# West Cliff Area 5

## Aquatic Ecology Monitoring 2002 to 2015

59916047

Prepared for
South32

26 May 2016

# Contact Information

**Cardno (NSW/ACT) Pty Ltd**
**Trading as Cardno Ecology Lab**

Level 9, The Forum
203 Pacific Highway
St Leonards NSW 2065

Telephone: 02 9496 7700
Facsimile: 02 9499 3902
International: +61 2 9496 7700
www.cardno.com.au

# Document Information

| | |
|---|---|
| Prepared for | South32 |
| Project Name | Aquatic Ecology Monitoring 2002 to 2015 |
| File Reference | 59916047_R003_Rev0_West Cliff Area 5 Aquatic Ecology 2015.docm |
| Job Reference | 59916047 |
| Date | 26 May 2016 |
| Version Number | Rev 0 |
| Effective Date | 26 May 2016 |
| Date Approved: | 26 May 2016 |

# Document History

| Version | Effective Date | Description of Revision | Prepared by: | Reviewed by: |
|---|---|---|---|---|
| Rev A | 07/04/2016 | Draft for Client Review | Dan Pygas | Dr Craig Blount |
| Rev 0 | 26/05/2016 | Final | Dan Pygas | Gary Brassington<br>Josh Carlon<br>(South 32) |

# Executive Summary

## Introduction and Methods

South32 has extracted coal from the Bulli Seam in Area 5 of West Cliff Colliery in the Southern Coalfield of New South Wales using longwall mining techniques.  The sequence of longwall extraction was as follows:

> Longwalls 31-33: July 2005 to September 2011;

> Longwall 34: February 2010 to September 2011;

> Longwall 35: October 2011 to July 2013;

> Longwall 36: August 2013 to May 2014;

> Longwall 37: April 2014 to February 2015; and

> Longwall 38: February 2015 to February 2016.

Cardno Ecology Lab was commissioned by South32 to design and implement a monitoring program to detect potential changes in aquatic ecology that may arise due to the impact of mining-related subsidence on the physical and chemical characteristics of sections of the Georges River.

The latest round of aquatic ecology monitoring, undertaken in November 2015, included further after-extraction monitoring for Longwalls 35 to 37 and the first year of monitoring after the commencement of extraction of Longwall 38.

The monitoring program focuses on three main indicators:

> Aquatic habitat, including fish habitat, aquatic macrophytes and riparian vegetation;

> Aquatic macroinvertebrates sampled in accordance with the Australian River Assessment System (AUSRIVAS); and

> Fish sampled using backpack electrofishing.

Limited *in situ* water quality sampling is undertaken to assist with interpretation of trends in the above indicators.

The results of this survey (November 2015) were compared with those obtained in May 2002, March 2005, November 2007, September 2008, May 2010, May 2012, December 2012, November 2013 and December 2014.

## Identified Mining Impacts and Assessment

Data collected during December 2014 and November 2015 suggested that impacts to indicators of aquatic ecology in some sections of the river, previously observed in November 2013 following physical mining impacts experienced in the Georges River extraction of Longwall 35, have recovered to some degree. Recovery is almost certainly a result of the restoration (at least temporarily) of pool water levels and flow in affected areas of the Georges River attributed to the additional releases of water from Brennans Creek Dam which were implemented as an ameliorative measure following extraction of Longwall 35.  These findings are supported by statistical analyses, which did not indicate the presence of any widespread impacts to indicators of aquatic ecology following the commencement of extraction of Longwall 35.

There is no evidence to suggest the extraction of Longwalls 36 to 38 has had any impact on aquatic ecology. This finding is not surprising considering that minor physical impacts and no significant impacts to water quality have resulted from extraction of these Longwalls.

The physical impacts of mining associated with extraction of Longwall 35 were first identified in February 2013, and included fracturing of bedrock, loss of water flow and reductions in pool water levels.  In November 2013, corresponding reductions in the number of macroinvertebrate taxa and the numbers of fish and large mobile invertebrates were observed at one of the two sites on the Georges River affected by subsidence and there was also evidence of a reduction in the OE50 Taxa Score (an AUSRIVAS biotic measure of aquatic habitat and water quality) at the other site.  Aquatic macrophytes became desiccated at both sites. These changes were attributed to subsidence caused by mining. As no changes to ecological indicators were evident at sites further downstream in November 2013, impacts due to extraction of Longwall 35 appear to have been localised to the areas affected by subsidence caused by mining. The re-establishment of pool water levels and flow following releases of water from Brennans Creek Dam in the second half of 2014 likely explains the observed increase (recovery) in the number of macroinvertebrate taxa and fish generally, and improvement in habitat quality, at the sites in December 2014. The observation, however, of some persistent reductions in pool water level and flow at one of these sites in November 2015 suggests that aquatic ecology is still affected by physical impacts associated with longwall extraction and that any natural remediation of fractures, pool water levels and flow may take some time.

Analysis of water quality and flow data collected by other consultants as part of End of Panel Reports for Longwalls 35 to 38 did not indicate any significant changes attributed to mining. Also, there was no conclusive evidence of impacts to water quality as a result of the mining in the data collected by Cardno Ecology Lab. This finding suggests that the impacts to aquatic indicators observed in November 2013 were due to the physical disturbance associated with extraction of Longwall 35, rather than any change in water quality.

### Recommendations

It is recommended that increased discharges from Brennans Creek Dam are maintained for as long as practicable whenever low pool water levels and flow are experienced in the Georges River. This will reduce any potential further impacts to aquatic biota associated with loss of habitat, flow and connectivity.

Due to the ongoing impact (low flow and pool water levels) observed at one site following extraction of Longwall 35, and to provide after-extraction monitoring for Longwall 38, it is recommended that monitoring be undertaken during the spring 2016 AUSRIVAS sampling season. This monitoring would provide the second and first year of after extraction data for Longwalls 37 and 38, respectively. Further monitoring in spring 2017 would provide at least two years of after extraction data for Longwalls 35 to 38. This would also provide longer-term information on the persistence and recovery of previously identified impacts to ecological indicators associated with the extraction of Longwall 35. This collection of additional post mining data would facilitate the assessment of the impact of the longwall extraction on the aquatic habitat and biota in the Georges River. It would also provide information that will help inform any future remediation efforts in the Georges River following the completion of mining in West Cliff Area 5. The ongoing aquatic ecology monitoring associated with Pollution Reduction Program 20 would provide information on the effect of mine water discharge from West Cliff Colliery on the Georges River.

Given that extraction of West Cliff Area 5 Longwalls has been completed, South32 is preparing a Georges River Remediation Plan for West Cliff Area 5 Longwalls 32 to 38. Remediation options may include repairing of rock fractures to minimise flow diversions and restore pool water level and flow to baseline levels. It is recommended that monitoring of aquatic ecology be done to provide information on the response of aquatic ecology indicators (habitat, macroinvertebrates and fish) to any remediation efforts, noting that remediation efforts may also potentially result in some negative impacts to aquatic ecology. Depending on the timing and extent of any remediation efforts, such sampling could be incorporated into any 2016 and 2017 ongoing monitoring. An increase in the level of replication effort (e.g. number of AUSRIVAS samples collected per site in each Survey) and / or incorporation of quantitative methods of sampling macroinvertebrates (e.g. artificial collector, suction and SURBER sampling) may be required for monitoring the rehabilitation program to provide additional certainty about conclusions made from the monitoring data.

# Table of Contents

# Appendices

# Tables

# Figures

# 1 Introduction

South32 has used longwall mining techniques to extract coal from the Bulli Seam in Area 5 of West Cliff Colliery in the Southern Coalfield of New South Wales. The schedule of Longwall extraction was as follows:

- Longwalls 31-33: July 2005 to September 2011;
- Longwall 34: February 2010 to September 2011;
- Longwall 35: October 2011 to July 2013;
- Longwall 36: August 2013 to May 2014;
- Longwall 37: April 2014 to February 2015; and
- Longwall 38: February 2015 to February 2016.

Cardno Ecology Lab (formerly The Ecology Lab Pty Ltd) was commissioned by South32 to assess the potential impact of longwall mining-related subsidence on indicators of aquatic ecology of the Georges River and other nearby watercourses within the West Cliff Area 5 mine area through the implementation of a monitoring program. The aims of the monitoring program are to:

- Assess the occurrence of fish and macroinvertebrates and condition of aquatic habitat that have potential to be affected by subsidence related impacts; and,
- Determine whether any changes observed in aquatic habitat or biota may be linked to subsidence related impacts.

This report provides the results of investigations undertaken in November 2015 in accordance with the recommendations made in the Subsidence Management Plans (SMPs) for Longwalls 34 to 36. The investigations also incorporate the monitoring associated with the extraction of Longwalls 37 and 38 as detailed in the Extraction Plan (BHPBIC 2014a) and associated Biodiversity Management Plan (BHPBIC 2014b) for these Longwalls. The specific aims of the November 2015 investigations were to:

- Undertake further after extraction monitoring for Longwalls 35 and Longwall 36, the first year of after extraction monitoring of Longwall 37 and the first year of monitoring after the commencement of extraction of Longwall 38;
- Determine whether any changes in aquatic habitat or biota have occurred at sites adjacent to longwall extraction by comparing the findings undertaken following the commencement of extraction with those from previous investigations undertaken at these and at control sites ;
- Determine if any changes to indicators of aquatic ecology are due to potential subsidence-related impacts; and
- Provide recommendations on further studies, if any, that would be required to identify impacts to ecological indicators, and, if so, suggest any ameliorative and impact minimisation strategies that may be warranted.

# 2 Previous Investigations

Cardno Ecology Lab has produced a number of reports on the aquatic habitat and biota associated with the Georges River and other watercourses in the vicinity of West Cliff Area 5. These have incorporated the results of baseline surveys, predictions of mine-subsidence impacts, threatened species assessments and results of monitoring during and after mining.

The potential effects of subsidence on aquatic habitats and biota have been assessed in several reports. The effects of Longwalls 29 to 33 were assessed by The Ecology Lab (2003). Further reports on aquatic habitats and biota potentially subject to impacts from the proposed mining of Longwalls 31 to 33 (The Ecology Lab 2005a) and 34 to 36 (The Ecology Lab 2008a) were included in the Subsidence Management Plans (SMPs) submitted to The Department of Primary Industries (Mineral Resources), as part of the approvals process. The effects of mining of Longwalls 37 and 38 on aquatic habitat and biota were assessed in the Flora and Fauna Assessment for these Longwalls (Cardno Ecology Lab 2012a) which formed part of the Extraction Plan (BHPBIC 2014a) and Biodiversity Management Plan (BHPBIC 2014b).

The results of ongoing monitoring undertaken during and / or immediately after the extraction of Longwalls 31 to 36 have been described in their respective End of Panel Reports (The Ecology Lab 2007, 2008b; Cardno Ecology Lab 2010a; 2011, BHPBIC 2014c) and in the ongoing Aquatic Ecology Monitoring reports (The Ecology Lab 2008c; Cardno Ecology Lab 2010a, 2012b, 2013, 2014 and 2015).

## 2.1 Predicted Impacts

The predictions of potential impacts on aquatic habitats and biota due to the extraction of Longwalls 31-33, 34-36 and 37-38 are summarised in **Sections 2.1.1** to **2.1.3**. It is noted that West Cliff Area 5 Longwalls were located some distance away from the Georges River to minimise the potential for subsidence impacts.

### 2.1.1 Longwalls 31 to 33

> Flow diversion and pool drainage may occur due to fracturing, and spring discharge of groundwater to the Georges River may occur due to upland subsidence (MSEC 2005). These impacts may in turn result in changes to water quality, acidification, and increased metal concentrations, with the magnitude of these impacts being dependent on the volumes of any diversions, discharges and flow within the river (Ecoengineers 2005); and,

> The loss of aquatic habitat and biota due to pool drainage and flow diversions would be limited and temporary, assuming water levels returned to background levels not long after disturbance (The Ecology Lab 2005a). Drained pools would constitute barriers to fish passage. However, licensed discharges and ameliorative measures should allow flow to resume, resulting in only transient impacts, if any, to migratory fish.

### 2.1.2 Longwalls 34 to 36

> Minor localised increases in levels of ponding and flooding in the Georges River may occur, together with very small changes in river alignment and minor fracturing, but no significant water loss (MSEC 2007). Compressive buckling and dilation of the topmost bedrock may occur along the alignments of Mallaty Creek and Leafs Gully and, to a lesser extent, along the alignments of Nepean Creek. In areas with exposed bedrock, there may be some sub-surface diversion of flows and drainage of pools;

> Subsidence induced fracturing in the Georges River and Mallaty Creek may result in some sub-surface diversion of flows and drainage of pools (MSEC 2007). These impacts were expected to have only minor, localised impacts on aquatic biota in the Georges River (The Ecology Lab 2008a);

> Flow diversions could lead to minor, short-term and localised increases in the acidity of water, reductions in dissolved oxygen levels and increased concentrations of heavy metals (Ecoengineers 2007). However, such changes in water quality were likely to have significant impacts on aquatic ecology only if they coincide with low flows. Any concurrent impacts on aquatic biota and ecology are otherwise likely to be minor, localised and short term (The Ecology Lab 2008a).

> Any water loss in Mallaty Creek could result in the loss of aquatic habitat and biota from the affected area. Once flow is re-established, re-colonisation by aquatic flora and fauna should occur (The Ecology Lab 2008a);

### 2.1.3 Longwalls 37 to 38

> No significant impacts to the physico-chemical features of the Georges River due to the extraction of Longwalls 37 and 38 were predicted (MSEC 2012). While fracturing and flow diversion may occur, these impacts are expected to be short-lived, minor and localised in their extent;

> There would be negligible diversion of flows, negligible changes in the natural drainage behaviour of pools, negligible iron staining and negligible increases in turbidity in at least 80% of the Georges River (BHPBIC 2014a);

> The predicted changes in ponding, flooding and stream alignment due to vertical subsidence would be negligible (BHPBIC 2014a);

> Fracturing of the river bed and the induction or enhancement of ferruginous springs would be localised and would have negligible effects on aquatic habitats or biota in the Georges River (BHPBIC 2014a);

> If fracturing occurs, there may be some diversion of surface flows and draining of pools in areas with exposed bedrock, however, in areas with alluvial beds, fractures are likely to be filled with alluvium during subsequent flow events (BHPBIC 2014a);

> Flow diversions and draining of pools in drainage lines would result in localised reductions in aquatic habitat. These would be temporary if infilling of fractures occurred. Due to the relatively limited aquatic habitat supported by ephemeral habitat and its abundance in the local area, such effects would likely be negligible in a local and regional context (Cardno Ecology Lab 2012a).

## 2.2 Findings

The findings of potential impacts to aquatic habitats and biota due to the extraction of Longwalls 31 to 33, 34 to 36 and 37 to 38 are summarised below:

### 2.2.1 Longwalls 31 to 33

***Longwall 31***

> The surface monitoring undertaken by BHPBIC during and following extraction of Longwall 31 did not reveal any fracturing of the pool substratum or retaining rock bars or loss of water within the Georges River (Comur Consulting 2007). No impacts to water quality were identified; and

> There was no indication of any impacts to aquatic habitat and macroinvertebrates in the Georges due to extraction of Longwall 31 (The Ecology Lab 2007).

***Longwall 32***

> The surface monitoring undertaken during and/or following extraction of Longwall 32, indicated that minor iron staining, minor rock bar fracture and limited gas release had occurred (BHPBIC 2008);

> There were no detectable impacts on flow, levels of ponding, scouring or desiccation within the Georges River (MSEC 2008). The analysis of water quality undertaken after extraction of this longwall did not identify any significant changes in salinity, pH, DO, sulphate, nickel or zinc levels (Ecoengineers 2008); and

> No evidence of any impacts to aquatic ecology that could be associated with extraction of Longwall 32 (The Ecology Lab 2008b).

***Longwall 33***

> Monitoring undertaken by the Illawarra Coal Environmental Field Team (ICEFT) indicated rock fractures, flow diversions and low water levels, iron staining and gas releases in the Georges River (Comur Consulting 2010);

> No significant impact on water quality due to gas releases, although a small loss of flow associated with flow diversions was observed (Ecoengineers 2010). Short term elevations in manganese and zinc

concentrations and reductions in dissolved oxygen in the Georges River that did occur may have been due to iron staining;

- No evidence of impacts to aquatic habitats and biota (Cardno Ecology Lab 2010a). Changes in the condition of aquatic habitats and biota were not linked with changes to water quality; and,
- There was no evidence to suggest that small changes in the condition of the aquatic macroinvertebrates observed following extraction of Longwall 33 were related to subsidence (Cardno Ecology Lab 2012b and 2013). There was no evidence of any adverse effects on aquatic habitat or fish populations.

### 2.2.2 Longwalls 34 to 38

#### *Longwall 34*

- Monitoring undertaken by ICEFT indicated a zone of minor fracturing in the Georges River at Rockbar 41 and an associated zone of minor iron staining in Pool 40d, above Rockbar 41 (Comur Consulting 2012). No flow diversions were identified in these areas and pool water levels were consistent with baseline levels. In Mallaty Creek, minor compression fracturing, surface flow diversions and localised reductions in pool water levels were observed at Pool MC 109, but water was present at the pools upstream and downstream; and,
- No significant water quality impacts were observed in the Georges River and Mallaty Creek (Ecoengineers 2011) and no evidence of any impacts to aquatic ecology in the Georges River were observed during extraction of Longwall 34 (Cardno Ecology Lab 2010b). There was no evidence to suggest that the small changes in the condition of the aquatic macroinvertebrates observed following extraction of Longwall 34 were related to the effects of subsidence (Cardno Ecology Lab 2012b and 2013). There was no evidence of any adverse effects on aquatic habitat or fish populations in the Georges River.

#### *Longwall 35*

- Monitoring undertaken by ICEFT in the Georges River between February and November 2013 indicated physical mining impacts (fracturing, diversion of flows and lowering of pool water levels and associated loss of river connectivity during low flow conditions) associated with the extraction of Longwall 35 (BHPBIC 2013a to c). Physical mining impacts associated with this longwall were first observed during weekly monitoring in February 2013 (fracturing) and March 2013 (gas releases). Minor flow diversion were observed in May 2013 and larger flow diversions observed in September 2013. Additional releases from Brennans Creek Dam were successful in returning pool water levels to pre-mining levels (at least temporarily). However, following cessation of additional releases, pool water levels fell below baseline levels. On 20 November 2013, following further additional releases from Brennans Creek Dam two weeks after the November 2013 aquatic ecology field investigations, pool water levels were at or above pre-mining levels (BHPBIC 2013c). Water levels during the December 2014 aquatic ecology sampling appeared unaffected (Cardno Ecology Lab 2015). During significant rainfall events and increased flow from Brennans Creek Dam water levels in these pools are similar to baseline, however, water levels decrease during periods of low rainfall and reduced releases from Brennans Creek Dam (South32 2016).
- Analysis of water quality data did not identify any significant water quality impacts in the Georges River following the observed physical mining impacts due to extraction of Longwall 35 (BHPBIC 2013a, Ecoengineers 2013).
- Subsidence associated with extraction of Longwall 35 appeared to have impacted aquatic ecology indicators sampled in November 2013 (Cardno Ecology Lab 2014). These impacts included a direct loss of aquatic habitat, a potential reduction in numbers of macroinvertebrate taxa, evidence of a reduction in aquatic habitat quality and the desiccation of macrophytes adjacent to affected areas. There also appeared to have been a reduction in the numbers of fish and larger mobile macroinvertebrates at one site. No changes to aquatic indicators were evident at sites further downstream; impacts to aquatic ecology that did occur appeared restricted to the areas directly affected by mining subsidence. Increased water releases from Brennans Creek Dam temporarily restored pool water levels, which would have minimised impacts to aquatic ecology. The results of the November 2014 investigations (Cardno Ecology Lab 2015) suggested that the affected macroinvertebrate and fish communities were recovering.

***Longwalls 36 to 38***

> Monitoring associated with Longwalls 36 and 37 by ICEFT did not identify any new gas release zones, changes in pool water level and flow or changes to the appearance of the Georges River due to extraction of these longwalls (BHPBIC 2014c and 2015). Some rock fracturing, iron staining and impacts to flow and water levels were identified during this monitoring, however, these impacts were attributed to extraction of Longwall 35. While some iron staining, fracturing and associated flow diversion was observed during, and was attributed to, extraction of Longwall 38 (South 32 2016; MSEC 2016), low pool water levels observed during extraction of this longwall were attributed to Longwall 35. A fracture and localised flow diversion at rockbar 49 attributed to extraction of Longwall 38 was also observed on 10 December 2015.

> No impacts to water quality in the Georges River were identified that could be associated with the extraction of Longwall 36 (Ecoengineers 2013) (BHPBIC 2014c). No significant impacts to water quality in the Georges River were observed following extraction of Longwall 37 and 38 (Ecoengineers 2015; Geoterra 2016).

> There was no evidence to suggest the extraction of Longwalls 36 and 37 has had any impact on indicators of aquatic ecology (Cardno Ecology Lab 2015).

The results of the most recent survey undertaken in November 2015 are presented and discussed in **Sections 4** to **5** of this report.

As two or more years of after extraction data have been collected for Longwalls 33 and 34 (Cardno Ecology Lab 2012b), and there was no evidence of more than minor and short term impacts to aquatic ecology associated with these Longwalls, no further ongoing monitoring in relation to these longwalls is considered necessary. Notwithstanding this, identification of any mining impacts (such as fracturing and reductions in pool water levels) potentially associated with these longwalls would trigger additional surveys of aquatic ecology.

# 3 Study Methods

## 3.1 Field Methods

### 3.1.1 Study Sites and Survey Dates

The following sites in the Georges River (and their designation in relation to the monitoring program) were sampled on 5 and 6 November 2015 (**Figure 3.1**):

> Site 6 (upstream control);

> Site 7 (upstream control);

> Site 8 (impact for Longwalls 35 and 38);

> Site 9 (impact for Longwalls 35 and 36);

> Site 10 (impact for Longwalls 36 and 37); and,

> Site 11 (downstream control).

Monitoring at Sites 1 to 4 adjacent to Longwalls 29 to 32 ceased after autumn 2010 and monitoring at Site 5 adjacent to Longwall 32 ceased after November 2011. Following a review of the monitoring program and the very limited aquatic habitat supported by Mallaty Creek, monitoring at Site 12 on this creek was discontinued November 2011.

Previously, Sites 6 and 7 provided impact data for Longwalls 33 and 34, but in the absence of any detectable changes to aquatic indicators occurring at these sites that could be associated with mining (see **Section 2.2**), they have now been re-defined as control sites for the current assessment

Each study site is approximately 100 m long. Their GPS co-ordinates are listed in **Appendix A** and the timing of the aquatic surveys relative to the extraction of each longwall is shown in **Table 3.1**.

**Table 3-1 Timing of extraction of Longwalls 31 to 38 and aquatic ecology surveys undertaken in West Cliff Area 5 2002 to 2015. Dark grey shading indicates surveys within the extraction period of each longwall and light grey shading indicates surveys within two years of the completion of extraction.**

| LW | Start | Finish | May 02* | Mar 05* | Nov 07** | Sep 08 | May 10 | Nov 11 | May 12*** | Dec 12 | Nov 13 | Dec 14 | Nov 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Report Reference | | | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) |
| 31 | Aug 06 | Dec 06 | | | ▒ | ▒ | | | | | | | |
| 32 | Feb 07 | Jun 08 | | | ■ | ▒ | ▒ | | | | | | |
| 33 | Jul 08 | Dec 09 | | | | ■ | ▒ | ▒ | | | | | |
| 34 | Feb 10 | Sep 11 | | | | | ■ | ▒ | ▒ | ▒ | | | |
| 35 | Oct 11 | Jul 13 | | | | | | ■ | ■ | ■ | ▒ | ▒ | |
| 36 | Aug 13 | May 14 | | | | | | | | | ■ | ▒ | ▒ |
| 37 | Apr 14 | Feb 15 | | | | | | | | | | ■ | ▒ |
| 38 | Apr 15 | Feb 16 | | | | | | | | | | | ■ |

(1)The Ecology Lab (2003), (2)The Ecology Lab (2005a), (3)The Ecology Lab (2008a), (4)The Ecology Lab (2008c), (5)Cardno Ecology Lab (2010b), (6)Cardno Ecology Lab (2012b), (7)Cardno Ecology Lab (2012a), (8) Cardno Ecology Lab (2013), (9) Cardno Ecology Lab (2014), (10) Cardno Ecology Lab (2015), (11) current study

*Sites 7 to 11 not sampled in May 2002 and March 2005, **Sites 10 and 11 not sampled in November 2007, ***AUSRIVAS sampling not undertaken in May 2012.

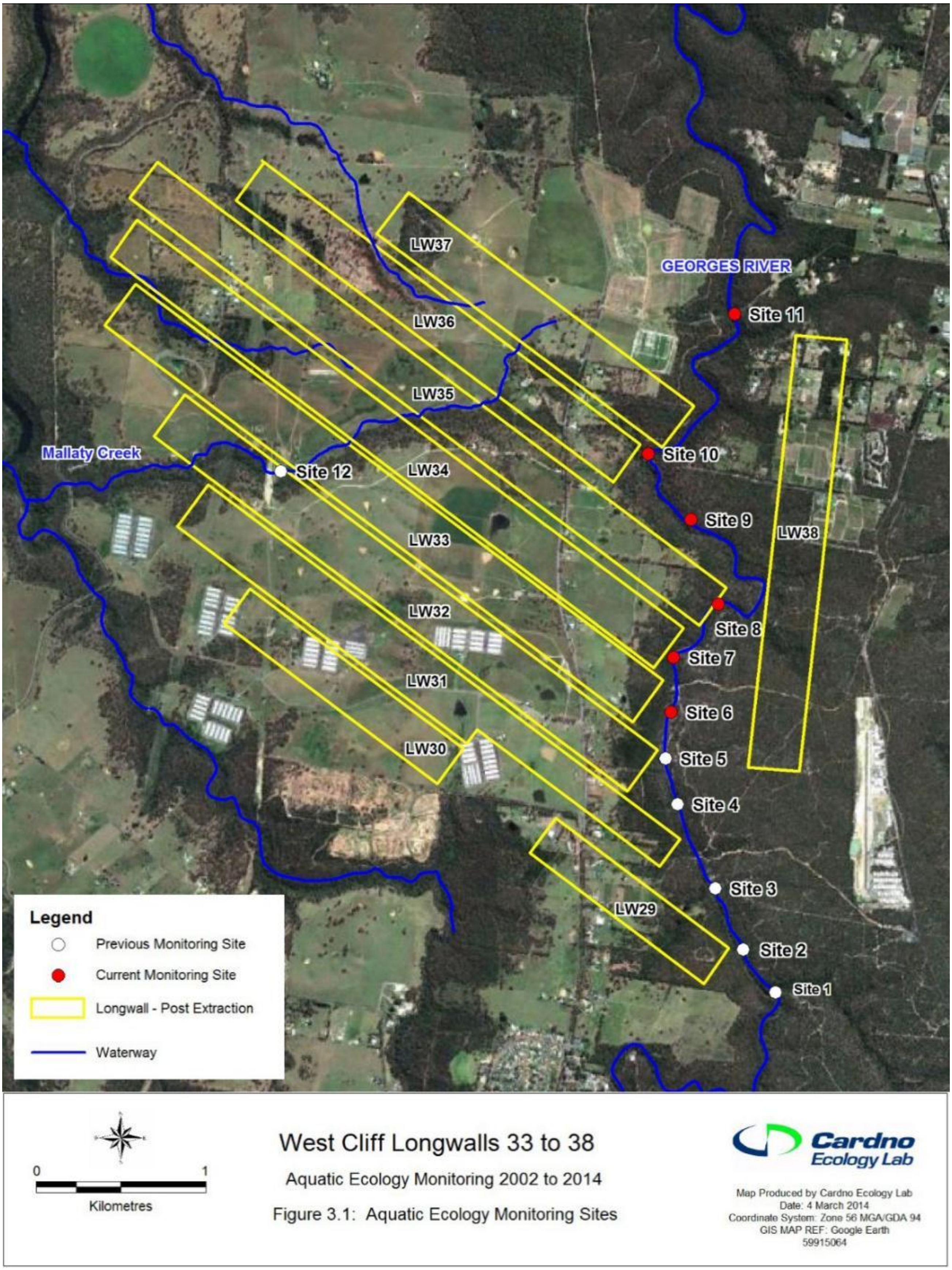


**Figure 3-1 Aquatic Ecology Monitoring Sites for the West Cliff Area 5 Aquatic Ecology Monitoring Program**

### 3.1.2 Habitat Assessment

A qualitative assessment of the condition of aquatic habitats was compiled for the Georges River, based on the following attributes:

- In-stream features such as sequence of pools, runs and riffles (shallow areas with broken water);
- Stream substratum;
- Potential refuge areas during periods of low flow (e.g. large deep pools);
- Presence of fish habitat including snags, bank undercuts and aquatic plants, and,
- Presence of any barriers to fish passage.

Photographs of the watercourse at each site on the Georges River were taken using a digital camera to assist in the descriptions.

### 3.1.3 Water Quality

Water quality was measured *in situ* with a YSI 6920 water quality probe and meter that were calibrated prior to sampling. Water quality was measured at each site before aquatic fauna were sampled to avoid disturbance to the waterway. The following variables were recorded just below the surface:

- Temperature (°C);
- Conductivity (µs/cm);
- pH;
- Dissolved oxygen (% saturation);
- Oxidation reduction potential (ORP) (mV); and,
- Turbidity (ntu).

Duplicate readings of each variable were taken in accordance with Australian Guidelines for protection of aquatic ecosystems (ANZECC/ARMCANZ 2000).

### 3.1.4 Aquatic Macroinvertebrates

Aquatic macroinvertebrates associated with edge habitats were sampled using the AUSRIVAS rapid assessment methodology (RAM) (Turak *et al*. 2004). Riffle habitat was not sampled, because this habitat was not represented in all the stretches of creek surveyed. Edge samples were collected with dip nets (250 µm mesh) over a period of 3-5 mins from a 10 m length of habitat within a 100 m reach of the creek at each site. The dip net was used to agitate and scoop up material from vegetated river edge habitats. Where the habitat was discontinuous, patches of habitats with a total length of 10 m were sampled over the 100 m reach. Each RAM sample was rinsed from the net onto a white sorting tray from which animals were picked live using forceps and pipettes. Each tray was picked for a minimum period of forty minutes, after which they were picked at ten minute intervals either until no new specimens had been found or total of 60 minutes (i.e. the initial 40 minutes plus up to another 20 minutes) had elapsed. Care was taken to collect cryptic and fast moving animals in addition to those that were conspicuous and / or slow-moving. The animals collected at each site were placed into a labelled jar containing 70% alcohol / water.

Environmental variables, including alkalinity, modal river width and depth, percentage boulder or cobble cover, latitude and longitude were recorded in the field. These are required for running the AUSRIVAS predictive model for edge habitat. Distance from source, altitude, and land-slope were determined from appropriate topographic maps. Mean annual rainfall was determined in the laboratory from the regional precipitation maps presented in the AUSRIVAS Sampling and Processing Manual (Turak *et al*. 2004).

### 3.1.5 Fish

Fish and large mobile invertebrates, such as freshwater crayfish, occurring at each site were sampled using a back-pack electrofisher (Model Smith-Root LR24). The back-pack electrofisher was operated around the edge of pools, around snags and aquatic vegetation, overhanging banks and rocky crevices. Electrofishing was conducted in sets of four, two minute shots at each site. Fish were collected in a small scoop net, identified and measured.  Native species were released unharmed, non-indigenous species were not returned to the water, as per the conditions of our scientific collection permit.

## 3.2 Laboratory Methods

AUSRIVAS samples were sorted under a binocular microscope (at 40 X magnification) and identified to family level with the exception of Oligochaeta and Polychaeta (to class), Ostracoda (to subclass), Nematoda and Nemertea (to phylum), Acarina (to order) and Chironomidae (to subfamily).  Up to ten animals of each family were counted, in accordance with the latest AUSRIVAS protocol (Turak *et al.* 2004).

## 3.3 Data Analysis

### 3.3.1 Descriptive Statistics

#### *3.3.1.1 Water Quality*

Mean water quality measurements were compared with the (ANZECC/ARMCANZ 2000) default trigger values (DTVs) for protection of aquatic ecosystems for physical and chemical stressors for slightly disturbed upland rivers in southeast Australia.

Water quality data collected during the aquatic ecology monitoring program were intended to aid in the interpretation of macroinvertebrate data.  More detailed water quality monitoring, analysis and assessment is undertaken by the ICEFT and other consultants.

#### *3.3.1.2 Aquatic Macroinvertebrates*

The AUSRIVAS protocol uses an internet-based software package to determine the environmental condition of a waterway based on predictive models of the distribution of aquatic macroinvertebrates at reference sites (Coysh *et al.* 2000).  The ecological health of the creek is assessed by comparing the macroinvertebrate assemblages collected in the field (i.e. 'observed') with macroinvertebrate assemblages expected to occur in reference waterways with similar environmental characteristics.  The data from this study were analysed using the NSW models for pool edge habitat sampled in spring.  The AUSRIVAS predictive model generates the following indices:

> OE50Taxa Score – The ratio of the number of macroinvertebrate families with a greater than 50% predicted probability of occurrence that were actually observed (i.e. collected) at a site to the number of macroinvertebrate families expected with a greater than 50% probability of occurrence.  OE50 taxa scores provide a measure of the impairment of macroinvertebrate assemblages at each site, with values close to 0 indicating an impoverished assemblage and values close to 1 indicating that the condition of the assemblage is similar to that of the reference streams.

> Overall Bands derived from OE50Taxa scores which indicate the level of impairment of the assemblage. These bands are graded as described in **Table 3.1**.

**Table 3-2 AUSRIVAS Bands and corresponding OE50 Taxa Scores for AUSRIVAS edge habitat sampled in spring**

| Band | Description | Spring OE50 Score |
|---|---|---|
| X | Richer invertebrate assemblage than reference condition | >1.16 |
| A | Equivalent to reference condition | 0.84 to 1.16 |
| B | Sites below reference condition (i.e. significantly impaired) | 0.52 to 0.83 |
| C | Sites well below reference condition (i.e. severely impaired) | 0.20 to 0.51 |
| D | Impoverished (i.e. extremely impaired) | ≤0.19 |

The SIGNAL2 biotic index (Stream Invertebrate Grade Number Average Level) developed by Chessman (2003) was also used to determine the environmental quality of sites on the basis of the presence or absence of families of macroinvertebrates.  This method assigns grade numbers between 1 and 10 to each macroinvertebrate family, based largely on their responses to chemical pollutants.  The sum of all grade numbers for that site was then divided by the total number of families recorded in each site to obtain an average SIGNAL2 index.  The SIGNAL2 index therefore uses the average sensitivity of macroinvertebrate families to present a snapshot of biotic integrity at a site.  SIGNAL2 values are as follows:

- SIGNAL > 6 = Healthy habitat;
- SIGNAL 5 – 6 = Mild pollution;
- SIGNAL 4 – 5 = Moderate pollution; and,
- SIGNAL < 4 = Severe pollution.

### 3.3.2 Statistical Analyses of Macroinvertebrate Data

#### *3.3.2.1 Analytical Framework*

The aim of the statistical analysis was to identify differences in the selected indicators of aquatic ecology at the impact sites that were in a different direction, or of a different magnitude, to those at the control sites. Statistically significant differences provide evidence that an impact may have occurred. Evidence is assessed by examining data from before the commencement of extraction and that collected after commencement. If such changes are detected, they would be related to observations of any physical and water quality changes in the Georges River in an attempt to explain the pattern of changes and explore the potential cause of any impact. Only data from spring surveys when Sites 6 to 11 were sampled (September 2008, November 2011, December 2012, November 2014, December 2014 and November 2015) have been included. This helps ensure a balanced data set (thereby helping to maintain the validity of the statistical tests) and prevents any potential confounding effect that could occur due to including data collected in autumn and spring).

The analyses are focussed on impacts that may have occurred to indicators after the commencement of extraction of Longwalls 35 to 38. Longwall 35 commenced extraction in October 2011, however, data collected in December 2012 have been included as before extraction data. At this time extraction of Longwall 35 was taking place several hundred metres from the river and weekly monitoring did not identify any physical mining impacts associated with this longwall until February 2013, with fracturing and pool water level reductions not observed for some time after (**Section 2.2.2**). Together with the absence of any observed impacts to water quality, impacts to macroinvertebrates would have been unlikely to have occurred at this time, and none were detected (Cardno Ecology Lab 2013).

Analyses of multivariate (assemblages) and univariate (biotic indices) data from AUSRIVAS sampling in edge habitat were undertaken.

#### *3.3.2.2 Multivariate Analyses*

A matrix of differences in the types of taxa between all possible pairs of samples was compiled by calculating their respective Bray-Curtis dissimilarity coefficients. Permutational analysis of variance (PERMANOVA+ in Primer v6) was used to examine spatial differences and temporal changes, and their interaction, in macroinvertebrate assemblage presence / absence data sampled using AUSRIVAS. Differences in the levels of factors and interaction terms were examined by *post hoc* permutational t-tests. Only statistical differences with a significance level of $P \leq 0.05$ were considered. Significant differences between groups (e.g. impact versus control) may arise due to differences between group means, differences in dispersion (equivalent to variance) among groups or a combination of both. Each of these outcomes could be indicative of an impact.

Multivariate patterns in the data were examined using the Principal Coordinates Ordination (PCO) routine in Permanova+. This is a generalised form of Principal Components Analysis (PCA) in which samples are projected onto linear axes based on their dissimilarities in a way that best describes the patterns among them using as few dimensions as possible (Clarke and Gorley 2006). The amount of variation "explained" by each principal axis is indicated and the dissimilarity between data points can be determined from their distances apart on the axes (Anderson et al. 2008).

The Similarity Percentages (SIMPER) routine can be used to determine which taxa were responsible for discriminating between groups for significant factors (Clarke 1993). However, as the results of the analyses were not indicative of an impact (**Section 4.4.3**), SIMPER was not considered appropriate. SIMPER could not be used to determine which taxa were responsible for differences between individual Surveys at each site as only one replicate was collected per site per survey.

#### *3.3.2.3 Univariate Analyses*

Permanova+ was used to examine spatial differences and temporal changes in the number of taxa, OE50 Taxa Scores and SIGNAL2 Indices derived from AUSRIVAS modelling. In this case, the analyses were based on a Euclidean distance matrix of all possible pairs of samples of the variable of interest. Only statistical differences with a significance level of $P \leq 0.05$ were considered.

The PERMANOVA approach does not require the data conform to a normal distribution unlike “traditional” ANOVA. As is the case with multivariate analyses, 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. A potential impact could be expected to affect both the magnitude and dispersion of an indicator (e.g. number of taxa). If a statistically significant difference between groups is detected that could be indicative of a mining impact, the proportion of the statistical difference attributable to the difference in variance between pairs of groups would be explored using the PERMDISP procedure. This procedure tests for a statistical difference between variances. If there is no statistical difference between variances, the statistical difference detected between groups is most likely due to differences between group means. When a statistical difference between variances is detected, the difference between groups could be due to both the difference in variance and the mean between groups.

#### *3.3.2.4 Design and Interpretation*

The analytical design was:

- **Phase**: A fixed factor with two levels: Before (commencement of extraction), and After (commencement of extraction);
- **Treatment**: A fixed factor with two levels, Control and Impact; and
- **Survey**: A random factor with three levels nested within Phase (September 2008, November 2011 and December 2012 nested in Before and November 2013, December 2014 and November 2015 nested within After).

Sites provided replicate samples with Sites 6, 7 and 11 grouped in the Impact Treatment and Sites 8, 9 and 10 grouped in the Control Treatment.

The statistically significant interaction of the Phase and Treatment factors could potentially provide evidence of a substantial, long-term change in the biotic community following the commencement of extraction of Longwalls 35 to 38 as a whole. Thus, this interaction was the main focus of these analyses. The statistically significant interaction of Treatment and Survey within Phase could also provide evidence of, albeit shorter term, changes due to mining. Such comparisons indicate how differences between Treatments vary among Surveys, with particular patterns of change potentially indicative of an effect due to commencement of extraction of individual longwalls. It is noted that analyses have been undertaken using data collected in spring only, limiting conclusions regrading changes that may occur during other seasons.

Statistically significant main effects (factors) cannot provide evidence for or against an impact occurring. Thus, for brevity, they were not described in detail or graphed. For each biotic index, the value for each Survey undertaken at Sites 6 to 11 from 2002 to 2015 was graphed and interpreted visually to place the results in the context of longer term sampling in the Georges River (i.e. during Surveys not included in the analyses).

In each case, the non-statistically significant (at $P > 0.25$) Treatment x Survey interaction term was pooled with the residual to allow a more sensitive test of the Treatment x Phase interaction. The results of the pooled tests only have been presented.

It is noted that due to the nature of the sampling (i.e. monitoring at the same sites through time, all located on the same watercourse) data may not be statistically independent. Generally, the consequence of potential non-independence is an increase in the Type 1 error (false positive) rate. This would be expected to result in more liberal tests, and, thus, could be considered precautionary in the context of detecting an impact. However, it could also conceivably result in an increase in the Type 2 error (false negative) rate, if any disturbance occurring at the impact sites affected control sites farther downstream (control Site 11 is downstream of impact Sites 8 to 10). The potential effects of any non-independence need to be taken into consideration when interpreting the results of the statistical analyses.

Statistical analysis of fish data was not undertaken. Due to the inherently large natural variability present in these data, and many samples consisting of zero fish, statistical tests were not considered appropriate. Rather, examination of raw data was undertaken in an attempt to identify obvious changes in the number of individuals and species caught at each site through time, which could be indicative of a potential effect due to mining.

# 4 Results

## 4.1 Observed Mining Impacts

The physical mining impacts observed by ICEFT during extraction of Longwalls 35 to 38 are summarised in **Section 2.2.2**. Specific observed impacts included:

> Gas releases first observed in Pools 58 and 60 during March and April 2013;
> Fracturing in Pools 42 45, 53, 54, 56, 57, 58, and Rockbars 42, 43, 45 and 57 from May 2013 to September 2013;
> Fracturing and Minor flow diversion at Rockbar 45 in May 2013;
> Iron staining in Pool 56 in August 2013 and Pool 42 in September 2013; and
> Pool water loss at Pools 38, 44, 51, 54, 56, 57, 58 and 60 from September to November 2013.

The location of the affected pools relative to the monitoring sites is provided in **Figure 4.1**. These impacts occurred during and soon after extraction of Longwall 35. These, and some additional fracturing and low pool water levels observed at these and adjacent sections of the river (including fracturing in Pool 1 in June 2014) during extraction of Longwalls 36 and 37 are attributed to Longwall 35. The iron staining in Pool 49 and fracturing and flow diversions at Rockbar 49 observed during extraction of Longwall 38 are attributed to Longwall 38. However, low pool water levels observed during extraction of this longwall are attributed to Longwall 35.

All except one pool (Pool 38) are located downstream of Control Sites 6 and 7. The remainder are interspersed among the Impact Sites (Sites 8, 9 and 10). Control Site 11 is located some distance downstream of these areas.

No impacts to water quality in the Georges River associated with extraction of these longwalls were observed (**Section 2.2.2**).

## 4.2 Aquatic Habitat and General Observations

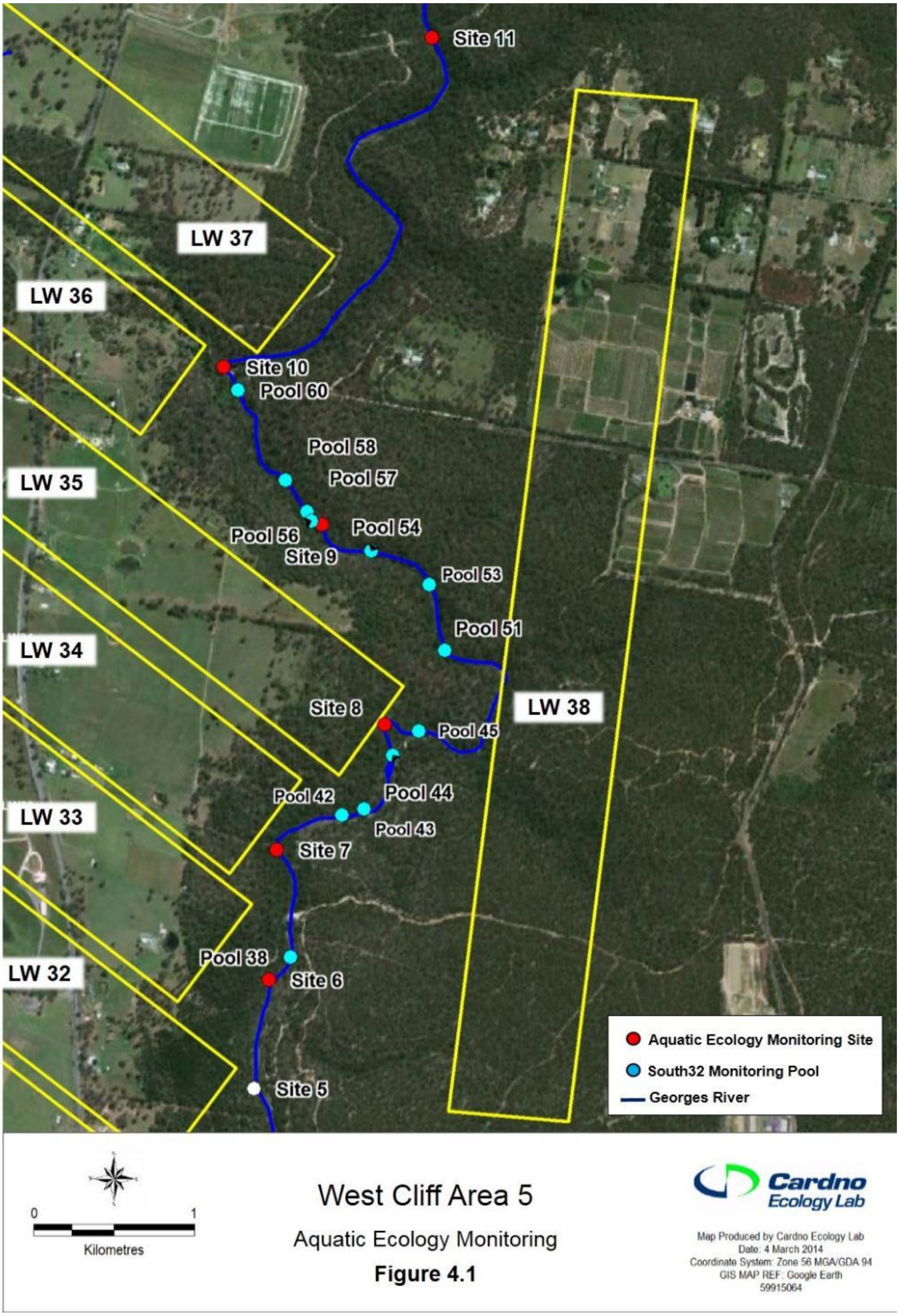
The section of the Georges River within the study area is fed by a number of tributaries which drain rural properties, urban development and vegetated areas. The upstream section of the river (Site 6) (**Figure 3.1**) is characterised by long shallow pools connected by sections of shallow flow over bedrock. Further downstream (Sites 7-11) the river consists of deeper pools with connecting flow through boulder fields. The substratum throughout the study area includes large areas of sandstone bedrock, accumulations of sand and silt within pools, and sections with boulders and cobbles.

Riparian vegetation was in good condition, as was the case during previous investigations. It consisted predominantly of native species such as mat rush (*Lomandra* sp.) and sawgrass (*Gahnia* sp.) plus a few introduced taxa. Mature trees were common and gaps in vegetation generally occurred only at road crossings.

Throughout the monitoring program, large dense beds of cumbungi (*Typha* sp.) and smaller patches of spike rush (*Juncus* sp.) and clubrush (*Isolepis* sp) were the most common emergent aquatic macrophytes. Pondweed (*Potamogeton* sp.) was also present at Sites 7 and 8 and *Vallisneria* sp. at Site 6. All these species have been observed previously. At least 20 species of aquatic macrophytes have been recorded in the reach of the Georges River within and adjacent to the current monitoring sites (**Appendix B**).

Small waterfalls and cascades are present at many of the sites sampled. The only artificial structure present in this section of the river is the culvert at the Blackburn Road crossing near Site 10.

Changes in flow, pool water levels and aquatic habitat have been observed at Sites 8 and 9 following the physical mining impacts observed between February and November 2013 (**Plates 1a** to **h**). In December 2012, no impacts were evident (**Plates 1a** and **e**). During November 2013 fracturing, flow diversions and reduction in pool water levels and aquatic habitat were observed at both sites, most of the riverbed at these sites was dry and nearby aquatic macrophytes had become desiccated (**Plates 1b** and **f**) (Cardno Ecology



West Cliff Area 5

Aquatic Ecology Monitoring

**Figure 4.1**

Map Produced by Cardno Ecology Lab
Date: 4 March 2014
Coordinate System: Zone 56 MGA/GDA 94
GIS MAP REF: Google Earth
59915064

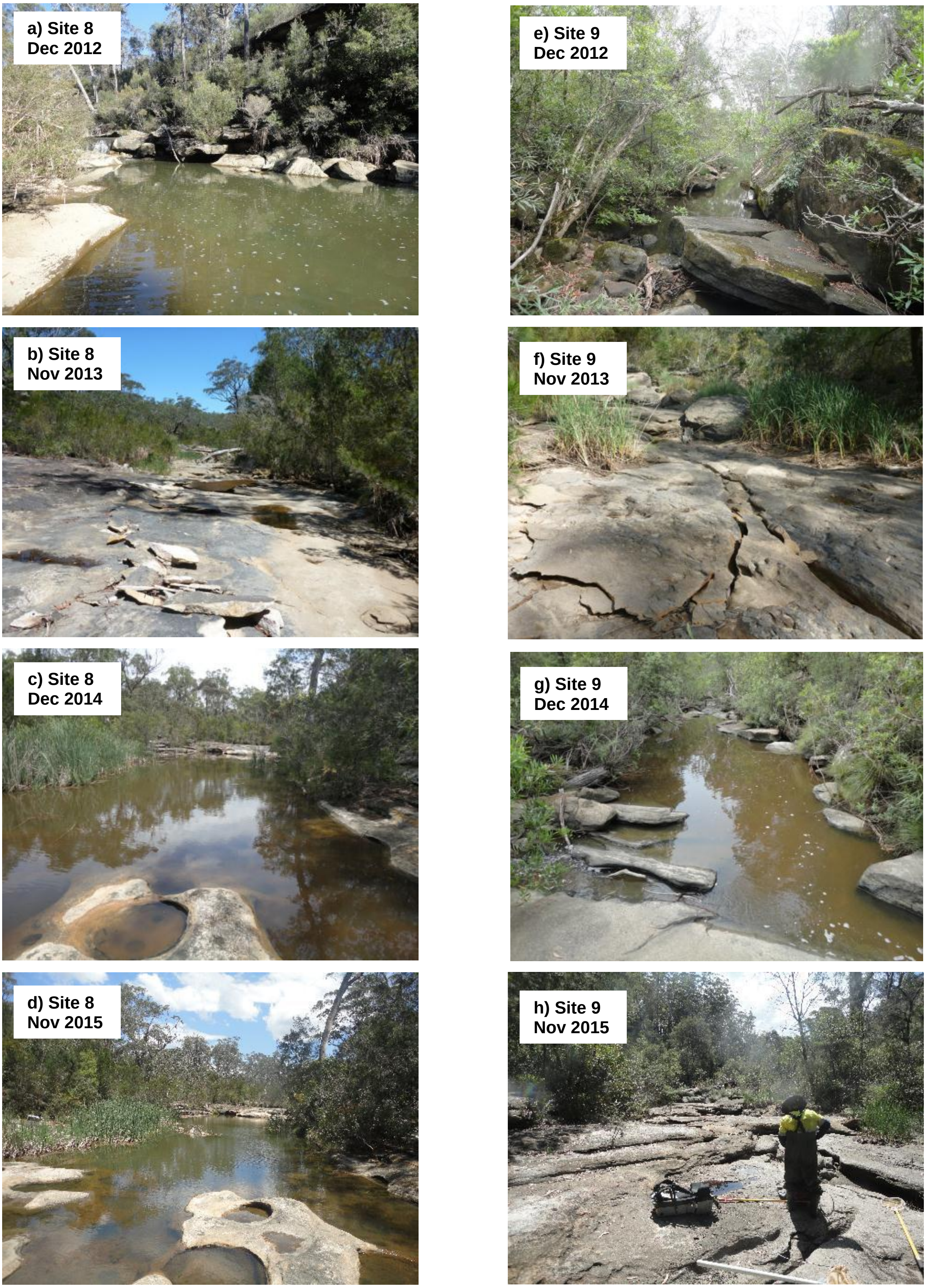


**Plate 1: a) to d) Site 8 and e) to h) Site 9 in December 2012 (prior to Longwall 35 physical impacts) and in subsequent surveys in November 2013, December 2014 and November 2014**

Lab 2014). By December 2014, and following additional releases of water from Brennans Creek Dam, flow and pool water levels at these sites were similar to that prior to the observed impacts (**Plates 1c** and **g**) (Cardno Ecology Lab 2015). During the latest investigation in November 2015 flow and pool water levels at Site 8 appeared normal (**Plate 1d**), and, although water was present in some pools within and adjacent to Site 9, sections of this site were still dry (**Plate 1h**).

## 4.3 Water Quality

The mean values of the water quality indicators measured *in situ* at Sites 6 to 11 from September 2008 to November 2015 are presented in **Appendix C**.

The main findings across the Surveys are summarised as follows:

> Temperature of the water ranged from 10.3 to 23.9 C and reflected seasonal trends. The measurements taken during particular surveys varied by between 2° and 5° C across sites, but there were no obvious trends along the river;

> Conductivity ranged from 751 to 2353 µS/cm and exceeded the upper DTV (ANZECC ARMCANZ 2000) on each occasion. The lowest and highest levels were recorded in September 2008 and May 2010 during extraction of Longwalls 33 and 34, respectively.

> Conductivity was similar across sites during November 2011 and May 2012 but differed during the other surveys. It was relatively high in May 2010, December 2012 and November 2013. This finding may have been related to releases from Brennans Creek Dam and other catchment inflows;

> pH ranged from 7.6 to 9.2 and exceeded the upper DTV on all but three occasions (Site 8, May 2010 and Site 10, November 2013 and November 2015);

> Dissolved oxygen levels ranged from 52.4% to 121.3% saturation. Levels were below the lower DTV at every site on at least one occasion. Values in excess of the upper DTV were recorded once each at Sites 6 to 8. The 52.4% saturation level recorded at Site 10 in November 2013 was by far the lowest recorded at any site during the monitoring program;

> Oxidation reduction potential (ORP) ranged from 50 to 465 mV. ORP levels were fairly similar across sites in each sampling event. The ORP values recorded during 2011 to 2012 were higher than those measured during other surveys; and

> Turbidity ranged from 0.2 to 28.9 ntu. The turbidity dropped below the lower DTV at least once at all the sites on the Georges River. Values in excess of the upper DTV were recorded at Site10.

Apart from the low dissolved oxygen measure at Site 10 in November 2013, there are no changes in these limited water quality data that could potentially be related to extraction of Longwalls 35 to 38. Measures recorded from November 2013 are comparable to those measured prior to this during November 2008 to December 2012. They are also comparable to measures of water quality sampled at Sites 6 to 9 in November 2007 and Site 6 in May 2002 and March 2005 (Cardno Ecology Lab 2015).

It should be noted that the water quality data collected by Cardno Ecology Lab is intended to assist in the interpretation of aquatic ecology data and allows only limited conclusions to be drawn about temporal variation in the various indicators. Water quality data are collected more frequently and interpreted by ICEFT and other specialist consultants. No impacts to water quality in the Georges River associated with extraction of the Longwalls 35 to 38 were observed in these assessments (**Section 2.2.2**).

## 4.4 Aquatic Macroinvertebrates

### 4.4.1 Identified Taxa

In total, 45 macroinvertebrate taxa were identified from the AUSRIVAS edge samples from Sites 6 to 11 in November 2015 (**Appendix D**). Seven taxa, including Chironomidae (non-biting midges), Dytiscidae (diving beetles) and Hydrophilidae (water scavenger beetles) occurred at all, or all except one, site. These pollution tolerant taxa live near the pool edge and can survive for some time out of water (Gooderham and Tsyrlin 2002). Caenidae (a family of mayfly), another pollution tolerant taxon, were also found at each site and pollution tolerant baetid mayflies were found at all except one site. Relatively few pollution sensitive taxa were found in the Georges River, though Telephlebiidae (dragonflies) and Leptophlebiidae (prong-gilled mayflies) were found at half of the sites or more, and Austrocorduliidae (a Genus of dragonfly) were recorded at one site.

Most of these patterns of occurrence have been relatively consistent throughout 2008 to 2015 (i.e. when data are available from Sites 6 to 11). However, the occurrence of leptophlebiids has varied somewhat among surveys. For example, in December 2014 leptophlebiids were found at each site except Site 6, in November 2013 they were found at all sites except Site 9; in December 2012 this taxon was found only at Sites 6, 10 and 11, and in November 2011 it was not found at any of the sites sampled during this current survey. This taxon was found at Site 8 to 11 in November 2015. Caenid and baetid occurrence has also been similarly variable among surveys. Chrionomidae have occurred at every site on each occasion during the entire West Cliff Area 5 monitoring program. In addition to Leptophlebiidae, several other common taxa (those sampled at Site 9 and at other sites during several surveys) were absent from Site 9 in November 2013 (Cardno Ecology Lab 2015). These included Caeindae, Batidae Physidae, Ostracoda, Coenagrionidae, Hemicordulidae, Tanhypodinea and Ecnomidae. The majority of these taxa are pollution tolerant (SIGNAL2 grade 5 or less), although Leptophlebiidae is pollution sensitive (grade 8).

The Genus Austrocorduliidae includes the Sydney hawk dragonfly (*Austrocordulia leonardi*), listed as threatened under the *Fisheries Management Act 1994*. The one specimen collected at Site 11 in November 2015 was not identified as the Sydney hawk dragonfly. The Adams emerald dragonfly (*Archaeophya adamsi*), also listed as threatened under the *Fisheries Management Act 1994*, was not present in any of the samples.

### 4.4.2 Biotic Indices

The number of taxa, OE50 Taxa Scores and SIGNAL2 Indices derived from AUSRIAVS sampling at Sites 6 to 11 from May 2002 to November 2015 are presented in **Appendix E** (note only data from spring of 2008 to 2015 has been included in the analyses (**Section 3.3.2.1**)).

Over this time, between 9 and 32 taxa have been identified from the AUSIRVAS samples. The lowest number of taxa recorded was at Site 9 in November 2013.

The OE50 Taxa Score has ranged from 0.32 (Band C: macroinvertebrate assemblages severely impaired relative to reference condition) to 1.02 (Band A: equivalent to reference condition). It was often below 0.84 (Band B: significantly impaired relative to reference condition), but relatively low, and below 0.52 (Band C) on three occasions only (Site 8 in November of 2011 and 2013, and Site 6 in November 2013).

The SIGNAL2 Index ranged from 3.5 (indicative of severe pollution) to 4.8 (indicative of moderate pollution). There has been very little change in this index at any of the sites.

### 4.4.3 Statistical Analyses

PERMANOVA analyses are presented in **Table 4.1**. The statistical analyses did not yield any statistically significant sources of variation that could be indicative of an impact occurring following the commencement of extraction of Longwalls 35 to 38. The only statistically significant variation was the main effect of Survey within Phase for assemblages, number of taxa and OE50 Taxa Score. This is not indicative of an impact (**Section 3.3.2.4**).

**Table 4-1 Summary of results of PERMANOVA analyses undertaken using AUSRIVAS data collected in spring surveys from November 2007 to December 2014. * = P ≤ 0.05, ** = P ≤ 0.01, *** = P ≤ 0.001, ns = not statistically significant. See Appendix F for full results.**

| Indicator | Phase | Treatment | Survey (Phase) | Treatment x Phase | Treatment x Survey (Phase) |
|---|---|---|---|---|---|
| Assemblage | ns | ns | * | ns | ns (pooled) |
| Number of Taxa | ns | ns | ns | ns | ns (pooled) |
| OE50 Taxa Score | ns | ns | ns | ns | ns (pooled) |
| SIGNAL2 Index | ns | ns | ns | ns | ns (pooled) |

Note: Treatment x Survey (Phase) pooled with the residual at P > 0.25

There was generally little evidence of any grouping of assemblages in the PCO, with the points tending to form a diffuse cloud (**Figure 4.1**). Two of the points, however, did appear to differ, these were the assemblages sampled at Site 6 in November 2011 and at Site 9 in November 2013. These assemblages were located away from the other points and towards the bottom right, and bottom left, of the PCO, respectively. There was also some limited evidence of differences between assemblages from Sites 6 and 7 and those from Site 11, with assemblages sampled from Site 6 and 7 tending to group at the bottom right, and those from Site 11 tending to group at the top left, of the PCO.

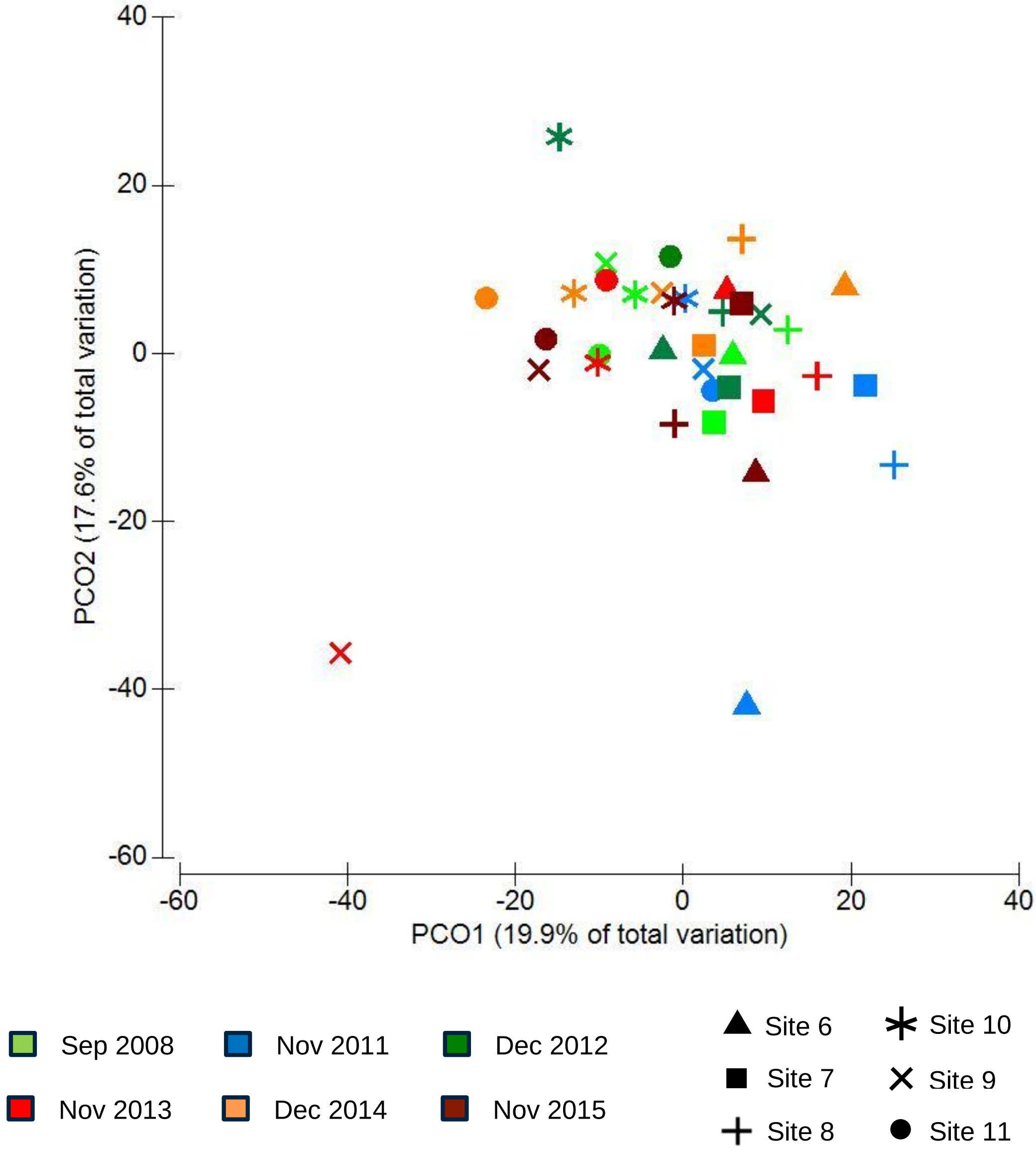


**Figure 4-1 Principle Component Ordination (PCO) of AUSRIVAS macroinvertebrate edge assemblages sampled at Sites 6 to 11 on the Georges River during 2008 to 2015. Each symbol represents one sample (replicate).**

## 4.5 Fish

Five fish species were caught by electrofishing in November 2015 (**Table 4.2**). As in previous surveys, several freshwater eels and non-native eastern gambusia (*Gambusia holbrooki*) were also observed, but not caught, whilst electrofishing. These could have been either long-finned (*Anguilla reinhardtii*) (also caught at Site 6) or short-finned (*Anguilla australis*) (also caught at Sites 6, 10 and 11) eels. Eastern gambusia were the most widespread and abundant species. The genus *Hypseleotris* sp. (carp gudgeons), which were caught at Site 10 include several species such as firetail gudgeon (*Hypseleotris galii*). It is often difficult to differentiate this species from other carp gudgeons in the field. Freshwater crayfish (Family Parastacidae) and freshwater shrimp (Family Atyidae) were also observed and caught at each site in AUSRIVAS dip nets and whilst electrofishing. Native Cox's gudgeon (*Gobiomorphus* coxii) were also caught at Site 10. No fish were caught at Site 7 in November 2015.

All of these species have been recorded during previous electrofishing surveys undertaken for the monitoring program (**Appendix H**). During December 2014, gudgeons (Famility Eleotridae) were generally more abundant at the three most downstream sites, and eastern gambusia more abundant at the three upstream most sites. There are no obvious trends in fish data collected in November 2015 or in Surveys prior to December 2014.

No fish were caught at Site 9 in November 2013, despite fish being caught there in November 2011, May 2012 and December 2012 (Cardno Ecology Lab 2015). No fish were caught at Site 9 in September 2008, however, few fish were also caught at the other sites during this survey. Four species of fish were caught at Site 9 in December 2014. Only one species (eastern gambusia) was caught here in November 2015, as was the case at Sites 6 and 8. In general, aside from eastern gambusia, fewer fish were caught in November 2015 than in most previous surveys.

Flathead gudgeon (*Philypnodon gradiceps*) were caught at Site 9 in December 2014. Although this was the only survey in which this species was caught, it is a common and widespread species that has previously been caught in the Georges River (Cardno Ecology Lab 2012a).

No observations were made that would suggest other major changes to fish assemblages at the impact sites (e.g. fish kills).

**Table 4-2 Fish species caught by backpack electrofishing at Sites 6 to 11 on the Georges River during the aquatic ecology monitoring undertaken for the West Cliff Longwalls from 2002 to 2013.**

| Scientific Name | Common Name | May 2002 | Mar 2005 | Sep 2008 | May 2010 | Nov 2011 | May 2012 | Dec 2012 | Nov 2013 | Dec 2014 | Nov 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Anguilla* sp. | Freshwater eel | | | | | | | x | x | x | |
| *Anguilla australis* | Short-finned eel | | | | | | | x | | x | X |
| *Anguilla reinhardtii* | Long-finned eel | x | x | x | | x | x | x | x | x | x |
| *Gambusia holbrooki* | Eastern gambusia | x | x | x | x | x | x | x | x | x | X |
| *Gobiomorphus coxii* | Cox's gudgeon | | | | | x | x | x | x | x | X |
| *Hypseleotris* spp. | Carp gudgeon | x | x | x | x | x | x | x | x | x | x |
| *Philypnodon gradiceps* | Flathead gudgeon | | | | | | | | | x | |

# 5 Discussion

## 5.1 Aquatic Habitat

The findings of the November 2015 investigations provide further evidence to suggest that the impacts to aquatic habitat that occurred at Site 8 in November 2013 following the physical mining impacts associated with extraction of Longwall 35 have recovered, at least temporarily while flows from Brennans Creek Dam have increased. During November 2013, reductions in pool water levels and the complete drying of some pools at Sites 8 and 9 had led to a direct loss of aquatic habitat and likely some biota (Cardno Ecology Lab 2014). The desiccation of macrophytes represented both a loss of aquatic biota and also habitat, as these plants would have provided shelter and food for many other aquatic species. Other impacts to aquatic ecology associated with the physical impacts included the loss of longitudinal connectivity during low flow conditions due to the drying of pools and loss of flow over rock bars. Recovery was first evident in December 2014, and included a return of flow and increase in pool water levels to those experienced prior to extraction of Longwall 35. During December 2014 and November 2015 water and flow was present in pools at Site 8 that were dry in November 2013 and there was little evidence of any desiccation of macrophytes. A similar level of recovery was also evident at Site 9 in December 2014. However, in November 2015 some sections of river within, and adjacent to Site 9 were dry (though water did reappear a few hundred metres downstream). This suggest that impacts to pool water levels (potentially from leakage through fractures) persisted at this site, and that natural recovery to normal levels may take some time longer.

Additional releases of water from Brennans Creek Dam in the second half of 2014 likely resulted in the re-establishment of pool water levels and flow in the Georges River during the December 2014 survey (BHPBIC 2014c). While physical impacts observed during extraction of Longwalls 36 and 37 were attributed to Longwall 35, it is possible the relatively minor impacts attributed to extraction Longwall 38, and any cumulative impact associated with extraction of all these Longwalls, would influence the timing and magnitude of recovery of physical and biotic impacts in the Georges River due to mining.

Aside from the observed physical mining impacts and associated effects on aquatic habitat, primarily associated with extraction of Longwall 35, the aquatic habitat in sections of Georges River visited in this study is generally in good condition. The relatively undisturbed riparian strip present at the section of river visited contributes strongly to the overall condition of aquatic habitat and biota in this section of the Georges River. It helps to stabilise river banks and helps prevent erosion and sediment mobilisation. Furthermore, riparian vegetation is a source of in-stream woody debris, which provides important habitat for many species of aquatic fauna, including fish. The relatively dense beds of macrophytes observed at the sites visited would also fulfil many important ecological roles, including the provision of refuge and nursery habitat for aquatic fauna, serve as a source of food for macroinvertebrates and fish and are important in nutrient cycling.

Under normal flow conditions, the deep pools present at the majority of study sites would provide habitat for fish and may be important refuge areas for them during extended dry periods with low flows. Natural features such as small waterfalls and cascades may impede fish passage during low to moderate flows, as would the culvert at Site 10. During high flows, fish should be able to pass these barriers with little difficulty. Eels (*Anguilla* spp.) and Cox's gudgeon are likely to be able to do so even during periods of relatively low flow.

## 5.2 Water Quality

The absence of any observed impacts to water quality in the Georges River in the assessments undertaken for the End of Panel Reports for Longwalls 35 to 38 (**Section 2.2.2**) suggests that the physical impacts associated with longwall extraction have had little or no effect on water quality in the river. Although the data collected by Cardno Ecology Lab suggests relatively low dissolved oxygen and high turbidity levels at Site 10 in November 2013, these data are very limited and there was no evidence of any concurrent changes in macroinvertebrates, fish or macrophytes at this site (see **Sections 5.3 and 5.4**). The quality of water within this reach of the upper Georges River is determined by rainfall, rural and urban runoff and licensed discharges of mine water from Appin East and West Cliff pit tops, in addition to any potential effects associated with mine-induced subsidence. A change in the relative contributions of the major inputs to the river is most likely responsible for the relatively high conductivities noted in the Georges River during most Surveys.

Cardno Ecology Lab has undertaken several investigations into the effect of mine water discharge from West Cliff Colliery and Appin Colliery on the aquatic ecology of the Georges River (The Ecology Lab 2004a to g, 2005b, 2006a and b). These studies indicated that diverse aquatic macroinvertebrate assemblages occur at ECs within 1000 to 4000 µS/cm. Some taxa, including pollution tolerant (SIGNAL2 Grade: 3) freshwater shrimp (Family: Atyidae), and pollution sensitive (SIGNAL2 Grade 8) leptophelbiid mayflies, were found to be less abundant at sites subject to discharge than at reference sites not subject to discharge. Other taxa, such as the pollution tolerant baetid (SIGNAL2 Grade: 5) and caenid (SIGNAL2 Grade: 4) mayflies, were more abundant at sites subject to discharge. All these taxa were sampled during current and previous surveys (see **Section 5.3**).

Further investigations into the effect of mine water discharge from West Cliff Colliery were undertaken in relation to West Cliff Colliery Pollution Reduction Program (PRP) 10, including a freshwater shrimp translocation experiment (Cardno Ecology Lab 2009 and 2010c). The findings of these studies, together with those from an Australian Coal Association Research Program (ACARP) funded study into the effects of saline water discharge on aquatic biota in the Southern and Hunter Coalfields of NSW (Cardno Ecology Lab 2010d) indicated that while elevated salinity does affect aquatic biota, it is not the primary cause of aquatic ecotoxicity associated with mine water discharge. It should be noted that the Georges River within the shale influenced reaches may naturally have a somewhat high EC (Ecoengineers 2012). To further investigate the ‘whole of effluent’ toxicity of the mine water discharge from West Cliff Colliery (which may include aluminium, arsenic, nickel and zinc, and flocculants), an ecotoxicology study was undertaken by Ecoengineers (2012) as part of Pollution Reduction Program 11. Water collected from Brennans Creek Dam and water being discharged from the dam via the Licensed Discharge Point (LDP) 10 collected between May and June 2012 was not found to be ecotoxic to water flies (*Ceriodaphnia* sp.) and freshwater shrimp (*Paratya* sp.). However, untreated, and to a lesser extent, clarified (dosed with flocculent) mine process water was found to be ecotoxic to these species.

More recent PRPs, including PRP 18 and 19, are aimed at further minimising the impact of discharges from Brennans Creek Dam by modifying the discharge point (PRP 18) and reducing the level of contaminants in discharge water (PRP 19). PRP 20 requires the implementation of an Aquatic Health Monitoring Program to investigate the effect of mine discharge of aquatic ecology of Brennans Creek and the Upper Georges River and to assess the success of PRP 19. The first round of baseline aquatic health monitoring prior to the implementation of PRP 20 was undertaken in October and November 2013 (Niche Environment and Heritage 2014) and the second in November 2015 (Niche Environment and Heritage 2016). The findings of the 2013 study were similar to those of earlier studies undertaken by Cardno Ecology Lab, with pollution sensitive Leptophlebiidae being more abundant, and pollution tolerant taxa, including Caenidae less abundant, at sites subject to discharge compared with reference sites not subject to discharge.

## 5.3 Macroinvertebrates

Statistical analyses did not detect any long term and / or extensive impact to macroinvertebrate indicators. However, the relatively low number of macroinvertebrate taxa in the AUSRIVAS sample collected at Site 9 and the relatively low OE50 Taxa Score from Site 8 in November 2013 could be related to subsidence associated with the extraction of Longwall 35 (Cardno Ecology Lab 2014). Site 8 is just downstream of Pool 44, and Site 9 is downstream of Pools 51 and 54, and encompasses part of Pool 56 (**Figure 5.1**). Reductions in water levels due to subsidence have been observed in all of these pools. The loss of connectivity and flow associated with the drying of these pools could explain why fewer taxa were found at these sites in November 2013. Colonisation of pools by macroinvertebrates could have been hindered or prevented by a lack of connectivity during low flow conditions, and while relatively mobile taxa may have been able to colonise disconnected pools, others may not have. It would also take some time for taxa to colonise previously dry pools, especially pools that were disconnected from upstream and/or downstream flow. As well as the direct physical impacts primarily associated with extraction of Longwall 35, changes to water quality associated with physical impacts could have influenced aquatic ecology, however, none were identified (**Section 5.2**).

In any case, the greater number of taxa and OE50 Taxa Score observed at Sites 9 and 8, respectively, in December 2014 and November 2015 suggest that the macroinvertebrate assemblages at these sites has recovered since the changes to these indicators observed in November 2013 (despite reductions in pool water levels and flow still evident at Site 9 in November 2015). This finding is almost certainly related to the additional flows released from Brennans Creek Dam and the resulting re-establishment of pool water levels, flow and connectivity in affected sections of river (albeit not completely at Site 9 in November 2015). As such, there is no evidence of impacts to macroinvertebrates occurring in data collected subsequent to November 2013. Also, similar changes were not apparent downstream at Sites 10 and 11, suggesting any impacts to macroinvertebrates in November 2013 were localised to the areas directly affected by physical mining impacts. However, it is also noted that potential contaminants in water discharged from Brennans Creek Dam may be affecting macroinvertebrates in the Georges River irrespective to any affect due to subsidence (**Section 5.2**). The suggested recovery in macroinvertebrate data is supported by the results of the statistical analyses. Despite fewer taxa being found at Site 8 and 9 in November 2013 than what may otherwise be expected, there was no evidence in the SIGNAL2 Index data to suggest that the macroinvertebrate fauna at these, or any other site sampled, was becoming increasingly dominated by pollution tolerant taxa during this or later surveys.

The pattern of occurrence of individual taxa among sites and surveys also provides very limited evidence of an effect due to mining. The absence of several taxa (including leptophlebiids and caenids) from Site 9 only, and the absence of baetids from Sites 9 and 10 only, in November 2013 may have been related to the physical mining impacts described here and associated with extraction of Longwall 35 (Cardno Ecology Lab 2014). However, the occurrence of these taxa, and also Atyidae, all of which have been shown to respond to mine water discharge in the Georges River, is relatively variable among sites and surveys. This suggests either relatively great natural variability and / or variability in the timing and volume of mine water discharge to the Georges River. Examination of the raw data suggest that the difference between the assemblage sampled at Site 9 in November 2013 and all other assemblages sampled apparent in the PCO (**Figure 4.4**), appears due to the absence of several pollution tolerant taxa and one pollution sensitive taxon at Site 9. This is likely to be due to the reduction in aquatic habitat and flow observed here, as no impacts to water quality were observed (**Section 5.2**). The presence of pollution sensitive Leptophlebiidae and pollution tolerant Caenidae at all or most sites in December 2014 and November 2015 could suggest that this section of the Georges River currently experiences an intermediate influence due to mine water discharge from West Cliff Colliery. Each of these taxa has been shown to respond to potential pollution in mine water discharge to the Georges River (**Section 5.2**).

The results of the statistical analyses and PCO indicate that the structure of macroinvertebrate assemblages at Site 11 differ somewhat from those at Sites 6 and 7. This may be explained by several factors, including differences between habitats irrespective of mining (the aquatic habitat at Site 11 is somewhat different to that at Site 6 (**Section 4.2**), differences in water flow and the influence of potential contaminants associated with water releases from Brennans Creek Dam or a combination of these factors.

In general, the aquatic macroinvertebrate fauna in the Georges River appears to have experienced some degree of environmental stress prior to, and hence independent of, mining and continues to do so. This is evident in OE50 Taxa Scores and SIGNAL2 Indices often indicative of poor water and / or habitat quality and water pollution, respectively. This may be associated with the relatively high conductivity in the river detected during most Surveys (**Section 5.2**) as well as any other potential contaminants in mine discharge water.

## 5.4 Fish

On the whole, species composition of the fish assemblages sampled in December 2014 and November 2015 was comparable with that observed during the previous surveys. Each fish species, except flathead gudgeon, sampled in previous surveys was recorded in the current survey. Flathead gudgeon was sampled in the Georges River as part of this monitoring program in December 2014, though this species is known from other work to occur here (Cardno Ecology Lab 2012a). While there was some evidence to suggest fewer fish in general were sampled in December 2015 compared with November 2014, similar numbers have been sampled previously and there is no evidence in data collected in December 2015 of impact to fish assemblages.

The observation of only one species (non-native eastern gambusia) at Site 9 in November 2015 could, at least partly, be related the absence of water in some sections of the river at this site (and associated effects on habitat availability and connectivity). However, it may also be due to natural variation, considering the low numbers of fish sampled at all sites during this Survey. The presence of four native species of fish at Site 9 during December 2014, when flow and pool water levels were similar to that observed prior to the physical mining impacts observed in November 2013, suggests that fish can return to this section of the river soon after any increase in flow and water levels.

The absence of fish and larger mobile invertebrates (freshwater crayfish and shrimp) at Site 9 in November 2013 suggests these fauna experienced impacts associated with the extraction of Longwall 35 (Cardno Ecology Lab 2014). It is possible that some of the pools that were present at this site had drained earlier in 2013 and that fish and larger mobile invertebrates have not yet had the opportunity to recolonise these pools. During November 2013, several of the pools were disconnected from upstream or downstream flow, or both. Although a loss of river connectivity during low flow conditions could impact the passage of migratory fish species (e.g. eels and the Cox's gudgeon), with potential consequences for these species upstream and downstream of the affected areas, there was no suggestion that an impact to fish occurred at sites upstream and downstream of Site 9 (including Site 8 where physical impacts were observed) in November 2013 (Cardno Ecology Lab 2014).

Carp gudgeons are relatively undescribed and several species may be present on the east coast of Australia. At least two species have been identified from the Georges River over the course of the monitoring program, likely firetail gudgeon and possibly also Lake's carp gudgeon Other species within this genus may also have been sampled, however, due to many overlapping characteristics and in the absence of published taxonomic keys it is impossible to identify them with any confidence.

# 6 Conclusion

The data collected during the most recent Surveys in December 2014 and November 2015 suggest that aquatic habitat, macroinvertebrates and fish that were affected by the physical mining impacts observed in November 2013 associated with the extraction of Longwall 35, have mostly recovered. Recovery is most evident at Site 8, where pool water levels and flow appeared normal during the two recent surveys. While recovery in fish and macroinvertebrate indicators is also evident at Site 9, this site still appears to be affected by reductions in aquatic habitat and connectivity due to persistent low pool water levels and flow, which were below baseline levels in some sections in November 2015. Recovery that has been observed is almost certainly a result of the restoration (at least temporarily) of pool water levels and flow in affected areas of the Georges River following the increased releases from Brennans Creek Dam. This measure would have reduced impacts to aquatic ecology related to reduced water levels and flow and changes to river connectivity.

The impacts to aquatic ecology observed in November 2013 appeared to be linked to the direct loss of aquatic habitat and river connectivity associated with the lowering of pool water levels and loss of flow following subsidence. Impacts to river connectivity would also be expected to affect the ability of fish to move upstream and downstream of the affected areas, although there is no evidence of this in the data. In November 2013, impacts to aquatic ecology due to extraction of Longwall 35 appear localised to areas affected by the physical mining impacts, as no changes to aquatic ecology were evident at sites further downstream from Sites 8 and 9. Furthermore, the results of the statistical analyses do not indicate any widespread or persistent impacts have occurred following the commencement of extraction of Longwall 35. While the observations in December 2014 suggest that impacts to aquatic ecology were short-term, it is considered that flow and pool water levels will need to be maintained in the area (i.e. via increased releases from Brennans Creek Dam) until any natural and / or planned remediation has taken place. The low pool water levels and flow at Site 9 in November 2015 suggests that impacts to aquatic habitat and connectivity here at least, may be persistent.

There is no evidence to suggest the extraction of Longwalls 36 and 37 has had any impact on indicators of aquatic ecology. This is not surprising considering that no physical impacts (additional to those observed for Longwall 35), or any significant impacts to water quality have been attributed to mining of these Longwalls. Similarly, there is no evidence that the relatively minor physical impacts observed during extraction of Longwall 38 have affected aquatic ecology. Despite this, it is possible that the cumulative effect of any impact associated with extraction of each of these longwalls, may have contributed to the severity, extent and rate of recovery of impacts to aquatic ecology attributed to Longwall 35.

Potential changes to water quality due to subsidence could also be a contributing factor to the observed impacts to aquatic indicators, however, there is little or no evidence of any impacts to water quality from the mining. Potential pollutants associated with mine water discharge from the West Cliff Colliery via Brennans Creek Dam could be influencing macroinvertebrates (and other aspects of aquatic ecology) in this section of the river irrespective of any affect due to subsidence. However, the presence of pollution sensitive Leptophlebiidae, which have been shown to be less abundant at sites on the Georges River subject to discharge compared with reference sites, suggests that this section of river is not influenced to any great extent by any potential contaminants in mine water discharge. It is also possible that the volume of water discharged from Brennans Creek Dam, and the contributions to Georges River flow from rainfall, rural and urban run-off, together with local effects due to flow diversions following subsidence, have a greater influence on aquatic biota than any effect due to potential pollution in mine water discharge, at least in the section of river sampled in this study.

# 7 Recommendations

It is recommended that increased discharges from Brennans Creek Dam be maintained for as long as practicable whenever low pool water levels and flow resulting from mining are experienced in the Georges River. This will help minimise impacts to aquatic ecology associated with loss of habitat, flow and connectivity. It may also assist in maintaining water flow and connectivity during drought.

Due to the ongoing impacts observed following extraction of Longwall 35, and to provide the second and first year of after extraction data for Longwalls 37 and 38, respectively, it is also recommended that further monitoring be undertaken during the spring 2016 AUSRIVAS sampling season. Further monitoring in spring 2017 would also provide at least two years of after extraction data for Longwalls 35 to 38. This would provide further information on the persistence and recovery of previously identified impacts to ecological indicators associated with longwall extraction. Collection of additional after extraction data will facilitate the assessment of the impact of the longwall extraction on the aquatic habitat and biota in the Georges River. It will also provide information that will help further assess the impacts to aquatic ecology associated with the extraction of Longwall 35, and help inform any future remediation efforts in the Georges River following the completion of mining in West Cliff Area 5. The ongoing aquatic ecology monitoring associated with PRP 20 will provide information on the effect of mine water discharge from West Cliff Colliery on the Georges River.

South32 are currently preparing a Georges River remediation plan for West Cliff Area 5 Longwalls 32 to 38. Remediation options would likely include repairing rock fractures to minimise flow diversions and restore pool water level and flow to baseline levels. Monitoring of aquatic ecology should be undertaken to provide information on the response of aquatic ecology indicators (habitat, macroinvertebrates and fish) to any remediation efforts, noting that remediation efforts may also potentially result in some short term negative impacts to aquatic ecology. Depending on the timing and extent of any remediation efforts, such sampling could likely be incorporated into ongoing monitoring. An increase in the level of replication effort (e.g. number of AUSRIAVS samples collected per site in each Survey) and / or incorporation of quantitative methods of sampling macroinvertebrates (e.g. artificial collector, suction and SURBER sampling) may also be needed to provide additional certainty around the conclusions.

# 8 References

Anderson, M.J., Gorley, R.N. and Clarke, K.R. (2008). PERMANOVA+ for PRIMER: Guide to Software and Statistical Methods. Primer-E, Plymouth.

ANZECC/ARMCANZ (2000). Australian and New Zealand Guidelines for Fresh and Marine Waters. Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand. BHPBIC (2010). West Cliff Mine, Longwall 33: End of Panel Report – Illawarra Coal Environmental Field Team.

BHPBIC (2008). West Cliff Mine, Longwall 32: End of Panel Report – Illawarra Coal Environmental Field Crew.

BHPBIC (BHP Billiton-Illawarra Coal) (2013a). West Cliff Area 5 Longwall 35 End of Panel Report. November 2013.

BHPBIC (BHP Billiton Illawarra Coal) (2013b). West Cliff Area 5 Longwall 35 Impact report 1 November 2013.

BHPBIC (BHP Billiton Illawarra Coal) (2013c). West Cliff Area 5 Longwall 35 Impact Report 21 November 2013.

BHPBIC (BHP Billiton Illawarra Coal) (2014a). Extraction Plan. West Cliff Area 5. Longwalls 37 and 38. Rev B.

BHPBIC (BHP Billiton Illawarra Coal) (2014b). Biodiversity Management Plan. Annex D. West Cliff Area 5. Longwalls 37 and 38 Extraction Plan.

BHPBIC (BHP Billiton Illawarra Coal) (2014c). West Cliff Area 5. Longwall 36. End of Panel Report.

BHPBIC (BHP Billiton Illawarra Coal) (2015). Longwall 37 End of Panel. Landscape Monitoring Report.

Bioanalysis (2009). Illawarra Coal – Bulli Seam Operations – Aquatic Ecology Assessment. Report Prepared for Illawarra Coal Holdings Pty. Ltd.

Cardno Ecology Lab (2009). West Cliff Colliery Pollution Reduction Program 10. Glass Shrimp Translocation Experiment. Report prepared for BHPBIC.

Cardno Ecology Lab (2010a). West Cliff Colliery Longwall 33 End of Panel Report. Aquatic Habitat and Biota. Report prepared for BHPBIC.

Cardno Ecology Lab (2010b). West Cliff Longwalls 31-36, Aquatic Ecology Monitoring Autumn 2010. Job Number: EL0809014. Report prepared for BHPBIC.

Cardno Ecology Lab (2010c). West Cliff Colliery. Pollution Reduction Program 10 – Discharge of Water from Brennans Creek Dam. PRP 10.1 Report.

Cardno Ecology Lab (2010d). Effects of Mine Water Salinity on Freshwater Biota. Report to the Australian Coal Association Research Program. January 2010

Cardno Ecology Lab (2011). Review of Aquatic Fauna and Flora for West Cliff Longwall 34. Report prepared for BHPBIC.

Cardno Ecology Lab (2012a). West Cliff Longwalls 37-38. Aquatic Flora and Fauna Assessment. Report Prepared for BHP Billiton – Illawarra Coal.

Cardno Ecology Lab (2012b). West Cliff Longwalls 33-36. Aquatic Ecology Monitoring May 2002-November 2011. Report Prepared for BHP Billiton – Illawarra Coal.

Cardno Ecology Lab (2013). West Cliff Longwalls 33-38. Aquatic Ecology Monitoring May 2002 – December 2012.

Cardno Ecology Lab (2014). West Cliff Longwalls 33-38. Aquatic Ecology Monitoring 2002-2013.

Cardno Ecology Lab (2015). West Cliff Longwalls 31 to 38. Aquatic Ecology Monitoring 2002 to 2014

Chessman, B. C. (2003). New sensitivity grades for Australian river macroinvertebrates. *Marine and Freshwater Research.* 54: pp. 95-103.

Clarke K. R. (1993). Non-parametric multivariate analyses of changes in assemblage structure. *Australian Journal of Ecology,* **18**: pp. 117-143.

Clarke K.R. and Gorley R.N. (2006). Primer V6: User Manual/Tutorial. Primer-E, Plymouth.

Comur Consulting (2007). End of Panel Report for Longwall 31A at West Cliff Colliery. Report prepared for BHPBIC.

Comur Consulting Pty Ltd (2010). West Cliff Colliery Longwall 33. End of Panel Report. Prepared from BHP Billiton. March 2010.

Comur Consulting Pty Ltd (2012). West Cliff Colliery Longwall 34. End of Panel Report. Prepared from BHP Billiton. January 2012.

Gooderham, J. and Tsyrlin, E. (2002). The Waterbug Book. A Guide to the Freshwater Macroinvertebrates of Temperate Australia. CSIRO Publishing, Collingwood, Victoria.

Coysh, J, Nichols, S. Ransom, G., Simpson, J., Norris, R., Barmuta, L. and Chessman, B. (2000). AUSRIVAS Macroinvertebrate Bioassessment Predictive Modelling Manual.

Ecoengineers (2005). Assessment of Water Quality Effects, West Cliff Colliery Longwalls 31 to 33. Report prepared for Comur Consulting Pty Ltd.

Ecoengineers (2007). Assessment of Water Quality Effects, West Cliff Colliery Longwalls 34 to 36. Report prepared for Comur Consulting Pty Ltd

Ecoengineers (2008). End of Panel Assessment of Water Flow and Quality effects – West Cliff Colliery Longwall 32. Report prepared for BHPBIC.

Ecoengineers (2010). End of Panel Assessment of Water Flow and Quality effects – West Cliff Colliery Longwall 33. Report prepared for BHPBIC.

Ecoengineers (2011). End of Panel Assessment of Water Flow and Quality Effects West Cliff Colliery Longwall 34. Prepared for BHP Billiton Illawarra Coal. November 2011.

Ecoengineers (2012). Pollution Reduction Program 11 – West Cliff Mine Water Discharge Ecotoxicity Study.

Cardno Ecology Lab (2013). West Cliff Longwalls 33-38 – Aquatic Ecology Monitoring May 2002 – December 2012.

Ecoengineers (2013). End of Panel Assessment of Water Flow and Quality Effects West Cliff Colliery Longwall 35. Prepared for BHP Billiton-Illawarra Coal. September 2013.

Ecoengineers (2015). End of Panel Assessment of Surface Water Effects. West Cliff Colliery Longwall 37

Geoterra (2016). End of Panel Assessment for Longwall 38. Surface and Groundwater Quality.

MSEC (Mine Subsidence Engineering Consultants Pty Ltd) (2005). Subsidence Impacts on Natural Features and Items of Infrastructure due to Mining Longwalls 31 to 33. Report prepared for BHPBIC.

MSEC (Mine Subsidence Engineering Consultants Pty Ltd) (2007). West Cliff Colliery Area 5 Report on the prediction of subsidence parameters and the assessment of on mine subsidence impacts on natural features and surface infrastructure resulting from the extraction of proposed Longwalls 34 to 36 in Area 5 at West Cliff Colliery in support of the SMP Application. Report Number MSEC326B. Report Prepared for BHP Illawarra Coal.

MSEC (Mine Subsidence Engineering Consultants Pty Ltd) (2008). End of Panel Subsidence Monitoring report for west Cliff Longwall 32. Report prepared for BHPBIC.

MSEC (Mine Subsidence Engineering Consultants Pty Ltd) (2012). West Cliff Colliery – Longwalls 37 and 38. Subsidence Predictions and Impact Assessments for the Natural Features and Surface Infrastructure in Support of the Extraction Plan. Report No. MSEC533. Prepared for BHP Billiton - Illawarra Coal. December 2012.

MSEC (Mine Subsidence Engineering Consultants Pty Ltd) South32 Illawarra Coal: West Cliff Colliery – Longwall 38. End of Panel Subsidence Monitoring Report for West Cliff Longwall 38.

Niche Environment and Heritage (2014). West Cliff Colliery – BHP Illawarra Coal. Pollution Reduction Program 20 – Aquatic Health Monitoring Report 2014. Fish and Macroinvertebrates.

Niche Environment and Heritage (2015). Appin North – South 32. Pollution Reduction Program 20 – Aquatic Health Monitoring Report 2015.

South32 (2016). West Cliff Longwall 38 End of Panel Landscape Report

The Ecology Lab (2003). West Cliff Workings - Effects of Mine Subsidence on Aquatic Habitat and Biota in Waterways near Appin. Report prepared for BHPBIC.

The Ecology Lab Pty Ltd (2004a). Ecological Effects of Mine Water Discharge from West Cliff Colliery into Brennans Creek - Interim Report: Module 2 AUSRIVAS Analysis, Prepared for: BHP Billiton - Illawarra Coal. The Ecology Lab Pty Ltd, Brookvale NSW.

The Ecology Lab Pty Ltd (2004b). Ecological Effects of Mine Water Discharge from West Cliff Colliery into Brennans Creek, Prepared for: BHP Billiton – Illawarra Coal.

The Ecology Lab Pty Ltd (2004c). Ecological Effects of Mine Water Discharge from Appin Colliery into the Georges River - Interim Report: Module 2 AUSRIVAS Analysis, Prepared for: BHP Billiton - Illawarra Coal.

The Ecology Lab Pty Ltd (2004d). Ecological Effects of Mine Water Discharge from Appin Colliery into the Georges River, Prepared for: BHP Billiton - Illawarra Coal .

The Ecology Lab Pty Ltd (2004e). Effects of Remediation of Georges River at Marhnyes Hole on Aquatic Ecology, Prepared for: BHP Billiton, Illawarra Coal.

The Ecology Lab Pty Ltd (2004f). Investigation of Baseline Stations for Monitoring Effects on Aquatic Ecology of Activities Associated with Coal Mining, Prepared for: BHP Billiton, Illawarra Coal.

The Ecology Lab Pty Ltd (2004g). Ecological Effects of Mine Water Discharge from Douglas Pit Top - Draft Report, Prepared for: BHP Billiton - Illawarra Coal.

The Ecology Lab (2005a). West Cliff Area 5. Effects of Mine Subsidence on Aquatic Habitat and Biota. Report prepared for BHPBIC. Report Number 14/0506 A.

The Ecology Lab Pty Ltd (2005b). Ecological Effects of Mine Water Discharge from Douglas Colliery: Autumn and Spring Surveys, 2004, Prepared for: BHP Billiton - Illawarra Coal.

The Ecology Lab Pty Ltd (2006a). Ecological Effects of Mine Water Discharge from Appin Colliery into the Georges River, Final Report for: BHP Billiton – Illawarra Coal.

The Ecology Lab Pty Ltd (2006b). Ecological Effects of Mine Water Discharge from West Cliff Colliery into Brennans Creek, Final Report for: BHP Billiton – Illawarra Coal.

The Ecology Lab (2007). West Cliff Colliery Longwall 31a End of Panel Report. Aquatic Habitat and Biota. Report prepared for BHPBIC.

The Ecology Lab (2008a). West Cliff Area 5 Longwalls 34-36. Assessment of Mine Subsidence Impacts on Aquatic Habitat and Biota. Report prepared for BHPBIC.

The Ecology Lab (2008b). West Cliff Colliery Longwall 32 End of Panel Report. Aquatic Habitat and Biota. Report prepared for BHPBIC.

The Ecology Lab (2008c). West Cliff Longwalls 31-36 - Spring 2008 Aquatic Ecology Monitoring. Report prepared for BHPBIC. Report Number 14/0809 A.

Turak, E., Waddell, N. and Johnstone, G. (2004). New South Wales (NSW) Australian River Assessment System (AUSRIVAS) Sampling and Processing Manual. Environmental Protection Authority. pp. 45.

West Cliff Area 5

Aquatic Ecology Monitoring 2002 to 2015

# APPENDIX

# A

## GPS COORDINATES OF AQUATIC ECOLOGY MONITORING SITES 6 TO

Cardno®
Shaping the Future

| Site | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|
| Easting | 296877 | 296886 | 297145 | 296970 | 296709 | 297204 |
| Northing | 6216094 | 6216418 | 6216736 | 6217230 | 6217614 | 6218446 |

Datum: WGS 84, Zone 56H

West Cliff Area 5

Aquatic Ecology Monitoring 2002 to 2015

# APPENDIX

# B

# AQUATIC MACROPHYTES RECORDED IN THE GEORGES RIVER

| Taxa | Bioanalysis (2009) (Site GR1)) | Bioanalysis (2009) (Site GR2) | Cardno Ecology Lab (2012b) |
|---|---|---|---|
| *Baumea articulata* | | | x |
| *Baumea juncea* | | | x |
| *Chorizandra cymbaria* | x | | |
| *Eleocharis sphacelata* | x | | |
| *Eleocharis* sp. | | | x |
| *Fimbristylis* sp. | | x | |
| *Gahnia clarkei* | x | | |
| *Hemarthria uncinata* | | x | |
| *Isolepis prolifer* | | | x |
| *Isolepis inundata* | x | x | |
| *Isolepis* sp. | | | x |
| *Juncus fockei* | | x | |
| *Juncus usitatus* | | | x |
| *Juncus polyanthemus* | x | | |
| *Lepidosperma filiforme* | x | x | |
| *Potamogeton sulcatus* | x | | |
| *Potamogeton ticarinatus* | | | x |
| *Potamogeton* sp. | | | x |
| *Schoenus melanostachys* | | x | |
| *Tristaniopsis laurina* | | x | |
| *Typha orientalis* | x | | |
| *Typha* spp. | | | x |
| *Vallisneria* sp. | | | x |

West Cliff Area 5

Aquatic Ecology Monitoring 2002 to 2015

# APPENDIX

# C

## MEAN VALUES OF WATER QUALITY INDICATORS FOR SITES 6 TO 11 ON THE GEORGES RIVER 2008 TO 2015

Cardno®
Shaping the Future

| Variable | DTV | Sep 2008 | | May 2010 | | Nov 2011 | | May 2012 | | Dec 2012 | | Nov 2013 | | Dec 2014 | | Nov 2015 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | M | SE | M | SE | M | SE | M | SE | M | SE | M | SE | M | SE | | |
| **Site 6** | | | | | | | | | | | | | | | | | |
| Temp(°C) | | 19.8 | 0.0 | 12.9 | 0.0 | 20.5 | 0.0 | 10.5 | 0.0 | 20.5 | 0.4 | 20.1 | 0.3 | 22.7 | 0.0 | 20.8 | 0.0 |
| EC (µS/cm) | 30-350 | 841 | 0 | 2353 | 7 | 1356 | 1 | 1028 | 0 | 2054 | 0 | 2069 | 5 | 1909 | 14 | 1823 | 0 |
| pH | 6.5-8.0 | 8.8 | 0.0 | 9.2 | 0.0 | 8.5 | 0.0 | 8.3 | 0.0 | 8.8 | 0 | 8.5 | 0.0 | 8.8 | 0.0 | 8.7 | 0.0 |
| ORP (mV) | | 144 | 0 | 414 | 1 | 398 | 2 | 447 | 2 | 77 | 9.1 | 59.3 | 2.4 | 142 | 3 | 129 | 0 |
| DO (% Sat) | 90-110 | | | 121.3 | 3.9 | 100.4 | 1.6 | 106.9 | 1.6 | 86.8 | 18.2 | 106.3 | 2.05 | 91.6 | 1.0 | 99.6 | 0.0 |
| Turbidity (NTU) | 2-25 | 14.0 | 2.6 | 1.0 | 0.1 | 10.6 | 0.7 | 5.8 | 0.9 | 0.2 | 0.1 | 2.1 | 0.0 | 13.8 | 0.3 | 8.9 | 0.0 |
| **Site 7** | | | | | | | | | | | | | | | | | |
| Temp (°C) | | 15.9 | 0.0 | 13.8 | 0.0 | 20.2 | 0.0 | | | 22.0 | 0.1 | 20.7 | 0.2 | 22.1 | 0.0 | 21.4 | 0.2 |
| EC (µS/cm) | 30-350 | 823 | 0 | 2275 | 1 | 1325 | 2 | | | 1905 | 12 | 1998 | 2 | 1719 | 0 | 1784 | 0 |
| pH | 6.5-8.0 | 8.9 | 0.0 | 8.8 | 0.0 | 8.3 | 0.0 | | | 8.4 | 0.0 | 8.4 | 0.0 | 8.4 | 0.0 | 8.7 | 0.0 |
| ORP (mV) | | 118 | 1 | 422 | 1 | 411 | 1 | | | 94 | 2.6 | 50.4 | 1.7 | 127 | 0 | 120 | 0 |
| DO (% Sat) | 90-110 | 95.0 | 0.1 | 77.4 | 3.9 | 76.6 | 0.5 | | | 88.1 | 10 | 86.5 | 1.9 | 82.5 | 0.0 | 112.5 | 0.5 |
| Turbidity (NTU) | 2-25 | 5.9 | 0.2 | 0.8 | 0.0 | 21.9 | 0.7 | | | 2.0 | 0.3 | 1.7 | 0.2 | 10.9 | 0.0 | 10.0 | 0.0 |
| **Site 8** | | | | | | | | | | | | | | | | | |
| Temp (°C) | | 16.4 | 0.0 | 14.5 | 1.0 | 19.7 | 0.0 | 10.7 | 0.2 | 21.0 | 0.3 | 20.5 | 0.6 | 23.9 | 0.0 | 22.8 | 0.1 |
| EC (µS/cm) | 30-350 | 844 | 1 | 2035 | 0 | 1285 | 5 | 1007 | 1 | 1824 | 5 | 1761 | 30 | 917 | 0 | 1712 | 2 |
| pH | 6.5-8.0 | 9.1 | 0.0 | 8.0 | 0.0 | 8.5 | 0.0 | 8.3 | 0.0 | 8.7 | 0 | 8.1 | 0.0 | 8.7 | 0.0 | 8.5 | 0.0 |
| ORP (mV) | | 119 | 0 | 442 | 0 | 392 | 2 | 465 | 7 | 95 | 0.5 | 57.5 | 3.0 | 123 | 1 | 80 | 1 |
| DO (% Sat) | 90-110 | 97.6 | 0.1 | 97.9 | 1.6 | 96.6 | 0.1 | 81.6 | 0.7 | 114.9 | 8.5 | 98.1 | 3.5 | 103.3 | 0.4 | 108.2 | 0.4 |
| Turbidity (NTU) | 2-25 | 5.8 | 0.1 | 11.3 | 0.1 | 22.0 | 0.4 | 1.1 | 0.2 | 1.1 | 0.1 | 6.0 | 0.2 | 8.1 | 0.1 | 9.3 | 0.0 |

| Variable | DTV | Sep 2008 | | May 2010 | | Nov 2011 | | May 2012 | | Dec 2012 | | Nov 2013 | | Dec 2014 | | Nov 2015 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | M | SE | M | SE | M | SE | M | SE | M | SE | M | SE | M | SE | | |
| **Site 9** | | | | | | | | | | | | | | | | | |
| Temp(°C) | | 16.5 | 0.0 | 11.5 | 0.0 | 21.6 | 0.0 | 10.6 | 0.4 | 20.0 | 0.0 | 18.5 | 0.0 | 22.3 | 0.0 | 22.0 | 0.0 |
| EC (µS/cm) | 30-350 | 969 | 1 | 2167 | 3 | 1293 | 0 | 1013 | 5 | 1801 | 2.0 | 1728 | 0 | 1743 | 9 | 1653 | 1 |
| pH | 6.5-8.0 | 9.0 | 0.0 | 8.8 | 0.0 | 8.6 | 0.0 | 8.4 | 0.0 | 8.8 | 0.0 | 8.4 | 0.0 | 8.6 | 0.0 | 8.2 | 0.0 |
| ORP (mV) | | 135 | 0 | 432 | 0 | 415 | 1 | 421 | 2 | 105 | 1 | 66.6 | 0.4 | 123 | 0 | 110 | 1 |
| DO (% Sat) | 90-110 | 107.3 | 0.0 | 92.6 | 2.0 | 94.6 | 0.5 | 100.5 | 3.0 | 93.1 | 0.7 | 81.7 | 0.2 | 86.4 | 0.1 | 89.6 | 0.0 |
| Turbidity (NTU) | 2-25 | 7.1 | 0.0 | 0.9 | 0.0 | 11.1 | 0.2 | 7.2 | 0.2 | 1.4 | 0.4 | 3.6 | 0.1 | 11.9 | 0.3 | 7.8 | 0.0 |
| **Site 10** | | | | | | | | | | | | | | | | | |
| Temp (°C) | | 15.4 | 0.0 | 11.5 | 0.0 | 21.5 | 0.0 | 10.3 | 0.0 | 19.8 | 0.5 | 16.6 | 0.0 | 22.1 | 0.0 | 20.1 | 0.0 |
| EC (µS/cm) | 30-350 | 950 | 1 | 2187 | 5 | 1292 | 2 | 1033 | 3 | 1826 | 5.5 | 1556 | 1 | 1719 | 0 | 1630 | 0 |
| pH | 6.5-8.0 | 9.0 | 0.0 | 8.8 | 0.0 | 8.5 | 0.0 | 8.5 | 0.0 | 8.8 | 0 | 7.6 | 0.0 | 8.4 | 0.0 | 8.0 | 0.0 |
| ORP (mV) | | 103 | 2 | 438 | 1 | 423 | 1 | 447 | 2 | 63 | 7.2 | 80.5 | 1.0 | 127 | 0 | 116 | 0 |
| DO (% Sat) | 90-110 | 90.7 | 0.1 | 100.4 | 0.2 | 80.6 | 0.3 | 89.8 | 0.8 | 92.1 | 8.6 | 52.4 | 0.3 | 82.5 | 0.0 | 71.6 | 0.0 |
| Turbidity (NTU) | 2-25 | 6.8 | 0.0 | 1.2 | 0.0 | 8.0 | 0.4 | 0.7 | 0.1 | 2.6 | 0.6 | 28.9 | 0.0 | 10.9 | 0.0 | 6.5 | 0.0 |
| **Site 11** | | | | | | | | | | | | | | | | | |
| Temp (°C) | | 14.6 | 0.0 | 11.6 | 0.0 | 20.6 | 0.0 | 10.7 | 0.0 | 19.1 | 0.1 | 17.8 | 0.3 | 22.7 | 0.0 | | |
| EC (µS/cm) | 30-350 | 751 | 2 | 2190 | 1 | 1274 | 5 | 1034 | 3 | 1775 | 2.5 | 1469 | 4 | 1703 | 2 | | |
| pH | 6.5-8.0 | 8.8 | 0.0 | 8.7 | 0.0 | 8.6 | 0.0 | 8.6 | 0.0 | 8.8 | 0.0 | 8.3 | 0.0 | 8.4 | 0.0 | | |
| ORP (mV) | | 138 | 0 | 465 | 15 | 465 | 1 | 443 | 1 | 106 | 1 | 53.4 | 0.1 | 126 | 0 | | |
| DO (% Sat) | 90-110 | 106.0 | 0.1 | 105.2 | 1.3 | 101.0 | 2.0 | 95.8 | 0.5 | 87.7 | 1.0 | 107.5 | 1.4 | 84.0 | 0.5 | | |
| Turbidity (NTU) | 2-25 | 9.6 | 0.1 | 0.9 | 0.0 | 10.0 | 0.4 | 5.9 | 0.3 | 1.1 | 0.3 | 9.3 | 0.4 | 9.7 | 0.0 | | |

(SE=Standard Error), n=2, except for turbidity where n=6). Default Trigger Values (DTVs) are for the protection of slightly disturbed upland rivers of South-east Australia (ANZECC/ARMCANZ 2000). Shading indicates mean values are outside of DTVs.

West Cliff Area 5

Aquatic Ecology Monitoring 2002 to 2015

# APPENDIX

# D

## MACROINVERTEBRATE TAXA FROM EDGE HABITAT AT SITES 6 TO 11 ON THE GEORGES RIVER IN NOVEMBER 2015

Shaping the Future

| Taxon | Site 6 | Site 7 | Site 8 | Site 9 | Site 10 | Site 11 |
|---|---|---|---|---|---|---|
| Aeshnidae | | | | 1 | 1 | |
| Austrocorduliidae | | | | | | 1 |
| Baetidae | 4 | 3 | 2 | | 1 | 1 |
| Caenidae | 2 | 10 | 2 | 10 | 6 | 3 |
| Calamoceratidae | | | | | | 1 |
| Ceratopogonidae | 3 | 3 | 1 | 3 | | 1 |
| Chironomidae/Chironominae | 10 | 10 | 10 | 3 | 10 | |
| Chironomidae/Orthocladiinae | 1 | 4 | 2 | 2 | 1 | |
| Chironomidae/Tanypodinae | 5 | 2 | 10 | 2 | 2 | 1 |
| Cladocera | 5 | 1 | | | 2 | |
| Coenagrionidae | 10 | 10 | 5 | 2 | 6 | 1 |
| Copepoda | 1 | | 2 | | 1 | 1 |
| Corixidae | 4 | | | 4 | | 1 |
| Culicidae | | | 4 | 1 | | |
| Dixidae | | | | | 3 | 1 |
| Dugesiidae | | | 2 | 2 | 1 | |
| Dytiscidae | 10 | 10 | 10 | 2 | 6 | 3 |
| Elmidae | 2 | | 4 | | | |
| Empididae | | | | 1 | | 1 |
| Gelastocoridae | 1 | | 1 | | | |
| Glossiphoniidae | | | | | 1 | |
| Gomphidae | 1 | 1 | 1 | 8 | 2 | |
| Gyrinidae | 1 | 1 | | | | |
| Hemicorduliidae | 4 | 10 | 3 | 3 | 3 | 4 |
| Hydracarina | | | 3 | 1 | 1 | 2 |
| Hydraenidae | | | | | 1 | 2 |
| Hydrobiosidae | | | | 1 | | |
| Hydrophilidae | 1 | 1 | 10 | | 3 | 3 |
| Hydroptilidae | 9 | 8 | 5 | | 1 | |
| Isostictidae | | 1 | | | | |
| Leptoceridae | 4 | 6 | 1 | 10 | 10 | 10 |
| Leptophlebiidae | | | 1 | 1 | 6 | 10 |
| Megapodagrionidae | | 1 | | 2 | 3 | 4 |
| Notonectidae | | 1 | 4 | | 2 | 1 |
| Oligochaeta | | 2 | | | 2 | 2 |
| Ostracoda | 3 | 2 | 3 | 2 | 10 | 10 |
| Physidae | | 2 | | 3 | 1 | 3 |
| Protoneuridae | 1 | | | | | |
| Scirtidae | | | | 1 | | 1 |
| Synlestidae | | 1 | | | | |
| Synthemistidae | | | | 2 | | 1 |
| Tabanidae | | 1 | | | | |
| Telephlebiidae | 5 | 1 | | | | 5 |
| Tipulidae | | | | 2 | | |
| Veliidae | 3 | | 1 | | | 1 |

Note: up to 10 individuals of each taxon counted

West Cliff Area 5

Aquatic Ecology Monitoring 2002 to 2015

# APPENDIX

# E

# NUMBERS OF MACROINVERTEBRATE TAXA, OE50 TAXA SCORES AND SIGNAL2 INDICES FOR AUSRIVAS EDGE SAMPLES FROM THE GEORGES RIVER 2002 TO 2015

Cardno®
Shaping the Future

| | Site 6 | Site 7 | Site 8 | Site 9 | Site 10 | Site 11 |
|---|---|---|---|---|---|---|
| Number of Taxa | | | | | | |
| May 2002 | 23 | | | | | |
| March 2005 | 9 | | | | | |
| November 2007 | 19 | 27 | 25 | 20 | | |
| September 2008 | 25 | 22 | 20 | 25 | 31 | 23 |
| May 2010 | 14 | 21 | 25 | 24 | 23 | 19 |
| November 2011 | 13 | 21 | 16 | 25 | 28 | 20 |
| December 2012 | 32 | 28 | 32 | 30 | 23 | 26 |
| November 2013 | 28 | 26 | 24 | 13 | 28 | 27 |
| December 2014 | 18 | 26 | 25 | 26 | 29 | 30 |
| November 2015 | 23 | 24 | 23 | 24 | 26 | 27 |
| OE50 Taxa Score | | | | | | |
| November 2007 | 0.67 | 1.00 | 0.70 | 0.78 | | |
| September 2008 | 0.65 | 0.87 | 0.80 | 0.74 | 0.93 | 0.90 |
| May 2010 | 0.35 | 0.58 | 0.77 | 0.71 | 0.78 | 0.60 |
| November 2011 | 0.32 | 0.56 | 0.44 | 0.78 | 0.79 | 0.62 |
| December 2012 | 1.01 | 0.82 | 1.02 | 0.93 | 0.80 | 0.80 |
| November 2013 | 0.89 | 0.96 | 0.37 | 0.87 | 0.79 | 0.88 |
| December 2014 | 0.69 | 0.90 | 0.80 | 0.67 | 1.00 | 1.00 |
| November 2015 | 0.53 | 0.62 | 0.65 | 0.53 | 0.70 | 0.92 |
| SIGNAL2 Index | | | | | | |
| May 2002 | 3.5 | | | | | |
| March 2005 | 3.9 | | | | | |
| November 2007 | 4.4 | 3.6 | 3.5 | 4.0 | | |
| September 2008 | 4.2 | 3.8 | 4.3 | 4.0 | 4.2 | 4.0 |
| May 2010 | 3.6 | 3.9 | 3.9 | 3.8 | 4.5 | 3.9 |
| November 2011 | 3.5 | 4.4 | 3.8 | 4.0 | 4.6 | 4.7 |
| December 2012 | 4.3 | 4.0 | 4.1 | 3.9 | 4.2 | 4.0 |
| November 2013 | 4.0 | 4.4 | 3.8 | 4.3 | 4.2 | 4.3 |
| December 2014 | 3.6 | 4.8 | 3.9 | 4.0 | 4.4 | 4.4 |
| November 2015 | 4.3 | 3.8 | 3.9 | 4.2 | 3.7 | 4.4 |

Note: OE50 Taxa Scores not calculated in May 2002 and March 2005

West Cliff Area 5

Aquatic Ecology Monitoring 2002 to 2015

# APPENDIX

# F

## RESULTS OF PERMANOVAS

Cardno®
Shaping the Future

## PERMANOVAs comparing macroinvertebrate assemblages, number of taxa, OE50 Taxa Scores and SIGNAL2 Indices obtained from AUSRIVAS samples collected from Sites 6 to 11 on the Georges River in September 2008, November 2011, December 2012, November 2013, December 2014 and November 2015

Assemblage

| Source of Variation | df | SS | MS | *F* | *P* |
|---|---|---|---|---|---|
| Phase | 1 | 1716 | 1716 | 0.933 | 0.501 |
| Treatment | 1 | 487 | 487 | 0.693 | 0.705 |
| **Survey (Phase)** | **4** | **7351** | **1838** | **2.618** | **<0.001** |
| Treatment x Phase | 1 | 1016 | 1016 | 1.448 | 0.185 |
| Residual (Pooled) | 28 | 19655 | 702 | | |
| Total | 35 | 30225 | | | |

Number of Taxa

| Source of Variation | df | SS | MS | *F* | *P* |
|---|---|---|---|---|---|
| Phase | 1 | 1.0 | 1.0 | 0.019 | 0.897 |
| Treatment | 1 | 2.8 | 2.8 | 0.147 | 0.700 |
| **Survey (Phase)** | **4** | **206.7** | **51.7** | **2.734** | **0.043** |
| Treatment x Phase | 1 | 28.4 | 28.4 | 1.505 | 0.227 |
| Residual (Pooled) | 28 | 529.1 | 18.9 | | |
| Total | 35 | 768.0 | | | |

OE50 Taxa Score

| Source of Variation | df | SS | MS | *F* | *P* |
|---|---|---|---|---|---|
| Phase | 1 | 0.000 | 0.000 | 0.000 | 0.997 |
| Treatment | 1 | 0.003 | 0.003 | 0.132 | 0.719 |
| **Survey (Phase)** | **4** | **0.423** | **0.106** | **4.607** | **0.005** |
| Treatment x Phase | 1 | 0.079 | 0.079 | 3.454 | 0.075 |
| Residual (Pooled) | 28 | 0.643 | 0.023 | | |
| Total | 35 | 1.149 | | | |

SIGNAL2 Index

| Source of Variation | df | SS | MS | *F* | *P* |
|---|---|---|---|---|---|
| Phase | 1 | 0.001 | 0.001 | 0.056 | 0.825 |
| Treatment | 1 | 0.061 | 0.061 | 0.592 | 0.446 |
| Survey (Phase) | 4 | 0.092 | 0.023 | 0.223 | 0.923 |
| Treatment x Phase | 1 | 0.100 | 0.100 | 0.965 | 0.339 |
| Residual (Pooled) | 28 | 2.909 | 0.104 | | |
| Total | 35 | 3.164 | | | |

Note: Residual pooled with Treatment x Survey (Phase) at P > 0.25

West Cliff Area 5

Aquatic Ecology Monitoring 2002 to 2015

# APPENDIX

# G

# NUMBERS OF FISH CAUGHT BY ELECTROFISHING AT SITES 6 TO 11 ON THE GEORGES RIVER 2008 TO 2015

Cardno®
Shaping the Future

| Scientific Name | Common Name | Site 6 | Site 7 | Site 8 | Site 9 | Site 10 | Site 11 |
|---|---|---|---|---|---|---|---|
| November 2015 | | | | | | | |
| *Anguilla* sp. | Freshwater eel | | | | | | |
| *Anguilla australis* | Short-finned eel | 1 | | | | 1 | 3 |
| *Anguilla reinhardtii* | Long-finned eel | 1 | | | | | |
| *Gambusia holbrooki* | Eastern gambusia | 45 | | >100 | 41 | 30 | 13 |
| *Gobiomorphus coxii* | Cox's gudgeon | | | | | 3 | |
| *Hypseleotris* spp. | Carp gudgeons | | | | | 1 | |
| *Philypnodon gradiceps* | Flathead gudgeon | | | | | | |
| December 2014 | | | | | | | |
| *Anguilla* sp. | Freshwater eel | | | | 1 | | 1 |
| *Anguilla australis* | Short-finned eel | 2 | 1 | | 1 | | |
| *Anguilla reinhardtii* | Long-finned eel | | | 1 | | | 2 |
| *Gambusia holbrooki* | Eastern gambusia | 16 | 29 | 32 | 1 | | 2 |
| *Gobiomorphus coxii* | Cox's gudgeon | 1 | | | 1 | 5 | 9 |
| *Hypseleotris* spp. | Carp gudgeons | | | | | 4 | 1 |
| *Philypnodon gradiceps* | Flathead gudgeon | | | | 1 | | |
| November 2013 | | | | | | | |
| *Anguilla* sp. | Freshwater eel | 1 | 1 | | | | 2 |
| *Anguilla australis* | Short-finned eel | | | | | | |
| *Anguilla reinhardtii* | Long-finned eel | | | | | | 1 |
| *Gambusia holbrooki* | Eastern gambusia | 4 | >50 | | | >50 | |
| *Gobiomorphus coxii* | Cox's gudgeon | | 2 | 5 | | 2 | 5 |
| *Hypseleotris* spp. | Carp gudgeons | 4 | | | | | |
| *Philypnodon gradiceps* | Flathead gudgeon | | | | | | |
| December 2012 | | | | | | | |
| *Anguilla* sp. | Freshwater eel | | | | 2 | | |
| *Anguilla australis* | Short-finned eel | 1 | | | | | 4 |
| *Anguilla reinhardtii* | Long-finned eel | 1 | 1 | 4 | 2 | 1 | 4 |
| *Gambusia holbrooki* | Eastern gambusia | 32 | 5 | 44 | 5 | 7 | 5 |
| *Gobiomorphus coxii* | Cox's gudgeon | 1 | 1 | 1 | 1 | 1 | 3 |
| *Hypseleotris* spp. | Carp gudgeons | | | | 2 | 5 | |
| *Philypnodon gradiceps* | Flathead gudgeon | | | | | | |
| May 2012 | | | | | | | |
| *Anguilla* sp. | Freshwater eel | | | | | | |
| *Anguilla australis* | Short-finned eel | | | | | | |
| *Anguilla reinhardtii* | Long-finned eel | | | 1 | 1 | 4 | 2 |
| *Gambusia holbrooki* | Eastern gambusia | 3 | 2 | 2 | 4 | 11 | 3 |
| *Gobiomorphus coxii* | Cox's gudgeon | | | | | | 1 |
| *Hypseleotris* spp. | Carp gudgeons | | 1 | | 5 | 5 | 1 |
| *Philypnodon gradiceps* | Flathead gudgeon | | | | | | |
| November 2011 | | | | | | | |
| *Anguilla* sp. | Freshwater eel | | | | | | |
| *Anguilla australis* | Short-finned eel | | | | | | |
| *Anguilla reinhardtii* | Long-finned eel | | 4 | 1 | | 2 | |
| *Gambusia holbrooki* | Eastern gambusia | | 17 | 6 | 11 | 4 | 27 |
| *Gobiomorphus coxii* | Cox's gudgeon | | 1 | | 1 | | |
| *Hypseleotris* spp. | Carp gudgeons | 8 | 1 | 2 | | 6 | 12 |
| *Philypnodon gradiceps* | Flathead gudgeon | | | | | | |

| Scientific Name | Common Name | Site 6 | Site 7 | Site 8 | Site 9 | Site 10 | Site 11 |
|---|---|---|---|---|---|---|---|
| May 2010 | | | | | | | |
| *Anguilla* sp. | Freshwater eel | | | | | | |
| *Anguilla australis* | Short-finned eel | | | | | | |
| *Anguilla reinhardtii* | Long-finned eel | | | | | | |
| *Gambusia holbrooki* | Eastern gambusia | 15 | | >100 | | 3 | |
| *Gobiomorphus coxii* | Cox's gudgeon | | | | | | |
| *Hypseleotris* spp. | Carp gudgeons | | | 1 | | 3 | |
| *Philypnodon gradiceps* | Flathead gudgeon | | *ns* | | *ns* | | *ns* |
| September 2008 | | | | | | | |
| *Anguilla* sp. | Freshwater eel | | | | | | |
| *Anguilla australis* | Short-finned eel | | | | | | |
| *Anguilla reinhardtii* | Long-finned eel | | | | | | 1 |
| *Gambusia holbrooki* | Eastern gambusia | 32 | 36 | 61 | | | 1 |
| *Gobiomorphus coxii* | Cox's gudgeon | | | | | | |
| *Hypseleotris* spp. | Carp gudgeons | | | | | | 11 |
| *Philypnodon gradiceps* | Flathead gudgeon | | | | | | |