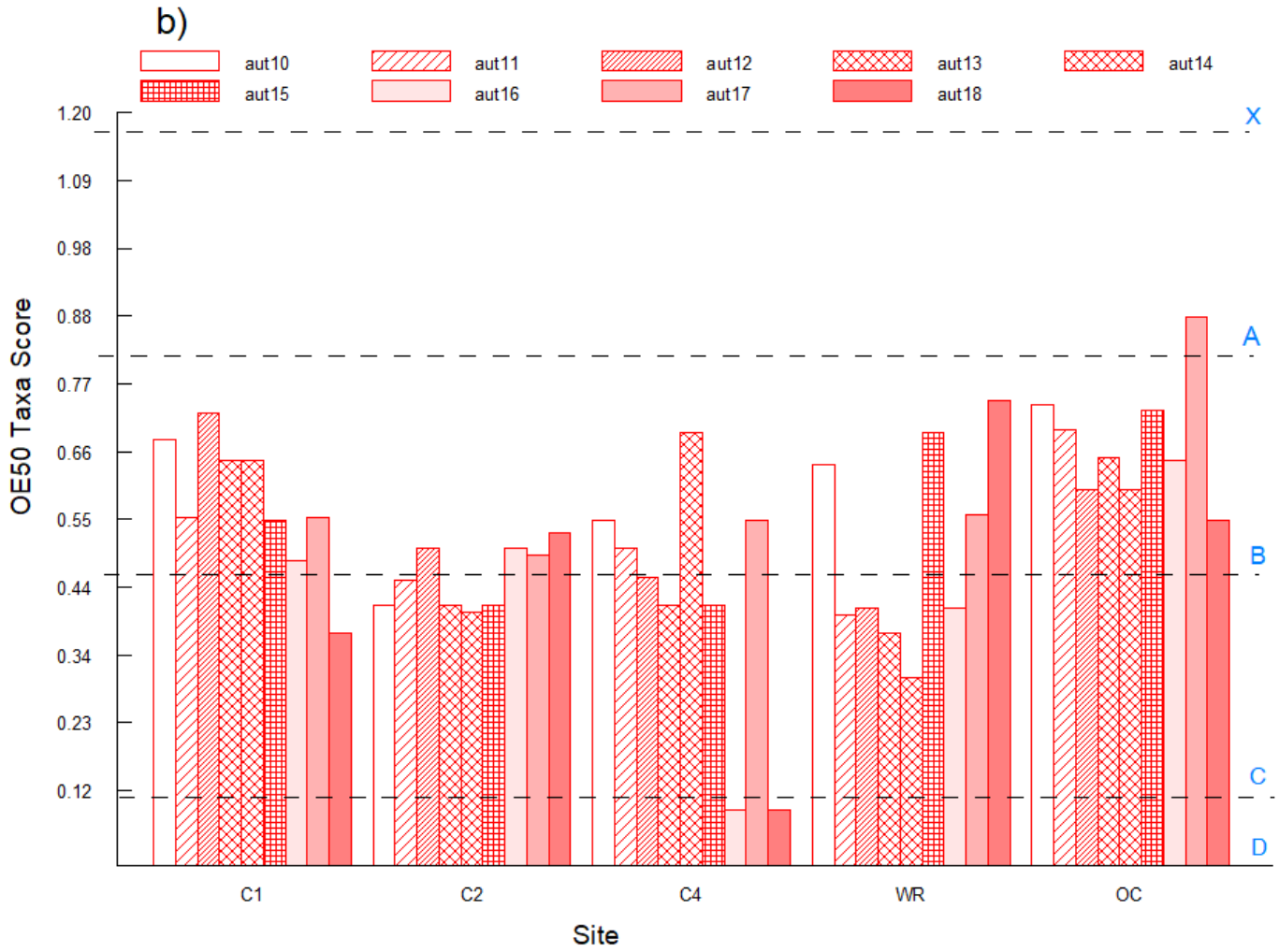


Figure 28b. Mean OE50 Taxa Scores and their respective Band Scores (X-D) from AUSRIVAS samples collected from edge habitat at each site in autumn between 2010 and 2018 (*n* = 2).

4.1.1.2 Aquatic Macrophytes

Location C1 v Controls

Prior Surveys (Spring 2008 – Autumn 2018)

To date, multivariate analyses have detected a significant change in the structure of the assemblage of aquatic macrophytes at Location C1 in spring 2017 and autumn 2018. Total cover and diversity of macrophytes at Location C1 have not differed significantly between periods in relation to the control locations.

The presence of the floating-attached species, *Triglochin procerum*, at the control locations but not at Location C1 has contributed greatly to observed differences in the structure of macrophyte assemblages between the treatment groups (Figure 29a). In addition, *Baumea juncea* has been common at Location C1 but not at either of the control locations. The submerged species, *Myriophyllum pedunculatum*, has only been recorded at the Woronora River location.

Current Survey (Spring 2018)

Similar to the findings of the spring 2017 (T19) and autumn 2018 (T20) surveys, multivariate analyses detected a significant 'before' to 'after' change in assemblages of aquatic macrophytes at Location C1 in relation to the control locations (Table 8, Figure 29a). *Post hoc* tests indicated that differences were partly due to the composition of assemblages at Location C1 changing significantly less between periods than at the control locations (Figure 29a).

SIMPER analyses indicate that the fern, *Gleichenia dicarpa*, contributed most to the structure of assemblages at Location C1 within the 'before' (38.2 %) and 'after' (27.1 %) period, followed by *Baumea juncea* (Before: 26.9 %; After: 27.1 %). In comparison, *Triglochin procerum* (29 %), *Lepidosperma filiforme* (25.0 %) and *Gleichenia dicarpa* (15.8 %) contributed most to assemblages at the control locations within the 'before' period, whereas *Gleichenia dicarpa* (57.7 %), *Lepidosperma filiforme* (17.4 %) and *Chorizandra cymbaria* (6.1 %) were ranked highest within the 'after' period.

Univariate analysis of mean diversity and cover of macrophytes did not detect any changes at Location C1 that might be related to mining of the Longwalls 23-27 area (Table 9, Figures 30a&b). Graphically, it can be seen that total diversity of macrophytes at Location C1 has changed little over time (Figure 30a). There was a considerable decline in cover at Location C1 after the spring 2017 (T19) survey (Figure 30b). There appears to have been a small decline in cover at the Woronora River location since the autumn 2018 (T20) survey (Figure 30b).

Location C2 v Controls

Prior Surveys (Spring 2008 – Autumn 2018)

A significant before-to-after change in assemblages was detected at Location C2 in spring 2014 (T13), autumn 2016 (T16), spring 2016 (T17), autumn 2017 (T18), spring 2017 (T19) and autumn 2018 (T20). A significant increase in species diversity was detected at Location C2 by the autumn 2017 (T18) and spring 2017 (T19) surveys, whilst a significant increase in total cover of macrophytes was detected in spring 2014 (T13).

Changes in the assemblage at Location C2 prior to the autumn 2017 survey did not appear to be related to mining activities given the absence of apparent physical changes to the riparian strip that might be associated with mining activities (e.g. gas release, altered pool-water levels or surface flow). Iron staining and falls in pool water levels below pre-mining levels were, however, noted at Location C2 by the spring 2016 and spring 2017 surveys, respectively. There appeared to be no flow into the study reach from upstream reaches affected by subsidence.

Current Survey (Spring 2018)

Similar to the findings of recent surveys (spring 2014 and autumn 2016 autumn 2018), a significant before-to-after change in the structure of the assemblage of aquatic macrophytes was detected at Location C2 in relation to the control locations (Table 8, Figure 29b). Similar to the findings for Location C1, pairwise tests indicated that differences were mostly due to the composition of assemblages at Location C2 changing significantly less between periods than at the control locations (i.e. Before v After at Location C2: $t = 1.31$, $P = 0.088$; Before v After at the Controls: $t = 1.63$, $P = 0.009$) (Figure 29a).

This result is reflected in the patterns seen in the PCoA, which shows that the centroids representing assemblages at the Woronora River and O'Hares Creek locations within the 'before' period tend to group separately from the centroids within the 'after' period (Figure 29a).

SIMPER analyses indicate that *Baumea juncea* has increased its contribution to assemblages at Location C2 (Before: 13 %; After: 32 %). Contributions made by the fern, *Gleichenia dicarpa*, decreased at Location C2 (Before: 33 %; After: 13 %) but increased at the controls (Before: 14 %; After: 57 %) (SIMPER). In spring 2018, *Lepidosperma filiforme* contributed 61 % to the structure of the assemblage at Location C2, whilst *Baumea juncea* contributed 32 %.

Analyses found no statistically significant interaction in the effects of Period and Impact on variability in mean diversity or percentage cover of aquatic macrophytes (Table 9, Figure 30a&b). Mean cover differed significantly at the scale of Period x Location (Impact), which indicates that variation among Locations is dependent on the Project Period and vice versa (Table 9, Figure 30b). Graphically, there appears to have been a considerable decrease in cover at Location C2 since the spring 2017 (T19) survey (Figure 30b).

Location C4 v Controls

Prior Surveys (Spring 2009 – Autumn 2018)

Analyses of temporal changes in the structure of assemblages of aquatic macrophytes (Figure 29c) and univariate estimates of total cover and species diversity (Figures 30a&b) at Location C4 have consistently found no significant changes in relation to control locations that would indicate an impact from mining.

Current Survey (Spring 2018)

For the first time since sampling commenced at Location C4 (i.e. spring 2009), analyses detected a significant before-to-after change in the structure of assemblages of aquatic macrophytes in relation to the controls (Table 8, Figure 29c). *Post-hoc* tests indicated that this result was mostly due to temporal differences in dispersion ($P = 0.001$) between periods at Location C4 in relation to the control locations. The Principle Co-ordinate Analysis (PCoA) indicates that there is greater dispersion among samples at Location C4 within the 'before' compared to 'after' period (Figure 29c).

SIMPER indicated that *Lepidosperma filiforme* (37.3 %), *Gleichenia dicarpa* (23.3%), *Lomandra fluviatilis* (20.3 %) contributed most to the structure of the macrophyte assemblage at Location C4 within the 'before' period whilst *Lepidosperma filiforme* (37.3 %), Viminaria juncea (24.9 %) and *Gleichenia dicarpa* (19.4 %) contributed most within the 'after' period.

Analyses of species diversity and total cover of aquatic macrophytes did not detect a significant interaction between the factors of interest (Pe and Im) (Table 9). Overall, species diversity of macrophytes at Location C4 appears to have differed little over time (Figure 30a). Graphically, there appears to have been a considerable decrease in cover at Location C4 since the spring 2017 (T19) survey (Figure 30b). Large reductions in pool water levels have been noted along the study reach since spring 2015, particularly at the upstream site (Site C4-1).

Table 8. PERMANOVA on Bray Curtis dissimilarities of macrophyte assemblage data (non-transformed) to compare locations sampled on Tributary C/Eastern Tributary (C1, C2 and C4) with control locations (Woronora River and O'Hares Creek). Percentages of Components of Variation (% CV) are shown.

C1					
Source	**df**	**MS**	***Pseudo-F***	***P***	**% CV**
Period = Pe	**1**	**34561**	**2.39**	**0.01**	**5.88**
Impact = Im	1	95974	1.89	0.09	8.50
Time (Pe) = Ti(Pe)	**19**	**5724**	**1.34**	**0.02**	**4.84**
Location (Im) = Lo(Im)	1	48504	1.05	0.38	2.27
Pe x Im	**1**	**28075**	**2.14**	**0.02**	**7.26**
Site (Lo(Im)) = Si(Lo(Im))	**3**	**44285**	**17.23**	**0.00**	**13.05**
Pe x Lo(Im)	1	10556	0.90	0.66	0.00
Ti(Pe) x Im	19	4569	1.07	0.34	3.12
Pe x Si(Lo(Im))	**3**	**10378**	**4.04**	**0.00**	**7.98**
Ti(Pe) x Lo(Im)	**19**	**4266**	**1.66**	**0.00**	**8.52**
Ti(Pe) x Si(Lo(Im))	57	2570	0.74	1.00	0.00
Residual	504	3480			38.58
C2					
Source	**df**	**MS**	***Pseudo-F***	***P***	**% CV**
Period = Pe	**1**	**26147**	**1.83**	**0.04**	**4.79**
Impact = Im	1	84434	1.51	0.18	7.10
Time (Pe) = Ti(Pe)	19	4902	1.22	0.09	3.97
Location (Im) = Lo(Im)	1	54649	1.23	0.21	4.87
Pe x Im	**1**	**28455**	**2.11**	**0.02**	**7.57**
Site (Lo(Im)) = Si(Lo(Im))	**3**	**42763**	**15.74**	**0.00**	**13.40**
Pe x Lo(Im)	1	11609	1.05	0.39	1.80
Ti(Pe) x Im	19	3791	0.95	0.65	0.00
Pe x Si(Lo(Im))	**3**	**9600**	**3.53**	**0.00**	**7.86**
Ti(Pe) x Lo(Im)	**19**	**4008**	**1.47**	**0.00**	**7.79**
Ti(Pe) x Si(Lo(Im))	57	2718	0.76	1.00	0.00
Residual	504	3554			40.86
C4					
Source	**df**	**MS**	***Pseudo-F***	***P***	**% CV**
Period = Pe	**1**	**29166**	**2.66**	**0.01**	**6.55**
Impact = Im	1	64447	1.20	0.33	4.84
Time (Pe) = Ti(Pe)	17	3587	1.06	0.34	1.94
Location (Im) = Lo(Im)	1	53409	1.36	0.13	6.48
Pe x Im	**1**	**18593**	**1.84**	**0.04**	**6.50**
Site (Lo(Im)) = Si(Lo(Im))	**3**	**37679**	**14.47**	**0.00**	**14.05**
Pe x Lo(Im)	1	8644	1.22	0.18	3.39
Ti(Pe) x Im	17	3340	0.98	0.55	0.00
Pe x Si(Lo(Im))	**3**	**5811**	**2.23**	**0.00**	**6.01**
Ti(Pe) x Lo(Im)	**17**	**3400**	**1.31**	**0.01**	**6.51**
Ti(Pe) x Si(Lo(Im))	51	2604	0.73	1.00	0.00
Residual	456	3590			43.74

Table 9. PERMANOVA analysis on Euclidean Distances of non-transformed total diversity and abundance of macrophytes collected from three locations within Tributary C and at two control locations. Bold numbers indicate significant results at *P* < 0.05.

C1		**Diversity**		**Abundance**	
Source	**df**	**MS**	***Pseudo-F***	**MS**	***Pseudo-F***
Period = Pe	1	**46.33**	**6.88**	6515	0.63
Impact = Im	1	1.76	0.84	63	0.09
Time (Pe) = Ti(Pe)	19	4.17	1.94	**2563**	**2.61**
Location (Im) = Lo(Im)	1	0.58	0.48	9048	1.16
Pe x Im	1	3.48	0.81	897	0.16
Site (Lo(Im)) = Si(Lo(Im))	3	1.85	1.40	**7253**	**13.65**
Pe x Lo(Im)	1	2.87	1.10	**9369**	**3.42**
Ti(Pe) x Im	19	4.09	1.90	**2237**	**2.28**
Pe x Si(Lo(Im))	3	1.66	1.26	**1909**	**3.59**
Ti(Pe) x Lo(Im)	19	2.15	1.62	**982**	**1.85**
Ti(Pe) x Si(Lo(Im))	57	1.32	1.02	531	0.91
Residual	504	1.30		584	
Total	629				
C2		**Diversity**		**Abundance**	
Source	**df**	**MS**	***Pseudo-F***	**MS**	***Pseudo-F***
Period = Pe	1	**51.40**	**6.18**	1405	0.21
Impact = Im	1	**10.30**	**6.04**	214	0.22
Time (Pe) = Ti(Pe)	19	**6.36**	**3.18**	1471	1.32
Location (Im) = Lo(Im)	1	0.00	0.35	4873	0.76
Pe x Im	1	8.97	2.54	1058	0.18
Site (Lo(Im)) = Si(Lo(Im))	3	1.41	1.18	**6134**	**10.12**
Pe x Lo(Im)	1	2.29	0.87	**10729**	**3.94**
Ti(Pe) x Im	19	2.04	1.02	1138	1.02
Pe x Si(Lo(Im))	3	1.99	1.67	**1761**	**2.91**
Ti(Pe) x Lo(Im)	19	2.00	1.68	1113	1.84
Ti(Pe) x Si(Lo(Im))	57	1.19	0.89	606	1.30
Residual	504	1.34		466	
Total	629				
C4		**Diversity**		**Abundance**	
Source	**df**	**MS**	***Pseudo-F***	**MS**	***Pseudo-F***
Period = Pe	1	12.91	2.49	3774	0.46
Impact = Im	1	0.93	2.80	69	0.26
Time (Pe) = Ti(Pe)	17	2.92	1.43	1252	1.02
Location (Im) = Lo(Im)	1	0.09	0.27	4185	0.70
Pe x Im	1	0.60	0.65	306	0.15
Site (Lo(Im)) = Si(Lo(Im))	3	3.13	2.38	**5354**	**12.75**
Pe x Lo(Im)	1	3.09	0.82	**9710**	**5.80**
Ti(Pe) x Im	17	0.97	0.48	798	0.65
Pe x Si(Lo(Im))	3	3.34	2.54	523	1.25
Ti(Pe) x Lo(Im)	17	2.04	1.55	**1223**	**2.91**
Ti(Pe) x Si(Lo(Im))	51	1.32	1.04	420	0.90
Residual	456	1.27		469	
Total	569				

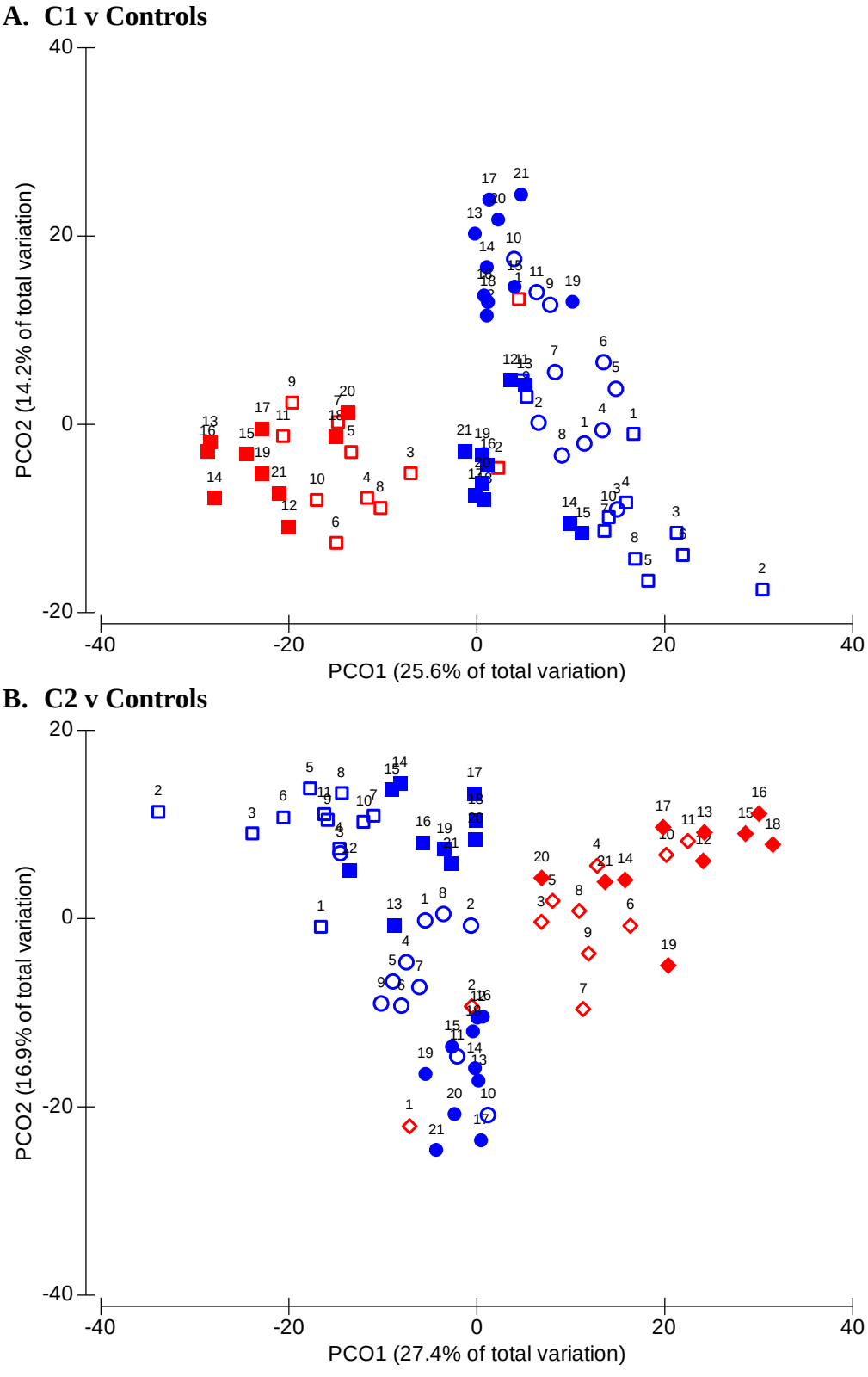


Figure 29. PCoA of centroids for assemblages of macrophytes sampled at locations a) C1 and b) C2 (red symbols) and two control locations (Woronora River: blue squares; O'Hares Creek (blue circles) between spring 2008 (T1) and spring 2018 (T21). Empty symbols: 'Before-mining'; Filled symbols: 'After-mining Longwalls 23-27'.

C. C4 v Controls

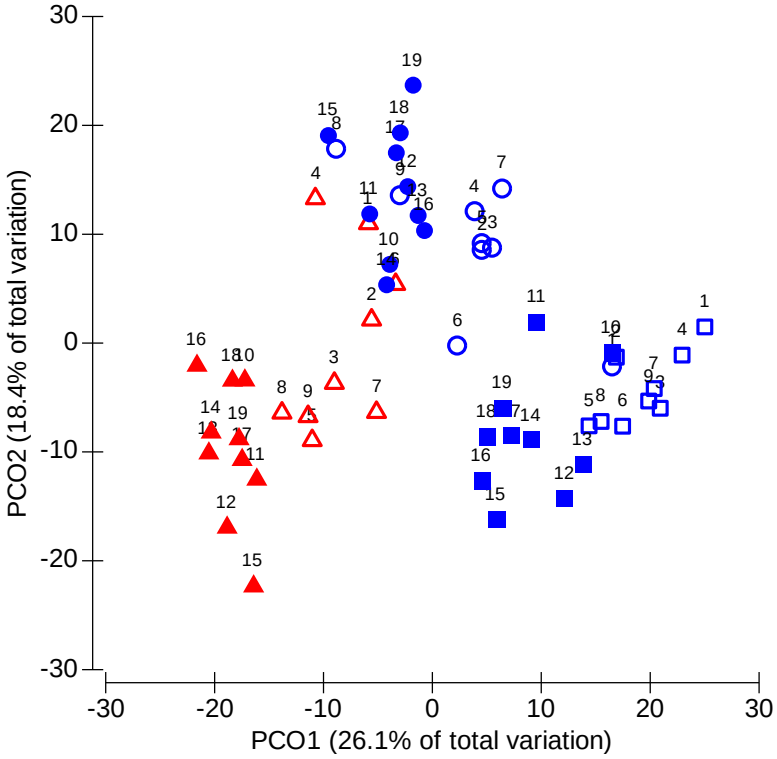


Figure 29 (Cont'd). PCoA of centroids for assemblages of macrophytes sampled at location c) C4 (red symbols) and two control locations (Woronora River: blue squares; O'Hares Creek (blue circles) between spring 2009 (T1) and spring 2018 (T19). Empty symbols: 'Before-mining'; Filled symbols: 'After-mining Longwalls 23-27'.

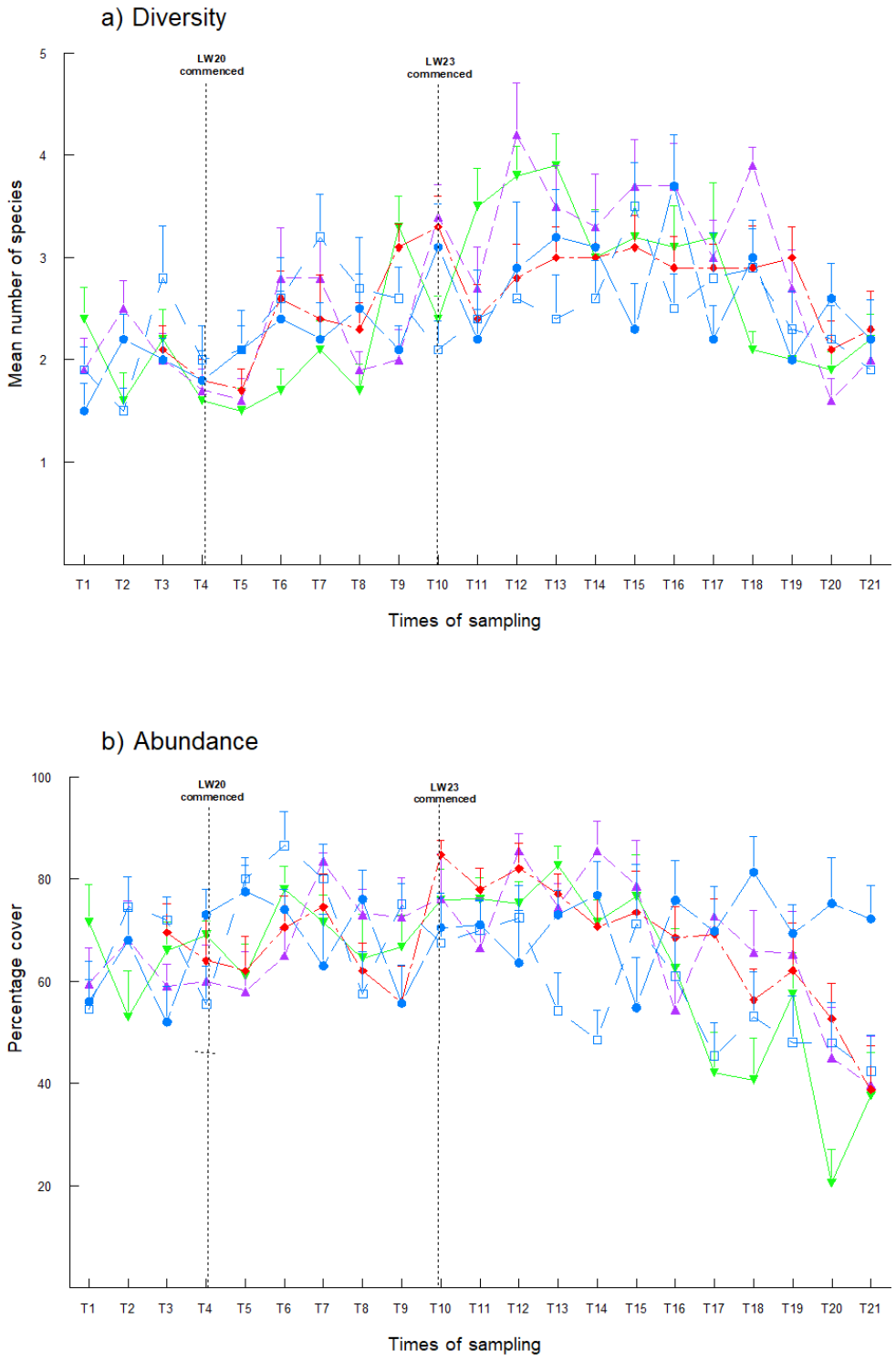


Figure 30. Mean (+SE) a) Number of species/quadrat (*n* = 10) and b) Percentage cover of aquatic macrophytes at locations on Tributary C/Eastern Tributary (C1: inverted triangles; C2: triangles; C4: diamonds) and the control locations (Woronora River: squares; O'Hares Creek: circles) between spring 2008 (T1) and spring 2018 (T21).

4.1.2 Tributary B vs Controls

4.1.2.1 Aquatic Macroinvertebrates

Quantitative Assessment

Prior Surveys (Spring 2009 – Autumn 2018)

Analyses have detected a significant before-to-after change in the structure of the assemblage of aquatic macroinvertebrates at Location B2 compared to the control locations since autumn 2014 (T10). SIMPER analyses showed that differences between the Before- and After-mining periods at Location B2 were mostly due to differences in abundances of the families Atyidae and Leptophlebiidae.

Analyses detected a significant before- to after-mining decrease in numbers of Leptophlebiidae at Location B2 in relation to the control locations in spring 2014 (T11), autumn 2015 (T12) and spring 2015 (T13), but not for subsequent surveys (i.e. autumn and spring 2016, autumn and spring 2017 and autumn 2018).

A significant before- to after-mining change in mean numbers of Atyidae has been detected at Location B2 since autumn 2018 (T18), in relation to the control locations. Mean numbers of Atyidae have decreased at Location B2 within the After- period.

Analyses indicated a significant before- to after-mining difference in mean diversity of macroinvertebrates at Location B2 in autumn 2014 (T10). There was no detectable difference by the time that the spring 2014 or subsequent surveys were undertaken.

No significant changes in mean total abundance of macroinvertebrates have been detected.

Current Survey (Spring 2018)

Consistent with findings from surveys done since autumn 2014 (T10), the structure of assemblages of aquatic macroinvertebrates at Location B2 changed significantly in relation to the control locations (Table 10, Figure 31). The PCoA ordination indicates that samples collected at B2 within the 'before' period tend to group separately from all other times of sampling at that location and from the controls locations (Figure 31). Pairwise comparisons of the 'before' and 'after' group means detected a significant change in assemblages at Location B2 (t = 2.13, P = 0.002) but not at the controls (t = 1.13, P = 0.28).

SIMPER indicated that Atyidae contributed most to the structure of the assemblage at Location B2 within the Before period (66.2 %), but was not ranked within the After-mining period (SIMPER). Leptophlebiidae were ranked second within the Before-period (21.3 %) and first within the After-period, contributing 44.0 % to the structure of the assemblage.

Similar to the findings from surveys done since spring 2016 (T15), univariate analyses detected a significant before- to after-mining change in mean numbers of Atyidae at Location B2 in relation to the control locations (Table 11, Figure 32d). Mean numbers of Atyidae have declined significantly at Location B2, to become similar to numbers recorded at the control locations (Figure 32d).

Analyses detected a significant before- to after-mining change in mean numbers of Leptophlebiidae at Location B2 in spring 2014 (T11), autumn 2015 (T12) and spring 2015 (T13), but not for subsequent surveys (i.e. spring and autumn 2018, spring and autumn 2017, spring and autumn 2016) (Table 11, Figure 32c). Graphically it can be seen that Leptophlebiidae were not collected at Location B2 or the control locations in spring 2018 (T19) (Figure 32c).

Mean diversity and abundance of macroinvertebrates have not differed significantly at Location B2 in relation to the control locations throughout the study period (Table 11, Figures 32a&b). Notably, samples were unable to be collected at the control location at Bee Creek in spring 2018 (T19), due to insufficient aquatic habitat (Figures 32a&b).

Table 10. PERMANOVA on Bray Curtis dissimilarities of macroinvertebrate (non-transformed) data comparing locations sampled on Tributary B with control locations (Bee Creek and Woronora Tributary).

Source	df	MS	Pseudo-*F*	*P*	% CV
Period (Pe)	**1**	**33786**	**3.83**	**0.00**	**9.04**
Impact (Im)	**1**	**55473**	**4.87**	**0.00**	**11.71**
Time (Pe)	**17**	**8355**	**1.67**	**0.03**	**9.52**
Location (Im)	1	7947	0.90	0.62	0.00
Pe x Im	**1**	**30578**	**5.71**	**0.00**	**12.94**
Site (Lo(Im))	**3**	**6054**	**3.09**	**0.00**	**5.58**
Pe x Lo(Im)	1	1765	0.48	1.00	0.00
Ti(Pe) x Im	17	4464	0.89	0.70	0.00
Pe x Si(Lo(Im))	3	2691	1.37	0.11	3.34
Ti(Pe) x Lo(Im)	**17**	**5001**	**2.55**	**0.00**	**14.81**
Ti(Pe) x Si(Lo(Im))	**51**	**1960**	**1.13**	**0.04**	**5.61**
Residual	228	1742			27.45

Table 11. PERMANOVA analyses on Euclidean Distances of total richness and abundance and abundances of Leptophlebiidae and Atyidae. Bold numbers indicate significant results at *P* < 0.05.

		Diversity		Abundance	
Source	**df**	**MS**	***PseudoF***	**MS**	***PseudoF***
Period = Pe	1	4.74	0.29	209	0.40
Impact = Im	1	15.99	0.41	197	0.88
Time (Pe) = Ti(Pe)	17	**59.16**	**4.58**	**2375**	**3.05**
Location (Im) = Lo(Im)	1	46.42	1.62	47	0.25
Pe x Im	1	3.87	0.66	578	1.19
Site (Lo(Im)) = Si(Lo(Im))	3	**19.60**	**3.16**	1214	2.72
Pe x Lo(Im)	1	1.51	0.38	78	0.47
Ti(Pe) x Im	17	23.82	1.84	1058	1.36
Pe x Si(Lo(Im))	3	7.52	1.21	326	0.73
Ti(Pe) x Lo(Im)	17	**12.93**	**2.08**	778	1.74
Ti(Pe) x Si(Lo(Im))	51	**6.21**	**1.45**	446	1.35
Residual	228	4.27		331	
Total	341				
		Leptophlebiidae		**Atyidae**	
Source	**df**	**MS**	***PseudoF***	**MS**	***PseudoF***
Period = Pe	1	506	2.38	**2374**	**9.08**
Impact = Im	1	**4741**	**14.77**	**2302**	**8.74**
Time (Pe) = Ti(Pe)	17	426	0.79	**259**	**85.94**
Location (Im) = Lo(Im)	1	25	0.29	3	0.29
Pe x Im	1	6	1.58	**2199**	**8.37**
Site (Lo(Im)) = Si(Lo(Im))	3	284	1.34	**243**	**3.62**
Pe x Lo(Im)	1	14	0.35	3	0.27
Ti(Pe) x Im	17	333	0.62	**260**	**86.46**
Pe x Si(Lo(Im))	3	110	0.52	**261**	**3.88**
Ti(Pe) x Lo(Im)	17	**542**	**2.54**	3	0.04
Ti(Pe) x Si(Lo(Im))	51	213	1.24	**67**	**4.53**
Residual	228	171		15	
Total	341				

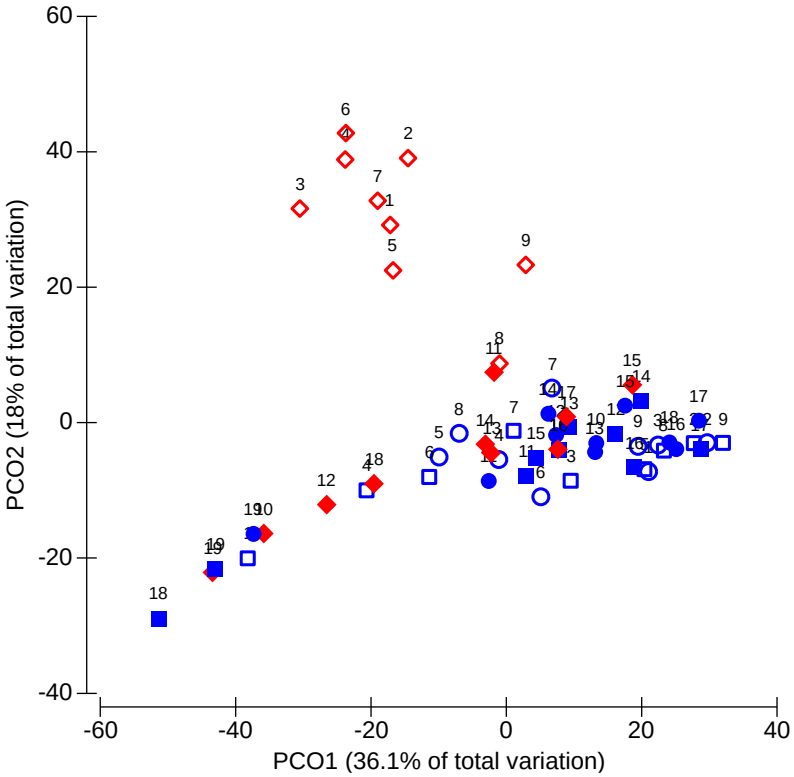


Figure 31. PCoA of centroids for aquatic macroinvertebrates sampled at Location B2 (red diamonds) and two control pools: Bee Creek (blue squares) and Woronora Tributary (blue circles) between spring 2009 (T1) and spring 2018 (T19). Empty symbols: 'Before-mining'; Filled symbols: 'After-mining' Longwalls 23-27.

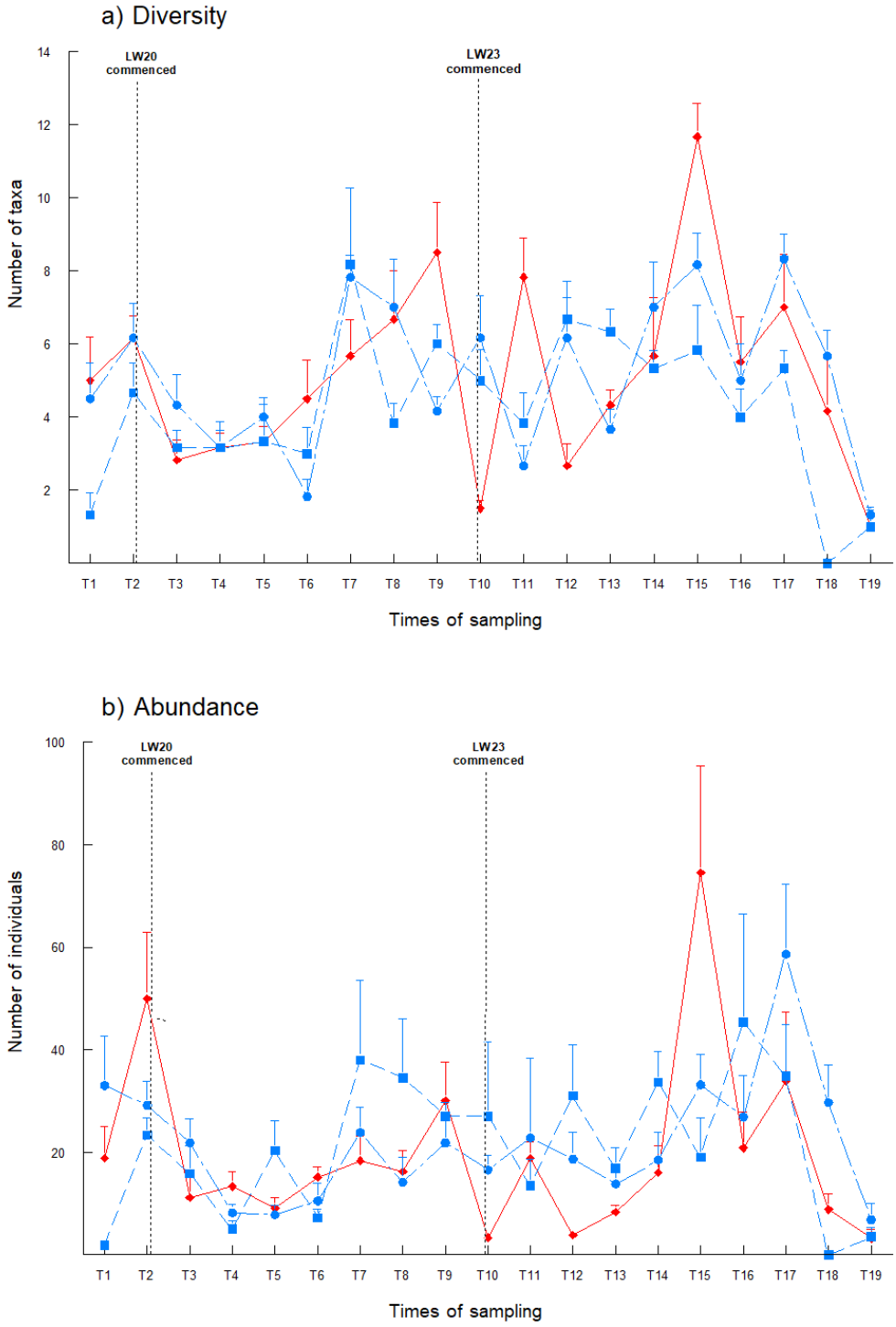


Figure 32. Mean number (+SE) of a) Taxa and b) Individuals of aquatic macroinvertebrates at location B2 (diamonds) and the control locations (Bee Creek = squares; Woronora Tributary = circles) between spring 2009 (T1) and spring 2018 (T19) (*n* = 6).

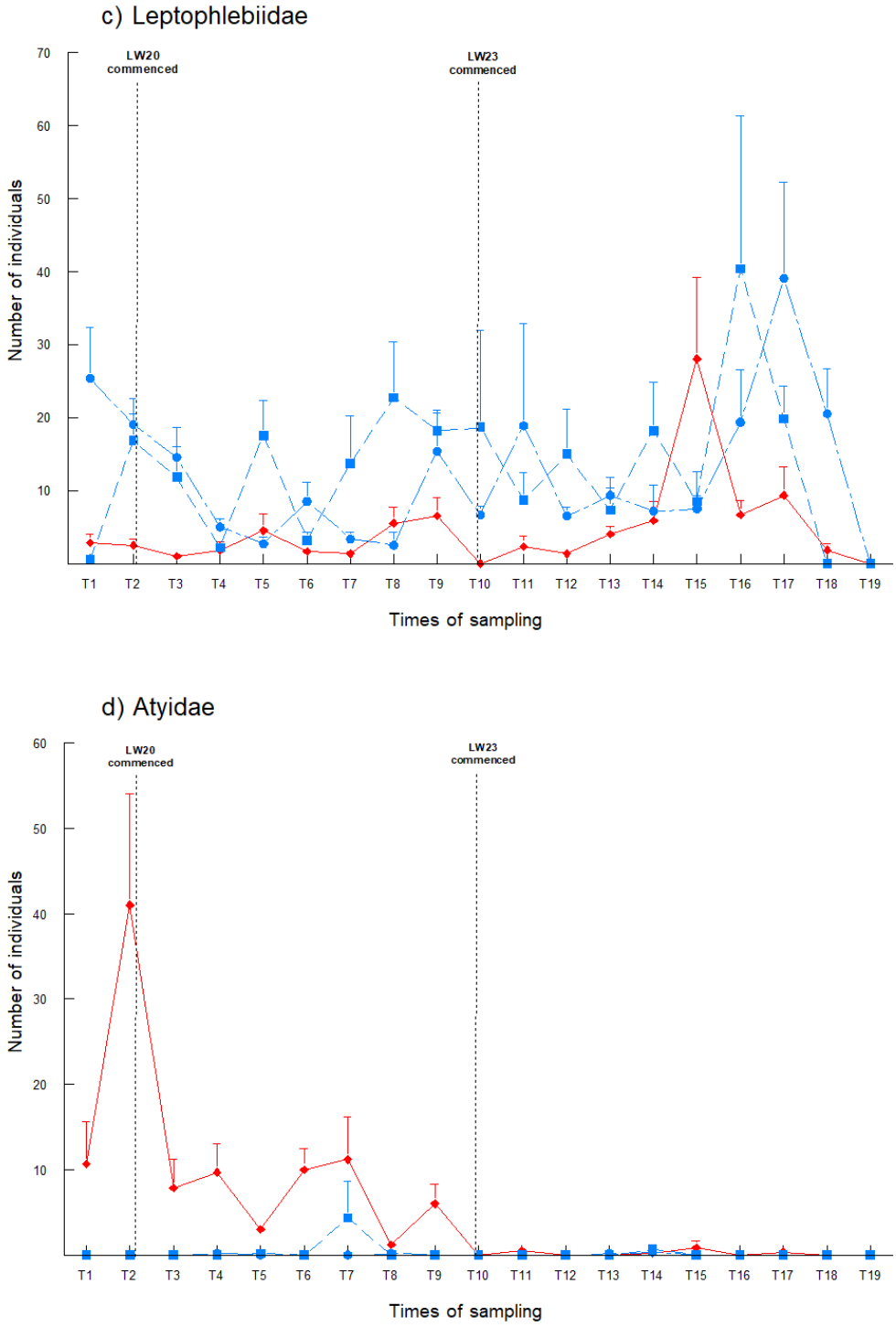


Figure 32. Mean number (+SE) of c) Leptophlebiidae and d) Atyidae at location B2 (diamonds) and the control locations (Bee Creek = squares; Woronora Tributary = circles) between spring 2009 (T1) and spring 2018 (T19) (*n* = 6).

AUSRIVAS Assessment

For AUSRIVAS surveys done in spring, OE50 scores ranged between 0.10 (WOT in spring 2009) and 0.81 (WOT in spring 2012) (Figure 33a). There was a considerable drop in the OE50 score between spring 2017 and 2018 at Location B2 (Figure 33a).

OE50 Taxa Scores for samples collected in autumn ranged from 0.28 (BC in autumn 2017) to 0.79 (Site WOT in autumn 2017) (Figure 33b). All of the OE50 Taxa scores were below 1.00 (Figure 28a&b), indicating that the number of taxa observed was less on all occasions than would be expected relative to the AUSRIVAS reference watercourses.

No location has achieved a Band A score (equivalent to AUSRIVAS reference condition) during the survey period (Figures 33a&b).

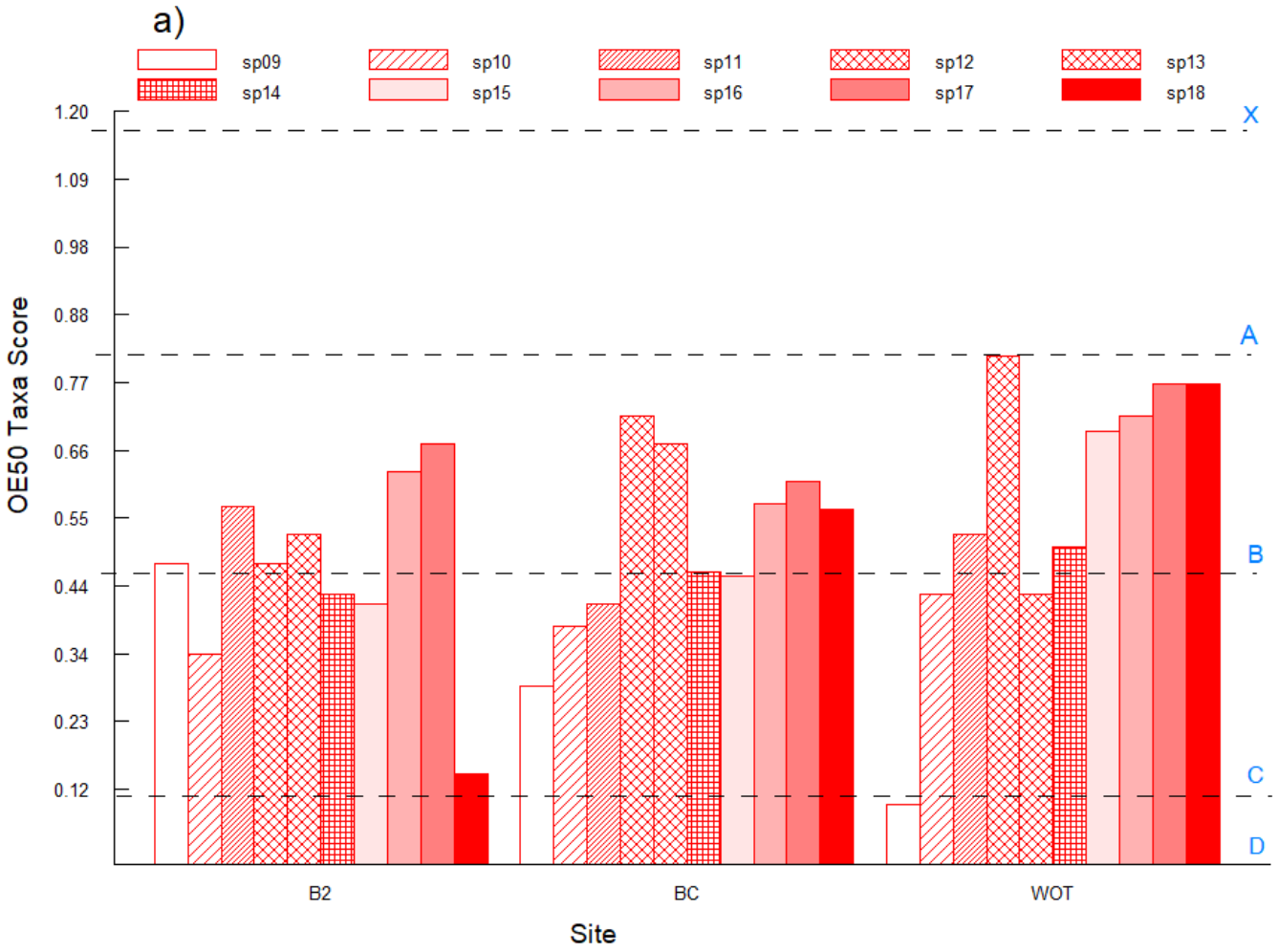


Figure 33a. Mean OE50 Taxa Scores and their respective Band Scores (X-D) from AUSRIVAS samples collected from edge habitat at each site in spring between 2009 and 2018 (*n* = 2).

Figure 33b. Mean OE50 Taxa Scores and their respective Band Scores (X-D) from AUSRIVAS samples collected from edge habitat at each site in autumn between 2010 and 2019 (*n* = 2). NB An AUSRIVAS sample was not collected at BC in autumn 2018 due to insufficient aquatic habitat.

4.1.2.2 Macrophytes

Prior Surveys (Spring 2009 – Autumn 2018)

To date, no mining related changes to aquatic macrophyte indicators have been evident.

Current Survey (Spring 2018)

Analyses found no measurable 'before' to 'after' changes in the composition of assemblages at Location B2 in relation to the control locations, which was reflected by the PCoA ordination (i.e. samples of assemblages did not tend to form any apparent groups) (Table 12, Figure 34). On this sampling occasion, *Empodisma minus* was ranked as contributing most to the assemblage at B2 (i.e. 26.8 %), followed by *Gleichenia dicarpa* (24.9 %) and *Lepidosperma filiforme* (19.8 %).

Similar to the findings of previous surveys, no significant changes in mean diversity or total cover of macrophytes were detected at Location B2 in relation to the control locations (Table 13, Figures 35a&b). Overall, mean diversity of aquatic macrophytes has changed little over time at Location B2 and the control locations (Figures 35a). Mean cover of macrophytes at Location B2 and the control locations appears to have decreased within the 'after' period, particularly at Bee Creek (Figure 35b).

Table 12. Summary of PERMANOVA on Bray Curtis dissimilarities of macrophyte (non-transformed) data comparing locations sampled on Tributary B with control locations (Bee Creek and Woronora Tributary). Percentages of Components of Variation (% CV) are shown.

Source	df	MS	Pseudo-*F*	*P*	% CV
Period (Pe)	**1**	**44784**	**3.18**	**0.01**	**9.17**
Impact (Im)	1	30150	0.51	0.95	0.00
Time (Pe)	**17**	**4198**	**1.35**	**0.03**	**5.12**
Location (Im)	**1**	**62464**	**3.00**	**0.00**	**12.19**
Pe x Im	1	5152	0.61	0.92	0.00
Site (Lo(Im))	**3**	**18608**	**6.68**	**0.00**	**10.39**
Pe x Lo(Im)	**1**	**10868**	**1.75**	**0.04**	**6.33**
Ti(Pe) x Im	17	2782	0.89	0.77	0.00
Pe x Si(Lo(Im))	**3**	**4670**	**1.68**	**0.04**	**5.07**
Ti(Pe) x Lo(Im)	17	3118	1.12	0.22	4.64
Ti(Pe) x Si(Lo(Im))	51	2785	0.81	1.00	0.00
Residual	456	3427			47.08
Total	569				

Table 13. PERMANOVA analysis on Euclidean Distances of non-transformed total diversity and abundance of macrophytes. Bold numbers indicate significant results at *P* < 0.05.

		Diversity		Abundance	
Source	**df**	**MS**	***PseudoF***	**MS**	***PseudoF***
Period = Pe	1	**91.88**	**7.86**	5457	0.99
Impact = Im	1	0.16	0.06	4704	3.90
Time (Pe) = Ti(Pe)	16	**4.05**	**3.16**	**1531**	**2.57**
Location (Im) = Lo(Im)	1	**22.00**	**14.43**	559	0.86
Pe x Im	1	1.56	0.31	3161	0.70
Site (Lo(Im)) = Si(Lo(Im))	3	0.31	0.29	633	1.28
Pe x Lo(Im)	1	**7.80**	**5.26**	4591	1.94
Ti(Pe) x Im	16	1.47	1.14	799	1.34
Pe x Si(Lo(Im))	3	0.40	0.38	**2025**	**4.10**
Ti(Pe) x Lo(Im)	16	1.28	1.20	595	1.20
Ti(Pe) x Si(Lo(Im))	48	1.07	1.00	494	1.18
Residual	432	1.07		420	
Total	539				

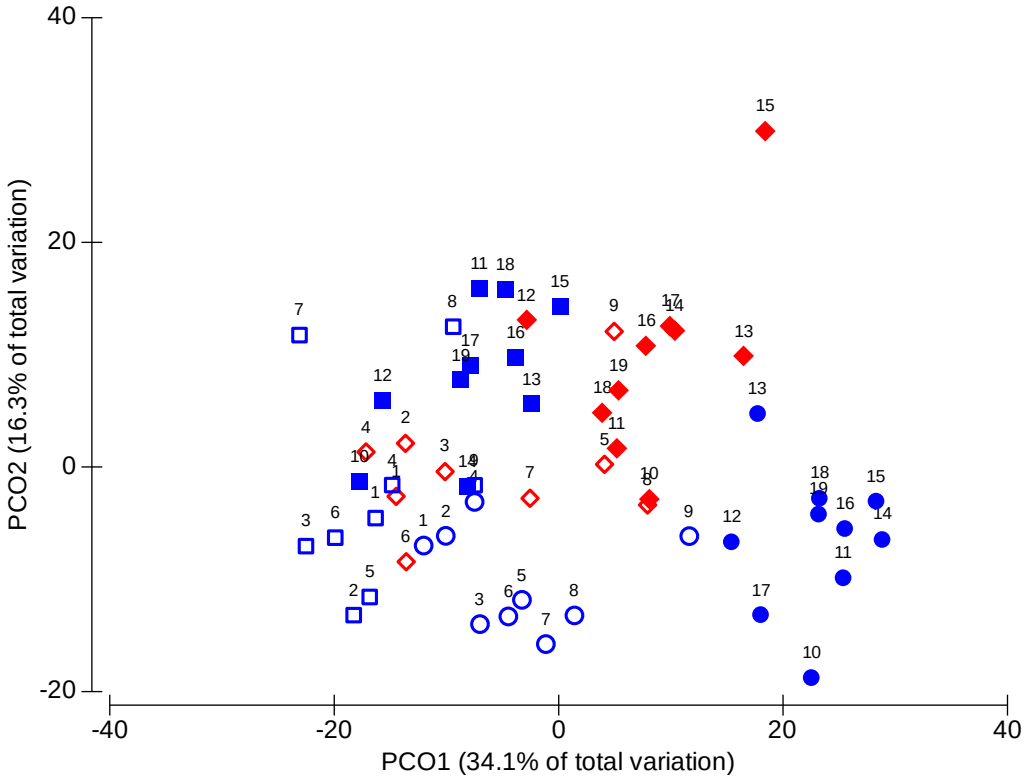


Figure 34. PCoA of centroids for aquatic macrophytes sampled at Location B2 (red diamonds) and two control pools: Bee Creek (blue squares) and Woronora Tributary (blue circles) between spring 2009 (T1) and spring 2018 (T19). Empty symbols: 'Before-mining'; Filled symbols: 'After-mining' Longwalls 23-27.

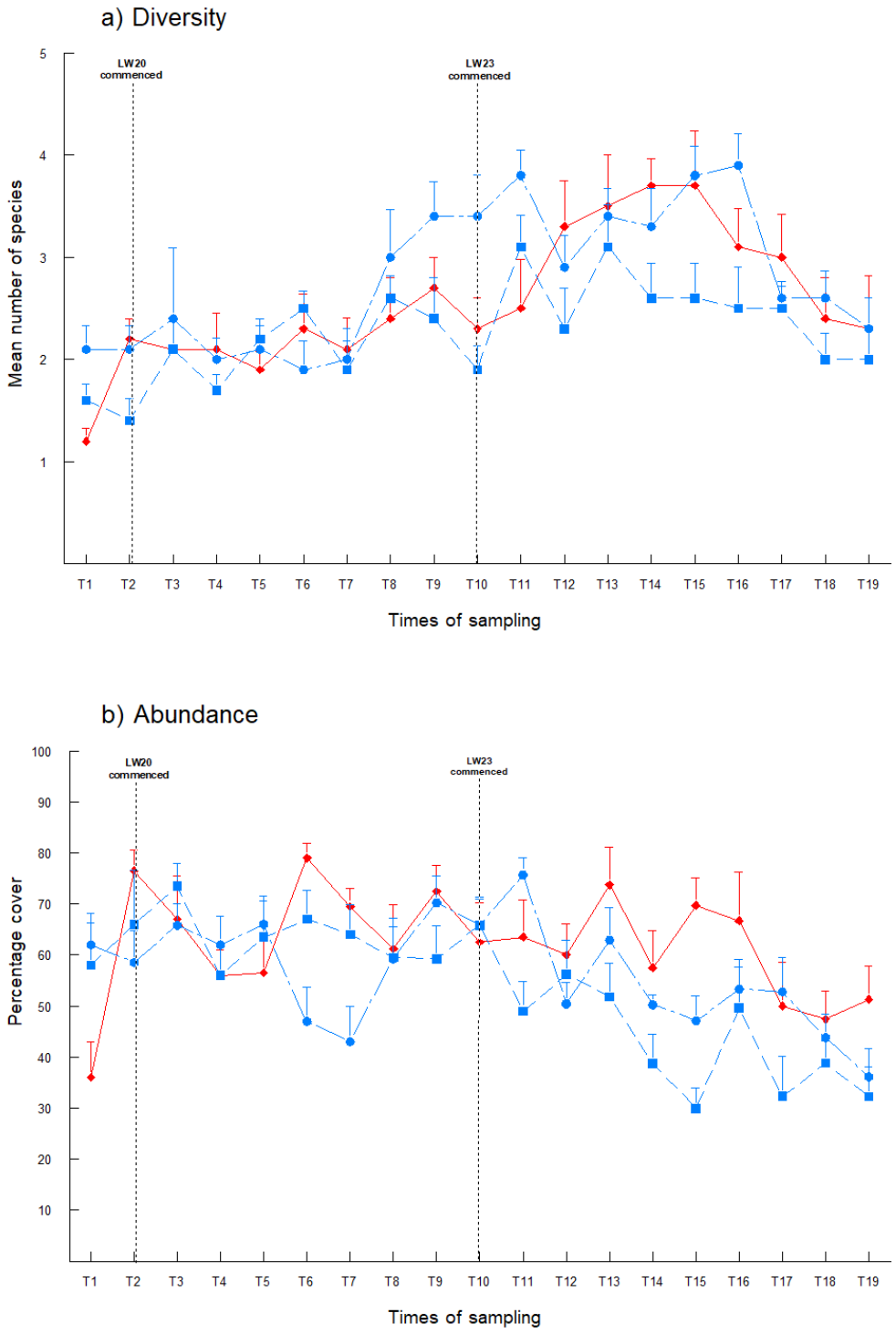


Figure 35. Mean (+SE) a) Number of species/quadrat and b) Total number of species of aquatic macrophytes at location B2 (diamonds) and the control locations (Bee Creek = squares; Woronora Tributary = circles) between spring 2009 (T1) and spring 2018 (T19).

4.2 Pool Monitoring Programme

The objective of the pool monitoring program is to obtain data relevant to the monitoring of the aquatic ecosystems to inform potential future stream remediation works.

Large Pool ETAH and small Pools ETAG, ETAI and ETAK on Tributary C / Eastern Tributary were dry at the time of the spring 2017 and autumn 2018 surveys and there was no surface flow for a considerable distance upstream or downstream of the pools. In spring 2018, water was present in Pool ETAH (up to ~10 cm deep in places), but the water level was well below pre-mining levels. Flow was apparent in and out of Pool ETAG and water level was similar to pre-mining levels. Pools ETAI and ETAK were dry.

The Longwalls 23-27 Water Management Plan indicated that the valley closure subsidence predictions would likely result in the cracking and dilation of bedrock resulting in the localised diversion of flow at Pools ETAH, ETAI, ETAJ, ETAK, ETAL. Pool ETAH was impacted by mining in late 2016. Metropolitan Coal will conduct stream remediation of pools on the Eastern Tributary in accordance with the Metropolitan Coal Rehabilitation Management Plan.

5.0 CONCLUSIONS

Sampling of aquatic indicators for the Longwalls 23-27 Aquatic Ecology Monitoring program was undertaken at potential impact places (i.e. stream locations and pools) sampled along Tributary C/Eastern Tributary and Tributary B and at appropriate control places. To date, nine to eleven monitoring surveys have been carried out prior to commencement of mining of Longwall 23 (i.e. from spring 2008 or spring 2009 to spring 2013) and ten surveys within the 'After-mining' (i.e. autumn 2014 to spring 2018) monitoring phase.

The objective of this monitoring program is to assess whether significant changes in aquatic macroinvertebrate and/or aquatic macrophyte indicators have occurred at the potential impact places sampled in Tributary C/Eastern Tributary and Tributary B following the commencement of mining of Longwall 23, in relation to the control places.

A summary of the main findings to date are presented below.

5.1 Stream Monitoring

Tributary C/Eastern Tributary (Locations C1, C2, C4)

Locations C1 and C4 overly the Longwalls 23-27 underground mining area while Location C2 is downstream of the Longwalls 23-27 underground mining area.

Since autumn 2014, subsidence associated with extraction of Longwalls 23-27 appears to have reduced the quality and availability of aquatic habitat at Locations C1 and C4. Impacts include iron staining and occasional falls in pool water levels. At Location C2, iron staining and a fall in pool water levels below pre-mining levels were first noted by the spring 2016 and spring 2017 surveys, respectively.

Multivariate and univariate analyses of the monitoring data were used to test whether there was evidence of significant change in aquatic macroinvertebrate and macrophyte indicators at Tributary C/Eastern Tributary locations before- versus after-commencement of mining the Longwalls 23-27 area (mining commenced in May 2014), in relation to Control locations.

To date, mean numbers of the mayfly family, Leptophlebiidae, have become significantly more variable within the after-period at Location C1 since autumn 2015. This result is thought to be indicative of an effect of mining. Multivariate analyses detected a significant before-to-after change in the structure of the assemblage of aquatic macroinvertebrates at Location C1 in relation to the control locations in spring 2016 (T17) but not for subsequent surveys (i.e. autumn and spring 2017 and autumn 2018). Assemblages of macrophytes at Location C1 appear to have experienced a degree of environmental stress (desiccation) since spring 2017 as a result of mining activities within the Longwalls 23-27 underground mining area.

Analyses for Location C2 have detected a significant decrease in mean numbers of the freshwater shrimp family, Atyidae, within the after-period since autumn 2016. Notably, reduced mean numbers of Atyidae have now persisted at Location C2 for three consecutive years. As a result, the aquatic ecology subsidence impact performance indicator, *The aquatic macroinvertebrate and macrophyte assemblages in streams are not expected to experience long-term impacts as a result of mine subsidence*, has been exceeded. Accordingly, an assessment against the performance measure, *Negligible impact on Threatened Species, Populations, or Ecological Communities*, is required (see Table 14).

In spring 2018, a significant change in mean abundance of aquatic macroinvertebrates was detected at Location C2 between the before- and after-periods, in relation to the control locations. These changes appear to be related to mining activities. The structure of the macrophyte assemblage at Location C2 also appears to have changed significantly within the after-period for Longwalls 23-27 although changes prior to the spring 2017 survey did not appear to be related to mining activities.

Temporal patterns in diversity of macroinvertebrates at Location C4 differed significantly between periods in autumn and spring 2018, in relation to the control locations. A significant decrease in Atyidae was detected at Location C4 within the after-period in autumn 2016 and spring 2018. Analyses detected a significant before-to-after mining change in the structure of assemblages of aquatic macrophytes at Location C4 in relation to the controls in spring 2018.

It is noted that Locations C1 and C2 are also sampled to assess potential impacts associated with mining of the Longwalls 20-22 area. To date, the main findings include:

- No significant changes to aquatic macroinvertebrate or macrophyte assemblages have been detected;
- A significant difference in patterns of change in mean numbers of the freshwater shrimp family, Atyidae, at Location C2 within the after-mining period in spring 2015 and autumn 2017 in relation to the control locations (BIOANALYSIS, 2019).

Tributary B (Location B2)

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

As described in the Longwalls 301-303 Biodiversity Management Plan (Metropolitan Coal, 2018), the aquatic ecology subsidence impact performance indicator, *The aquatic macroinvertebrate and macrophyte assemblages in streams are not expected to experience long-term impacts as a result of mine subsidence*, has been exceeded at Location B2 for macroinvertebrates since the spring 2016 survey and assessments have been made against the performance measure. Given the distance from Longwalls 301-303, Tributary B is not expected to experience any measurable subsidence or valley related movements resulting from the extraction of Longwalls 301-303.

5.2 Pool Monitoring

Large Pool ETAH and small Pools ETAG, ETAI and ETAK on Tributary C/Eastern Tributary were dry at the time of the spring 2017 and autumn 2018 surveys and there was no surface flow for a considerable distance upstream or downstream of the pools. In spring 2018, water was present in Pool ETAH (up to ~10 cm deep in places), but the water level was well below pre-mining levels. Flow was apparent in and out of Pool ETAG in spring 2018 and water level was similar to pre-mining levels. Pools ETAI and ETAK were dry.

The Longwalls 23-27 Water Management Plan indicated that the valley closure subsidence predictions would likely result in the cracking and dilation of bedrock resulting in the localised diversion of flow at Pools ETAH, ETAI, ETAJ, ETAK, ETAL. Pool ETAH was impacted by mining in late 2016.

Mining impacts have now persisted at Pools ETAH, ETAI, ETAJ, ETAK, ETAL for more than 3 consecutive years. As a result, the performance indicator, *The aquatic macroinvertebrate and macrophyte assemblages in pools are not expected to experience long-term impacts as a result of mine subsidence,* has been exceeded. Accordingly, an assessment against the performance measure, *Negligible impact on Threatened Species, Populations, or Ecological Communities,* is required (see Table 21).

Metropolitan Coal will conduct stream remediation of Pools on the Eastern Tributary in accordance with the Metropolitan Coal Rehabilitation Management Plan.

5.3 Metropolitan Coal Longwalls 301-303 Biodiversity Management Plan Trigger Action Response Plan

A reconciliation against the Trigger Action Response Plan in the Metropolitan Coal Longwalls 301-303 Biodiversity Management Plan has been completed (Table 14).

Table 14. Assessment of Environmental Performance – Underground Mining Area and Surrounds

Performance Measure	Performance Indicator	Monitoring Site(s) being Assessed	Parameters	Highest Significance Level/Trigger Recorded		Comments	Subsidence Impact Performance Indicator Exceeded?	Subsidence Impact Performance Measure Exceeded?
Monitoring of Aquatic Biota, Stream Monitoring								
Negligible impact on Threatened Species, Populations, or Ecological Communities	*The aquatic macroinvertebrate and macrophyte assemblages in streams are not expected to experience long-term impacts as a result of mine subsidence*[6]	Two sampling sites (approximately 100 m in length) at the following locations: - Locations ET1 and ET4 on the Eastern Tributary overlying Longwalls 20-27. - Location ET2 on the Eastern Tributary, downstream of Longwalls 20-27 and within the Longwalls 301-303 35 angle of draw and/or predicted 20 mm subsidence contour. - Control Locations: WR1 on Woronora River; and OC on O'Hares Creek.	Aquatic macroinvertebrates Aquatic macrophytes	Level 1	Data analysis indicates no significant changes in relation to control places pre-mining compared to post-extraction: - occur in the aquatic macroinvertebrate and macrophyte assemblages in the Eastern Tributary at Location ET1 and ET4 located within the LW23-27 mining area during the mining of LW301-303; or - occur in the aquatic macroinvertebrate and macrophyte assemblages in the Eastern Tributary at Location ET2 during the mining of LW301-303.	Locations ET1, ET2 and ET4 (all parameters excluding those noted in Levels 2 and 3 below).	No	No-
				Level 2	Data analysis indicates no significant changes in relation to control places pre-mining compared to post-extraction: - occur in the aquatic macroinvertebrate and macrophyte assemblages in the Eastern Tributary at Locations ET1 and ET4 located within the LW23-27 mining area during the mining of LW301-303; or - occur in the aquatic macroinvertebrate and macrophyte assemblages in the Eastern Tributary at Location ET2 during the mining of LW301-303.	Location ET1 (change in assemblage of macroinvertebrates in spring 2016 but not subsequently; altered composition of macrophyte assemblage since spring 2017). Location ET2 (decreased numbers of Atyidae since autumn 2016; significant change in abundance of macroinvertebrates in spring 2018; altered macrophyte assemblage within the after-period however, changes prior to spring 2017 do not appear to be related to mining). Location ET4 (altered patterns of diversity of macroinvertebrates in autumn and spring 2018; decreased numbers of Atyidae in autumn 2016 and spring 2018; altered macrophyte assemblage within the after-period in spring 2018).	No	No
				Level 3	Data analysis indicates significant long-term changes in relation to control places pre-mining compared to post-extraction: - occur in the aquatic macroinvertebrate and macrophyte assemblages in the Eastern Tributary at Locations ET1 and ET4 located within the LW23-27 mining area during the mining of LW301-303; or - occur in the aquatic macroinvertebrate and macrophyte assemblages in the Eastern Tributary at Location ET2 during the mining of LW301-303.	Location ET1 (increased Leptophlebiidae since autumn 2015).	Yes	Assessment to be conducted

		Larger pool ETAH on the Eastern Tributary, overlying Longwalls 20-27. Smaller pools ETAG, ETAK and ETAI on the Eastern Tributary, overlying Longwalls 20-27. One larger control pool on Woronora River (Pool WP) and one larger control pool on O'Hares Creek (Pool OC). Three smaller control pools on Woronora River (Pools WP-A, WP-B and WP-C) and three smaller control pools on O'Hares Creek (Pools OC-A, OC-B and OC-C).	Aquatic macroinvertebrates Aquatic macrophytes	Level 3	Data analysis indicates significant long-term changes in relation to control places pre-mining compared to post-extraction: - occur in the aquatic macroinvertebrate and macrophyte assemblages at pools ETAG, ETAH, ETAI or ETAK.	Larger pools: - Pool ETAH on Eastern Tributary. Smaller pools: - Pools ETAG, ETAK and ETAI on the Eastern Tributary.	Yes	Assessment to be conducted

6.0 ACKNOWLEDGEMENTS

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APPENDICES

Appendix 1a. GPS positions (UTMs) for stream monitoring sample locations on the Tributary C, Tributary B, Bee Creek, Woronora Tributary, Woronora River and O'Hares Creek (spring 2018).

System	Location	Site	Easting	Northing
Tributary C	1	1	03116117	6214117
	1	2	0311642	6214197
	2	1	0312168	6215399
	2	2	0312167	6215577
	4	1	0311804	6214445
	4	2	0312021	6214502
Tributary B	2	1	0310043	6215073
	2	2	0310150	6215142
Bee Creek	1	1	0308947	6220285
	1	2	0308978	6220292
Woronora Tributary	1	1	0307680	6219108
	1	2	0307746	6219154
Woronora River	1	1	0307943	6219059
	1	2	0307934	6219105
O'Hares Creek	1	1	0303812	6213711
	1	2	0303636	6213577

Appendix 1b. GPS positions (UTMs) for pools sampled on Tributary C/Eastern Tributary, Woronora River and O'Hares Creek (spring 2018).

System	Site Code	Easting	Northing
Tributary C			
ETAG	ETAG-1	0312223	6214780
ETAH	ETAH-1&2	0312238	6214820
ETAI	ETAI-1	0312216	6214885
ETAK	ETAK-1	0312216	6214936
Large Control Pools			
Woronora River Pool	WP-1&2	0307930	6219115
O'Hares Creek Pool	OC-1&2	0303745	6213657
Small Control Pools			
Woronora River Pool	WP-A	0307916	6218965
	WP-B	0307915	6218872
	WP-C	0307893	6218882
O'Hares Creek Pool	OC-A	0303544	6213500
	OC-B	0303507	6213541
	OC-C	0303477	6213641

Appendix 2a. Spring 2018 Estimated Cover of Aquatic Macrophyte Species at Stream Sites

	Tributary C / Eastern Tributary						Tributary B		Bee Creek		Woronora Tributary		Woronora River		O'Hares Creek	
Species	**C11**	**C12**	**C21**	**C22**	**C41**	**C42**	**B21**	**B22**	**BC1**	**BC2**	**WOT1**	**WOT2**	**WR11**	**WR12**	**OC1**	**OC2**
Baumea juncea	1	3	3	3	2	1	0	0	0	0	0	0	0	0	0	0
Baumea rubiginosa	0	0	0	2	0	0	1	0	0	1	1	1	0	1	0	0
Baumea teretifolia	0	0	0	0	0	0	1	0	0	0	0	0	0	0	3	2
Centrolepis fascicularis	0	0	0	2	0	0	0	0	0	0	0	0	1	1	0	2
Chara/Nitella spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1
Chorizandra cymbaria	1	1	0	2	0	0	2	2	1	0	0	1	0	1	0	1
Dicksonia antarctica	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Drosera binata	0	0	0	0	0	0	1	0	0	0	1	0	0	0	1	0
Drosera spatulata	0	0	0	1	0	1	1	0	0	0	1	1	0	1	0	2
Empodisma minus	3	2	2	2	0	2	3	1	2	1	3	3	2	1	2	1
Eurychorda complanata	0	0	0	0	0	0	0	0	3	1	0	0	0	0	0	1
Gahnia clarkei	1	1	0	0	2	1	2	0	2	3	2	2	3	0	1	1
Gleichenia dicarpa	0	2	1	3	1	3	3	0	1	1	3	2	3	3	3	0
Glossosstigma sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2
Isolepis inundata	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	1
*Isolepis prolifera**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Juncus planifolius	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	2
Lepidosperma filiforme	2	1	3	0	2	3	3	3	3	3	3	2	3	3	2	2
Lepyrodia scariosa	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0
Lomandra fluviatilis	0	0	2	3	3	2	0	1	0	0	0	0	0	0	0	3
Lomandra longfolia	1	0	0	1	0	1	0	1	0	0	0	1	0	0	0	1
Myriophyllum pedunculatum	0	0	0	0	0	0	0	0	0	0	0	0	3	1	0	0
Schoenus brevifolius	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0
Sticherus flabellatus	0	0	0	0	0	0	2	0	0	3	0	0	2	0	2	0
Triglochin procerum	0	0	0	0	0	0	0	0	0	0	0	0	3	3	2	0
Viminaria juncea	3	2	3	1	3	3	2	2	3	1	3	3	0	0	2	0
Xyris operculata	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0

* Denotes introduced species

Site Codes: C11 = Tributary C, Location 1, Site 1, etc.

Appendix 2b. Spring 2018 Percentage Cover of Aquatic Macrophyte Species at Stream Sites (0.25 m^2 quadrats)

	Tributary C / Eastern Tributary																			
Species	**C11-1**	**C11-2**	**C11-3**	**C11-4**	**C11-5**	**C12-1**	**C12-2**	**C12-3**	**C12-4**	**C12-5**	**C21-1**	**C21-2**	**C21-3**	**C21-4**	**C21-5**	**C22-1**	**C22-2**	**C22-3**	**C22-4**	**C22-5**
Baumea juncea	0	0	0	0	0	50	0	5	20	50	0	5	0	10	0	5	50	0	0	60
Baumea rubiginosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	5	0	0	0
Baumea teretifolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Centrolepis fascicularis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chorizandra cymbaria	0	0	0	0	0	0	15	0	0	0	0	0	0	0	0	0	0	20	0	0
Drosera binata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Drosera spatulata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Empodisma minus	15	10	5	15	0	0	10	75	0	0	0	0	0	10	0	0	0	0	0	0
Eurychorda complanata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gahnia clarkei	0	0	0	0	0	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0
Gleichenia dicarpa	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	5	0	35	15
Glossostigma sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Isolepis inundata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
*Isolepis prolifera**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Juncus planifolius	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lepidosperma filiforme	0	0	0	2	15	0	15	0	0	0	5	10	10	2	15	0	0	0	0	0
Lomandra fluviatilis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	60	0	0
Lomandra longfolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Myriophyllum pedunculatum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Schoenus brevifolius	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	40	0
Sticherus flabellatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Triglochin procerum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Viminaria juncea	0	15	5	15	0	0	0	5	2	10	0	0	0	20	0	0	0	0	0	0

* Denotes introduced species

Site Codes: C11-1 = Tributary C, Location 1, Site 1, Replicate 1, etc.

Appendix 2b. Spring 2018 Percentage Cover of Aquatic Macrophyte Species at Stream Sites (0.25 m^2 quadrats)

	Tributary C / Eastern Tributary										Tributary B									
Species	**C41-1**	**C41-2**	**C41-3**	**C41-4**	**C41-5**	**C42-1**	**C42-2**	**C42-3**	**C42-4**	**C42-5**	**B21-1**	**B21-2**	**B21-3**	**B21-4**	**B21-5**	**B22-1**	**B22-2**	**B22-3**	**B22-4**	**B22-5**
Baumea juncea	0	0	0	0	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Baumea rubiginosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Baumea teretifolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0
Centrolepis fascicularis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chorizandra cymbaria	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	20	0	0	30
Drosera binata	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0
Drosera spatulata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Empodisma minus	0	0	0	0	0	0	0	0	5	30	60	0	15	35	20	0	0	0	0	0
Eurychorda complanata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gahnia clarkei	0	0	0	15	0	35	0	0	0	0	0	8	0	0	0	0	0	0	0	0
Gleichenia dicarpa	0	0	0	0	0	5	3	15	0	10	15	0	45	20	25	0	0	0	0	0
Glossostigma sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Isolepis inundata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
*Isolepis prolifera**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Juncus planifolius	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lepidosperma filiforme	0	5	10	0	0	5	12	25	0	0	0	4	0	0	8	30	0	55	0	0
Lomandra fluviatilis	95	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lomandra longfolia	0	0	0	0	0	0	0	15	0	0	0	0	0	0	0	0	0	0	0	0
Myriophyllum pedunculatum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Schoenus brevifolius	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sticherus flabellatus	0	0	0	0	0	0	0	0	0	0	0	45	0	0	0	0	0	0	0	0
Triglochin procerum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Viminaria juncea	0	10	4	0	0	20	15	4	15	10	0	0	8	4	10	0	0	0	35	0

* Denotes introduced species

Site Codes: C11-1 = Tributary C, Location 1, Site 1, Replicate 1, etc.

Appendix 2b. Spring 2018 Percentage Cover of Aquatic Macrophyte Species at Stream Sites (0.25 m^2 quadrats)

	Bee Creek										Woronora Tributary									
Species	**BC1-1**	**BC1-2**	**BC1-3**	**BC1-4**	**BC1-5**	**BC2-1**	**BC2-2**	**BC2-3**	**BC2-4**	**BC2-5**	**WOT1-1**	**WOT1-2**	**WOT1-3**	**WOT1-4**	**WOT1-5**	**WOT2-1**	**WOT2-2**	**WOT2-3**	**WOT2-4**	**WOT2-5**
Baumea juncea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Baumea rubiginosa	0	0	0	0	0	0	4	0	0	0	0	2	0	0	0	0	0	0	0	0
Baumea teretifolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Centrolepis fascicularis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chorizandra cymbaria	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0
Drosera binata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Drosera spatulata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Empodisma minus	0	20	0	0	0	0	0	0	20	0	0	0	2	0	0	0	15	0	0	0
Eurychorda complanata	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gahnia clarkei	0	0	0	45	0	3	2	0	0	0	2	0	0	0	30	0	0	0	0	0
Gleichenia dicarpa	15	0	0	4	0	0	0	15	0	0	50	25	50	40	0	8	0	0	0	0
Glossosstigma sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Isolepis inundata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
*Isolepis prolifera**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Juncus planifolius	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lepidosperma filiforme	0	10	0	0	0	0	35	0	30	18	0	0	2	0	0	0	0	5	5	20
Lomandra fluviatilis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lomandra longfolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Myriophyllum pedunculatum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Schoenus brevifolius	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sticherus flabellatus	0	0	0	0	0	30	0	25	0	20	0	0	0	0	0	0	0	0	0	0
Triglochin procerum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Viminaria juncea	0	0	2	4	0	0	0	0	10	0	10	25	5	0	5	15	15	0	15	10

* Denotes introduced species

Site Codes: C11-1 = Tributary C, Location 1, Site 1, Replicate 1, etc.

Appendix 2b. Spring 2018 Percentage Cover of Aquatic Macrophyte Species at Stream Sites (0.25 m^2 quadrats)

	Woronora River 1										O'Hares Creek									
Species	**WR11-1**	**WR11-2**	**WR11-3**	**WR11-4**	**WR11-5**	**WR12-1**	**WR12-2**	**WR12-3**	**WR12-4**	**WR12-5**	**OC1-1**	**OC1-2**	**OC1-3**	**OC1-4**	**OC1-5**	**OC2-1**	**OC2-2**	**OC2-3**	**OC2-4**	**OC2-5**
Baumea juncea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Baumea rubiginosa	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Baumea teretifolia	0	0	0	0	0	0	0	0	0	0	0	2	0	15	45	0	0	0	15	0
Centrolepis fascicularis	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	20	5	4	0
Chorizandra cymbaria	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Drosera binata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Drosera spatulata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	8	0	0
Empodisma minus	0	0	0	0	0	0	0	0	10	0	0	2	0	0	0	0	0	0	0	0
Eurychorda complanata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	45	0	0
Gahnia clarkei	0	0	45	0	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gleichenia dicarpa	0	50	10	8	20	0	0	40	0	60	0	80	95	80	45	0	0	0	0	0
Glossostigma sp.	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	15	0	0	0
Isolepis inundata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
*Isolepis prolifera**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0
Juncus planifolius	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0
Lepidosperma filiforme	0	10	10	15	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0
Lomandra fluviatilis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	70	0	0	0	70
Lomandra longfolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Myriophyllum pedunculatum	0	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Schoenus brevifolius	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sticherus flabellatus	0	0	0	0	0	0	0	0	0	0	75	0	0	0	0	0	0	0	0	0
Triglochin procerum	70	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0
Viminaria juncea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

* Denotes introduced species

Site Codes: C11-1 = Tributary C, Location 1, Site 1, Replicate 1, etc.

Appendix 3. Spring 2018 AUSRIVAS Sampling of Stream Sites - Macroinvertebrate Taxa and Abundance

	Tributary C / Eastern Tributary						Tributary B		Bee Creek		Woronora Tributary		Woronora River		O'Hares Creek	
Taxa	**C11**	**C12**	**C21**	**C22**	**C41**	**C42**	**B21**	**B22**	**BC1**	**BC2**	**WOT1**	**WOT2**	**WR11**	**WR12**	**OC1**	**OC2**
Acariformes	0	0	0	0	0	0	0	0	0	0	1	1	1	0	1	1
Aeshnidae	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Atyidae	0	0	0	0	0	3	0	0	0	0	0	0	22	41	2	1
Baetidae	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Brentidae	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Ceinidae	0	0	0	1	0	0	0	0	0	0	0	0	0	0	12	0
Ceratopogonidae	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0
Chironomidae (L.) - Chironominae	0	0	4	1	0	1	0	0	20	9	3	4	0	1	1	9
Chironomidae (L.) - Tanypodinae	0	0	1	1	1	0	0	0	3	5	3	0	0	0	2	0
Cordulephyidae	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Corixidae	0	0	0	1	0	0	0	0	0	0	9	0	0	1	0	0
Culicidae	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
Dytiscidae	0	0	5	11	6	4	5	0	4	3	2	3	0	2	6	5
Elmidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	2
Gelastocoridae	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gerridae	0	0	0	2	0	0	0	0	0	0	14	0	0	1	3	1
Gripopterygidae	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0
Gomphidae	0	0	0	0	0	0	0	0	0	0	2	0	0	1	1	0
Gyrinidae	0	0	2	0	0	0	0	0	0	3	5	0	6	2	0	0
Hydrophilidae	0	0	0	0	0	0	1	0	1	1	0	0	0	0	3	0
Leptoceridae	0	0	0	0	0	1	0	0	0	2	10	19	6	25	2	0
Leptophlebiidae	0	0	2	2	0	2	5	0	3	18	19	10	16	4	20	6
Libellulidae	0	0	0	1	0	0	4	0	0	0	1	0	0	0	0	0
Megapodagrionidae	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Mesoveliidae	0	0	0	1	0	0	0	0	0	0	0	0	1	1	0	0
Notonectidae	0	1	0	3	0	7	0	0	0	0	17	5	2	3	5	3
Parastacidae (*Cherax* sp.)	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
Psephenidae	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0
Pyralidae	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0
Scirtidae	0	0	0	0	0	0	0	0	0	0	0	3	0	2	0	0
Synthemistidae	0	0	0	0	0	0	1	0	2	1	0	0	0	0	0	0
Telephlebiidae	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unkonwn Coleoptra larvae	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Total Taxa	**2**	**2**	**5**	**11**	**2**	**6**	**5**	**0**	**8**	**9**	**15**	**8**	**8**	**16**	**14**	**8**

Site Codes: C11 = Tributary C, Location 1, Site 1, Rep. 1, etc.

Appendix 4. Spring 2018 Quantitative Sampling of Stream Sites - Macroinvertebrate Taxa and Abundance

	Tributary C / Eastern Tributary																	
Taxa	**C11-1**	**C11-2**	**C11-3**	**C12-1**	**C12-2**	**C12-3**	**C21-1**	**C21-2**	**C21-3**	**C22-1**	**C22-2**	**C22-3**	**C41-1**	**C41-2**	**C41-3**	**C42-1**	**C42-2**	**C42-3**
Aeshnidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acariformes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Athericidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Atyidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Austrocorduliidae (*Austrocordulia refracta*)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Caenidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Ceinidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ceratopogonidae	0	0	0	0	1	0	0	0	1	1	1	0	0	0	0	0	0	0
Chironomidae	2	0	0	0	1	11	5	0	1	0	1	2	3	3	2	2	3	4
Coenagrionidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cordulephyidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Corixidae	0	0	0	0	0	0	0	0	0	0	1	7	0	0	0	0	0	0
Culicidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dixidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dugesiidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dytiscidae	0	0	0	2	0	8	1	0	4	5	0	4	4	1	3	0	0	0
Elmidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gerridae	0	0	0	0	0	0	0	0	0	1	3	4	0	0	0	0	0	0
Gomphidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gripopterygidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gyrinidae	0	0	0	0	0	0	0	1	0	0	0	1	0	1	0	1	1	0
Hemicorduliidae	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Hydrometridae	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Hydrophilidae	0	0	0	0	0	0	1	0	0	0	0	1	1	0	0	0	0	1
Hydroptilidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Leptoceridae	0	0	0	0	0	0	0	0	0	0	1	2	0	0	0	0	0	0
Leptophlebiidae	1	0	1	0	0	0	0	0	0	1	0	8	0	0	0	0	0	2
Libellulidae	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
cf Lumbriculidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Megapodagrionidae	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Mesoveliidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	3
Notonectidae	0	0	1	0	0	0	0	0	0	3	2	4	0	0	1	0	0	0
Pleidae	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0
Pyralidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Scirtidae	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sphaeriidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Synlestidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Synthemistidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tipulidae	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Veliidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2
Total Macroinvertebrates	**3**	**1**	**2**	**2**	**3**	**21**	**7**	**1**	**6**	**14**	**9**	**33**	**8**	**6**	**7**	**8**	**4**	**12**
Number of Taxa	**2**	**1**	**2**	**1**	**3**	**4**	**3**	**1**	**3**	**8**	**6**	**9**	**3**	**4**	**4**	**4**	**2**	**5**

Site Codes: C11-1 = Tributary C, Location 1, Site 1, Rep. 1, etc.

Appendix 4. Spring 2018 Quantitative Sampling of Stream Sites - Macroinvertebrate Taxa and Abundance

	Tributary B						Bee Creek						WoronoraTributary					
Taxa	**B21-1**	**B21-2**	**B21-3**	**B22-1**	**B22-2**	**B22-3**	**BC1-1**	**BC1-2**	**BC1-3**	**BC2-1**	**BC2-2**	**BC2-3**	**WOT1-1**	**WOT1-2**	**WOT1-3**	**WOT2-1**	**WOT2-2**	**WOT2-3**
Aeshnidae	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acariformes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Athericidae	0	0	1	0	0	0	0	0	0	0	0	0	1	11	20	1	1	2
Atyidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Austrocorduliidae (*Austrocordulia refracta*)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Caenidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ceinidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ceratopogonidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chironomidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coenagrionidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0
Cordulephyidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Corixidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Culicidae	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dixidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Dugesiidae	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0
Dytiscidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Elmidae	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0
Gerridae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gomphidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gripopterygidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gyrinidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hemicorduliidae	0	1	4	0	11	0	0	5	4	0	4	1	0	0	0	0	0	0
Hydrometridae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydrophilidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydroptilidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Leptoceridae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Leptophlebiidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Libellulidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
cf Lumbriculidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Megapodagrionidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mesoveliidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Notonectidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pleidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pyralidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Scirtidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sphaeriidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Synlestidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Synthemistidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tipulidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Veliidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Macroinvertebrates	**1**	**2**	**5**	**0**	**11**	**0**	**0**	**12**	**4**	**0**	**4**	**1**	**1**	**11**	**21**	**5**	**1**	**2**
Number of Taxa	**1**	**2**	**2**	**0**	**1**	**0**	**0**	**3**	**1**	**0**	**1**	**1**	**1**	**1**	**2**	**2**	**1**	**1**

Site Codes: C11-1 = Tributary C, Location 1, Site 1, Rep. 1, etc.

Appendix 4. Spring 2018 Quantitative Sampling of Stream Sites - Macroinvertebrate Taxa and Abundance

	Woronora River 1						O'Hares Creek					
Taxa	**WR11-1**	**WR11-2**	**WR11-3**	**WR12-1**	**WR12-2**	**WR12-3**	**OC1-1**	**OC1-2**	**OC1-3**	**OC2-1**	**OC2-2**	**OC2-3**
Aeshnidae	0	0	0	0	0	0	0	0	0	0	0	0
Acariformes	0	0	0	0	1	0	2	1	0	2	0	2
Athericidae	0	0	0	0	0	0	0	0	0	0	0	0
Atyidae	21	15	17	18	33	11	2	1	12	1	3	0
Austrocorduliidae (*Austrocordulia refracta*)	0	0	0	0	0	0	0	0	3	0	0	0
Caenidae	0	0	0	0	0	0	0	1	0	0	0	1
Ceinidae	0	0	0	0	0	0	0	31	1	0	0	0
Ceratopogonidae	1	0	0	1	0	0	0	1	0	0	0	1
Chironomidae	1	2	1	1	0	0	1	18	6	9	4	10
Coenagrionidae	0	0	0	0	0	0	0	0	0	0	0	0
Cordulephyidae	0	0	0	0	0	0	0	0	0	4	0	0
Corixidae	0	1	0	3	0	0	0	0	0	0	1	1
Culicidae	0	0	0	0	0	0	0	0	0	0	0	0
Dixidae	0	0	0	0	0	0	0	2	1	0	0	0
Dugesiidae	0	0	0	0	0	0	0	1	0	1	0	0
Dytiscidae	1	0	0	0	1	0	7	4	0	10	9	8
Elmidae	4	0	0	0	1	0	6	1	1	1	0	4
Gerridae	0	1	1	2	0	0	2	1	1	7	2	2
Gomphidae	0	0	2	0	0	0	3	0	0	0	1	1
Gripopterygidae	1	1	0	1	0	2	0	0	0	0	0	0
Gyrinidae	1	2	0	2	0	1	0	0	0	0	0	0
Hemicorduliidae	0	0	0	0	0	0	0	0	0	0	0	0
Hydrometridae	0	0	0	0	0	0	0	0	0	0	0	0
Hydrophilidae	0	0	0	0	0	0	3	3	0	0	3	1
Hydroptilidae	0	0	1	0	0	0	0	0	0	0	0	1
Leptoceridae	1	3	5	8	6	7	1	1	1	0	0	0
Leptophlebiidae	18	5	15	1	1	1	3	2	29	4	3	4
Libellulidae	0	0	0	0	0	0	0	0	0	0	3	0
cf Lumbriculidae	0	0	0	0	0	0	0	0	0	0	1	0
Megapodagrionidae	0	0	0	0	0	0	0	0	0	0	2	0
Mesoveliidae	0	11	13	6	0	3	0	0	0	0	0	0
Notonectidae	3	1	1	8	10	3	0	0	0	8	4	4
Pleidae	0	0	0	0	0	0	0	0	0	0	0	0
Pyralidae	0	0	2	1	3	1	0	0	0	0	0	0
Scirtidae	0	0	0	1	1	2	0	0	0	0	0	0
Sphaeriidae	0	0	0	0	0	0	0	0	0	0	1	0
Synlestidae	0	0	0	0	0	0	1	0	0	0	0	0
Synthemistidae	0	0	1	0	0	0	0	0	0	0	0	0
Tipulidae	0	0	0	0	0	1	0	0	0	0	0	0
Veliidae	2	3	1	0	0	1	0	0	0	0	0	2
Total Macroinvertebrates	**54**	**45**	**60**	**53**	**57**	**33**	**31**	**68**	**55**	**47**	**37**	**42**
Number of Taxa	**11**	**11**	**12**	**13**	**9**	**11**	**11**	**14**	**9**	**10**	**13**	**14**

Site Codes: C11-1 = Tributary C, Location 1, Site 1, Rep. 1, etc.

Appendix 5. Spring 2018 Quantitative Sampling of Stream Sites - Water Quality

	Tributary C/Eastern Tributary																	
Taxa	**C11-1**	**C11-2**	**C11-3**	**C12-1**	**C12-2**	**C12-3**	**C21-1**	**C21-2**	**C21-3**	**C22-1**	**C22-2**	**C22-3**	**C41-1**	**C41-2**	**C41-3**	**C42-1**	**C42-2**	**C42-3**
Temperature (°C)	19.2	19.07	19.06	24.62	24.66	24.6	19.13	19.12	19.08	17	16.85	16.85	15.87	15.89	15.89	17.45	17.5	17.5
pH	6.94	6.9	6.88	6.96	6.98	6.99	6.66	6.67	6.68	7.02	7.03	7.03	7.11	7.1	7.1	6.78	6.77	6.77
Conductivity (µs/cm)	146	146	146	151	151	151	212	212	212	232	232	232	197	197	197	205	200	200
Dissolved Oxygen (%Sat)	78.1	76.7	75.6	94.3	96.9	98	59.9	59.7	59.2	49.9	48.2	47.6	76.5	76.1	65.8	36.4	38.1	38.2
Turbidity (NTU)	38.6	37.4	36.8	19.3	19.7	20.3	58.3	57.5	57.1	63.2	62.8	62.4	57.9	56.3	57.3	54.9	54.3	53.4
REDOX (mv)	492	494	494	505	504	503	665	665	635	609	605	603	617	618	618	516	513	513
Alkalinity (mg/L)	18	N/R	N/R	18	N/R	N/R	17	N/R	N/R	25	N/R	N/R	25	N/R	N/R	25	N/R	N/R
Total Phosphorous (mg/L)	<0.02	<0.02	N/R	<0.02	<0.02	N/R	<0.02	<0.02	N/R	<0.02	<0.02	N/R	<0.02	<0.02	N/R	<0.02	<0.02	N/R
Total Nitrogen (mg/L)	0.09	0.17	N/R	0.11	0.05	N/R	<0.05	<0.05	N/R	<0.05	<0.05	N/R	0.06	<0.05	N/R	0.06	<0.05	N/R

N/R = Not recorded

	Tributary B - Location 2						Bee Creek						Woronora Tributary					
Taxa	**B21-1**	**B21-2**	**B21-3**	**B22-1**	**B22-2**	**B22-3**	**BC1-1**	**BC1-2**	**BC1-3**	**BC2-1**	**BC2-2**	**BC2-3**	**WOT1-1**	**WOT1-2**	**WOT1-3**	**WOT2-1**	**WOT2-2**	**WOT2-3**
Temperature (°C)	16.57	16.45	16.41	18.41	18.46	18.45	15.04	15.04	15.04	15.54	15.39	15.39	17.22	17.23	17.23	14.62	14.61	14.6
pH	6.62	6.61	6.6	7.27	7.26	7.26	4.98	4.97	4.97	5.63	5.61	5.6	5.86	5.85	5.85	5.97	5.96	5.95
Conductivity (µs/cm)	433	434	435	416	415	416	230	230	230	204	204	204	93	93	93	104	104	104
Dissolved Oxygen (%Sat)	42.8	42.2	42.2	79.6	79.1	79.1	9.5	13.6	13.7	40.3	40.2	40.2	68.3	68.1	67.5	45.9	45.5	45.3
Turbidity (NTU)	35.9	35.1	34.9	10.3	10.3	10.2	5.3	4.6	4.4	9.4	8.9	8.7	68.4	70.2	71.2	67.4	67.4	67.4
REDOX (mv)	575	574	573	577	573	572	531	531	532	531	534	537	624	625	626	600	601	603
Alkalinity (mg/L)	60	N/R	N/R	65	N/R	N/R	5	N/R	N/R	5	N/R	N/R	0	N/R	N/R	0	N/R	N/R
Total Phosphorous (mg/L)	<0.02	<0.02	N/R	24.00	<0.02	N/R	<0.02	30	N/R	<0.02	<0.02	N/R	<0.02	<0.02	N/R	<0.02	<0.02	N/R
Total Nitrogen (mg/L)	0.14	0.06	N/R	0.08	0.1	N/R	0.36	0.44	N/R	0.09	0.11	N/R	0.25	0.23	N/R	0.4	0.27	N/R

N/R = Not recorded

	Woronora River 1						O'Hares Creek					
Taxa	**WR11-1**	**WR11-2**	**WR11-3**	**WR12-1**	**WR12-2**	**WR12-3**	**OC1-1**	**OC1-2**	**OC1-3**	**OC2-1**	**OC2-2**	**OC2-3**
Temperature (°C)	17.1	17.1	17.1	18.41	18.43	18.47	22.38	22.36	22.36	24.6	24.6	24.6
pH	6.95	6.95	6.94	6.75	6.74	6.73	6.71	6.67	6.65	7.02	7	6.99
Conductivity (µs/cm)	123	127	127	119	119	119	108	108	108	114	114	114
Dissolved Oxygen (%Sat)	55.7	55.5	55.4	64.1	63.4	63.3	97.5	97.1	96.9	102.5	102.3	102.1
Turbidity (NTU)	68.0	68.0	68.0	70.8	70.6	70.8	22	21.8	21.7	23.0	23.0	22.8
REDOX (mv)	662	662	662	667	667	667	597	598	598	575	575	575
Alkalinity (mg/L)	5	N/R	N/R	5	N/R	N/R	5	N/R	N/R	5	N/R	N/R
Total Phosphorous (mg/L)	24	<0.02	N/R	<0.02	<0.02	N/R	<0.02	<0.02	N/R	<0.02	<0.02	N/R
Total Nitrogen (mg/L)	0.22	0.16	N/R	0.15	0.14	N/R	0.18	0.16	N/R	0.19	0.26	N/R

N/R = Not recorded

Site Codes: C11-1 = Tributary C, Location 1, Site 1, etc.

Appendix 6a. Spring 2018 Estimated Cover of Aquatic Macrophytes at Large Pool Sites

	Tributary C - Pool		Woronora Pool		O'Hares Creek Pool	
Species	**ETAH1**	**ETAH2**	**WP1**	**WP2**	**OC1**	**OC2**
Baumea juncea	2	0	0	0	0	0
Baumea rubiginosa	0	1	2	1	0	0
Baumea teretifolia	0	0	0	0	3	2
Centrolepis fascicularis	0	0	1	1	0	0
Chara/Nitella spp.	0	0	0	0	2	3
Chorizandra cymbaria	0	0	2	1	0	0
Dicksonia antarctica	0	0	0	0	0	1
Drosera binata	0	0	0	0	1	1
Drosera spatulata	0	0	1	1	0	0
Empodisma minus	2	0	0	1	2	2
Eurychorda complanata	0	0	3	0	0	0
Gahnia clarkei	0	0	1	0	1	2
Gleichenia dicarpa	1	1	2	3	3	3
Glossostigma sp.	0	0	1	1	0	0
*Isolepis prolifera**	0	0	0	0	1	0
Lepidosperma filiforme	2	2	0	3	2	2
Lomandra longifolia	1	2	1	0	0	0
Myriophyllum pedunculatum	0	0	3	1	0	0
Sticherus flabellatus	0	0	0	0	2	2
Triglochin procerum	0	0	3	3	2	2
Viminaria juncea	2	2	0	0	2	2

Site Codes: ETAH1 = Pool ETAH, Site 1, etc.

Appendix 6b. Spring 2018 Percentage Cover of Aquatic Macrophyte Species at Large Pool Sites (0.25 m2 quadrats)

	Pool ETAH on Eastern Tributary/Tributary C										Pool WP on Woronora River									
Species	**ETAH1-1**	**ETAH1-2**	**ETAH1-3**	**ETAH1-4**	**ETAH1-5**	**ETAH2-1**	**ETAH2-2**	**ETAH2-3**	**ETAH2-4**	**ETAH2-5**	**WP1-1**	**WP1-2**	**WP1-3**	**WP1-4**	**WP1-5**	**WP2-1**	**WP2-2**	**WP2-3**	**WP2-4**	**WP2-5**
Baumea juncea	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Baumea rubiginosa	0	0	0	0	0	2	0	0	0	0	0	0	0	15	0	3	0	0	0	0
Baumea teretifolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Centrolepis fascicularis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0
Chara/Nitella spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chorizandra cymbaria	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0
Empodisma minus	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0
Eurychorda complanata	0	0	0	0	0	0	0	0	0	0	10	5	0	0	70	0	0	0	0	0
Gleichenia dicarpa	0	0	0	0	0	0	0	0	0	0	10	75	0	5	0	0	0	40	0	60
Glossosstigma sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
Lepidosperma filiforme	0	0	10	20	0	0	10	0	8	0	0	0	0	0	0	0	10	0	0	0
Lomandra longifolia	0	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Myriophyllum pedunculatum	0	0	0	0	0	0	0	0	0	0	0	0	95	0	20	20	0	0	0	0
Sticherus flabellatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Triglochin procerum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0
Viminaria juncea	0	15	0	0	0	10	0	5	5	0	0	0	0	0	0	0	0	0	0	0

	Pool OC on O'Hares Creek									
Species	**OP1-1**	**OP1-2**	**OP1-3**	**OP1-4**	**OP1-5**	**OP2-1**	**OP2-2**	**OP2-3**	**OP2-4**	**OP2-5**
Baumea juncea	0	0	0	0	0	0	0	0	0	0
Baumea rubiginosa	0	0	0	0	0	0	0	0	0	0
Baumea teretifolia	0	2	0	15	45	0	0	0	15	0
Centrolepis fascicularis	0	0	0	0	0	0	0	0	0	0
Chara/Nitella spp.	0	0	0	0	0	0	0	0	0	35
Chorizandra cymbaria	0	0	0	0	0	0	0	0	0	0
Empodisma minus	0	2	0	0	0	0	20	0	0	0
Eurychorda complanata	0	0	0	0	0	0	0	0	0	0
Gleichenia dicarpa	0	80	95	80	45	55	35	20	20	0
Glossosstigma sp.	0	0	0	0	0	0	0	0	0	0
Lepidosperma filiforme	0	0	0	0	0	5	0	5	0	0
Lomandra longifolia	0	0	0	0	0	0	0	0	0	0
Myriophyllum pedunculatum	0	0	0	0	0	0	0	0	0	0
Sticherus flabellatus	75	0	0	0	0	0	0	70	0	0
Triglochin procerum	0	0	0	0	0	0	0	0	0	55
Viminaria juncea	0	0	0	0	0	0	0	0	55	0

Site Codes: ETAH1-1 = Pool ETAH, Site 1, Replicate 1, etc.

Appendix 7. Spring 2018 Quantitative Sampling of Large Pools - Macroinvertebrate Taxa and Abundance

	Pool ETAH on Tributary C						Pool WP on Woronora River						Pool OC on O'Hares Creek					
Taxa	**ETAH1-1**	**ETAH1-2**	**ETAH1-3**	**ETAH2-1**	**ETAH2-2**	**ETAH2-3**	**WP1-1**	**WP1-2**	**WP1-3**	**WP2-1**	**WP2-2**	**WP2-3**	**OP1-1**	**OP1-2**	**OP1-3**	**OP2-1**	**OP2-2**	**OP2-3**
Aeshnidae	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Acariformes	0	0	0	0	0	0	0	0	1	0	1	0	0	0	2	2	1	0
Atyidae	0	0	0	0	0	0	16	16	33	18	33	11	0	1	3	2	1	12
Austrocorduliidae (*Austrocordulia ref*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Caenidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0
Ceinidae	0	0	0	0	0	0	0	0	0	0	0	0	5	1	0	0	31	1
Ceratopogonidae (L.)	0	0	0	0	0	0	1	1	0	1	0	0	0	1	0	0	1	0
Chironomidae	12	4	0	0	0	0	0	1	5	1	0	0	0	1	1	1	18	6
Corixidae	1	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0
Dixidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1
Dugesiidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Dytiscidae (A. & L.)	9	4	0	0	0	0	1	0	2	0	1	0	1	2	6	7	4	0
Elmidae (A. & L.)	0	0	0	0	0	0	0	1	1	0	1	0	0	4	4	6	1	1
Gerridae	0	0	0	0	0	0	0	0	0	2	0	0	5	0	0	2	1	1
Gomphidae	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	3	0	0
Gripopterygidae	0	0	0	0	0	0	0	0	1	1	0	2	0	0	0	0	0	0
Gyrinidae (A. & L.)	0	0	0	0	0	0	0	4	0	2	0	1	0	0	0	0	0	0
Hydrophilidae (A.)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3	0
Leptoceridae	0	0	0	0	0	0	4	1	16	8	6	7	0	0	1	1	1	1
Leptophlebiidae	1	1	0	0	0	0	3	0	9	1	1	1	0	1	9	3	2	29
Libellulidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Mesovelliidae	0	0	0	0	0	0	5	1	0	6	0	3	0	0	0	0	0	0
Nepidae	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Notonectidae	0	0	0	0	0	0	9	2	3	8	10	3	2	3	4	0	0	0
Pleidae	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Pyralidae	0	0	0	0	0	0	0	2	1	1	3	1	0	0	0	0	0	0
Scirtidae (A. & L.)	1	0	0	0	0	0	0	0	0	1	1	2	0	0	0	0	0	0
Synlestidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Synthemistidae	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0
Tipulidae	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Veliidae	0	0	0	0	0	0	1	1	1	0	0	1	0	0	1	0	0	0
Unknown larvae (cf Coleoptra)	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Macroinvertebrates	**24**	**10**	**0**	**0**	**0**	**0**	**40**	**32**	**76**	**53**	**57**	**33**	**14**	**14**	**34**	**31**	**68**	**55**
Total Taxa	**5**	**4**	**0**	**0**	**0**	**0**	**8**	**12**	**13**	**13**	**9**	**11**	**5**	**8**	**12**	**11**	**14**	**9**

Site Codes: ETAH-1 = Pool ETAH, Site 1, Replicate 1, etc.

Appendix 8. Spring 2018 Quantitative Sampling of Large Pools - Water Quality

	Pool ETAH on Tributary C/Eastern Tributary						Pool WP on Woronora River					
Taxa	**ETAH1-1**	**ETAH1-2**	**ETAH1-3**	**ETAH2-1**	**ETAH2-2**	**ETAH2-3**	**WP1-1**	**WP1-2**	**WP1-3**	**WP2-1**	**WP2-2**	**WP2-3**
Temperature (°C)	18.14	18.14	18.13	17.78	17.78	17.78	17.7	17.7	17.0	18.4	18.4	18.5
pH	4.52	4.51	4.5	4.65	4.65	4.65	6.76	6.76	6.75	6.75	6.74	6.73
Conductivity (µs/cm)	250	250	250	237	237	242	121	121	121	119	119	119
Dissolved Oxygen (%Sat)	58	50.1	47.7	57.6	54	52.5	62.2	62	62.1	64.1	63.4	63.3
Turbidity (NTU)	57.5	57.1	56.9	59	59.2	59	69.2	69.0	68.6	70.8	70.6	70.8
REDOX (mv)	699	697	696	703	703	702	670	670	669	667	667	667

	Pool OC on O'Hares Creek					
Taxa	**OC1-1**	**OC1-2**	**OC1-3**	**OC2-1**	**OC2-2**	**OC2-3**
Temperature (°C)	22.38	22.36	22.36	22.06	22.01	22.03
pH	6.71	6.67	6.65	6.57	6.49	6.44
Conductivity (µs/cm)	108	108	108	109	109	109
Dissolved Oxygen (%Sat)	97.5	97.1	96.9	94.7	93.3	92.7
Turbidity (NTU)	22	21.8	21.7	25.4	24.1	23.8
REDOX (mv)	597	598	598	610	618	618

Site Codes: ETAH1-1 = Pool ETAH, Site 1, Replicate 1, etc.

Appendix 9a. Spring 2018 Estimated Cover of Aquatic Macrophytes at Small Pool Sites.

	Tributary C/Eastern Tributary			Woronora River			O'Hares Creek		
Species	**ETAG**	**ETAI**	**ETAK**	**WPA**	**WPB**	**WPC**	**OCA**	**OCB**	**OCC**
Baumea juncea	2	2	0	0	0	0	0	0	0
Baumea rubiginosa	0	1	0	1	0	0	0	0	0
Baumea teretifolia	0	0	0	0	0	0	0	1	0
Centrolepis fascicularis	0	0	0	1	1	0	0	1	0
Chara/Nitella spp.	0	0	0	0	1	0	1	1	2
Chorizandra cymbaria	1	0	0	1	1	0	0	1	0
Dicksonia	0	0	0	0	0	0	1	0	0
Drosera spatulata	0	0	0	1	1	0	1	0	0
Empodisma minus	2	1	0	0	1	1	3	3	2
Eurychorda complanata	0	0	0	1	3	0	1	0	2
Gahnia clarkei	0	0	0	1	0	0	1	1	2
Gleichenia dicarpa	1	0	0	3	1	1	2	3	3
Glossostigma sp.	0	0	0	1	0	0	1	0	0
Isolepis inundata	0	0	0	0	0	0	0	0	1
Juncus planifolius	0	0	0	2	2	0	0	0	1
Lepidosperma filiforme	1	0	3	2	2	2	2	2	2
Leptocarpus tenax	0	1	0	0	0	0	0	0	0
Lomandra fluviatilis	3	2	0	0	2	2	3	2	3
Lomandra longifolia	1	0	1	0	0	0	1	1	1
Myriophyllum pedunculatum	0	0	0	1	1	0	0	0	0
Sticherus flabellatus	0	0	0	1	2	1	1	1	0
Triglochin procerum	0	0	0	3	3	1	0	0	0
Viminaria juncea	1	2	1	0	0	0	0	0	2

* Denotes introdued species

Site Codes: ETAG = Pool ETAG, etc.

Appendix 9b. Spring 2018 Percentage Cover of Aquatic Macrophyte Species at Small Pool Sites (0.25 m2 quadrats)

	Pool ETAG on Tributary C					Pool ETAI on Tributary C					Pool ETAK on Tributary C				
Species	**ETAG-1**	**ETAG-2**	**ETAG-3**	**ETAG-4**	**ETAG-5**	**ETAI-1**	**ETAI-2**	**ETAI-3**	**ETAI-4**	**ETAI-5**	**ETAK-1**	**ETAK-2**	**ETAK-3**	**ETAK-4**	**ETAK-5**
Baumea juncea	20	0	0	0	70	0	60	0	0	0	0	0	0	0	0
Baumea rubiginosa	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
Baumea teretifolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Centrolepis fascicularis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chorizandra cymbaria	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0
Empodisma minus	0	0	8	0	0	0	0	0	5	0	0	0	0	0	0
Eurychorda complanata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gahnia clarkei	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gleichenia dicarpa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Juncus planifolius	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lepidosperma filiforme	0	5	0	0	0	0	0	0	0	0	15	15	10	5	4
Lomandra fluviatilis	0	0	0	0	0	0	0	75	0	0	0	0	0	0	0
Lomandra longifolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Sticherus flabellatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Triglochin procerum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Viminaria juncea	0	0	0	0	0	0	0	10	0	0	0	0	2	0	0

* Denotes introdued species

Site Codes: ETAG1 = Pool ETAG, Replicate 1, etc.

Appendix 9b. Spring 2018 Percentage Cover of Aquatic Macrophyte Species at Small Pool Sites (0.25 m2 quadrats)

	Pool A on Woronora River					Pool B on Woronora River					Pool C on Woronora River				
Species	**WPA-1**	**WPA-2**	**WPA-3**	**WPA-4**	**WPA-5**	**WPB-1**	**WPB-2**	**WPB-3**	**WPB-4**	**WPB-5**	**WPC-1**	**WPC-2**	**WPC-3**	**WPC-4**	**WPC-5**
Baumea juncea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Baumea rubiginosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Baumea teretifolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Centrolepis fascicularis	0	0	2	0	0	0	0	55	0	0	0	0	0	0	0
Chorizandra cymbaria	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Empodisma minus	0	0	0	0	0	0	0	0	4	0	10	0	0	0	0
Eurychorda complanata	40	0	0	0	0	0	25	0	4	60	0	0	0	0	0
Gahnia clarkei	0	0	0	0	40	0	0	0	0	0	0	0	0	0	0
Gleichenia dicarpa	0	60	0	60	15	0	10	0	0	0	5	0	10	0	0
Juncus planifolius	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0
Lepidosperma filiforme	15	0	0	0	15	0	0	0	0	0	0	0	40	0	0
Lomandra fluviatilis	0	0	0	0	0	0	0	0	60	0	0	40	10	80	60
Lomandra longifolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sticherus flabellatus	0	0	0	0	0	0	40	0	0	0	0	0	0	0	0
Triglochin procerum	0	0	25	0	0	0	0	8	0	0	0	0	0	0	0
Viminaria juncea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

* Denotes introdued species

Site Codes: ETAG1 = Pool ETAG, Replicate 1, etc.

Appendix 9b. Spring 2018 Percentage Cover of Aquatic Macrophyte Species at Small Pool Sites (0.25 m2 quadrats)

	Pool A on O'Hares Creek					Pool B on O'Hares Creek					Pool C on O'Hares Creek				
Species	**OCA-1**	**OCA-2**	**OCA-3**	**OCA-4**	**OCA-5**	**OCB-1**	**OCB-2**	**OCB-3**	**OCB-4**	**OCB-5**	**OCC-1**	**OCC-2**	**OCC-3**	**OCC-4**	**OCC-5**
Baumea juncea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Baumea rubiginosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Baumea teretifolia	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0
Centrolepis fascicularis	0	0	0	0	0	0	0	12	0	0	0	0	0	0	0
Chorizandra cymbaria	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0
Empodisma minus	95	0	0	50	25	50	0	25	40	2	5	40	0	0	0
Eurychorda complanata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30
Gahnia clarkei	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10
Gleichenia dicarpa	0	0	0	15	30	25	20	0	0	10	95	0	0	70	35
Juncus planifolius	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lepidosperma filiforme	0	0	0	0	10	0	0	25	0	20	0	0	0	5	0
Lomandra fluviatilis	0	95	55	0	0	0	25	0	0	0	0	20	90	0	0
Lomandra longifolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sticherus flabellatus	0	0	15	0	0	0	0	0	0	0	0	0	0	0	0
Triglochin procerum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Viminaria juncea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

* Denotes introdued species

Site Codes: ETAG1 = Pool ETAG, Replicate 1, etc.

Appendix 10. Spring 2018 Quantitative Sampling of Small Pools - Macroinvertebrate Taxa and Abundance

	Pool ETAG on Tributary C			Pool ETAI on Tributary C			Pool ETAK on Tributary C			Pool A on Woronora River			Pool B on Woronora River			Pool B on Woronora River		
Taxa	**ETAG-1**	**ETAG-2**	**ETAG-3**	**ETAI-1**	**ETAI-2**	**ETAI-3**	**ETAK-1**	**ETAK-2**	**ETAK-3**	**WPA1-1**	**WPA1-2**	**WPA1-3**	**WPB1-1**	**WPB1-2**	**WPB1-3**	**WPC1-1**	**WPC1-2**	**WPC1-3**
Acariformes	0	0	0	0	0	0	0	0	0	1	1	0	0	0	3	4	0	0
Aeshnidae	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Atyidae	0	0	0	0	0	0	0	0	0	0	22	1	60	27	31	0	0	0
Austrocorduliidae (*Austrocord*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Baetidae	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Caenidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Calamoceratidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ceratopogonidae	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Chironomidae	5	1	2	0	0	0	0	0	0	1	2	2	0	0	3	1	0	0
Cordulephyidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Corixidae	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Dixidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dytiscidae	3	4	6	0	0	0	0	0	0	0	1	1	0	0	0	9	0	0
Ecnomidae	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Elmidae	0	0	0	0	0	0	0	0	0	0	1	0	8	1	10	0	0	0
Gelastocoridae	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gerridae	0	0	0	0	0	0	0	0	0	1	1	0	5	0	3	0	0	0
Gomphidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gripopterygidae	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0
Gyrinidae	2	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
Hydrometridae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Hydrophilidae	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Hydroptilidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Leptoceridae	0	0	0	0	0	0	0	0	0	0	1	0	3	4	2	2	0	0
Leptophlebiidae	0	0	1	0	0	0	0	0	0	9	7	3	0	0	3	23	0	0
Megapodagrionidae	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Mesovellidae	0	0	0	0	0	0	0	0	0	0	1	0	2	0	1	0	0	0
Notonectidae	2	0	1	0	0	0	0	0	0	0	2	1	5	3	12	2	0	0
Pleidae	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Psephenidae	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0
Pyralidae	0	0	0	0	0	0	0	0	0	0	2	1	2	0	0	0	0	0
Synlestidae	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Synthemistidae	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0
Telephlebiidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tipulidae	0	1	0	0	0	0	0	0	0	0	0	0	1	3	1	0	0	0
Veliidae	0	0	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0
Unidentified Anisoptera	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Macroinvertebrates	**13**	**6**	**13**	**0**	**0**	**0**	**0**	**0**	**0**	**13**	**46**	**13**	**88**	**45**	**72**	**41**	**0**	**0**
Total Taxa	**5**	**3**	**7**	**0**	**0**	**0**	**0**	**0**	**0**	**5**	**15**	**9**	**9**	**9**	**13**	**6**	**0**	**0**

Site Codes: ETAG1-1 = Pool ETAG, Replicate 1, etc.

Appendix 10. Spring 2018 Quantitative Sampling of Small Pools - Macroinvertebrate Taxa and Abundance

	Pool A on O'Hares Creek			Pool B on O'Hares Creek			Pool C on O'Hares Creek		
Taxa	**OPA1-1**	**OPA1-2**	**OPA1-3**	**OPB1-1**	**OPB1-2**	**OPB1-3**	**OPC1-1**	**OPC1-2**	**OPC1-3**
Acariformes	1	1	0	0	0	1	1	1	0
Aeshnidae	0	0	0	0	0	0	0	0	0
Atyidae	2	5	0	3	2	1	0	9	0
Austrocorduliidae (*Austrocord*	0	0	0	0	0	0	0	1	0
Baetidae	0	0	1	0	0	0	0	0	0
Caenidae	1	0	2	0	0	0	0	0	0
Calamoceratidae	0	1	0	1	0	1	0	0	0
Ceratopogonidae	0	0	0	0	0	1	0	2	0
Chironomidae	2	6	3	2	0	9	1	11	1
Cordulephyidae	0	0	1	0	0	0	0	2	0
Corixidae	0	0	0	0	0	0	0	0	0
Dixidae	0	0	1	0	0	0	0	0	0
Dytiscidae	2	4	5	0	3	0	1	1	0
Ecnomidae	0	0	0	1	0	0	0	0	0
Elmidae	2	0	0	2	0	0	0	7	4
Gelastocoridae	0	0	0	0	0	0	0	0	0
Gerridae	3	0	0	0	1	1	0	0	0
Gomphidae	1	2	0	3	0	0	0	8	0
Gripopterygidae	0	0	0	0	0	0	0	0	0
Gyrinidae	3	0	0	0	0	0	0	0	0
Hydrometridae	0	0	0	0	0	0	0	0	0
Hydrophilidae	0	1	1	1	2	0	0	0	0
Hydroptilidae	4	3	3	3	0	0	0	1	0
Leptoceridae	1	4	0	2	0	1	0	1	0
Leptophlebiidae	1	8	1	2	0	4	1	30	0
Megapodagrionidae	0	0	0	0	0	0	0	0	0
Mesovellidae	0	0	0	0	0	0	0	0	0
Notonectidae	0	1	3	0	0	2	0	2	0
Pleidae	0	0	0	0	0	0	0	0	0
Psephenidae	0	0	0	0	0	0	0	0	0
Pyralidae	0	0	0	0	0	0	0	0	0
Synlestidae	0	0	0	0	0	0	0	0	0
Synthemistidae	0	0	0	1	0	0	0	0	0
Telephlebiidae	0	0	0	1	0	0	0	1	0
Tipulidae	0	0	0	0	0	0	0	0	0
Veliidae	0	0	1	1	0	0	0	0	0
Unidentified Anisoptera	0	0	0	0	0	0	0	1	0
Total Macroinvertebrates	**23**	**36**	**22**	**23**	**8**	**21**	**4**	**78**	**5**
Total Taxa	**12**	**11**	**11**	**13**	**4**	**9**	**4**	**14**	**2**

Site Codes: ETAG1-1 = Pool ETAG, Replicate 1, etc.

Appendix 11. Spring 2018 Quantitative Sampling of Small Pools - Water Quality

	Pool ETAG on Tributary C			Pool ETAI on Tributary C			Pool ETAK on Tributary C			Pool A on Woronora River		
Taxa	**ETAG1-1**	**ETAG1-2**	**ETAG1-3**	**ETAI1-1**	**ETAI1-2**	**ETAI1-3**	**ETAK1-1**	**ETAK1-2**	**ETAK1-3**	**WPA1-1**	**WPA1-2**	**WPA1-3**
Temperature (°C)	16.57	16.58	16.58	I/A	I/A	I/A	I/A	I/A	I/A	16.79	16.79	16.82
pH	7.33	7.32	7.31	I/A	I/A	I/A	I/A	I/A	I/A	6.97	6.97	6.97
Conductivity (µs/cm)	174	174	174	I/A	I/A	I/A	I/A	I/A	I/A	128	128	128
Dissolved Oxygen (%Sat)	86.2	85.6	85.1	I/A	I/A	I/A	I/A	I/A	I/A	73.8	72.6	72.2
Turbidity (NTU)	54.4	50.9	50.9	I/A	I/A	I/A	I/A	I/A	I/A	69.4	69.4	69.2
REDOX (mv)	582	584	584	I/A	I/A	I/A	I/A	I/A	I/A	654	654	654

I/A: Insufficient Aquatic Habitat

	Pool B on Woronora River			Pool C on Woronora River			Pool A on O'Hares Creek			Pool B on O'Hares Creek		
Taxa	**WPB1-1**	**WPB1-2**	**WPB1-3**	**WPC1-1**	**WPC1-2**	**WPC1-3**	**OCA1-1**	**OCA1-2**	**OCA1-3**	**OCB1-1**	**OCB1-2**	**OCB1-3**
Temperature (°C)	17.67	18.22	18.46	17.31	17.34	17.29	24.85	24.86	24.86	24.17	24.17	24.16
pH	6.66	6.63	6.62	6.58	6.57	6.57	7.35	7.03	7.27	7.65	7.61	7.58
Conductivity (µs/cm)	116	113	114	122	122	122	113	113	113	115	110	115
Dissolved Oxygen (%Sat)	61.4	62.9	62.1	70.4	69.8	69.6	102.9	101.5	101.5	102.5	102.1	101.8
Turbidity (NTU)	73	69	69	66.4	66.2	66.6	19	19.2	18.7	23.3	23.5	23.5
REDOX (mv)	635	635	635	643	643	645	544	555	555	523	523	524

	Pool C on O'Hares Creek		
Taxa	**OCC1-1**	**OCC1-2**	**OCC1-3**
Temperature (°C)	23.11	23.11	23.09
pH	7.75	7.51	7.48
Conductivity (µs/cm)	112	112	112
Dissolved Oxygen (%Sat)	110.2	107.1	106.5
Turbidity (NTU)	24.1	24.1	24.1
REDOX (mv)	503	505	505

N/R = Not Recorded

Site Codes: ETAG = Pool ETAG, Site, Rep. 1, etc