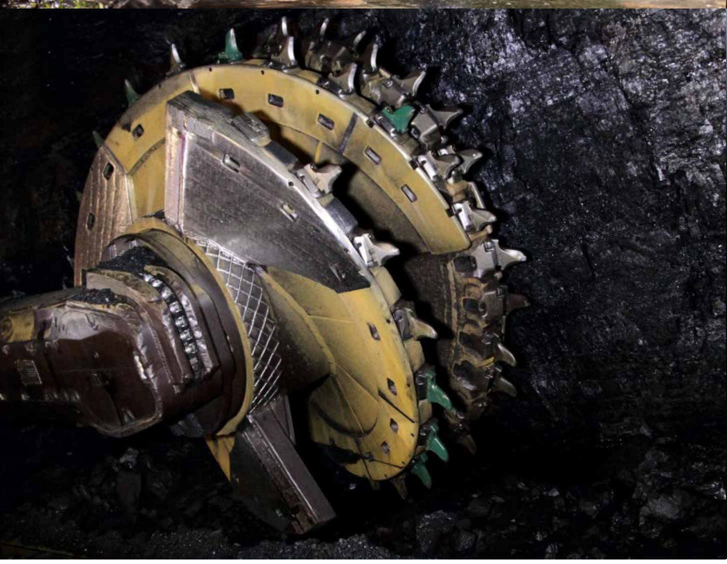

APPIN AREA 7 LONGWALL 706 END OF PANEL REPORT

ATTACHMENT E – AQUATIC ECOLOGY REPORT

Appin Areas 7 and 9

Aquatic Ecology Monitoring 2003 to 2015

59916047

Prepared for
South32 – Illawarra Coal

14 March 2016

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Executive Summary

South 32 Illawarra Coal extracts coal from the Bulli Seam in Area 7 of the Appin Colliery in the Southern Coalfield of New South Wales using longwall mining techniques. Appin Area 7 consists of Longwalls 701 to 710.

The sequence of Longwall extraction has been as follows:

> Longwall 701: 27 October 2007 to 9 May 2008;
> Longwall 702: 18 September 2008 to 20 May 2009;
> Longwall 703: 22 October 2009 to 3 March 2011;
> Longwall 704: 7 May 2011 to 29 July 2012;
> Longwall 705: 7 September 2012 to 27 March 2014; and
> Longwall 706: 23 April 2014 to 28 November 2015.

Extraction of Longwall 707 commenced 7 January 2016, and will be followed by Longwalls 708 to 710. South32 also has approval to extract coal from Appin Area 9 Longwalls 901 to 904, also part of Appin Colliery. Extraction of Longwall 901 commenced 19 January 2016, with extraction of Longwalls 902 to 904 to follow.

Cardno Ecology Lab was commissioned by South32 to design, implement and report on 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 the Nepean River.

The latest round of aquatic ecology monitoring, undertaken in November 2015, included post-extraction monitoring for Longwall 705, during-extraction monitoring for Longwall 706, and further pre-extraction monitoring for Longwalls 707 to 710. The second year of pre-extraction monitoring for Appin Area 9 Longwalls 901 to 904 was also undertaken. Monitoring of Longwalls 701 to 704 ceased in 2014 following the collection of at least two years of post-extraction data for each longwall.

The monitoring program focuses on the following indicators:

> Aquatic habitat, including fish habitat and riparian vegetation;
> Aquatic macroinvertebrates sampled in accordance with the Australian River Assessment System (AUSRIVAS) and derived biotic indices;
> Fish sampled using bait traps (Appin Areas 7 and 9) and backpack electrofishing (Appin Area 9), and
> Species composition of aquatic macrophytes.

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

The results of this survey were compared with those obtained in November 2008 and December of 2010, 2011, 2012, 2013 and 2014. Data collected prior to this are also presented to provide further context to the investigation, although not assessed statistically.

Appin Area 7

Monitoring undertaken by South32 and other specialist consultants during extraction of Longwalls 705 and 706 identified isolated gas releases in the Nepean River. No fracturing, changes in water levels and flow or changes in water quality have been attributed to mining.

There were no observed impacts to indicators of aquatic ecology (number of taxa and biotic indices derived from macroinvertebrate sampling) that could be attributed to extraction of Longwalls 705 and 706. Differences in the number of taxa between Impact and Control Reaches prior to extraction, and between Control Reaches after extraction of Longwall 706, were not related to mining. Likewise, an increase in the OE50 Taxa Score (a biotic index of aquatic habitat and water quality) at the Impact Reach and a decrease at a Control Reach following the commencement of extraction of Longwall 706 was also unrelated to mining.

Rather, such changes, and other statistically significant differences in various indicators were attributed to natural variation, rather than mining.

The somewhat poor condition of the macroinvertebrate fauna sampled in the Nepean River prior to, and following extraction, was not related to mining. Poor water quality, particularly water at the bottom of the water column, and alteration to the natural flow regime of the river due to several flow controlling structures within, upstream and downstream of the study area, may explain the often depauperate macroinvertebrate assemblages sampled.

Similarly, there was no evidence of any changes to fish and aquatic macrophytes attributable to mining. The fish assemblage sampled in the Nepean River following the commencement of extraction of these longwalls was comparable with that sampled prior to extraction and no fish kills or any other observations that may suggest an impact due to mining have been observed. Over the course of the monitoring program large changes in the distribution of aquatic macrophytes have occurred. Despite this, the species composition of macrophytes has been relatively consistent and the number and type of species identified in December 2015 were very similar to those identified in December 2013 and 2014. Given the absence of any observed macrophyte desiccation and die-back, there is no evidence to suggest that changes in macrophyte diversity and distributions are outside what would be expected due to natural variation.

Appin Area 9

The findings of the two pre-extraction surveys undertaken for Appin Area 9 Longwalls 901 to 904 suggest that the Control sites are largely comparable to the Impact sites and that they would provide suitable control data for the ongoing monitoring program. Some differences in macroinvertebrate and fish assemblages between the two downstream Control sites and those farther upstream (the remaining four Control and two Impact sites) were evident, and could be to differences in aquatic habitat and / or hydrology between these areas. These should be taken into account when interpreting the results of sampling once extraction of these longwalls begins.

Recommendations

1. Monitoring for Longwalls 705 to 710 should continue each year in the AUSRIVAS spring sampling season while extraction is underway and for at least two years thereafter. The next survey should be undertaken in November / December 2016 to align with the timing of sampling undertaken in recent years. This survey would provide further post-extraction data for Longwall 705, the first year of post-extraction data from Longwall 706, the first year of during-extraction data for Longwall 707 and further pre-extraction data for Longwalls 708 to 710;
2. Extraction of Longwall 901 commenced 19 January 2016, thus, the first survey following commencement of extraction of Longwall 901 should be undertaken in the spring 2016 AUSRIVAS sampling season. This should be done in conjunction with sampling for Longwalls 705 to 710. This survey would also provide further pre-extraction data for Longwalls 902 to 904; and
3. Due to the relatively small numbers of species and individuals of fish caught in bait traps in Appin Area 9 in December 2014 and November 2015, sampling of fish using this method should cease. Sampling of fish using backpack electrofishing is recommended to continue. This is consistent with the recommendations in Cardno Ecology Lab (2015).

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1 Introduction

South32 Illawarra Coal uses longwall mining techniques to extract coal from the Bulli Seam in Area 7 of Appin Colliery in the Southern Coalfield of New South Wales. Appin Area 7 consists of Longwalls 701 to 710. The sequence of Longwall extraction has been as follows:

> Longwall 701: 27 October 2007 to 9 May 2008;
> Longwall 702: 18 September 2008 to 20 May 2009;
> Longwall 703: 22 October 2009 to 3 March 2011;
> Longwall 704: 7 May 2011 to 29 July 2012;
> Longwall 705: 7 September 2012 to 27 March 2014; and
> Longwall 706: 23 April 2014 to 28 November 2015.

Extraction of Longwall 707 commenced 7 January 2016, with extraction of Longwalls 708 to 710 to follow. In addition, South32 has approval to extract coal from Appin Area 9 Longwalls 901 to 904, also part of Appin Colliery. Extraction of Longwall 901 commenced 19 January 2016, with extraction of Longwalls 902 to 904 to follow.

The Subsidence Management Plan (SMP) for Longwalls 701 to 704 (Hansen Consulting 2006) was approved in November 2006. The SMP for Longwalls 705 to 710 (Cardno Forbes Rigby 2008), which are situated to the north of Longwalls 701-704, was approved in February 2008 (Longwalls 705 and 706) and September 2012 (Longwalls 707 – 710). The Extraction Plan (EP) for Longwalls 901 to 904 (BHPBIC 2013) was approved in September 2014. The SMPs and EP satisfy legislative conditions and outline the monitoring and management activities required to assess and mitigate potential impacts due to mining.

Cardno NSW/ACT Pty Ltd (trading as Cardno Ecology Lab and formerly The Ecology Lab Pty Ltd) was commissioned by South32 to assess the potential impact of mine subsidence on ecological indicators of the Nepean River within the Appin Area 7 and 9 mine areas through the implementation of an aquatic ecological monitoring program. The aims of the monitoring program are to:

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

In this report, the results are presented for investigations undertaken in November 2014 in accordance with the recommendations made in the SMPs for Longwalls 705-710 and the Extraction Plan for Longwalls 901 to 904. Monitoring associated with Longwalls 701 to 704 ceased in 2014 following the completion of at least two years of post-extraction data collection for these longwalls and the absence of any observed changes to indicators of aquatic ecology that could be due to mining.

The specific aims of the current investigations are to:

> Undertake the second year of post-extraction monitoring for Longwall 705, the second year of during-extraction monitoring for Longwall 706 and the second year of pre-extraction monitoring for Longwalls 901 to 904. Data collected during this current survey also provides further pre-extraction data for Longwalls 707 to 710;
> Determine whether any changes in aquatic habitat or biota have occurred at sites adjacent to longwall extraction by comparing the findings of the current investigation with those from previous investigations undertaken at these and at control sites;
> Determine if any changes 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, recommend any ameliorative and impact minimisation strategies that may be warranted.

2 Previous Investigations

Cardno Ecology Lab has produced numerous reports on the aquatic habitat and biota associated with the Nepean River and nearby watercourses. These have incorporated reviews of existing literature, the results of baseline surveys, threatened species searches, predictions of mine-subsidence impacts on aquatic ecology, and results of during and post-mining monitoring. In this section, a timeline of these studies is presented, along with a summary the findings of the various aquatic ecological investigations undertaken following the commencement of extraction and the findings of subsidence predictions and associated monitoring of mining impacts undertaken by South32 and specialist consultants.

2.1 Appin Area 7

The initial investigation in September 2003 included a review of existing literature on aquatic ecology in the study area, a description of the fieldwork undertaken to define the ecological conditions of the relevant watercourses, an assessment of the likely impacts on aquatic habitats and biota based on subsidence / upsidence prediction; and recommendations for additional work (The Ecology Lab 2004).

Following a substantial change in the mine layout, South32 commissioned a further field study (September 2005) for inclusion in the SMP, this addressed the effects of mine subsidence on aquatic ecology in the area that could potentially be affected by the mining of Longwalls 701-704 (The Ecology Lab 2006).

The April 2008 field study provided further data to support the assessment of potential effects of mine subsidence on aquatic habitats and biota resulting from the proposed mining of Longwalls 705-710 (The Ecology Lab 2008a). This assessment was included in the SMP for Longwalls 705-710 submitted to the Department of Primary Industries Mineral Resources (Cardno Forbes Rigby 2008).

Additional monitoring in accordance with the recommendations made in the SMPs for Longwalls 701-704 and 705-710 was undertaken in November 2008 (The Ecology Lab 2009), December 2010 (Cardno Ecology Lab 2011a), December 2011 (Cardno Ecology Lab 2012a), December 2012 (Cardno Ecology Lab 2013) December 2013 (Cardno Ecology Lab 2014) and December 2014 / January 2015 (Cardno Ecology Lab 2015).

Aquatic ecology assessments were prepared by Cardno Ecology Lab following extraction of Longwalls 701-704 to support the End of Panel reports for these longwalls (The Ecology Lab 2008b and Cardno Ecology Lab 2009, 2011b and 2012b).

2.1.1 Predicted Impacts

The predicted subsidence parameters, natural characteristics of the watercourses overlying the SMP Areas and experience gained during mining of similar areas indicates that longwall mining is unlikely to have any significant impact on water flow, water quality and water depth in the Nepean River or its tributaries (MSEC 2005 and 2008). MSEC predicted that the river may undergo a maximum subsidence of 90-295 mm and 255-345 mm after extraction of Longwalls 701 to 704 and 705 to 710, respectively. This could affect the level of the river bed and banks, with some sections of the river becoming slightly shallower. Mining may also cause minor fracturing of the river bed, but this is not predicted to lead to significant water loss or reductions in flow due to the flooded nature of the river and regulatory influence of Menangle Weir (MSEC 2005 and 2008). There could also be some release of gases and minor iron staining (Ecoengineers 2008). Such impacts are unlikely to affect flow characteristics or the connectivity of aquatic habitats and biota (The Ecology Lab 2004 and 2008a). It is possible that changes in the depth of the river bed could expose some wetted substrata in shallow areas of the river and have a localised impact on the extent and composition of macrophyte beds. All currently extracted and proposed longwalls have been set back from the Nepean River by at least 180 m in order to minimise subsidence effects (MSEC 2008).

In the small, ephemeral watercourses overlying the SMP Areas (including; Foot Onslow Creek, Navigation Creek, Harris Creek, Ousedale Creek, Leafs Gully and small unnamed drainages) mine-related subsidence would lead to an increase in flooding and ponding, fracturing of stream beds and drainage of some pools MSEC (2005 and 2008). Prior to mining, these watercourses were reduced to isolated pools during dry periods, provide minimal to moderate aquatic habitat and are generally highly disturbed by stock access, presence of degraded riparian vegetation, extensive erosion and flow interruption from construction of farm dams (The Ecology Lab 2008a). The potential for temporary draining of pools within small ephemeral surface watercourses may result in the localised loss of aquatic habitat and any biota unable to relocate to nearby habitat. Such impacts were considered to be relatively minor because of the limited aquatic habitat present.

2.1.2 Findings

2.1.2.1 Longwalls 701 to 704

Longwall 701

> Surface monitoring undertaken during and / or following extraction of Longwall 701 (BHPBIC 2008a and b) identified gas releases in four areas within the Nepean River near this longwall and in a single small area in Elladale Creek. These emissions ceased by October 2008. Minor iron staining was also observed at the time of gas releases. No physical impacts or changes to flow and water quality were detected.

> There was no evidence that gas releases and iron staining had adversely affected aquatic habitat or biota. There was no evidence to suggest changes in the distribution, extent and composition of macrophytes related to mining (Cardno Ecology Lab 2008b and 2009). Large-scale changes in the extent of macrophyte beds occurred regardless of mining and any changes in macrophyte beds related to mine subsidence would be difficult to distinguish from background variation.

Longwall 702

> Three new gas release zones and the reactivation of one gas release zone (associated with the extraction of Longwall 701) were identified following subsidence due to extraction of this longwall (BHPBIC 2009; MSEC 2009). No fracturing, flow diversions, further iron staining or changes to water quality were observed.

> No impact on aquatic habitat and biota following gas releases was observed (Cardno Ecology Lab 2009).

Longwall 703

> Three new gas release zones in the Nepean River were identified near this longwall during extraction (BHPBIC 2011, Cardno Ecology Lab 2011a and b). No fracturing, changes in water levels, flow or changes to water quality were observed (BHPBIC 2010; BHPBIC 2011, Ecoengineers 2011).

> No significant impact to aquatic habitat and biota due to mining of Longwalls 701 to 703 was detected (Cardno Ecology Lab 2011a and b). While marked changes in the distribution, extent and composition of macrophyte beds have been observed after the commencement of extraction, similar changes were apparent before extraction (Cardno Ecology Lab 2011a). Changes in macrophytes were attributed to localised differences in the depth of the water column, aspect of the site relative to the sun, suitability of the substratum for attachment, shading effects from vegetation on the banks, water flow, water transparency and availability of nutrients rather than any effect due to mining.

Longwall 704

> Three gas release zones in the Nepean River adjacent to this longwall were identified just prior to the aquatic ecology sampling (BHPBIC 2012). Other gas release zones identified just upstream and near Longwalls 701 and 702 had been inactive for several months prior to sampling for aquatic ecology (BHPBIC 2012). There was no evidence of fracturing, uplift, changes in flow, water levels or water quality (Ecoengineers 2012a, MSEC 2012a).

> Changes in a biotic index of aquatic habitat and / or quality (OE50 Taxa Score) at one of the monitoring sites more likely represented natural variation, rather than any potential impact due to mining (Cardno Ecology Lab 2012a). There was no evidence of any impact to other aquatic biota.

No changes to aquatic ecology indicators that could be associated with extraction of Longwalls 701 to 704 were detected following statistical analysis of macroinvertebrate data collected during and for at least two years thereafter extraction (Cardno Ecology Lab 2015). There was also no evidence that mining of these longwalls had any impact on fish and macrophytes. This was not surprising given that no water quality or physical mining impacts (other than some isolated gas releases) were identified. In the absence of any observed changes to aquatic ecology indicators that could be due to mining, it was recommended that ongoing monitoring at sites relevant to these longwalls only (Sites 3, 4, X1 and X2) should cease (Cardno Ecology Lab 2015).

2.1.2.2 Longwalls 705 to 710

Longwall 705

> Surface monitoring undertaken by ICEFT did not indicate any impacts to water levels or the appearance of the Nepean River or its tributaries during the extraction of Longwall 705 (BHPBIC 2014a). No fracturing of the river bed, surface water flow diversions, iron staining, uplift or changes in water level (aside from normal fluctuations associated with rainfall and SCA discharges) were observed in the Nepean River during extraction of Longwall 705 (MSEC 2014). No fracturing, ponding, flooding or desiccation was observed in the monitored tributaries of the Nepean River. No loss or diversions of flow or impacts to water quality were observed in the Nepean River during extraction of this longwall (Ecoengineers 2014a);

> Three new gas release zones (Gas Zones 16, 17 and 18) were detected adjacent to Longwalls 701 to 704 during extraction of Longwall 705. These releases were located some distance upstream of Longwalls 705 to 710 and likely represented cumulative impacts associated with the extraction of Longwalls 701 to 704 and 705. Gas Zones 16, 17 and 18 were last observed as active on 17 January, 19 February and 2 June 2014, respectively; and

> There was no evidence in aquatic macroinvertebrate, macrophyte and fish data to indicate a change to aquatic ecology had occurred following gas releases (Cardno Ecology Lab 2014 and 2015).

Longwall 706

> Monitoring undertaken by ICEFT did not indicate any impacts to water levels or the appearance of the Nepean River or its tributaries during the extraction of Longwall 706 (South32 2016). No fracturing and iron staining were observed (MSEC 2016) and no flow diversions, impacts to surface water quality in the Nepean River and its tributaries were observed (Geoterra 2016) during extraction of Longwall 2015;

> Several previously identified gas release zones (Gas Zones 5, 14 and 18) were observed to be active during extraction of Longwall 706 (BHPBIC 2014c). These zones were first identified upstream of Longwall 706 during 2008 to 2014. A new active gas release zone (Gas Zone AA7_LW706_001) was identified on the Nepean River on 13 August 2014 (BHPBIC 2014c, Cardno Ecology Lab 2015). This area was located above Tower Mine Longwall 16, which was extracted during 1998 to 1999 and located 3.8 km south west of Longwall 706. Gas Zone 5 was last observed to be active on 13 August 2014 and Gas Zone 14 on 11 December 2015 (though was observed as active twice only in 2015). Gas Zone AA7_LW706_001 was still active (albeit only with minimal gas release) on 11 January 2016 (Illawarra Coal Environmental Field Team (ICEFT) Pers. Comm. 11 January 2016).

> There was no evidence in aquatic macroinvertebrate, macrophyte and fish data collected in December 2014 to indicate a change to aquatic ecology had occurred following the gas releases identified prior to this (Cardno Ecology Lab 2015).

2.2 Appin Area 9

The Aquatic Ecology Assessment for Appin Longwalls 901 to 904 was undertaken in May 2012 (Cardno Ecology Lab 2012c). This assessment formed part of the Biodiversity Management Plan for the EP (BHPBIC 2014a). It included a review and synthesis of existing information on the aquatic habitats and biota that may be affected by extraction of these longwalls and identified potential impacts to aquatic habitats and biota due to the physical and water quality impacts predicted by MSEC (2012b) and Ecoengineers (2012b). It also recommended ways to avoid or minimise such impacts, including the implementation of ongoing monitoring of aquatic habitats and biota.

2.2.1 Predicted impacts

Extraction of Longwalls 901 to 904, which have been set back from the Nepean River at least 125 m, are predicted to result in 30 mm of subsidence and 110 mm of upsidence (MSEC 2012b). The river is not predicted to experience any significant changes in the levels of ponding, flooding or scouring of the river banks, or any significant changes in the water levels or stream alignment due to longwall extraction. Minor and isolated fracturing of the river bed could occur, however, it is not expected to result in any loss of surface water flows (BHPBIC 2014a). Fracturing could occur in the drainage lines above or immediately adjacent to the proposed longwalls. In areas of exposed bedrock, some diversion of surface water flows and the draining of pools may occur in associated drainage lines. It was considered unlikely that there would be any net loss of water from the catchment.

Minor gas releases, associated iron precipitate and reductions in concentrations of dissolved oxygen may occur due to extraction of Longwalls 901 to 904, but these would have negligible environmental consequences (BHBPIC 2014a). Other environmental consequences due to potential impacts to water quality in the Nepean River and drainage lines due to extraction, such as changes to pH and concentrations of metals following fracturing, would be negligible.

There are unlikely to be any measurable impacts on the availability or connectivity of aquatic habitats in the downstream reach of the Nepean River due to its flooded nature and very low gradient (Cardno Ecology Lab 2012c). In the upstream reach, any fracturing that occurs is expected to be isolated and minor in nature, so the potential for impacts on surface flow is limited. The predicted changes in ponding, flooding or scouring of the river banks would have negligible effects on aquatic habitats or biota in the Nepean River. The effects on aquatic ecology due to the predicted changes in water quality would also be negligible. Effects to aquatic habitat and biota due to any diversion of flows and draining of pools in drainage lines would be minimal, due to the limited aquatic habitat provided by these areas.

2.2.2 Findings

During the first baseline survey in Appin Area 9 (December 2014) a total of eight sites were monitored. While differences in aquatic habitat between the six most upstream sites (four Control and two Impact) and the two downstream sites (Controls) were identified (e.g. differences in water depth, flow velocity and substratum), statistical analysis of macroinvertebrate data did not reveal any evidence of differences in biotic indices and assemblage structure prior to extraction. This suggested that macroinvertebrate communities at Control sites are largely comparable to those at Impact sites

Fish assemblages at the six sites farthest upstream differed from those at sites farther downstream. Coxs gudgeon were found at the six farthest upstream, and Australian bass were found only at the most upstream site. This likely reflects the different habitat and hydrology present between these two groups of sites. The occurrence of Australian bass at the most upstream site only could also be due to the presence of Maldon Weir, which probably represents a barrier to farther upstream migration for this species causing to it aggregate immediately downstream of the weir. Differences in habitat and hydrology also likely explain the smaller number of species and smaller extent of aquatic macrophytes observed at the six upstream sites compared with the two sites farthest downstream.

Overall, the findings of the first pre-extraction survey for Appin Area 9 suggested that while differences in aquatic habitat and fish assemblages exist among some sites, macroinvertebrate assemblages are largely comparable among sites. This suggested that the selected Control sites would provide data suitable as a baseline for the ongoing monitoring program.

3 Study Methods

3.1 Field Methods

Table 3-1 identifies the paired monitoring sites in the Nepean River, their reach (Reach 1 at the downstream (northern) extent) to Reach 8 at the upstream (southern) extent) and their designation (i.e. Impact or Control) relevant to each longwall. Sites 1, 2, 5 to 8 and X3 to X8 were visited on 4 to 5 November 2015 (hereafter referred to as November 2015). Monitoring at Sites 3, 4, X1 and X2 associated with Longwalls 701 to 704 ceased in 2014 following the completion of monitoring for these longwalls (**Section 2.1.2.1**). The locations of sites are identified in **Figure 3.1** and their GPS coordinates are presented in **Appendix A**. Each site is approximately 100 m long.

Table 3-1 Appin Area 7 and 9 aquatic ecology monitoring sites on the Nepean River, their respective Reach and their designation (i.e. Impact or Control) relevant to each longwall

<table>
<tr><th>Reach</th><th>Designation</th><th>Relevant Longwalls</th><th>Sites</th><th>Status</th></tr>
<tr><td>Reach 1</td><td>Control</td><td>702 to 704 and 705 to 710</td><td>7, 8</td><td></td></tr>
<tr><td rowspan="2">Reach 2</td><td>Control</td><td>701 to 704</td><td rowspan="2">5, 6</td><td></td></tr>
<tr><td>Impact</td><td>705 to 710</td><td></td></tr>
<tr><td>Reach 3</td><td>Impact</td><td>702 to 704</td><td>X1, X2</td><td>Monitoring ceased</td></tr>
<tr><td>Reach 4</td><td>Impact</td><td>701 to 704</td><td>3, 4</td><td>Monitoring ceased</td></tr>
<tr><td>Reach 5</td><td>Control</td><td>701 to 704, 705 to 710 and 901 to 904</td><td>1, 2</td><td></td></tr>
<tr><td>Reach 6</td><td>Impact</td><td>901 to 904</td><td>X3, X4</td><td></td></tr>
<tr><td>Reach 7</td><td>Control</td><td>901 to 904</td><td>X5, X6</td><td></td></tr>
<tr><td>Reach 8</td><td>Control</td><td>901 to 904</td><td>X7, X8</td><td></td></tr>
</table>

Notes: Sites 5 and 6 became impact sites for Longwalls 705-710 following commencement of extraction of Longwall 705. Reach 1 (Sites 7 and 8) did not form part of the monitoring for Longwall 701 as this reach was not sampled for macroinvertebrates during the single baseline survey for this Longwall (September 2003).

The section of the Nepean River around the townships of Douglas Park and Appin (in South Western Sydney) and a number of small, ephemeral watercourses, Foot Onslow Creek, Navigation Creek and their respective tributaries and Harris Creek and a number of small, unnamed drainages flow through the SMP Areas. Monitoring at Sites F1 and F2 on Foot Onslow Creek ceased after December 2012. The aquatic habitat in the sections of this creek is extremely limited and further monitoring is no longer appropriate. Monitoring at Site N1 on Navigation Creek has been postponed and will be considered closer to the extraction date of adjacent Longwall 710.

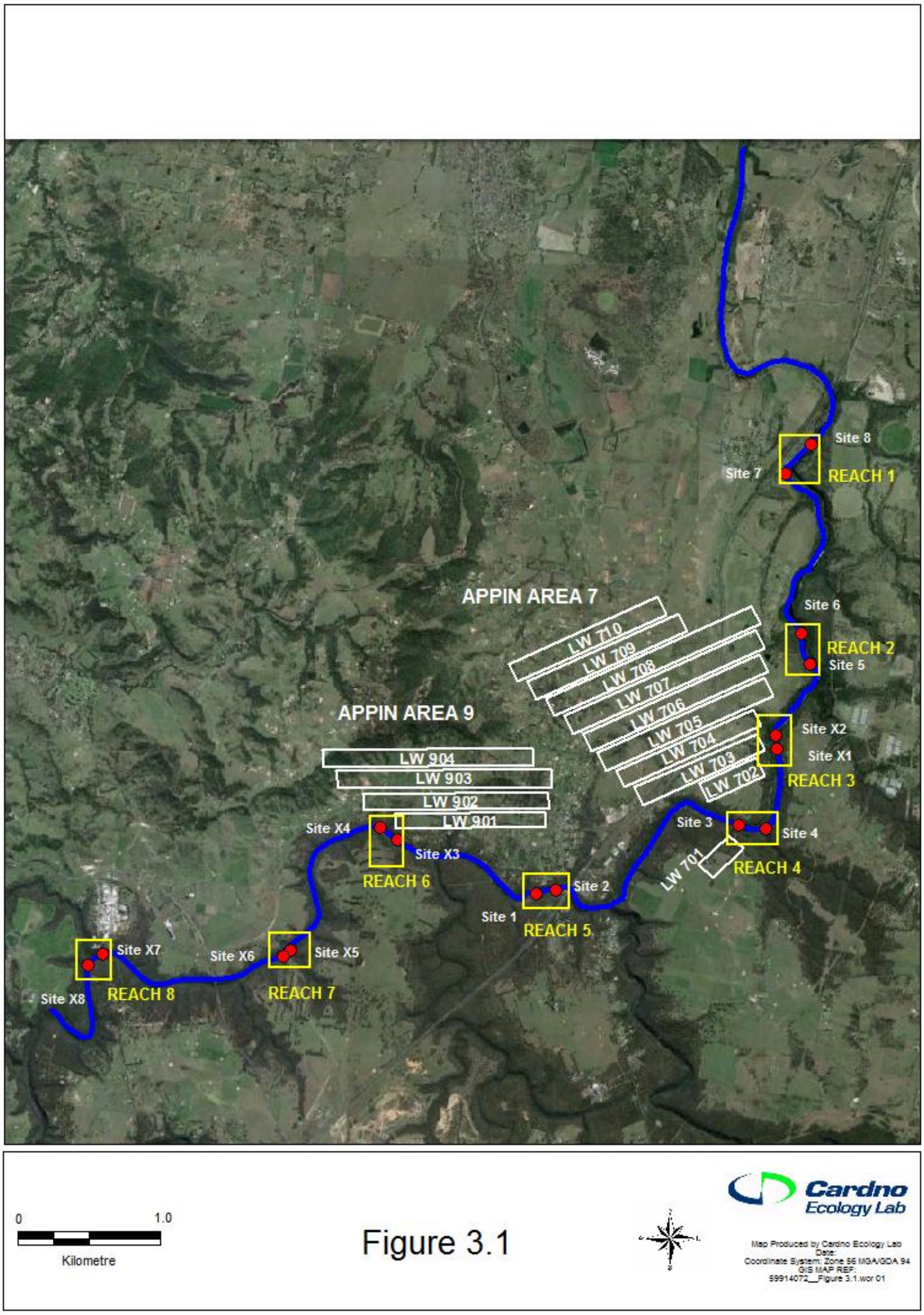

Figure 3-1 Aerial image displaying the aquatic ecology monitoring sites on the Nepean River and their respective Reaches in relation to Appin Area 7 and 9 Longwalls. Sites 1, 2, X1 and X2 were not visited in the current study (Section 3.1).

3.1.2 Timing

Monitoring undertaken in relation to Longwalls 705 to 710 and 901 to 904 is summarised in **Table 3-2**.

Table 3-2 Aquatic ecology monitoring events undertaken to date at sites relevant to Appin Area 7 Longwalls 705 to 710. Monitoring included *in situ* water quality, AUSRIVAS macroinvertebrates, and fish sampling and assessment of macrophytes unless otherwise identified. Bef and Aft indicate whether surveys were done before or after, respectively, commencement of extraction of each Longwall (LW)

LW	Extraction Period			Survey									
No.	Start	Finish	Impact Sites	Sep 03	Sep 05	Apri 08	Nov 08	Dec 10	Dec 11	Dec 12	Dec 13	Dec 14	Nov 15
Report Reference				**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**
Notes:				**a**	**b**	**c**			**d**	**e**	**f**	**g**	
705	Sep 12	Mar 14	5, 6	Bef	Bef	Bef	Bef	Bef	Bef	Aft	Aft	Aft	Aft
706	Apr 14	Nov 15	5, 6	Bef	Bef	Bef	Bef	Bef	Bef	Bef	Bef	Aft	Aft
707-710	Not yet commenced		5, 6	Bef	Bef	Bef	Bef	Bef	Bef	Bef	Bef	Bef	Bef
901-904	Not yet commenced		X3, X4									Bef	Bef

Report Reference: (1) The Ecology Lab (2004), (2) The Ecology Lab (2006), (3) The Ecology Lab (2008b), (4) The Ecology Lab (2009), (5) Cardno Ecology Lab (2011a), (6) Cardno Ecology Lab (2012a), (7) Cardno Ecology Lab (2013), (8) (Cardno Ecology Lab 2014), (9) Cardno Ecology Lab (2015) and (10) current study.

Notes: a) Sites 1 to 6 only, b) macrophyte assessment at Sites 1 to 6 only, c) fish sampling only, d) macroinvertebrate and fish sampling only, Sites 7 and 8 not sampled, e) macroinvertebrate and fish sampling only, Sites 7 and 8 were also not sampled for any indicator, f) macrophyte assessment undertaken in January 2014, no water quality, fish and macroinvertebrate sampling at Sites 3 and 4, g) Sites X5 and X6 sampled in January 2015.

3.1.3 Water Quality

Previously, water quality was measured *in situ* with a Yeokal or YSI 6920 water quality probe and meter. However, due to malfunction during sampling in 2015 there were no water quality data from that time collected by Cardno Ecology Lab. However, *in situ* water quality data (temperature (C), conductivity (µs/cm), pH, dissolved oxygen (% saturation) and oxidation reduction potential) (ORP) (mV)) measured in the Nepean River in the vicinity of the aquatic ecology monitoring sites in October and November 2015 were provided by ICEFT. Data are available from 12 sites (NR0, NR2, NR4 to NR7, NR9, NR11 to NR13, NR50 and NR110). NR110 is the most upstream site, located adjacent to Sites X5 and X6, and NR13 is the most downstream site, located between Sites 6 and 7, monitored by ICEFT.

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 present at the sites surveyed. Edge samples were collected with dip nets (250 µm mesh) over a period of 3-5 mins from a total of 10 m of habitat within a 100 m reach of the river 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 live animals were removed ("picked") 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 in water. The aim of the live picking is to pick as many macroinvertebrate taxa as possible. There is no set minimum or maximum number of animals to be collected, however, at least 20 chironomids were collected where possible to help ensure that an adequate representation of all subfamilies was obtained.

Environmental variables, including alkalinity, modal river width and depth, percentage boulder or cobble cover, latitude and longitude were recorded in the field. These variables were 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 sourced from the regional precipitation maps presented in the AUSRIVAS Sampling and Processing Manual (Turak *et al*. 2004).

3.1.5 Fish

Five baited traps (350 mm long, 200 mm wide with an entrance that tapered to a 45 mm aperture, with 3 mm mesh size) were deployed overnight (approximately 12 hours) at sites in Appin Area 7 (Sites 1 to 2 and 5 to 8) and for approximately 1 hour in Appin Area 9 (Sites 1, 2 and X3 to X8). Each trap was baited with 70 ml of a mixture of chicken pellets and sardines and deployed amongst macrophytes and snags (submerged woody debris). Caught fish were identified and released. Numbers of fish collected incidentally in the macroinvertebrate dip net samples were also recorded.

Fish were also sampled at Appin Area 7 sites using a seine net (10 m x 1 m x 3 mm mesh). At each site, the net was deployed one or two times near macrophyte beds in order to provide additional information on fish species that may not have been caught by bait trapping. Seine nets were not deployed at Appin Area 9 Sites X3 to X8 as the river bed at these sites consisted of large boulders which made seine netting ineffective.

Fish and large mobile invertebrates, such as freshwater crayfish, occurring at each Appin Area 9 site were also sampled using a back-pack electrofisher (Model Smith-Root LR24). The backpack 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. Only two shots were undertaken at Site X3 due to lack of suitable habitat and deep water that prevented the use of the electrofisher. 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.

3.1.6 Aquatic Macrophytes

A species inventory of macrophytes was compiled and observations of any signs of desiccation, die back or other features of the macrophytes that could be indicative of potential mining related impacts were recorded at each site. A bathyscope and modified rake were used to view and collect samples of macrophytes.

Prior to December 2012, the extent of each aquatic macrophyte species and group of species was mapped in detail at each site using a Differential GPS. The results of these studies indicated that the distribution, extent and composition of aquatic macrophytes was naturally highly variable, and that it would be very difficult to detect any changes due to mining above background variation (**Section 2.1.2**). Following a review of this monitoring component, the focus was shifted to detection of broader scale changes to species composition at each site, rather than the fine scale changes in the extent of beds documented previously. The current method is more appropriate to the magnitude of change that would be required to confidently link changes in aquatic macrophytes with potential mining impacts.

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 AUSRIVAS protocol (Turak *et al*. 2004).

3.3 Data Analysis

3.3.1 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 lowland rivers in southeast Australia.

In situ water quality data were used to aid the interpretation of macroinvertebrate data. More detailed water quality monitoring, analysis and assessment is undertaken by the ICEFT and consultants.

3.3.2 Aquatic Macroinvertebrates

3.3.2.1 Biotic Indices

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 river was 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 and autumn. 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 rivers.

> Overall Bands derived from OE50Taxa scores which indicate the level of impairment of the assemblage. These bands are graded as described in **Table 3.3**.

Table 3-3 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 (highly tolerant of pollution) and 10 (highly sensitive to pollution) 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.

The calculation of the SIGNAL2 Index was calculated using un-weighted SIGNAL2 grade data. Weighting SIGNAL2 grades according to abundance may bias the SIGANL2 Index towards naturally more abundant taxa.

3.3.2.2 Statistical Methods

Statistical analyses were performed on macroinvertebrate data only. Fish data collected using bait traps at Appin Area 7 sites were not analysed due to the relatively great variation present in data among sites, the large number of zero counts and also inconsistent deployment times among surveys. Rather, broad temporal patterns in the occurrence of fish species at Appin Area 7 sites were examined. This is considered sufficient due the relatively great spatial and temporal variation often present in fish assemblage data.

Similarly, fish data collected using bait traps and backpack electrofishing at Appin Area 9 sites were not analysed due the relatively great variation and large number of zeros present in these data.

3.3.2.2.1 Approach to Interpretation of Analyses and Data Presentation

The objective of the statistical analyses was to identify differences in the selected indicators of aquatic ecology at the Impact sites that may differ from those at the Control sites. Statistically significant differences can provide evidence that an impact may have occurred. Evidence is assessed by examining data from before the commencement of extraction of Longwalls 705 and 706 and that collected after commencement.

The statistically significant interaction of Reach x Phase could potentially provide evidence of a substantial, long-term change in the biotic community due to mining. Thus, this interaction was the main focus of the analyses and *post-hoc* tests for pairs of Reaches and Phases were examined. The statistically significant interaction of Reach x Survey within Phase may also provide evidence of, albeit likely shorter-term, changes associated with mining. However, in this instance, only *post-hoc* tests between pairs of Reaches were explored in detail. Such comparisons indicate how differences among Reaches may vary among Surveys, with particular patterns of change potentially indicative of an effect due to mining. Comparisons between pairs of Surveys have not been explored in detail due to the nesting of Survey within Phase, which prevents comparisons between pairs of Surveys from different Phases.

Differences in the timing of extraction, and thus also potential impacts, required separate analyses for Longwalls 705 and 706.

Although data from Sites 3, 4, X1 and X2, which are not relevant to Longwalls 705 to 710 and 901 to 904 (**Section 3.1**), and from September 2003 (**Section 3.3.2.2.2**) were not included in the statistical analyses, these data were appended (**Appendix D**) and graphed to provide greater context to the Appin Area 7 and 9 monitoring programs.

Data from September 2003 were not analysed as this event occurred several years prior to the commencement of extraction of Longwalls 705 and 706 (September 2012 to April 2014) and, thus, data from this survey likely do not represent environmental conditions present just prior to the commencement of extraction of these longwalls. Macroinvertebrate assemblages and biotic indices from September 2003 were often found to be statistically different from those during 2008 to 2014, while differences among other surveys were much less common during this time (Cardno Ecology Lab 2015). No macroinvertebrate data were collected in September 2005 and April 2008 (**Table 3.1**), thus, these surveys are not represented in the analyses.

The variation in the two years of pre-extraction data collected for Longwalls 901 to 904 is also explored to help confirm the suitability of the Control sites selected for ongoing monitoring.

3.3.2.2.2 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 (Anderson *et al*. 2008; Clarke and Gorley 2006). 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 $P \leq 0.05$ are considered. Significant differences between groups may arise due to differences between group means, differences in dispersion (equivalent to variance) among groups or a combination of both. Either outcome could be indicative of an impact. Moreover, only significant statistical interactions are potentially indicative of an impact, hence significant main effects are not considered in detail.

The analytical design for Longwalls 705 and 706 was:

> **Phase**: A fixed factor with two levels: Before (commencement of extraction) and After (commencement of extraction);

> **Survey**: A random factor with seven levels: November 2008, December of 2010, 2011, 2012, 2013 and 2014 and November 2015) nested within Phase. The nesting of a particular survey within the Before or After Phase depended on the specific longwall and the timing of extraction (as per **Table 3.2**);

> **Reach**: A fixed factor with three levels: Reaches 1, 2 and 5 (as per **Table 3.1**):

The analytical design for Longwalls 901 to 904 was:

> **Survey**: A random factor with two levels: December 2014 and November 2015; and

> **Reach**: a fixed factor with four levels: Reaches 5 to 8, as per **Table 3.1**

During each Survey two replicate samples were collected from each Reach (i.e. one from each Site).

Multivariate patterns in the data can be examined using Principal Coordinates Ordination (PCO). 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). PCO was not undertaken for Longwalls 705 and 706 in this instance, as PERMANOVA did not indicate any statistically significant interactive effect (**Section 4.3.2**).

3.3.2.2.3 Univariate Analyses

Permanova+ was used to examine spatial differences and temporal changes in the number of taxa, OE50 Taxa Scores and SIGNAL2 Indices. These analyses were based on a Euclidean distance matrix of all possible pairs of samples of the variable of interest and with $P \leq 0.05$.

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 affect both the magnitude and dispersion of an indicator (e.g. number of taxa). If a statistically significant difference between groups was 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 was explored using the PERMDISP procedure to determine whether variances were statistically different. 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.

3.3.3 QA/QC Procedures

Data generated in the field were checked for accuracy and completeness before leaving each site. On return to the laboratory, field data sheets were photocopied, entered into spread sheet format and checked. Spread sheet files were locked prior to analysis to prevent accidental over-writes or corruption.

In the laboratory, the remains of each macroinvertebrate sample were retained and checked by another staff member to ensure that no invertebrate taxa were missed. A staff member with appropriate training and experience checked the identifications and counting of samples.

4 Results

4.1 Aquatic Habitat and General Observations

No change in the condition of riparian vegetation and aquatic habitat was observed in November 2015 compared with previous surveys. Riparian vegetation at the sites visited was largely undisturbed, consisting of numerous large, established trees with few breaks in cover. The aquatic habitat at the most downstream sites (Sites 1, 2, and 5 to 8) (**Plate 1a** and **b**) differed from that further upstream (Sites X3 to X8) (**Plates 1c** to **h**). At these downstream sites, the Nepean River, and aquatic habitat, consisted primarily of wide (approximately 30 m) channel, relatively deep and slow flowing water and sand / bedrock substrata (at least along the river edges). At the sites further upstream, the channel was narrower (approximately 10 to 20 m), shallower and faster flowing (especially at sites X3 and X4) and the substrata included coarse pebbles, cobbles, boulders and bedrock. Two flow controlling structures occurred in the study area: Maldon Weir immediately upstream of Site X8; and Douglas Park Weir, just downstream of Site 2. The water level downstream of Douglas Park Weir was regulated by a weir located at Menangle, several kilometres downstream (MSEC 2005 and 2008). During sampling in 2015, the water level at Site X7 appeared slightly elevated and was turbid due to inflow of turbid water from a tributary just upstream. This may have hampered observations of some habitat features and aquatic macrophytes.

4.2 Water Quality

The mean values of the surface water quality indicators measured *in situ* by ICEFT in October and November 2015 are presented in **Appendix B**. The main findings are summarised as follows:

> Temperature ranged from 18.2 to 22.9 C;

> Conductivity ranged from 84 to 406 µS/cm and was outside the DTVs twice at NR5 (located between Site 2 and 3) on 26 October and 12 November, where it was below the lower DTV;

> pH ranged from 7.1 to 8.5 and was above the upper DTV at most sites on at least one occasion, though often only marginally;

> Dissolved oxygen ranged from 79.6 to 120.5% saturation and was below the lower DTV twice (NR110 and NR6) and above the upper DTV on three occasions (NR0, NR2 and NR7), though often only marginally; and

> Oxidation Reduction Potential (ORP) ranged from 320 to 416 mV.

4.3 Aquatic Macroinvertebrates

4.3.1 General Findings

Fifty-six macroinvertebrate taxa were identified from the AUSRIVAS edge samples collected in November 2015 (**Appendix C**). In total, from September 2003 to November 2015, 91 taxa were identified from the 82 AUSRIVAS edge samples collected from the Nepean River. During this time, the most common taxa (those occurring in 70 or more of the samples) were Hydracarina (water mites), Corixidae (waterboatmen), Chironominae (non-biting midge) and Leptoceridae (caddisfly). Leptoceridae and Hydracarina are somewhat pollution sensitive (SIGNAL2 grade 6) and Corixidae and Chironominae are pollution tolerant (SIGNAL2 grade 2 or 3).

Of the 82 taxa that were assigned a SIGNAL2 grade, 66 were very to moderately pollution tolerant (SIGNAL2 grade 1 to 5). Twelve pollution sensitive taxa (SIGNAL2 grade 7 and above) were also sampled, these included Telephlebiidae and Corduliidae (families of dragonfly), Leptophlebiidae (a family of mayfly), Galamoceratidae (a family of caddisfly), Gripopterygiidae (a family of stonefly) and Elmidae (riffle beetles). Telephlebiidae, Leptophlebiidae, Galamoceratidae and Elmidae occurred in over a third of all samples collected, Corduliidae and Gripopterygiidae occurred once only.

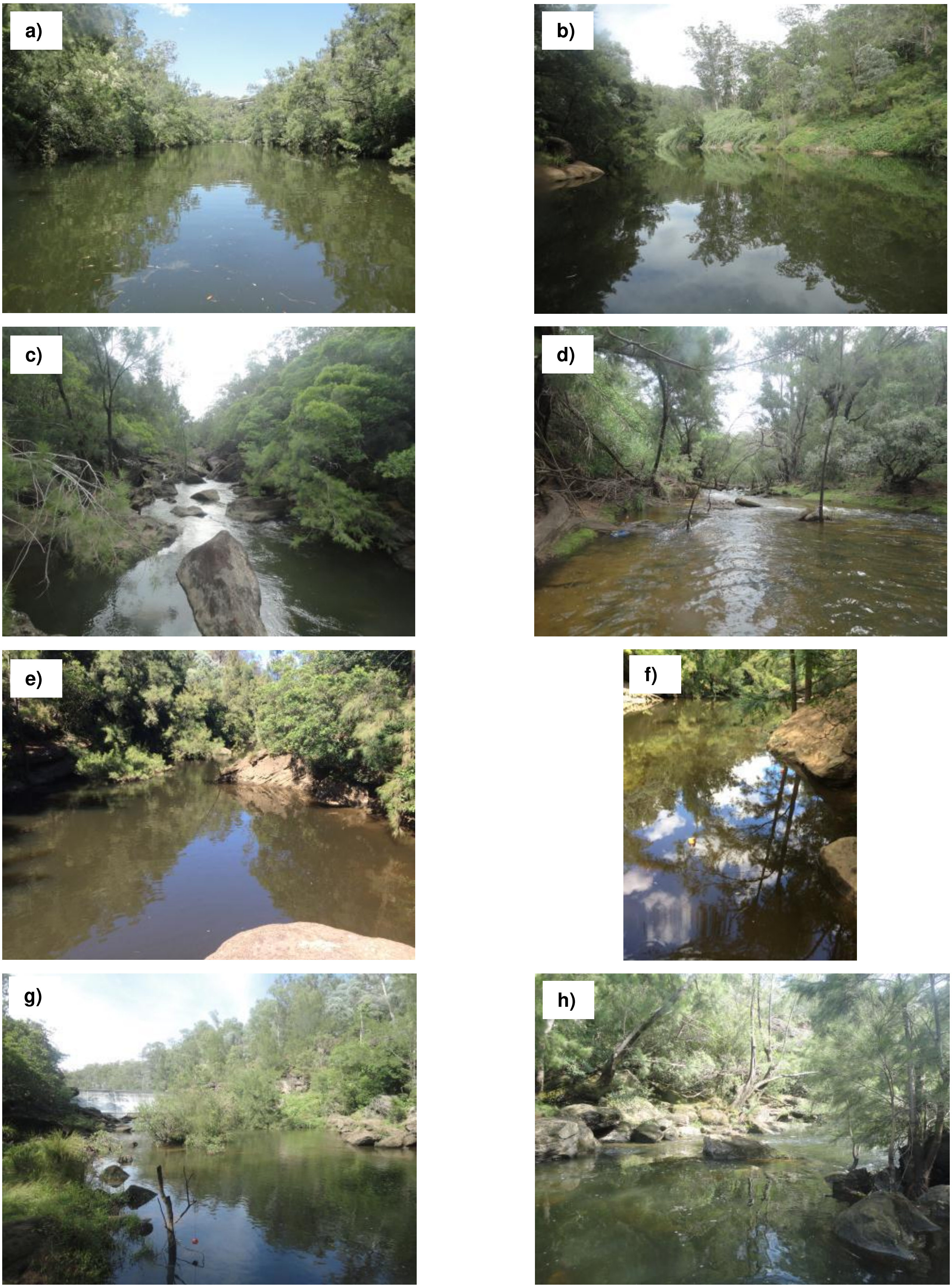

Plate 1 a and b) Wide channel and relatively deep and slow flowing water typical of Sites 1 to 8, X1 and X2, narrower channel and relatively deep and faster flowing water at c) Site X3, d) Site X4, e) Site X5, f) Site X6, g) Site X7 and h) Site X8 (photographs taken in December 2014)

AUSRIVAS indices and the number of taxa identified from AUSRIVAS samples from each site sampled from September 2003 to November 2015 are presented in **Appendix D**. During this time, the number of taxa per sample has ranged from 13 to 34, the OE50 Taxa Score has ranged from 0.47 (Band C – severely impaired relative to reference condition) to 1.11 (Band A - equivalent to reference condition) and the SIGNAL2 Index ranged from 3.0 (indicative of severe pollution) to 4.6 (indicative of moderate pollution).

4.3.2 Longwalls 705 and 706 – Changes in Macroinvertebrate Fauna

Of the eight PERMANOVA analyses undertaken using data relevant to Longwalls 705 to 706 (those from Reaches 1, 2 and 5 during November 2008 to November 2015), two yielded results that were potentially indicative of an impact (**Table 4-1**). These were the number of taxa and OE50 Taxa Score for Longwall 706. However, the patterns of change in these indicators were not indicative of an effect due to mining (**Sections 4.3.3.2** and **4.3.3.3**). Other statistically significant sources of variation were the main effects of Phase (indicative of temporal variability independent of Reach – one analysis), Reach (indicative of spatial variability independent of time – three analyses) and Survey within Phase (which indicated short term temporal variability independent of Reach – three analyses).

Table 4-1 Summary of results of PERMANOVA analyses undertaken using AUSRIVAS data collected from edge habitat at sites relevant to Longwalls 705 and 706 during November 2008 to November 2015. * = P ≤ 0.05, ** = P ≤ 0.01, *** = P ≤ 0.001, ns = P > 0.05. RED = Redundant due to statistically significant interaction term. The full results of the analyses are presented in Appendix E

Indicator	Phase	Reach	Survey (Phase)	Reach x Phase	Reach x Survey (Phase)
Longwall 705					
Assemblage	ns	**	***	**ns**	**ns**
Number of Taxa	ns	ns	ns	**ns**	**ns**
OE50 Taxa Score	ns	*	ns	**ns**	**ns**
SIGNAL2 Index	***	ns	ns	**ns**	**ns**
Longwalls 706					
Assemblage	ns	**	***	**ns**	**ns**
Number of Taxa	RED	RED	*	*	**ns**
OE50 Taxa Score	RED	RED	ns	***	**ns**
SIGNAL2 Index	ns	ns	ns	**ns**	**ns**

4.3.2.2 Assemblages

Analyses of assemblages showed significant main effects for Reach and Survey, but no terms indicative of an impact.

4.3.2.3 Number of Taxa

PERMANOVA indicated no significant variation in relation to Longwall 705, but there was a statistically significant interactive effect of Reach and Phase for Longwall 706, indicating a statistically significant interactive effect of Reach and Phase for Longwall 706, indicating that the variation among Reaches depended on the Phase, and / or vice versa. *Post-hoc* tests showed that:

> Impact Reach 2 was statistically different from Control Reach 5 in the Before Phase; and

> For Control Reach 5, the Before Phase was statistically different from the After Phase.

Thus, differences between Reaches in the Before Phase and between Phases at a Control Reach are not due to mining.

4.3.2.4 OE50 Taxa Score

PERMANOVA indicated no significant effects that could be attributed to mining of Longwall 705, but there was a statistically significant difference between Reach and Phase associated with Longwall 706. *Post-hoc* tests showed that:

> Impact Reach 2 was statistically different from Control Reaches 1 and 5 in the Before Phase. Thus, such differences are not due to mining (**Section 4.3.2.3**); and

> The Before Phase was statistically different from the After Phase at Control Reach 1 and Impact Reach 2.

PERMDISP indicated that the statistical difference between Phases for Reaches 1 and 2 was due to a difference in means rather than variance (PERMDISP P > 0.05). It is apparent that there was an increase in the OE50 Taxa Score at Reach 2, and a decrease at Reach 1, following commencement of extraction (**Figure 4.1**). An increase in OE50 Taxa Score at Reach 2 is therefore unlikely to be related to mining.

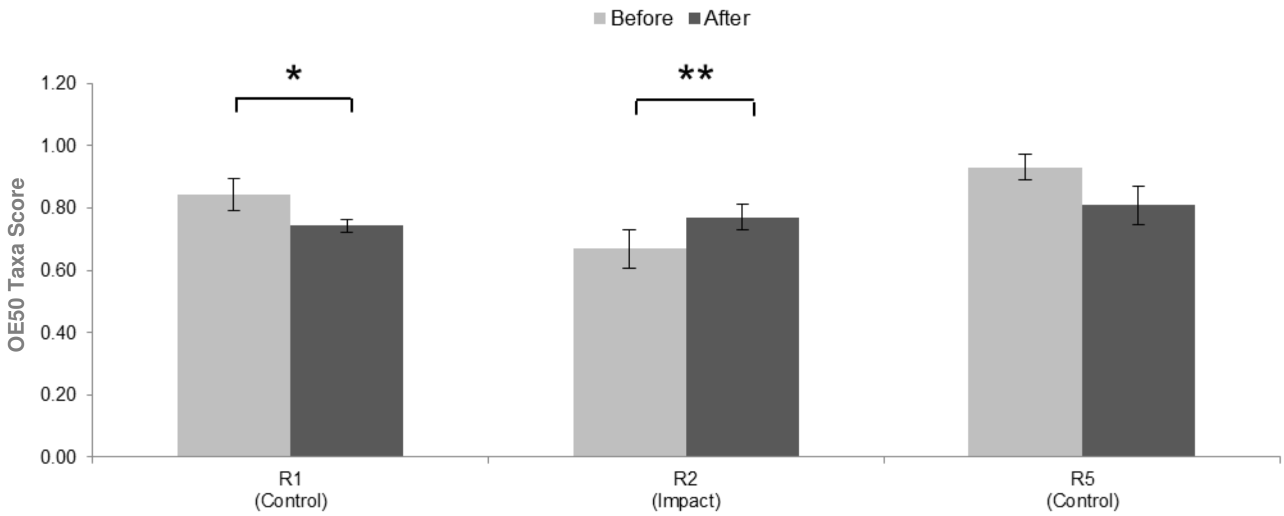

Figure 4-1 OE50 Taxa Scores from AUSRIVAS samples collected from edge habitat at Reaches (R) 1, 2 and 5 on the Nepean River in the Before and After Phases of extraction of Longwall 706. * and ** indicate statistical differences at P ≤ 0.05 and P ≤ 0.01, respectively. n = 8, except R1 Before n = 4 and R2 and R5 Before n = 6.

4.3.2.5 SIGNAL2 Index

PERMANOVA indicated a statistically significant main effect of Phase for Longwall 705 (i.e. the Before Phase was statistically different from the After Phase) but no statistical interaction. Thus, this index provides no evidence of an impact due to mining at either longwall.

4.3.3 Longwalls 901 to 904

Analyses for Longwalls 901 to 904 (those from Reaches 5 to 8 in November 2008 and November 2015) are presented in **Table 4-2**. None of the indices showed statistically significant interactions, suggesting that variation is consistent, and not statistically different, between Surveys and among Reaches prior to commencement of extraction.

Table 4-2 Summary of results of PERMANOVA analyses undertaken using AUSRIVAS data collected from edge habitat at sites relevant to Longwalls 901 to 904 during December 2014 and November 2015. * = P ≤ 0.05, ** = P ≤ 0.01, *** = P ≤ 0.001, ns = P > 0.05. The full results of the analyses are presented in Appendix F

Indicator	Survey	Reach	Survey x Reach
Longwalls 901 to 904			
Assemblage	**	**	ns
Number of Taxa	ns	ns	ns
OE50 Taxa Score	ns	ns	ns

SIGNAL2 Index	ns	*	ns

The results of the PCO tend to support the findings of the PERMANOVA tests. It is apparent that assemblages sampled in December 2014 differ from those sampled in November 2015, with those from December 2014 and November 2015 tending to group to the right and left of the PCO, respectively. There was also some evidence of differences between Reaches, with assemblages from Reach 5 tending to group to the top, and those from Reach 7 tending to group towards the bottom, of the PCO. Assemblages from Reaches 6 and 7 also appeared to differ, with those from Reach 6 tending to group above those from Reach 7. However, there was little evidence in the PCO of a substantial difference in assemblages sampled from Reaches 5 and 6, with assemblages from these two Reaches tending to group relatively close.

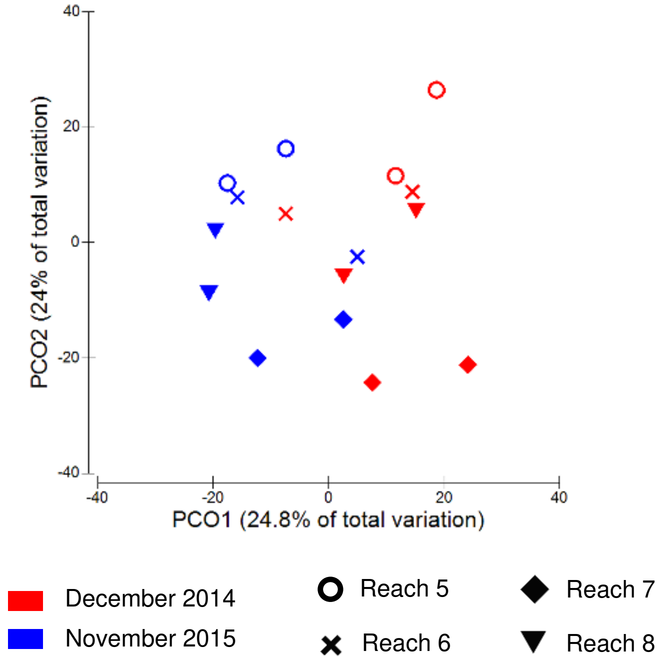

Figure 4-2 Principle Component Ordination (PCO) of AUSRIVAS macroinvertebrate edge assemblages sampled at Reaches 5 to 8 for Longwalls 901 to 904 in December 2014 and November 2015 on the Nepean River.

4.4 Fish

Two species of fish were caught by bait trapping at Appin Area 7 sites in 2015: flathead gudgeon (*Philypnodon grandiceps*) and firetail gudgeon (*Hypseleotris galii*) (**Appendix G**). Firetail gudgeon were caught at each site visited (Sites 1, 2 and 5 to 8) and flathead gudgeon were caught at Sites 1, 6, 7 and 8. Eastern gambusia (*Gambusia holbrooki*) were also observed near the river banks at most sites. These species have been caught previously in this section of the Nepean River during monitoring for Appin Area 7 (**Table 4.3**). Dwarf flathead gudgeon (*Philypnodon macrostomus*), freshwater catfish (*Tandanus tandanus*) and empire gudgeon (*Hypseleotris compressa*) were not caught in bait traps in November 2015, but were found either in one previous survey only (2008 in the case of empire gudgeon) or in very low numbers in earlier surveys (in the case of freshwater catfish and dwarf flathead gudgeon). Dwarf flathead gudgeon, flathead gudgeon, firetail gudgeon, eastern gambusia and Australian smelt (*Retropinna semoni*) were caught in seine nets at these sites in November 2015. Also, dwarf flathead gudgeon, flathead gudgeon and eastern gambusia were caught in AUSRIVAS dip net samples. Freshwater shrimp (Family: Atyidae) were dip netted at several sites.

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

Table 4-3 Fish species caught by bait trapping in the Nepean River during the aquatic ecology monitoring undertaken for the Appin Area 7 Longwalls from September 2003 to December 2014

Scientific Name	Common Name	Sep 2003	April 2008	Nov 2008	Dec 2010	Dec 2011	Dec 2012	Dec 2013	Dec 2014	Nov 2015
Philypnodon grandiceps	Flathead gudgeon	x	x	x	x	x	x	x	x	x
Hypseleotris galii	Firetail gudgeon	x	x	x	x	x	x	x	x	x
Philypnodon macrostomus	Dwarf flathead gudgeon	x		x	x	x	x	x		
Gambusia holbrooki	Eastern gambusia		x		x			x	x	
Retropinna semoni	Australian smelt		x		x	x	x	x		
Tandanus tandanus	Freshwater catfish					x	x			
Hypseleotris compressa	Empire gudgeon			x						

Species of fish caught in bait traps and whilst backpack electrofishing at Appin Area 9 sites are presented in **Table 4.4**. Raw data is presented in **Appendices G** and **H**. Each species caught in 2015 was also caught in 2014. However, no fish were caught in bait traps deployed at Sites X3 to X8 in 2015. The only fish caught in bait traps were flathead gudgeon at Site 1 and firetail gudgeon at Sites 1 and 2. Coxs gudgeon (*Gobiomorphus coxii*) was the most widespread and abundant species caught whilst backpack electrofishing (Sites X3 to X8), along with fewer numbers of flathead gudgeon, longfinned eel (*Anguilla reinhardtii*) (Site 1, X3 and X8) and Australian smelt (Sites X3 and X8). All these species were caught in 2014.

Table 4-4 Fish species caught by bait trapping and backpack electrofishing in the Nepean River at Appin Area 9 sites in December 2014 and November 2015

Scientific Name	Common Name	Bait Traps		Backpack Electrofishing	
		Dec 2014	Nov 2015	Dec 2014	Nov 2015
Philypnodon grandiceps	Flathead gudgeon	x	x	x	x
Hypseleotris galii	Firetail gudgeon	x	x	x	
Anguilla reinhardtii	Longfinned eel			x	x
Gambusia holbrooki	Eastern gambusia			x	
Retropinna semoni	Australian smelt			x	x
Gobiomorphus coxii	Coxs gudgeon	x		x	x
Macquaria novemaculeata	Australian bass			x	

4.5 Aquatic Macrophytes

In 2015, nine species of aquatic macrophytes were recorded across the six sites sampled for Area 7 (Sites 1, 2 and 5 to 8) (**Appendix I**). All species, except clasped pondweed (*Potamogeton perfoliatus*), identified previously were observed during the current survey. Hydrilla (*Hydrilla verticillata*), floating pondweed (*Potamogeton tricarinatus*), elodea (*Elodea canadensisi*) and ribbonweed (*Vallisneria* sp.) were the most common species, occurring at most (at least 4 of 6) sites visited. The invasive alligator weed (*Alternanthera philoxerides*) was observed along the banks at Sites 7 and 8. Few macrophytes were observed at Sites X3 to X8. Watercress (*Rorippa nasturtium-aquaticum*) was observed at Sites X5 to X8, while curly pondweed at Site X8, floating pondweed at Sites X3 and X4 and alligator weed were observed at Sites X5 and X6. Alligator weed can grow prolifically and compete with native flora, disrupting the aquatic environment by blanketing the surface and impeding the penetration of light. It is declared a noxious weed throughout NSW and is one of the highest priority weeds for detection and management in NSW. Watercress is native to Europe and is considered a weed in NSW. However, it is not listed as noxious and is naturalised (i.e. not displaying pest characteristics such as smothering native species) across southern and eastern parts of Australia. No macrophytes were observed at Site X7, though the turbid water at the time of sampling may have obscured some plants (**Section 4.1**). The species composition at each Appin Area 7 and 9 monitoring site (except Site 7, where watercress was observed previously but not in 2015) was identical to that observed in the most recent previous survey in 2014.

No signs of desiccation or die-back were observed during the inspection, which otherwise may have indicated a drop in water level.

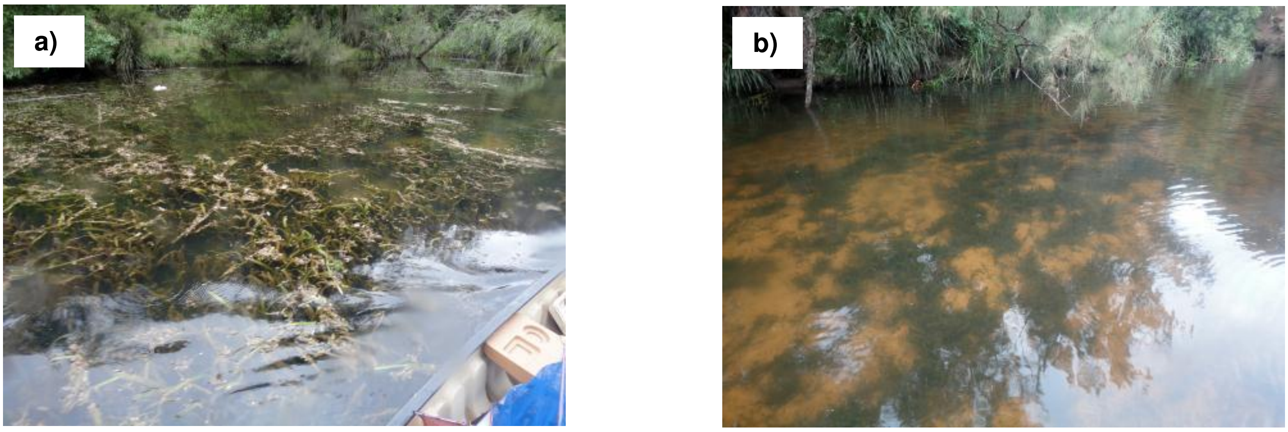

Plate 1 a) Dense beds of ribbonweed (*Vallisneria* sp.) at Site 8 and b) beds of pondweed (*Potamogeton* spp.) at Site 1

5 Discussion

5.1 Appin Area 7

5.1.1 Mining Impacts

No physical or water quality impacts due to extraction of Longwalls 705 and 706 have been identified (a new gas release zone was identified in the Nepean River during extraction of Longwall 706 on 13 August 2014, however, this was some distance upstream of this longwall and its activation was attributed to Tower Mine Longwall 16, extracted between 1998 and 1999) (**Section 2.1.2.2**). It is conceivable that this, and other gas release zones that were either first identified and / or active following extraction of these longwalls (i.e. Gas Zones 5, 14, 16, 17 and 18), could represent cumulative physical mining impacts associated with the extraction of Longwalls 701 to 704. As of 11 January 2016 only Gas Zones 14 and AA7_LW706_001 were currently, or recently, active (**Section 2.1.2.2**).

5.1.2 Aquatic Habitat and Water Quality

There was no evidence of any change in aquatic habitat associated with mining in the current assessment. The aquatic habitat in sections of Nepean River visited in this study is generally in good condition although the AUSRIVAS modelling does not fully support this observation. The relatively undisturbed riparian strip present would help to enhance aquatic habitat and biota in this section of the river. It would help to stabilise river banks and help 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. It is also an important source of allochthonous material such as insects and leaves etc. The relatively dense patches of macrophytes observed at most sites 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 assist in nutrient cycling. The AUSRIVAS Band Scores calculated from most AUSRIVAS samples were generally Band B. This indicates macroinvertebrate assemblages that are less diverse than expected by comparison with the model's reference condition (**Section 5.1.3**), suggesting impaired habitat and / or water quality.

Water in Nepean River is sourced from rainfall within catchment areas, licensed discharges from collieries, sewage treatment plants, agricultural and industrial sites and stormwater runoff from urban areas and consequently its chemistry is highly variable (Geoterra, 2005). The surface water quality indicators measured by ICEFT just prior to the 2015 aquatic ecology survey were largely within, or very slightly outside, guidelines for the protection of aquatic ecosystems. These data are comparable with those from previous aquatic ecology surveys when surface water quality measures were also generally found to be within default trigger values DTVs (ANZECC/ARMCANZ (2000).

Deeper samples taken near the river bed have shown concentrations of dissolved oxygen at the river bed to be, on occasion, below the lower DTV (Cardno Ecology Lab 2014). Note: bottom water was not sampled in 2015 due to probe malfunction (**Section 3.1.3**)). Turbidity was also often below the lower DTV, but this is unlikely to be cause for concern. The low levels of dissolved oxygen measured previously are indicative of stratification of the water column with hypoxic water at the bottom and oxygenated water at the surface. Stratification can occur naturally in summer due to limited vertical mixing between the warm upper water layer and colder, denser layer(s), below. It can also occur due to inflow of saline water. Stratification could lead to impacts on aquatic systems, particularly if the water column mixes dramatically, possibly in a flood event. It can be deleterious to biota due to anoxia, or toxicity from contaminants liberated from bottom sediments during periods of reduced pH. Gas releases could also result in reductions in dissolved oxygen due to microbial consumption of dissolved methane (Ecoengineers 2009). It is possible that this process is contributing to the somewhat depauperate macroinvertebrate assemblages sampled in this section of the river. Macroinvertebrates may also be affected by alterations to the natural flow regime of the river caused by the several major flow controlling structures (e.g. Menangle and Maldon Weirs) present on the river. The degree of stratification, where previously apparent, appeared to vary among sites. This could be related to variation in the water depth of each site, with stratification more pronounced at deeper sites than at shallower sites.

5.1.3 Macroinvertebrates

5.1.3.1 General Findings

The aquatic macroinvertebrate fauna in this section of the Nepean 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 throughout the 2002 to 2015 monitoring period, with AUSRIVAS Band Scores generally being indicative of impaired macroinvertebrate assemblages (i.e. AUSRIVAS Band B) and SIGNAL2 Indices, indicative of moderate to severe water pollution. Despite this, several pollution sensitive taxa have been identified, and, on occasion, AUSRIVAS Bands were equivalent to the AUSRIVAS reference condition (i.e. Band A) and hence have been, at times, indicative of undisturbed macroinvertebrate assemblages. Due to the relatively undisturbed condition of the riparian vegetation, it is probable that poor water quality, such as low dissolved oxygen, and alteration to the natural flow regime of the river, may explain the somewhat depauperate condition of the macroinvertebrate fauna in this section of the river. It is possible, if not likely, that the macroinvertebrate assemblage in hypoxic sections of the river deeper than that sampled here is depauperate also.

5.1.3.2 Changes to Macroinvertebrates

Statistical analyses of the indices derived from AUSRIVAS indicated no evidence of any changes to macroinvertebrates that could be associated with the extraction of Longwalls 705 and 706. The statistical interaction between Phase and Reach for a number of taxa data was due to differences between Reaches in the Before Phase and between Phases at one of the Control Reaches. Such differences are not related to mining, but rather background variation. The statistical interaction between Phase and Reach for OE50 Taxa Score data was due to a difference between Reaches in the Before Phase (again, not related to mining) and an increase and a decrease in this indicator at an Impact and Control Reach, respectively. An increase in OE50 Taxa Score, and the improvement in aquatic habitat and / or water quality that this indicates, is very unlikely to be due to mining.

Statistical differences in indicators detected among Surveys and between Phases are also unrelated to mining. Such patterns are more likely related to variations in patterns of rainfall, and its effect on flow in the river. Likewise, differences among Reaches possibly reflect inter-reach variability in the influence of factors related to these, such as differences in the flow controlling effect of the various weirs located within, upstream and downstream of the section of river monitored.

5.1.4 Fish

Although fewer fish species were caught using bait traps in November 2015 (two species compared with three to five in previous surveys) there is no indication of any change due to mining. The two species that were caught in November 2015 were found at one or both of the Impact sites. Also, the few species sampled previously that were not caught in bait traps in November 2015 were either uncommon in previous surveys, found only in one previous survey, and / or caught using other techniques (seine netting and AUSRIVAS dip netting). There is no indication that the extraction of Longwalls 705 or 706 has had any effect on fish populations in the Nepean River.

5.1.5 Aquatic Macrophytes

There has been very little change in the composition of aquatic macrophytes observed at each site between 2013 and 2015, with no change in the composition of macrophytes observed at each site between 2014 and 2015 (with the exception of elodea and blunt pondweed), which were observed at Site 6 in 2015, but not in 2014, and the possible exception of Site X7, where turbid water may have obscured some plants in 2015). However, during these last three surveys some species were absent from Sites 5 and 6 (Impact sites for Longwalls 705 and 706) where they had previously been identified (macrophytes were previously inspected, and mapped at Sites 1 to 6 in 2003, 2005, 2008 and 2010 and at Sites 7 and 8 in 2008 and 2010). In most cases, these species were either not identified in all previous surveys and / or were found in low abundance (e.g. floating pondweed, which was not observed at Site 6 in 2013 to 2015, but was observed in low abundance prior to this). Curly pondweed occurred at Sites 5 and 6 during 2003 to 2010 (albeit on occasion in low abundance), though it was not observed at these sites during 2013 to 2015. However, it was also not observed at Sites 7 and 8 during 2013 to 2015, where it had previously been identified.

Consequently, and given the absence of any sign of macrophyte desiccation and die-back and any identified uplift or reductions in water levels in the Nepean River, there is no evidence to suggest that changes in macrophyte diversity and distributions are outside what would be expected due to natural variation. There is no indication that extraction of Longwalls 705 or 706 has affected aquatic macrophytes in the Nepean River.

5.2 Appin Area 9

The aquatic habitat at most Appin Area 9 sites is in good condition. As is the case with the section of the river monitored further downstream for Appin Area 7, the riparian strip is relatively undisturbed and would provide habitat in the form of woody debris and help stabilise banks. The AUSRIVAS Bands for the additional sites sampled as part of the Appin Area 9 monitoring program (Sites X3 to X8) are indicative of significantly impaired to undisturbed habitat (Bands B and A), while the SIGNAL2 Indices are indicative of moderate to severe water pollution. As is the case in Appin Area 7, poor water quality (pH has slightly exceeded guidelines for the protection of aquatic ecosystems at some sites) and alteration to the natural flow regime due to flow controlling structures such as Maldon Weir, could be affecting macroinvertebrates here.

Differences in the structure of macroinvertebrate assemblages detected statistically between Control Reach 5 and Impact Reach 6 and between Control reach 5 and Control Reach 7 could be related to the observed differences in aquatic habitat between the two downstream sites (Sites 1 and 2 – Reach 5) and the six most upstream sites (Sites X3 to X8 – Reaches 6 to 8) (e.g. differences in water depth, flow velocity and substratum). It should be noted, however, that differences between assemblages at Impact Reach 6 and Control Reach 7 were also detected, despite little observable difference in aquatic habitat between these areas. A statistically significant main effect of Reach was also detected for assemblages when data from December 2014 was available only, although differences between pairs of Reaches could not be resolved (Cardno Ecology Lab 2015). Differences in SIGNAL2 Indices between Impact Reach 6 and Control Reaches 7 and 8 could be related to differences in hydrological regime and / or flow velocity between these reaches associated with varying proximity to Maldon Weir. Reaches further upstream and closer to the weir would be expected to receive greater magnitude and variability in flows compared with those farther downstream. As with Appin Area 7, differences in assemblages between the two surveys in Appin Area 9 related to variations in patterns of rainfall, and its effect on flow in the river.

No differences in the number of taxa and OE50 Taxa Scores were detected between Reaches and Surveys. This could suggest that any effect due to future extraction of Longwalls 901 to 904 may be easier to detect in these indicators.

There is some evidence to suggest that the fish assemblage at Sites X3 to X8 differs from that at Sites 1 and 2. Coxs gudgeon and Australian bass have been found upstream of Sites 1 and 2 only. This likely reflects the different habitat and hydrology present at these two groups of sites. The occurrence of Australian bass at Site X8 only (in 2014) could also be due to the presence of Maldon Weir, which probably represents a barrier to further upstream migration for this species causing to it aggregate immediately downstream. It is also evident that backpack electrofishing was more effective than bait traps in sampling fish during these surveys.

The smaller number of species and smaller distribution of aquatic macrophytes observed at Sites X3 to X8, compared with that at sites further downstream in 2014 and 2015, likely reflect the differences in habitat and hydrology between these areas. Sites with slower water velocity and finer grain substratum (and the better root anchorage and nutrient retention this affords compared with coarser substratum), likely provide more suitable conditions for colonisation and growth of macrophytes. However, it is possible that more macrophytes would have been observed at Sites X7 and X8 had the water level and turbidity not been elevated during sampling.

The apparent differences in macroinvertebrate and fish assemblages between Control Reach 5 and Impact Reach 6 and Control Reach 7 (in the case of macroinvertebrates) and between Control Reach 5 and Reaches 6 to 8 (in the case of fish), and associated differences in aquatic habitat and hydrology, should be taken into account when interpreting the results of further sampling following the commencement of extraction of Longwalls 901 to 904.

6 Conclusion

No changes to aquatic ecology indicators that could be associated with extraction of Longwalls 705 or 706 have been detected in data collected following the commencement of extraction of these longwalls. This is not surprising given that no water quality or physical mining impacts (other than some isolated gas releases) have been identified. The gas releases identified in the Nepean River during extraction of these longwalls do not appear to have had any effect on macroinvertebrates, fish and macrophytes in the Nepean River. An increase in OE50 Taxa Score at the Impact Reach following the commencement of extraction of Longwall 706 is not due to mining. The somewhat poor condition of the macroinvertebrate fauna in the section of the Nepean River during the monitoring program is also not related to mining.

There is also no evidence that mining of these longwalls has had any impact on fish populations. The relatively large changes in the extent and distribution of aquatic macrophytes that have been observed since the commencement of monitoring represent natural variation unrelated to mining.

The findings of the second pre-extraction survey for Appin Area 9 suggest that while differences in aquatic habitat and macroinvertebrate and fish assemblages among some sites exist, these are largely evident between two most downstream sites (Sites 1 and 2) and those farther upstream (Sites X3 to X8). This suggests that data from Control Reaches 7 (Sites and X5 and X6) and 8 (Sites X7 and X8) may be more appropriate as a Control than that from Control Reach 5 (Sites 1 and 2). This should be taken into account during future comparisons. The absence of any statistically significant difference in the number of taxa and OE50 Taxa Score Data among Reaches suggest that, overall, potential changes due to mining may be more easily detected in these indicators.

7 Recommendations

1. Monitoring for Longwalls 705 to 710 should continue each year in the AUSRIVAS spring sampling season while extraction is underway and for at least two years thereafter. The next survey should be undertaken in November / December 2016 to align with the timing of sampling undertaken in recent years. This survey would provide further post-extraction data for Longwall 705, the first year of post-extraction data from Longwall 706, the first year of during-extraction data for Longwall 707 and further pre-extraction data for Longwalls 708 to 710;
2. Extraction of Longwall 901 commenced 19 January 2016, thus, the first during extraction survey for Longwall 901 should be undertaken in the spring 2016 AUSRIVAS sampling season. This should be done in conjunction with sampling for Longwalls 705 to 710. This survey would also provide further pre-extraction data for Longwalls 902 to 904; and
3. Due to the relatively small numbers of species and individuals of fish caught in bait traps in Appin Area 9 in December 2014 and November 2015, sampling of fish using this method should cease. Sampling of fish using backpack electrofishing is recommended to continue. This is consistent with the recommendations in Cardno Ecology Lab (2015).

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APPENDIX

A

GPS COODINATES OF APPIN AREA 7 AND 9 AQUATIC ECOLOGY MONITORING SITES ON THE NEPEAN RIVER

Site	Easting	Northing
Site 1 upstream extent	288463	6214100
Site 1 downstream extent	288780	6214152
Site 2 downstream extent	289008	6214219
Site 2 upstream extent	288851	6214182
Site 3 downstream extent (sampling ceased)	291889	6215263
Site 3 upstream extent (sampling ceased)	291644	6215370
Site 4 upstream extent (sampling ceased)	292071	6215217
Site 4 downstream extent (sampling ceased)	292281	6215350
Site 5 downstream extent	292791	6218045
Site 5 upstream extent	293002	6217805
Site 6 downstream extent	292647	6218567
Site 6 upstream extent	292785	6218240
Site 7 upstream extent	292582	6220829
Site 7 downstream extent	292581	6221116
Site 8 upstream extent	292815	6221295
Site 8 downstream extent	292963	6221582
Site X1 upstream extent (sampling ceased)	292378	6216501
Site X1 downstream extent (sampling ceased)	292348	6216638
Site X2 upstream extent (sampling ceased)	292356	6216590
Site X2 downstream extent (sampling ceased)	292379	6216875
Site X3 centre	286453	6214934
Site X4 centre	286194	6215120
Site X5 centre	284800	6213117
Site X6 centre	284680	6213032
Site X7 centre	281754	6212912
Site X8 centre	281655	6212798

Datum: WGS 84, Zone 56H

Aquatic Ecology Monitoring 2003 to 2015

APPENDIX

B

VALUES OF WATER QUALITY INDICATORS FOR WATER QUALITY MONITORIGN SITES ON THE NEPEAN RIVER VISITED BY ICEFT IN OCTOBER AND NOVEMBER 2015

Date	Site	Value
Temperature (C)		
15/10/2015	NR0	19.2
12/11/2015	NR0	20.5
12/11/2015	NR11	22.0
15/10/2015	NR110	20.2
12/11/2015	NR110	21.6
12/11/2015	NR12	21.9
12/11/2015	NR13	22.1
15/10/2015	NR2	19.7
12/11/2015	NR2	21.2
26/10/2015	NR4	20.5
12/11/2015	NR4	21.1
25/11/2015	NR4	22.1
26/10/2015	NR5	18.2
12/11/2015	NR5	19.0
15/10/2015	NR50	19.6
12/11/2015	NR50	20.8
26/10/2015	NR6	19.7
12/11/2015	NR6	20.5
25/11/2015	NR6	22.3
26/10/2015	NR7	19.7
12/11/2015	NR7	20.8
25/11/2015	NR7	22.9
12/11/2015	NR9	20.7
Conductivity (µs/cm) DTV: 125-2200		
15/10/2015	NR0	246
12/11/2015	NR0	301
12/11/2015	NR11	209
15/10/2015	NR110	274
12/11/2015	NR110	221
12/11/2015	NR12	188
12/11/2015	NR13	188
15/10/2015	NR2	321
12/11/2015	NR2	406
26/10/2015	NR4	195
12/11/2015	NR4	405
25/11/2015	NR4	200
26/10/2015	NR5	84
12/11/2015	NR5	84
15/10/2015	NR50	131
12/11/2015	NR50	200
26/10/2015	NR6	153
12/11/2015	NR6	299
25/11/2015	NR6	178
26/10/2015	NR7	128
12/11/2015	NR7	205
25/11/2015	NR7	134
12/11/2015	NR9	208

Date	Site	Value
pH DTV: 6.5-8.0		
15/10/2015	NR0	7.8
12/11/2015	NR0	8.2
12/11/2015	NR11	8.1
15/10/2015	NR110	8.1
12/11/2015	NR110	8.3
12/11/2015	NR12	7.5
12/11/2015	NR13	7.5
15/10/2015	NR2	8.1
12/11/2015	NR2	8.4
26/10/2015	NR4	7.9
12/11/2015	NR4	8.5
25/11/2015	NR4	7.5
26/10/2015	NR5	7.5
12/11/2015	NR5	7.5
15/10/2015	NR50	7.1
12/11/2015	NR50	7.3
26/10/2015	NR6	7.7
12/11/2015	NR6	8.3
25/11/2015	NR6	7.2
26/10/2015	NR7	7.6
12/11/2015	NR7	8.3
25/11/2015	NR7	7.2
12/11/2015	NR9	8.1
Dissolved oxygen (% saturation) DTV: 85-110		
15/10/2015	NR110	79.6
12/11/2015	NR110	106.2
15/10/2015	NR0	92.1
12/11/2015	NR0	120.5
15/10/2015	NR2	90.9
12/11/2015	NR2	116.0
26/10/2015	NR4	89.1
12/11/2015	NR4	101.0
25/11/2015	NR4	98.9
26/10/2015	NR5	87.4
12/11/2015	NR5	97.8
26/10/2015	NR6	83.0
12/11/2015	NR6	97.0
25/11/2015	NR6	93.3
26/10/2015	NR7	94.2
12/11/2015	NR7	98.6
25/11/2015	NR7	110.1
12/11/2015	NR9	99.4
15/10/2015	NR50	96.5
12/11/2015	NR50	109.5
12/11/2015	NR11	106.1
12/11/2015	NR12	102.0
12/11/2015	NR13	105.0

Date	Site	Value
Oxidation reduction potential (ORP) (mV)		
15/10/2015	NR0	135
12/11/2015	NR0	182
12/11/2015	NR11	147
15/10/2015	NR110	111
12/11/2015	NR110	153
12/11/2015	NR12	177
12/11/2015	NR13	188
15/10/2015	NR2	130
12/11/2015	NR2	139
26/10/2015	NR4	188
12/11/2015	NR4	182
25/11/2015	NR4	208
26/10/2015	NR5	190
12/11/2015	NR5	176
15/10/2015	NR50	131
12/11/2015	NR50	143
26/10/2015	NR6	193
12/11/2015	NR6	175
25/11/2015	NR6	180
26/10/2015	NR7	184
12/11/2015	NR7	136
25/11/2015	NR7	203
12/11/2015	NR9	150

DTV: the (ANZECC/ARMCANZ 2000) default trigger values (where applicable), grey shading indicates value outside of DTV.

Aquatic Ecology Monitoring 2003 to 2015

APPENDIX

C

MACROINVERTEBRATE TAXA FOUND IN AUSRIVAS SAMPLES COLLECTED FROM EDGE HABITAT AT MONITORING SITES ON THE NEPEAN RIVER IN SPRING 2015

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Taxon	Site											
	1	2	5	6	7	8	X3	X4	X5	X6	X7	X8
Dugesiidae			2	1	1	1					1	3
Nematoda						2						
Corbiculidae/Sphaeriidae		1			2	1	1	1				1
Lymnaeidae					1		1					1
Physidae	1	1	1	1	6			1				1
Oligochaeta	1	1	3	1	1	2	2	1		1	2	1
Cladocera		1	2		1	5		1	1		1	
Copepoda	3	10	5	6	3	3	3	2	2	2	3	2
Ostracoda			6	4	2							
Ceinidae									4			
Oniscidae		1				1					1	
Atyidae		1	1	2	2	2						
Araneae			1			1						
Hydracarina	10	10	10	10	5	8	8	10	10	2	10	3
Hypogastruridae		1										
Entomobryidae									1			
Caenidae		1				1	3	3				
Baetidae	2	7	1	2	4		10	3	2	1	5	1
Leptophlebiidae	1		1	6		1		10		1		
Coenagrionidae		1	1	1	10	3						
Isostictidae	1	1	1			3						
Protoneuridae	10	8	10	10	10	9						
Gomphidae			3	2								
Aeshnidae					4							
Telephlebiidae	4	2	1		1							
Austrocorduliidae		1										
Hemicorduliidae	1		1				4	2			1	
Synthemistidae						1						
Mesoveliidae									1			
Veliidae		4				3		2	10	5		2
Gerridae		2					1	2	10	2		7
Gelastocoridae				2							1	
Corixidae	5	4	10	8			10	10	10	8	10	10
Notonectidae									1	1	1	1
Pleidae					3							
Sialidae			1	2	2	3						
Dytiscidae	1	1	2		1	4	9			1	2	2
Hydrophilidae	3	5	6	2	10	7	8	2	2	3	7	5
Hydraenidae						2						
Scirtidae		1	1	1	1	1	1					
Elmidae	6	10		9	4	7	1	9		5	1	
Dixidae					1							
Culicidae	1	1	2						4	6		6
Chironomidae - Chironominae	4	6	6	3	1	9	6	10	1	1		10
Chironomidae - Orthocladiinae	3	2		2	3	5	10	10			1	
Chironomidae - Tanypodinae	1	2	3	6	2	4	2		2			
Ceratopogonidae			1	2				1	1	2		
Tipulidae	1					1				2		1
Empididae					1				2			
Dolichopodidae										1		
Hydroptilidae		4					3	2	1			
Philopotamidae								1				
Ecnomidae								3				
Atriplectididae						3						
Calamoceratidae					1							
Leptoceridae	10	10	10	10	10	10	10	10	8	2	10	8

Note: A maximum of 10 individuals of each taxon were counted per sample.

Aquatic Ecology Monitoring 2003 to 2015

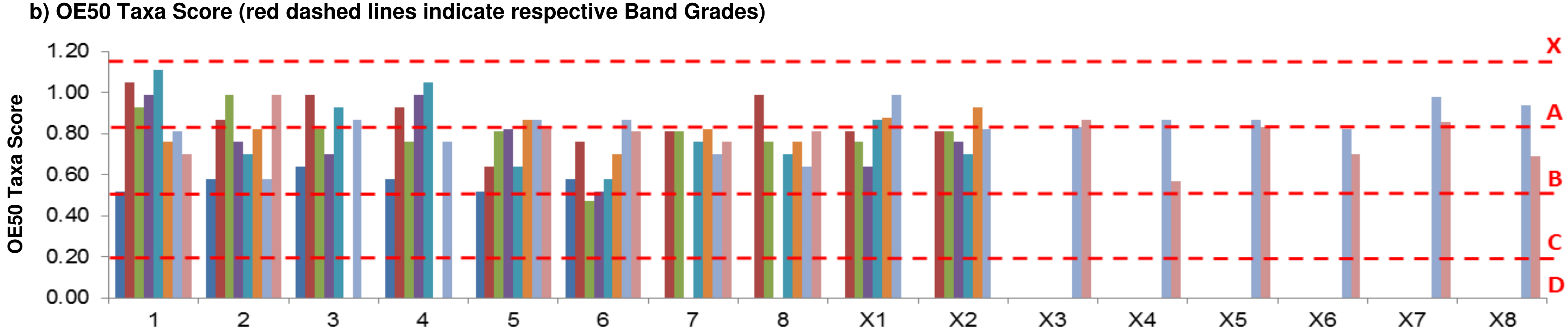
APPENDIX

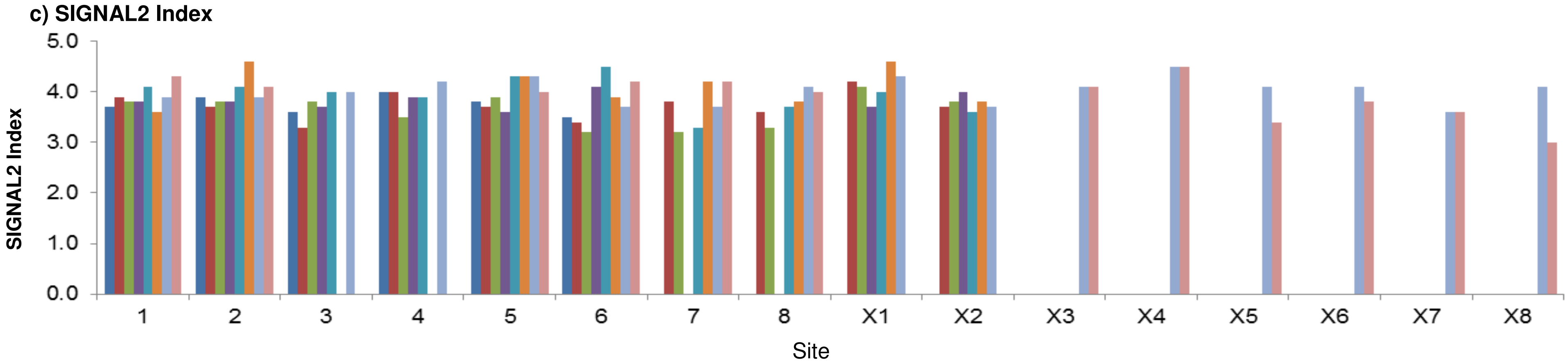
D

NUMBERS OF MACROINVERTEBRATE TAXA, OE50 TAXA SCORES AND SIGNAL2 INDICES FOR AUSRIVAS EDGE SAMPLES COLLECTED AT SITESON THE NEPEAN RIVER 2003 TO 2015

Reach	Reach 5		Reach 4		Reach 2		Reach 1		Reach 3		Reach 6		Reach 7		Reach 8	
Site:	1	2	3	4	5	6	7	8	X1	X2	X3	X4	X5	X6	X7	X8
Number of Taxa																
Sep 03	13	14	15	16	13	14										
Nov 08	32	30	32	32	25	27	33	30	31	27						
Dec 10	30	27	25	31	25	15	27	30	23	27						
Dec 11	28	24	19	30	28	21			24	27						
Dec 12	28	24	28	31	20	21	25	26	26	26						
Dec 13	19	22			25	22	22	20	22	27						
Dec 14	22	20	24	24	27	26	23	21	34	22	17	25	19	15	23	23
Nov 15	20	29			27	23	28	29			19	22	19	18	16	18
OE50 Taxa Score																
Sep 03	0.52	0.58	0.64	0.58	0.52	0.58										
Nov 08	1.05	0.87	0.99	0.93	0.64	0.76	0.81	0.99	0.81	0.81						
Dec 10	0.93	0.99	0.82	0.76	0.81	0.47	0.81	0.76	0.76	0.81						
Dec 11	0.99	0.76	0.70	0.99	0.82	0.52			0.64	0.76						
Dec 12	1.11	0.70	0.93	1.05	0.64	0.58	0.76	0.70	0.87	0.70						
Dec 13	0.76	0.82			0.87	0.70	0.82	0.76	0.88	0.93						
Dec 14	0.81	0.58	0.87	0.76	0.87	0.87	0.70	0.64	0.99	0.82	0.83	0.87	0.87	0.82	0.98	0.94
Nov 15	0.70	0.99			0.82	0.81	0.76	0.81			0.87	0.57	0.83	0.70	0.86	0.69
SIGNAL2 Index																
Sep 03	3.7	3.9	3.6	4.0	3.8	3.5										
Nov 08	3.9	3.7	3.3	4.0	3.7	3.4	3.8	3.6	4.2	3.7						
Dec 10	3.8	3.8	3.8	3.5	3.9	3.2	3.2	3.3	4.1	3.8						
Dec 11	3.8	3.8	3.7	3.9	3.6	4.1			3.7	4.0						
Dec 12	4.1	4.1	4.0	3.9	4.3	4.5	3.3	3.7	4.0	3.6						
Dec 13	3.6	4.6			4.3	3.9	4.2	3.8	4.6	3.8						
Dec 14	3.9	3.9	4.0	4.2	4.3	3.7	3.7	4.1	4.3	3.7	4.1	4.5	4.1	4.1	3.6	4.1
Nov 15	4.3	4.1			4.0	4.2	4.2	4.0			4.1	4.5	3.4	3.8	3.6	3.0


a) Number of Taxa
Sep 2003
Nov 2008
Dec 2010
Dec 2011
Dec 2012
Dec 2013
Dec 2014
Nov 2015
Number of Taxa
40
30
20
10
0
1
2
3
4
5
6
7
8
X1
X2
X3
X4
X5
X6
X7
X8


b) OE50 Taxa Score (red dashed lines indicate respective Band Grades)
OE50 Taxa Score
1.20
1.00
0.80
0.60
0.40
0.20
0.00
X
A
B
C
D
1
2
3
4
5
6
7
8
X1
X2
X3
X4
X5
X6
X7
X8


c) SIGNAL2 Index
SIGNAL2 Index
5.0
4.0
3.0
2.0
1.0
0.0
1
2
3
4
5
6
7
8
X1
X2
X3
X4
X5
X6
X7
X8
Site

APPENDIX E

PERMANOVAS COMPARING MACROINVERTEBRATE ASSEMBLAGES,NUMBER OF TAXA, OE50 TAXA SCORESAND SIGNAL2 INDICES LONGWALL 705 AND 706 MONITORING SITES

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A) Longwall 705

i) Assemblage

Source of Variation	df	SS	MS	*F*	*P*
Phase	1	2478	2478	1.582	0.118
Reach	**2**	**3063**	**1532**	**3.007**	**0.001**
Survey (Phase)	**5**	**8162**	**1632**	**2.798**	**<0.001**
Reach x Phase	2	1347	674	1.322	0.200
Reach x Survey (Phase)	9	4584	509	0.873	0.752
Residual	20	11670	583		
Total	39	31942			

Pairwise tests of Reach

Comparisons among Reaches	t	*P*
R5, R2	**2.000**	**0.026**
R5, R1	**1.691**	**0.047**
R2, R1	1.348	0.155

Pairwise tests of Surveys

Comparisons among Surveys	t	*P*
Within level 'Before' of factor 'Phase'		
Nov08, Dec10	**2.248**	**0.006**
Nov08, Dec11	**2.101**	**0.014**
Dec10, Dec11	**1.562**	**0.049**
Within level 'After' of factor 'Phase'		
Dec12, Dec13	1.359	0.109
Dec12, Dec14	**1.732**	**0.034**
Dec12, Nov15	**1.586**	**0.039**
Dec13, Dec14	1.119	0.303
Dec13, Nov15	1.342	0.105
Dec14, Nov15	**1.872**	**0.012**

ii) Number of Taxa

Source of Variation	df	SS	MS	*F*	*P*
Phase	1	110.25	110.25	5.388	0.066
Reach	2	64.18	32.09	2.414	0.151
Survey (Phase)	5	106.25	21.25	2.450	0.067
Reach x Phase	2	73.23	36.62	2.755	0.123
Reach x Survey (Phase)	9	119.63	13.29	1.532	0.211
Residual	20	173.50	8.68		
Total	39	632.98			

ii) OE50 Taxa Score

Source of Variation	df	SS	MS	*F*	*P*
Phase	1	0.012	0.012	1.497	0.204
Reach	**2**	**0.155**	**0.078**	**5.235**	**0.032**
Survey (Phase)	5	0.035	0.007	0.405	0.837
Reach x Phase	2	0.095	0.047	3.192	0.092
Reach x Survey (Phase)	9	0.133	0.015	0.850	0.589
Residual	20	0.349	0.017		
Total	39	0.759			

Pairwise tests of Reach

Comparisons among Reaches	t	P
R5, R2	2.548	0.055
R5, R1	2.689	0.055
R2, R1	1.452	0.218

iii) SIGNAL2 Score

Source of Variation	df	SS	MS	F	P
Phase	**1**	**1.270**	**1.270**	**28.278**	**<0.001**
Reach	2	0.350	0.175	2.271	0.161
Survey (Phase)	5	0.214	0.043	0.558	0.723
Reach x Phase	2	0.080	0.040	0.520	0.600
Reach x Survey (Phase)	9	0.694	0.077	1.006	0.471
Residual	20	1.533	0.077		
Total	39	4.354			

Pairwise tests of Phases

Comparisons among Reaches	t	P
Before, After	**5.318**	**<0.001**

B) Longwall 706

i) Assemblage

Source of Variation	df	SS	MS	F	P
Phase	1	2884	2884	1.796	0.066
Reach	**2**	**3254**	**1627**	**3.137**	**0.002**
Survey (Phase)	**5**	**8027**	**1605**	**2.752**	**<0.001**
Reach x Phase	2	1263	631	1.217	0.275
Reach x Survey (Phase)	9	4669	519	0.889	0.716
Residual	20	11670	583		
Total	39	31942			

Pairwise tests of Reach

Comparisons among Reaches	t	P
R5, R2	**2.054**	**0.021**
R5, R1	**1.921**	**0.032**
R2, R1	1.263	0.206

Pairwise tests of Surveys

Comparisons among Surveys	t	P
Within level 'Before' of factor 'Phase'		
Nov08, Dec10	**2.248**	**0.007**
Nov08, Dec11	**2.101**	**0.019**
Nov08, Dec12	1.498	0.056
Dec10, Dec11	**1.562**	**0.050**
Dec10, Dec12	**1.914**	**0.015**
Dec11, Dec12	**1.700**	**0.049**
Within level 'After' of factor 'Phase'		
Dec13, Dec14	1.119	0.304
Dec13, Nov15	1.342	0.103
Dec14, Nov15	**1.872**	**0.013**

ii) Number of Taxa

Source of Variation	df	SS	MS	*F*	*P*
Phase	1	72.97	72.97	2.376	RED
Reach	2	32.24	16.12	2.280	RED
Survey (Phase)	**5**	**153.58**	**30.72**	**3.541**	**0.018**
Reach x Phase	**2**	**129.23**	**64.61**	**9.139**	**0.010**
Reach x Survey (Phase)	9	63.63	7.07	0.815	0.603
Residual	20	173.50	8.68		
Total	39	632.98			

Pairwise tests of Surveys

Comparisons among Surveys	t	*P*
Within level 'Before' of factor 'Phase'		
Nov08, Dec10	1.980	0.068
Nov08, Dec11	1.605	0.162
Nov08, Dec12	**5.578**	**0.002**
Dec10, Dec11	0.331	0.780
Dec10, Dec12	0.857	0.436
Dec11, Dec12	0.982	0.364
Within level 'After' of factor 'Phase'		
Dec13, Dec14	1.616	0.149
Dec13, Nov15	2.374	0.053
Dec14, Nov15	1.644	0.150

Pairwise tests of Reach x Phase for pairs of Reaches

Comparisons among Reaches	t	*P*
Within level 'Before' of factor 'Phase'		
R5, R2	**3.573**	**0.044**
R5, R1	Negative	
R2, R1	5.795	0.063
Within level 'After' of factor 'Phase'		
R5, R2	2.079	0.214
R5, R1	1.678	0.229
R2, R1	0.485	0.683

Pairwise tests of Reach x Phase for pairs of Phases

Comparisons among Reaches	t	*P*
Within level 'R1' of factor 'Reach'		
Before, After	1.598	0.312
Within level 'R2' of factor 'Reach'		
Before, After	1.188	0.324
Within level 'R5' of factor 'Reach'		
Before, After	**3.330**	**0.028**

iii) OE50 Taxa Score

Source of Variation	df	SS	MS	*F*	*P*
Phase	1	0.001	0.001	0.102	RED
Reach	2	0.089	0.045	8.205	RED
Survey (Phase)	5	0.050	0.010	0.571	0.720
Reach x Phase	**2**	**0.179**	**0.090**	**16.508**	**<0.001**
Reach x Survey (Phase)	9	0.049	0.005	0.311	0.965
Residual	20	0.349	0.017		
Total	39	0.759			

Pairwise tests of Reach x Phase for pairs of Reaches

Comparisons among Reaches	t	*P*
Within level 'Before' of factor 'Phase'		
R5, R2	**10.836**	**0.014**
R5, R1	3.565	0.080
R2, R1	**6.560**	**0.012**
Within level 'After' of factor 'Phase'		
R5, R2	0.723	0.542
R5, R1	1.628	0.251
R2, R1	1.185	0.367

Pairwise tests of Reach x Phase for pairs of Phases

Comparisons among Reaches	t	*P*
Within level 'R1' of factor 'Reach'		
Before, After	**3.344**	**0.016**
Within level 'R2' of factor 'Reach'		
Before, After	**5.437**	**0.002**
Within level 'R5' of factor 'Reach'		
Before, After	0.891	0.424

iv) SIGNA2 Score

Source of Variation	df	SS	MS	*F*	*P*
Phase	1	0.903	0.903	5.417	0.071
Reach	2	0.431	0.215	3.189	0.104
Survey (Phase)	5	0.834	0.167	2.176	0.096
Reach x Phase	2	0.166	0.083	1.233	0.334
Reach x Survey (Phase)	9	0.608	0.068	0.881	0.550
Residual	20	1.533	0.077		
Total	39	4.354			

APPENDIX F

PERMANOVA COMPARING MACROINVERTEBRATE ASSEMBLAGES, NUMBER OF TAXA, OE50 TAXA SCORES AND SIGNAL2 INDICES FROM SITES RELVANT TO LONGWALLS 901 TO 904

A) Assemblage

Source of Variation	df	SS	MS	*F*	*P*
Survey	**1**	**2114**	**2114**	**4.155**	**0.007**
Reach	**3**	**4677**	**1559**	**3.064**	**0.002**
Survey x Reach	3	2188	729	1.433	0.140
Residual	8	4071	509		
Total	15	13050			

Pairwise tests of Surveys

Comparisons among Surveys	t	*P*
Within level 'Before' of factor 'Phase'		
Dec14, Nov15	**2.038**	**0.010**

Pairwise tests of Reach

Comparisons among Reaches	t	*P*
R5, R6	**1.834**	**0.037**
R5, R7	**2.326**	**0.026**
R5, R8	1.459	0.113
R6, R7	**1.960**	**0.038**
R6, R8	1.463	0.075
R7, R8	1.397	0.119

B) Number of Taxa

Source of Variation	df	SS	MS	*F*	*P*
Survey	1	0.56	0.56	0.050	0.822
Reach	3	51.19	17.06	1.525	0.267
Survey x Reach	3	50.19	16.73	1.495	0.285
Residual	8	89.50	11.19		
Total	15	191.44			

C) OE50 Taxa Score

Source of Variation	df	SS	MS	*F*	*P*
Survey	1	0.015	0.015	0.862	0.378
Reach	3	0.022	0.007	0.423	0.741
Survey x Reach	3	0.065	0.022	1.245	0.352
Residual	8	0.139	0.017		
Total	15	0.241			

D) SIGNAL2 Index

Source of Variation	df	SS	MS	*F*	*P*
Survey	1	0.176	0.176	2.520	0.154
Reach	**3**	**1.143**	**0.381**	**5.447**	**0.018**
Survey x Reach	3	0.463	0.154	2.208	0.168
Residual	8	0.559	0.070		
Total	15	2.341			

Pairwise tests of Reach

Comparisons among Reaches	t	*P*
R5, R6	1.867	0.155
R5, R7	1.938	0.106
R5, R8	2.209	0.060
R6, R7	**2.909**	**0.023**
R6, R8	**3.018**	**0.030**
R7, R8	1.069	0.346

Aquatic Ecology Monitoring 2003 to 2015

APPENDIX

G

FISH CAUGHT USING BAIT TRAPS IN 2015

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Site	Flathead Gudgeon (*Philypnodon grandiceps*)	Firetail Gudgeon (*Hypseleotris galii*)
Site 1	1	5
Site 2		7 (2)
Site 5		20
Site 6	1	12
Site 7	1	5
Site 8	5	3
Site X3		*No fish*
Site X4		*No fish*
Site X5		*No fish*
Site X6		*No fish*
Site X7		*No fish*
Site X8		*No fish*

Traps at Sites 1 to 8, X1 and X2 were deployed overnight. Traps at Sites X3 to X8 were deployed by day for 30 to 60 minutes. In addition, traps were also set separately at Sites 1 and 2 for 30 to 60 minutes to provide comparative data for Sites X3 to X8, these data are provided within parenthesis.

APPENDIX

H

NUMBERS OF EACH FISH SPECIES CAUGHT USING BACKPACK ELECTROFISHING AT SITES ON THE NEPEAN RIVER IN 2015

Site	Flathead Gudgeon (*Philypnodon grandiceps*)	Longfinned eel (*Anguilla reinhardtii*)	Australian smelt (*Retropinna semoni*)	Coxs gudgeon (*Gobiomorphus coxii*)
Site 1		1		
Rep 1				
Rep 2		1		
Rep 3				
Rep 4				
Site 2				*No fish*
Rep 1				
Rep 2				
Rep 3				
Rep 4				*No fish*
Site X3				
Rep 1		1	3	2
Rep 2				3
Site X4				
Rep 1				4
Rep 2				2
Rep 3				1
Rep 4				3
Site X5				
Rep 1				1
Rep 2				
Rep 3				2
Rep 4				1
Site X6				
Rep 1				1
Rep 2				2
Rep 3				1
Rep 4				1
Site X7				
Rep 1				2
Rep 2				1
Rep 3				1
Rep 4				
Site X8				
Rep 1	2	1		3
Rep 2		1		4
Rep 3				6
Rep 4		1		3

Each replicate = approximately 2 minutes of fishing effort. Only two replicates undertaken for Site X3 due to lack of suitable habitat and restrictions on the operating depth of the backpack electrofisher

Aquatic Ecology Monitoring 2003 to 2015

APPENDIX

I

SPECIES OF AQUATIC MACROPHYTES OBSERVED AT SITES ON THE NEPEAN RIVER IN 2015

Cardno® Shaping the Future

Common Name	Scientific Name	Site											
		1	2	5	6	7	8	X3	X4	X5	X6	X7	X8
Hydrilla	*Hydrilla verticulata*	x	x	x	x	x	x	x	x				
Curly pondweed	*Potamogeton crispus*	x	x										x
Floating pondweed	*Potamogeton tricarinatus*	x	x	x		x	x	x	x				
Blunt pondweed	*Potamogeton ochreatus*	x	x		x								
Elodea	*Elodea canadensis*	x	x	x	x	x	x						
Ribbonweed	*Vallisneria* sp.			x	x	x	x						
Alligator weed	*Alternanthera philoxeroides*					x	x			x	x		
Cumbungi	*Typha* sp.					x	x						
Tall spikerush	*Eleocharis sphacelata*					x							
Watercress	*Rorippa nasturtium-aquaticum*									x	x		x