Appin Areas 7 and 9

Aquatic Ecology Monitoring 2003 to 2017

59918064

Prepared for
South32 – Illawarra Coal

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Executive Summary

Introduction

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. Longwalls 701 to 707A were extracted between October 2007 and August 2016. Extraction of Longwall 707B commenced September 2017 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 and was completed 8 September 2017, with extraction of Longwalls 902 to 904 to follow.

Cardno 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 potential 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 2017, included post-extraction monitoring for Longwalls 705, 706 and 707A, during-extraction monitoring for Longwall 707B and further pre-extraction monitoring for Longwalls 708 to 710. This monitoring also provided the first year of after-extraction monitoring for Longwall 901. Monitoring of Longwalls 701 to 704 ceased in 2014 following the collection of at least two years of post-extraction data for each longwall.

Methodology

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; 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, December of 2010, 2011, 2012, 2013 and 2014 and November of 2015 and 2016.

Findings

Monitoring undertaken by South32 and other specialist consultants during extraction of Longwalls 705, 706, 707A, 707B and 901 identified 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 these longwalls. This was not surprising given no more than minor gas releases have been observed in the Nepean River associated with mining. No changes in water quality were observed due to these releases neither were any changes in water levels or diversions of flow. Statistically significant differences in these indicators among Surveys and Reaches on the Nepean River, where present, were attributed to natural spatial and temporal variation, rather than mining. The aquatic habitat in sections of Nepean River visited was generally in good condition, though the AUSRIVAS results did not fully reflect this observation, but, rather, suggested impaired habitat and / or water quality. 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. There is no evidence that any impaired aquatic habitat or water quality is due to any mining related disturbance in the Nepean River.

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. Most recently, high flows that have occurred in the river since the previous survey in 2016 appear to have had a substantial effect on the extent of aquatic macrophytes at some sites in the current survey. Despite this, the species composition of macrophytes has been relatively consistent and the number and type of species identified in November 2017 were very similar to those identified in December of 2013 and 2014 and November of 2015 and 2016. 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. In particular, changes to bank and river bed morphology due to recent flood events appears to have resulted in substantial localised changes in the coverage of macrophytes independent of mining.

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 2018 to align with the timing of sampling undertaken in recent years. This survey would provide further post-extraction data for Longwall 705, 706 and 707A, the second year of during-extraction data for Longwall 707B and further pre-extraction data for Longwalls 708 to 710; and
2. Monitoring of sites relevant to Appin Area 9 should be undertaken next in November 2019 (monitoring for Appin Area 9 is undertaken biennially). This survey would provide during or further pre-extraction data for Longwall 902, depending on whether extraction had commenced by this time. The requirement for monitoring associated with extraction of Longwalls 903 and 904 would be determined following completion of extraction of Longwall 902.

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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;
> Longwall 706: 23 April 2014 to 28 November 2015; and
> Longwall 707A: 7 January 2016 to 16 August 2016

Longwall 707B commenced in September 2016 and is currently underway, 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 and was completed on 8 September 2017, 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 to 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 (Cardno) (formerly Cardno Ecology Lab and 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.

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. This report presents results of monitoring for Longwalls 705 to 710 and 901 to 904 undertaken in November 2017. Monitoring of Longwalls 901 to 904 is undertaken at least every two years with baseline sampling undertaken in November of 2014 and 2015.

The specific aims of the current investigations were to:

> Undertake the further post-extraction monitoring for Longwall 705, the second year of monitoring following the commencement of extraction of Longwalls 706, 707A and 707B and the first monitoring event following the extraction of Longwall 901. Data collected during this survey also provides further pre-extraction data for Longwalls 708 to 710 and 902 to 904;
> 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 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 predictions of subsidence / upsidence; 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 to 710 (The Ecology Lab 2008a). This assessment was included in the SMP for Longwalls 705 to 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 to 704 and 705 to 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), December 2014 and January 2015 (hereafter referred to as December 2014) (Cardno Ecology Lab 2015), November 2015 (Cardno 2016), November 2016 (Cardno 2017).

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). The maximum predicted cumulative subsidence and upsidence, on the Nepean River, resulting from the extraction of Longwalls 701 to 710, is 60 mm and 380 mm respectively (MSEC 2008).. 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 may lead to an increase in flooding and ponding due to tilt, fracturing of stream beds and drainage of some pools due to strains 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 releases 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 or 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.

> 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).

Longwalls 707A and 707B

> No new gas release zones were identified on the Nepean River directly related to Longwalls 707A and 707B.

> Approximately four occasionally active gas zones identified on the Nepean River downstream of Douglas Park weir during extraction of previous longwalls were re-activated during extraction of Longwalls 707A and 707B.

End of Panel reporting for Longwalls 707A and 707B will be completed following completion of extraction of Longwall 707B.

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 2014b). 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 actions to 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 tilt associated with the 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

Baseline Surveys of Aquatic Ecology

During the first baseline survey in Appin Area 9 (December 2014) a total of eight sites were visited. 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.

Mining Impacts

- During March 2017 to January 2018, during and following the extraction of Longwall 901, ICEFT identified 26 gas release zones along adjacent sections of the Nepean River (South32 2017). These releases met the Level 1 Trigger criteria (release < 3,000 L/min) in the Trigger Action Response Plan (TARP) for Appin Area 9 (BHPBIC 2014b). These releases were located in an approximate 2 km section of the Nepean

River located just downstream of Impact Sites X3 and X4. As of January 2017 thirteen of these gas releases were active;

> No visible fracturing was observed in the Nepean River during extraction of Longwall 9 (the flooded valley and sediment profile limits observations of some sections of the river bed) (MSEC 2017), nor was any ponding, flooding or changes in stream alignment or any surface water flow diversions.

> Monthly monitoring by South32 indicated a decline in pool water levels at site NR0 (on the Nepean River just west of Longwall 901 and adjacent to aquatic ecology monitoring sites X3 and X4) relative to baseline levels, however, due to the limited water level data the cause for these changes was uncertain (HGEO 2018);

> Changes in electrical conductivity at some monitoring sites were identified, however, these were upstream of Longwall 901 and therefore not attributed to mining (HGEO 2018).

3 Study Methods

3.1 Field Methods

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, 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.

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 23 and 24 November 2017. 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

Reach	Designation	Relevant Longwalls	Sites	Status
Reach 1	Control	702 to 704 and 705 to 710	7, 8	
Reach 2	Control	701 to 704	5, 6	
	Impact	705 to 710		
Reach 3	Impact	702 to 704	X1, X2	*Monitoring ceased*
Reach 4	Impact	701 to 704	3, 4	*Monitoring ceased*
Reach 5	Control	701 to 704, 705 to 710 and 901 to 904	1, 2	
Reach 6	Impact	901 to 904	X3, X4	
Reach 7	Control	901 to 904	X5, X6	
Reach 8	Control	901 to 904	X7, X8	

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).

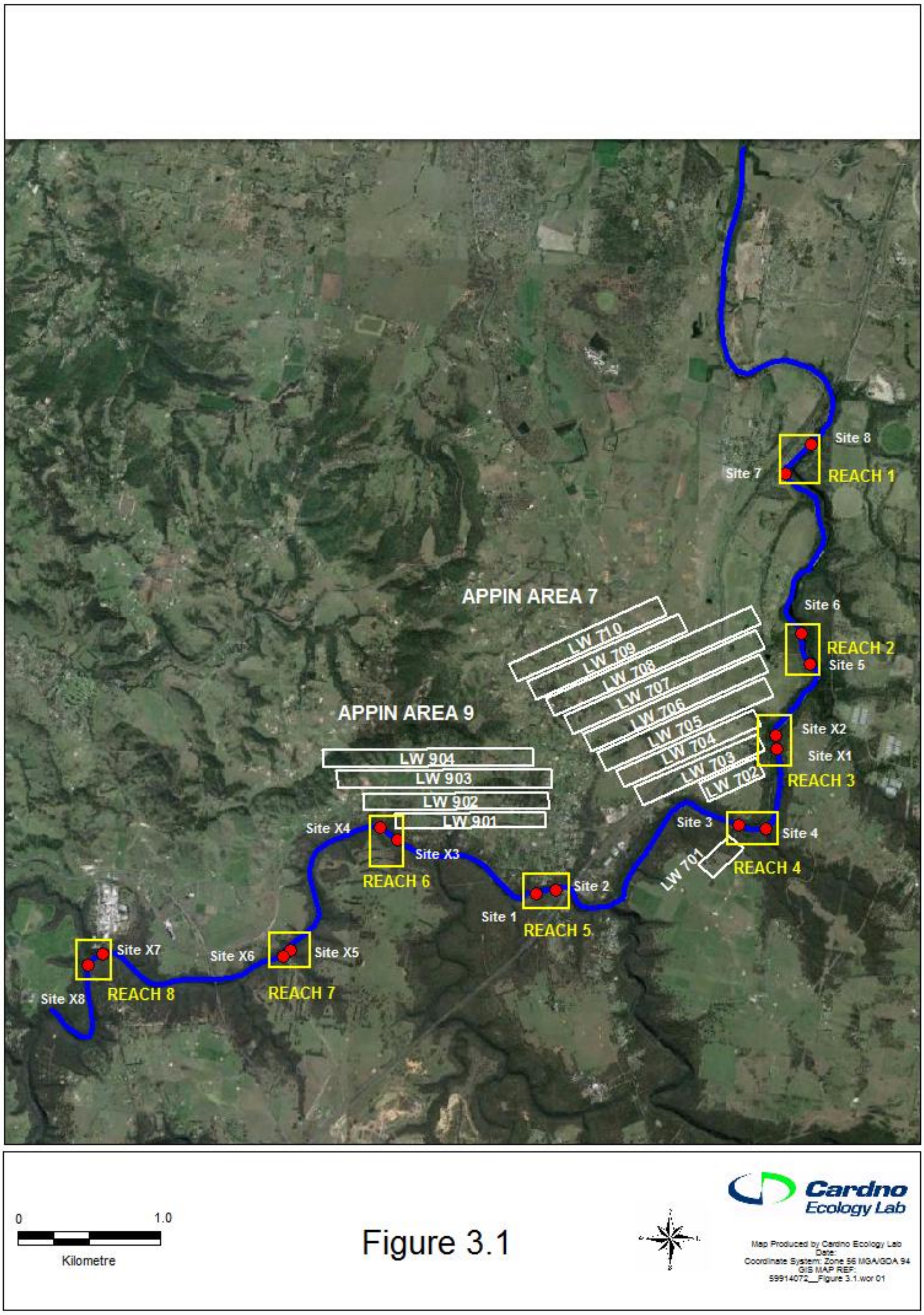

Figure 3-1 Aerial image displaying the aquatic ecology monitoring sites on the Nepean River and their respective Reaches in relation to Appin Area 7 and 9 Longwalls. Sites 3, 4, X1 and X2 were not visited in the current study.

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 and Appin Area 9 Longwalls 901 to 904. 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	Sep 03	Sep 05	Apr 08	Nov 08	Dec 10	Dec 11	Dec 12	Dec 13	Dec 14	Nov 15	Nov 16	Nov 17
Report Reference			**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**	**(11)**	**(12)**
Notes:			**a**	**b**	**c**			**d**	**e**	**f**	**g**			
705	Sep 12	Mar 14	Bef	Bef	Bef	Bef	Bef	Bef	Aft	Aft	Aft	Aft	Aft	Aft
706	Apr 14	Nov 15	Bef	Bef	Bef	Bef	Bef	Bef	Bef	Bef	Aft	Aft	Aft	Aft
707A/B	Jan 16	Underway	Bef	Bef	Bef	Bef	Bef	Bef	Bef	Bef	Bef	Bef	Aft	Aft
708-710	Not yet commenced		Bef	Bef	Bef	Bef	Bef	Bef	Bef	Bef	Bef	Bef	Bef	Bef
901	Jan 16	Sep 17									Bef	Bef		Aft
902-904	Not yet commenced										Bef	Bef		Aft

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), (10) Cardno (2016), (11) Cardno (2017) and (12) 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

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

> Temperature (°C);

> Conductivity (µs/cm);

> pH;

> Dissolved oxygen (% saturation);

> Oxidation reduction potential (ORP) (mV); and,

> Turbidity (ntu).

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

3.1.4 Aquatic Macroinvertebrates

Aquatic macroinvertebrates associated with edge habitats were sampled using the AUSRIVAS rapid assessment methodology (RAM) (Turak *et al.* 2004). Riffle habitat was not sampled because this habitat was not 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 a 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 Appin Area 7 sites (Sites 1 to 2 and 5 to 8) and for approximately 1 hour at Appin Area 9 sites (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. 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 done on macroinvertebrate data only. Fish data collected using bait traps at Appin Area 7 sites were not analysed statistically due to the considerable variation present in data among sites, the large number of zero counts and 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 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 considerable variation and large number of zeros present in these data.

3.3.2.2.1 Approach to Analyses, Interpretation 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, 706, 707A, 707B and 901 and that collected after commencement.

The analytical design for Appin Area 7 longwalls was:

> Survey: A fixed factor with eight levels: November 2008, December of 2010, 2011, 2012, 2013 and 2014 and November of 2015, 2016 and 2017; and

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

The analytical design for Appin Area 9 longwalls was:

> Survey: A fixed factor with three levels: November of 2014, 2015 and 2017; and

> Reach: A fixed factor with four levels: Reaches 5, 6, 7, and 8.

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

Statistically significant main effects (i.e. Survey and Reach) are not indicative of an impact, and, thus, were not considered in detail. The statistically significant interaction of Reach x Survey could potentially provide evidence of a change in the biotic community due to mining. Thus, this interaction was the focus of the analyses; *post-hoc* tests for pairs of Reaches and Surveys would be examined if it was found to be statistically significant source of variation, with consideration given to when each survey occurred relative to the commencement of extraction of Longwalls 705 and 706. Surveys in November 2008, December 2010 and December 2011 were undertaken prior to commencement of extraction of Longwalls 705, 706, 707A, 707B and those in November 2014 and November 2015 prior to commencement of extraction of Longwall 901 and thus provide a measure of background variability, or a ‘baseline’, with which any subsequent changes can be compared. Although data had also been collected in September 2003, these were not included in analyses as this event occurred several years prior to the commencement of extraction of Longwalls 705, 706, 707A and 707B (September 2012 to August 2016) and, thus, data from this survey likely do not represent environmental conditions present just prior to the commencement of extraction of these longwalls. This is supported from a review of previous analyses of macroinvertebrate assemblages and biotic indices which show data from September 2003 were often found to be statistically different from those during 2008 to 2014, whereas there were few differences among the other surveys during this period (Cardno Ecology Lab 2015). No macroinvertebrate data were collected in September 2005 and April 2008 (**Table 3.1**) and these surveys are not represented in the analyses.

Previously, an additional factor, Phase, was included in the analysis. Levels of the factor Survey were nested within one of two levels (Before or After extraction) of the factor Phase. The nesting of individual surveys with Before or After depended on the longwall under consideration, with a separate analysis undertaken for each. The current approach simplifies the analytical design and reduces the number of statistical tests and thus the risk of Type 1 error (false positive rate). It also enables comparisons of all possible pairs of Surveys at each Reach, not possible using such a design. The current approach was also considered more appropriate in the case when an additional data set is added to the analysis each year, thereby avoiding potential problems with an increasingly unbalanced statistical design.

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 $P \leq 0.05$ were 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. As above, only significant statistical interactions are potentially indicative of an impact, hence significant main effects were not considered in detail.

Multivariate patterns in the data can be examined using Principal Coordinates Analysis (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 in this instance, as PERMANOVA did not indicate any statistically significant interactive effect.

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 <u>QA/QC Procedures</u>

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

During November 2017 evidence of high flows, first observed during the previous survey in November 2016, was still present. These flows occurred between November of 2015 and 2016 and resulted in the uprooting of several large trees along the river bank near Site 7 (**Plate 1a** to **d**). High flows such as these are likely to result in substantial changes in the extent of aquatic macrophytes in the river (**Section Table 4-3**).

There was otherwise no observable change in the condition of riparian vegetation in November 2017 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 1e** and **f**) differed from that further upstream (Sites X3 to X8) (**Plates 1g** 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).

4.2 Water Quality

The mean values of the surface water quality indicators measured *in situ* in November 2017 are presented in **Appendix B**. The main findings are summarised as follows:

- Temperature ranged from 14.5 C to 25.4 C;
- Conductivity ranged from 170 µS/cm to 450 µS/cm and was within DTVs on each occasion;
- pH ranged from 6.1 to 7.9 and was above the upper DTV on one occasion, at the bottom of Site 7;
- Dissolved oxygen ranged from 12.3 % saturation to 108.9 % saturation and was below the lower DTV at Site 1, 5 to 8, though slightly only. At the bottom of Sites 5 to 8 the water was anoxic and well below the lower DTV;
- Oxidation Reduction Potential (ORP) ranged from -112 to 175 mV; and
- Turbidity ranged from 0.0 NTU to 11.4 NTU and was below the lower DTV on each occasion except at the bottom of Sites 5 and 6.

4.3 Aquatic Macroinvertebrates

4.3.1 General Findings

Fifty-one macroinvertebrate taxa were identified from the twelve AUSRIVAS edge samples collected in November 2017 (**Appendix C**). In total, from September 2003 to November 2017, 97 taxa were identified from the 100 AUSRIVAS edge samples collected from Appin Area 7 and 9 monitoring sites on the Nepean River. During this time, the most common taxa (those occurring in around 90 % 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 87 taxa that were assigned a SIGNAL2 grade, 68 were very to moderately pollution tolerant (SIGNAL2 grade 1 to 5). Fifteen 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, Synlestiddae and Gripopterygiidae occurred once only.

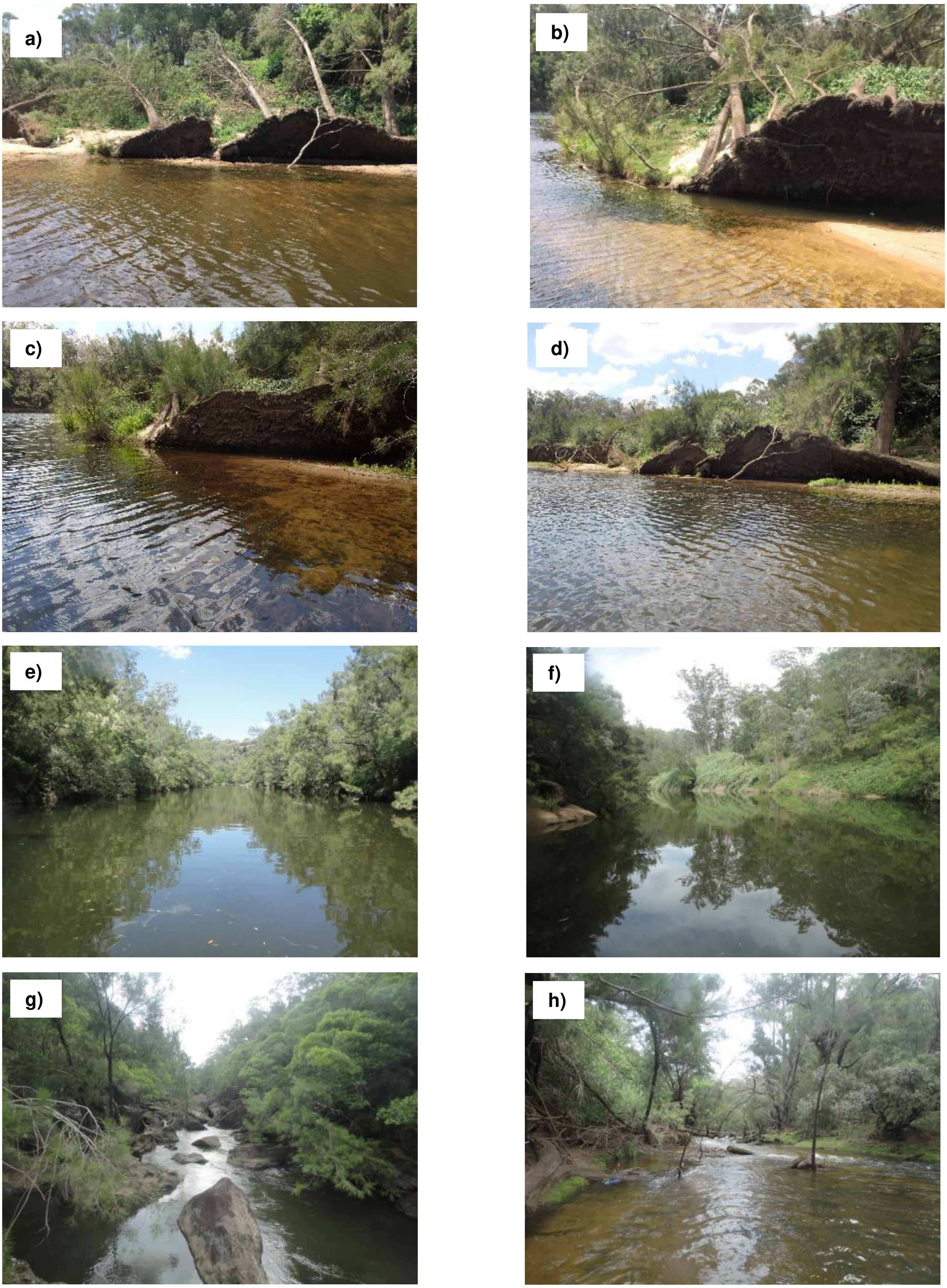

Plate 1 Uprooted trees observed in a) and b) November 2016 and in c) and d) November 2017 suggestive of elevated flow during floods, e) and f) wide channel and relatively deep and slow flowing water typical of Sites 1 to 8, g) and h) narrower and more shallow channel typical of Sites X3 to X8.

AUSRIVAS indices and the number of taxa identified from AUSRIVAS samples from each site sampled from September 2003 to November 2017 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 water pollution) to 4.6 (indicative of moderate water pollution). Although on average fewer taxa were samples at Reach 2 than at the other reaches in 2017, this was also the case during November 2008 to December 2012. Thus, this appears due likely to natural variation rather than any mining effect.

4.3.2 Changes in Macroinvertebrate Fauna

None of the PERMANOVA analyses undertaken using data from Reaches 1, 2 and 5 during November 2008 to November 2017 were indicative of an impact (**Table 4-1**). Statistically significant sources of variation were the main effects of Survey (indicative of temporal variability independent of Reach) for each indicator variable except OE50 Taxa Score and the main effect of Reach (indicative of spatial variability independent of time) for the multivariate structure of assemblages in data collected from Appin Area 7. In Appin Area 9, the only statistically significant sources of variation were the main effects of Survey and Reach for multivariate assemblage structure and of Survey for OE50 Taxa Score. Statistically significant main effects are not indicative of an impact (**Section 3.3.2.2.1**).

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 2017 and to Longwall 901 during December 2014 to November 2017. The full results of the analyses are presented in Appendix E.

Indicator	Survey	Reach	Survey x Reach
Appin Area 7			
Assemblage	***	***	ns
Number of Taxa	**	ns	ns
OE50 Taxa Score	ns	ns	ns
SIGNAL2 Index	**	ns	ns
Appin Area 9			
Assemblage	***	**	ns
Number of Taxa	ns	ns	ns
OE50 Taxa Score	**	ns	ns
SIGNAL2 Index	ns	ns	ns

* = P ≤ 0.05, ** = P ≤ 0.01, *** = P ≤ 0.001, ns = P > 0.05.

4.4 Fish

Four species of fish were caught by bait trapping at Appin Area 7 sites in 2017: flathead gudgeon (*Philypnodon grandiceps*), dwarf flathead gudgeon (Philypnodon macrostomus), eastern gambusia (*Gambusia holbrooki*) and firetail gudgeon (*Hypseleotris galii*) (**Appendix F**). Firetail gudgeon were caught at Sites 2, 6, 7 and 8 and flathead gudgeon at Sites 6 and 8. Eastern gambusia were caught at Site 5 and 6 and 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 4.2**). Freshwater catfish (*Tandanus tandanus*) and ornamental carp (C*yprinus carpio*) were also observed at Sites, 1, 7 and 8.

Juvenile freshwater catfish and empire gudgeon (*Hypseleotris compressa*) were not caught in bait traps or dip nets in November of 2016 and 2017, 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). Dwarf flathead gudgeon, flathead gudgeon, firetail gudgeon, eastern gambusia and Australian smelt (*Retropinna semoni*) were caught in seine nets at these sites in November 2017. Also, flathead gudgeon and eastern gambusia were caught in AUSRIVAS dip net samples.

Seven species of fish were caught whilst electrofishing at Appin Area 9 sites (**Appendix F**). These included juvenile and adult Coxs gudgeon (*Gobiomorphus coxii*), Australian smelt (*Retropinna semoni*), dwarf flathead gudgeon and carp gudgeon (*Hypseleotris* sp.) at impact Sites X3 and X4. The composition of fish species sampled in 2017 was comparable to that sampled in 2014, only Australian bass (*Macquaria novemaculeata*), which was sampled at Site X8 in 2015, was not sampled in 2017. Fewer Coxs gudgeon were sampled in 2017 than in 2014, but this was apparent across all sites. No fish have been caught in any of the bait traps deployed at Appin Area 9 Sites X3 to X8 during any survey.

No observations were made that would suggest other major changes to fish assemblages at the Appin Area 7 and 9 impact sites (e.g. fish kills).

Table 4-2 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 November 2017

Scientific Name	Common Name	Sep 03	Apr 08	Nov 08	Dec 10	Dec 11	Dec 12	Dec 13	Dec 14	Nov 15	Nov 16	Nov 17
Philypnodon grandiceps	Flathead gudgeon	x	x	x	x	x	x	x	x	x	x	x
Hypseleotris galii	Firetail gudgeon	x	x	x	x	x	x	x	x	x	x	x
Philypnodon macrostomus	Dwarf flathead gudgeon	x		x	x	x	x	x				x
Gambusia holbrooki	Eastern gambusia		x		x			x	x			x
Retropinna semoni	Australian smelt		x		x	x	x	x				x
Tandanus tandanus	Freshwater catfish					x	x					
Hypseleotris compressa	Empire gudgeon			x								

Table 4-3 Fish species caught by backpack electrofishing in the Nepean River during the aquatic ecology monitoring undertaken for the Appin Area 9 Longwalls in December 2014 and November of 2015 and 2017.

Scientific Name	Common Name	Dec 14	Nov 15	Nov 17
Philypnodon grandiceps	Flathead gudgeon	x	x	x
Macquaria novemaculeata	Australian bass	x		
Anguilla reinhardtii	Longfinned eel	x	x	x
Retropinna semoni	Australian smelt	x	x	x
Gobiomorphus coxii	Coxs gudgeon	x	x	x
Gambusia holbrooki	Eastern gambusia	x		x
Philypnodon macrostomus	Dwarf flathead gudgeon			x
Hypseleotris sp.	Carp gudgeon	x		x

4.5 Aquatic Macrophytes

In 2017, nine species of aquatic macrophytes were recorded across the six sites sampled for Area 7 (Sites 1, 2 and 5 to 8) (**Appendix G**). All species, except clasped pondweed (*Potamogeton perfoliatus*), identified prior to 2016, 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 species composition at each Appin Area 7 monitoring site was identical to that observed in the most recent previous survey in 2016. The only exception was the presence of tall spikerush (*Eleocharis sphacelata*) at Site 8 where it was not observed previously.

The apparent reduction in the extent of ribbonweed, in particular, at Sites 7 and 8 observed in 2016 (Cardno 2017) and compared with earlier surveys was not observed during the current survey. This was likely a result of re-growth following the high flow that occurred in the river prior to the November 2015 survey, which would also explain the nearby presence of uprooted trees (**Section 4.1**). High flows such as these would be expected to scour river banks and bed, moving sediment and dislodging aquatic macrophytes that would be washed downstream. Ribbonweed appeared to be colonising newly exposed areas of the river bed in 2016 (**Plate 2a** and **b**) and 2017 (**Plate 2c** and **d**) and there appeared to be a greater extent of tall spikerush at Sites 7 and 8 in 2017 than that observed previously.

The invasive alligator weed (*Alternanthera philoxerides*) was observed along the banks at Sites 7 and 8. 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 signs of desiccation or die-back were observed during the inspection, which otherwise may have indicated a drop in water level.

Plate 2. Beds of ribbonweed (*Vallisneria* sp.) at a) Site 8 and b) Site 7 in 2016 and c) and d) ribbonweed and tall spikerush (*Eleocharis sphacelata*) at Sites 7 and 8 in 2017.

5 Discussion

5.1 Appin Area 7

5.1.1 Physical and Water Quality Mining Impacts

No physical or water quality impacts due to extraction of Longwalls 705, 706, 707A and 707B 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 the Appin Area 7 goaf and Tower Mine Longwall 16, extracted between 1998 and 1999 (**Section 2.1.2.2**). Some previously identified gas release zones were also reactivated during extraction of Longwalls 707A and 707 B. 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.

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 reflect this observation, but, rather, impaired habitat and / or water quality (**Section 5.1.3**). The relatively undisturbed riparian strip present would enhance aquatic habitat and biota in this section of the river by stabilising river banks and helping 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.

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 Cardno have been 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. Turbidity was also often below the lower DTV, but this is unlikely to be cause for concern. The low levels of dissolved oxygen measured in November 2017 and 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 (**Section 5.1.3.1**). 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 2017 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. There is no evidence that any impaired aquatic habitat or water quality is due to any mining related disturbance in the Nepean River. 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 the deeper hypoxic sections of the river is depauperate also.

5.1.3.2 Changes to Macroinvertebrates

The lack of any statistical interaction between Survey and Reach for the macroinvertebrate indicators derived from AUSRIVAS provided no evidence of any changes to macroinvertebrates that could be associated with the extraction of Longwalls 705, 706, 707A and 707B.

Statistical differences in indicators detected among Surveys and Reaches are 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 and November 2016 (two species compared with three to five in previous surveys) four species were caught during the current survey and there is no indication of any change due to mining. The two species that were caught in November of 2015 and 2016 were found at one or both of the Impact sites. Also, the few species sampled prior to 2015 that were not caught in bait traps in 2015 and 2016 were either uncommon in previous surveys, found only in one previous survey, and / or caught using other techniques (seine netting and AUSRIVAS dip netting) or observed visually. There is no indication that the extraction of Longwalls 705, 706 707A and 707B 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 2017, 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. However, during these last four 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 2017. However, it was also not observed at Sites 7 and 8 during 2013 to 2017, where it had previously been identified.

It appears that the extent and species composition of aquatic macrophytes at these sites is highly dependent on flow variability, with high flows scouring away river sediments, and thus associated plants, and providing new areas for colonisation following high flows. This appears to be the explanation for the apparent reduction in the extent of ribbonweed observed at Sites 7 and 8 in November 2016 compared with previous surveys. Since this time, the extent of ribbonweed and tall spikerush has increased as these plants have colonised nearby areas of unvegetated sediment exposed areas following high flows.

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, 706, 707A and 707B has affected aquatic macrophytes in the Nepean River.

5.2 Appin Area 9

5.2.1 Physical and Water Quality Mining Impacts

No physical or water quality impacts due to extraction of Longwall 901 have been identified (**Section 2.2.2**). While several areas of gas releases in the Nepean River adjacent to Longwall 901 were identified during extraction, these do not appear to be associated with any visible fracturing or changes in water quality.

5.2.2 Aquatic Habitat and Water Quality

The aquatic habitat at Appin Area 9 impact sites is in good condition. No changes to riparian habitat have been observed that could be associated with extraction of Longwall 901. The AUSRIVAS Bands for the impact sites sampled as part of the Appin Area 9 monitoring program (Sites X3 to X8) are indicative of aquatic habitat and/or water quality significantly impaired relative to undisturbed habitat (Bands B) to equivalent to undisturbed habitat (Band 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 (Cardno 2016)) and alteration to the natural flow regime due to flow controlling structures such as Maldon Weir, could be affecting macroinvertebrates.

5.2.3 Macroinvertebrates

5.2.3.1 General Findings

The macroinvertebrate assemblage supported by the Nepean River in the vicinity of Appin Area 9 appears largely comparable to that present further downstream and adjacent to Appin Area 7 (**Section 5.1.3.1**).

5.2.3.2 Changes to Macroinvertebrates

The lack of any statistical interaction between Survey and Reach for the macroinvertebrate indicators derived from AUSRIVAS provided no evidence of any changes to macroinvertebrates that could be associated with the extraction of Longwall 901.

5.2.4 Fish

The absence of any apparent change in fish assemblages sampled in Appin Area 9 in 2017 is not surprising given no changes to aquatic habitat or water quality have been observed. The species composition sampled at Sites X3 and X4 in 2017 was comparable to that sampled at these sites in previous years. While fewer Coxs gudgeon were sampled in general in 2017 than in 2014, numbers caught in 2017 were comparable to those in 2015 prior to the commencement of extraction.

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) was likely associated with 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.

5.2.5 Aquatic Macrophytes

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. The two species of macrophyte observed at Sites X3 and X4 (hydrilla and curly pondweed) in 2014 and 2015 were present also in 2017 and there was no indication of changes in the species composition or extent (albeit variable among years based on visual observations), due to, for example, reduced water levels and desiccation, occurred at these sites that could be indicative of any mining impact.

5.2.6 Predicted and Observed Impacts

Table 5.1 summaries predicted and observed impacts to aquatic ecology associated with extraction of Longwall 901. No fracturing or flow diversions have been observed in the Nepean River. Although gas releases have been identified and associated with extraction of Longwall 901, there is no evidence these have affected aquatic macroinvertebrates, fish and aquatic macroinvertebrates.

Table 5-1 Predicted and observed impacts to aquatic ecology associated with Longwall 901

Attribute	Predicted Physical Impacts	Predicted Impacts on Aquatic Ecology	Observed Impacts to Aquatic Ecology
Nepean River			
Ponding, flooding and scouring of stream banks	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.	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	None identified during observations of aquatic macroinvertebrates, fish and aquatic macrophytes at aquatic ecology monitoring sites in 2017.
Fracturing of bedrock and diversion of surface flows	Minor and isolated fracturing of the river bed could occur, however, it is not expected to result in any loss of surface water flows	It is considered unlikely that there would be any net loss of water from the catchment. No significant changes in the quantity or quality of permanent aquatic habitat.	None identified during observations of aquatic macroinvertebrates, fish and aquatic macrophytes at aquatic ecology monitoring sites in 2017.
Gas releases	Minor gas releases, associated iron precipitate and reductions in concentrations of dissolved oxygen may occur due to extraction.	Negligible environmental consequences	None identified during observations of aquatic macroinvertebrates, fish and aquatic macrophytes at aquatic ecology monitoring sites in 2017.
Drainage Lines			
Fracturing of bedrock and diversion of surface flows	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.	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.	No fracturing observed in drainage lines

6 Conclusion

No changes to aquatic ecology indicators that could be associated with extraction of Longwalls 705, 706, 707A, 707B and 901 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 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 measurable effect on macroinvertebrates, fish and macrophytes in the Nepean River. 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, but rather reduced water quality associated with poor quality water from catchment run-off and the existing flow impeding structures (i.e. weirs) on the Neapean River.

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 relating to high flow periods, and unrelated to mining.

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 2018 to align with the timing of sampling undertaken in recent years. This survey would provide further post-extraction data for Longwall 705, 706 and 707A, the second year of during-extraction data for Longwall 707B and further pre-extraction data for Longwalls 708 to 710; and
2. Monitoring of sites relevant to Appin Area 9 should be undertaken next in November 2019 (monitoring for Appin Area 9 is undertaken biennially). This survey would provide during or further pre-extraction data for Longwall 902, depending on whether extraction had commenced by this time. The requirement for monitoring associated with extraction of Longwalls 903 and 904 would be determined following completion of extraction of Longwall 902.

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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

APPENDIX B

VALUES OF WATER QUALITY INDICATORS FOR WATER QUALITY MONITORING SITES ON THE NEPEAN RIVER VISITED IN NOVEMBER 2017

Cardno
Shaping the Future

Site/ Measure	DTV	Surface Water		Bottom Water	
		Mean	SE	Mean	SE
Site 1					
Temperature (°C)		22.5	0.0	21.9	0.0
Conductivity	125-2200	296	0	296	0
pH (units)	6.5-8.0	7.7	0.0	7.6	0.0
ORP (mV)		75	1	79	1
DO (% Sat)	85-110	85.5	0.0	83.2	0.0
Turbidity (NTU)	6-25	2.0	0.0	0.0	0.0
Site 2					
Temperature (°C)		24.1	0.0	24.5	0.0
Conductivity	125-2200	253	0	263	0
pH (units)	6.5-8.0	7.6	0.0	7.9	0.0
ORP (mV)		149	1	140	1
DO (% Sat)	85-110	85.3	0.0	89.2	0.0
Turbidity (NTU)	6-25	0.8	0.0	1.5	0.0
Site 5					
Temperature (°C)		23.2	0.0	14.5	0.0
Conductivity	125-2200	170	0	327	0
pH (units)	6.5-8.0	7.5	0.0	6.9	0.0
ORP (mV)		140	1	-112	1
DO (% Sat)	85-110	90.7	0.0	19.2	0.0
Turbidity (NTU)	6-25	0.6	0.0	11.4	0.0
Site 6					
Temperature (°C)		23.1	0.0	17.1	0.0
Conductivity	125-2200	173	0	178	0
pH (units)	6.5-8.0	7.6	0.0	6.9	0.0
ORP (mV)		145	1	52	1
DO (% Sat)	85-110	92.3	0.0	12.3	0.0
Turbidity (NTU)	6-25	2.0	0.0	10.1	0.0
Site 7					
Temperature (°C)		23.5	0.0	14.5	0.0
Conductivity	125-2200	163	0	130	0
pH(units)	6.5-8.0	7.5	0.0	6.8	0.0
ORP (mV)		163	1	175	1
DO (% Sat)	85-110	91.6	0.0	17.6	0.0
Turbidity (NTU)	6-25	1.7	0.0	1.0	0.0
Site 8					
Temperature (°C)		21.9	0.0	21.4	0.0
Conductivity	125-2200	175	0	170	0
pH(units)	6.5-8.0	6.5	0.0	6.1	0.0
ORP (mV)		56	1	44	1
DO (% Sat)	85-110	92.3	0.0	25.2	0.0
Turbidity (NTU)	6-25	0.0	0.0	0.0	0.0

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

Site/ Measure	DTV	Surface Water		Bottom Water	
		Mean	SE	Mean	SE
Site X3					
Temperature (°C)		23.4	0.0		
Conductivity	125-2200	247	0		
pH (units)	6.5-8.0	7.9	0.0		
ORP (mV)		146	0.5		
DO (% Sat)	85-110	94.2	0.0		
Turbidity (NTU)	6-25	2.5	0.0		
Site X4					
Temperature (°C)		22.4	0.0		
Conductivity	125-2200	242	0		
pH (units)	6.5-8.0	7.8	0.0		
ORP (mV)		152	2		
DO (% Sat)	85-110	95.9	0.1		
Turbidity (NTU)	6-25	0.5	0.0		
Site X5					
Temperature (°C)		24.4	0.0		
Conductivity	125-2200	237	0		
pH (units)	6.5-8.0	7.7	0.0		
ORP (mV)		159	0.5		
DO (% Sat)	85-110	99.2	0.0		
Turbidity (NTU)	6-25	2.5	0.0		
Site X6					
Temperature (°C)		24.4	0.0		
Conductivity	125-2200	222	0		
pH (units)	6.5-8.0	7.8	0.0		
ORP (mV)		144	2		
DO (% Sat)	85-110	98.9	0.1		
Turbidity (NTU)	6-25	0.3	0.0		
Site X7			0.0		
Temperature (°C)		22.7	0		
Conductivity	125-2200	454	0.0		
pH(units)	6.5-8.0	7.7	0.5		
ORP (mV)		33.2	0.0		
DO (% Sat)	85-110	108.9	0.0		
Turbidity (NTU)	6-25	0.0			
Site X8			0.0		
Temperature (°C)		22.6	0		
Conductivity	125-2200	450	0.0		
pH(units)	6.5-8.0	7.7	2		
ORP (mV)		149	0.1		
DO (% Sat)	85-110	90.8	0.0		
Turbidity (NTU)	6-25	0.3	0.0		

APPENDIX

C

MACROINVERTEBRATE TAXA FOUND IN AUSRIVAS SAMPLES COLLECTED FROM EDGE HABITAT AT MONITORING SITES ON THE NEPEAN RIVER IN NOVEMBER 2017

Taxon	Site:	1	2	5	6	7	8	X3	X4	X5	X6	X7	X8
Aeshnidae			1	3	1	1	2			2		4	
Atriplectididae				1									
Atyidae			1	2	5	3	4			1	2	1	1
Baetidae		1	1					10	6		1	1	
Caenidae		1				4					1		
Calamoceratidae		1					1					9	
Ceinidae					1			1					
Ceratopogonidae									1		1		1
Chironominae		2	1	6	4	1	4	3	1	1			10
Cladocera		7	3		1	2					2	4	7
Coenagrionidae		2											
Copepoda		10	6	4	10	10		1		2		10	10
Corbiculidae/Sphaeriidae		2			1			1					1
Corixidae		4	2	3	3	15	10	8	10	10	10	10	20
Corydalidae				1				6					
Culicidae			1			2			1				5
Diptera		1											
Dixidae										1	2	1	
Dugesiidae		1				1						2	
Dytiscidae			1	1		1		1				1	1
Ecnomidae			1										
Elmidae		6	1	1		4	1	2		3	1		7
Entomobryidae		2								2			
Gelastocoridae									1				
Gerridae						1		3	1				
Gomphidae		1				1		1					
Gyrinidae						1							
Haliplidae								2				2	10
Hemicorduliidae		1				2	2						1
Hydracarina		10	10	2	10	6	3	4	6	10	4		6
Hydrobiosidae													2
Hydrochidae		5		1		7				10	10	1	4
Hydrophilidae		2	1	1	1	5		2			2		8
Hydroptilidae						2			2				
Isostictidae						2				1			
Leptoceridae		10	10	10	10	10	10	8	3	10	10	10	8
Leptophlebiidae				1	1			1					1
Libellulidae						6		1			1		3
Lymnaeidae				1						1		1	
Megapodagrionidae		1					1						
Nepidae		1								1			
Notonectidae								1		1			1
Oligochaeta			1				1	1	2				3
Oniscigastridae		1											
Physidae		1							1			3	1
Pleidae		1					1						
Protoneuridae		2	2	1			7	1		4		4	
Scirtidae				3	1		3					2	
Stratiomyidae		1			1								
Tanypodinae		1		2	1	1	2	6		2	3	4	10
Tipulidae						1							
Veliidae				1		2			2	2			

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

APPENDIX D

NUMBERS OF MACROINVERTEBRATE TAXA, OE50 TAXA SCORES AND SIGNAL2 INDICES FOR AUSRIVAS EDGE SAMPLES COLLECTED AT SITESON THE NEPEAN RIVER 2003 TO 2017

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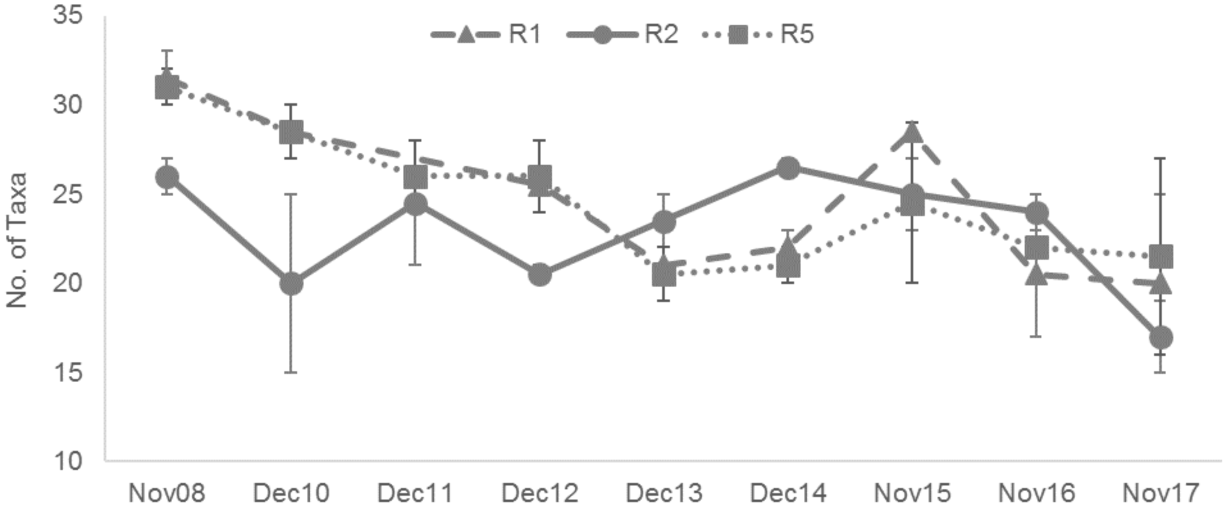
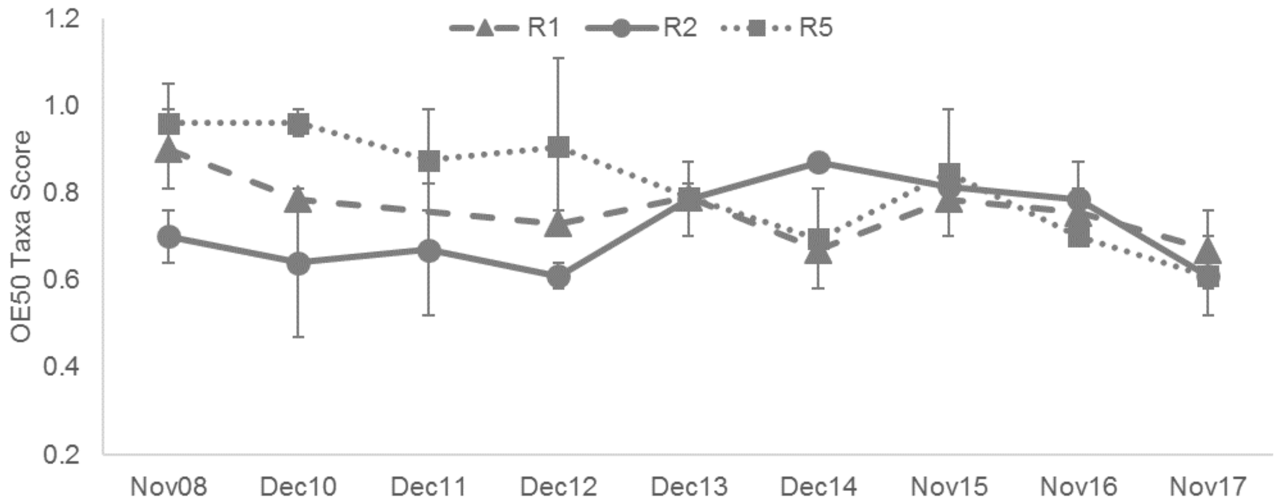
Reach	Reach 5		Reach 4		Reach 2		Reach 1		Reach 3		Reach 6		Reach 7		Reach 8	
Site:	1	2	3	4	5	6	7	8	X1	X2	X3	X4	X5	X6	X7	X8
Number of Taxa																
Sep 03	13	14	15	16	13	14										
Nov 08	32	30	32	32	25	27	33	30	31	27						
Dec 10	30	27	25	31	25	15	27	30	23	27						
Dec 11	28	24	19	30	28	21			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
Nov 16	22	22			25	23	17	24								
Nov 17	27	16			19	15	25	15			21	13	18	14	19	23
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
Nov 16	0.70	0.70			0.87	0.70	0.70	0.81								
Nov 17	0.64	0.58			0.7	0.52	0.76	0.58			0.76	0.53	0.58	0.52	0.64	0.82
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
Nov 16	4.1	4.6			4.5	4.1	4.0	4.2								
Nov 17	4.2	3.8			4.5	4.3	3.9	4.6			4.1	3.7	3.8	4.7	3.9	3.8

A) Appin Area 7

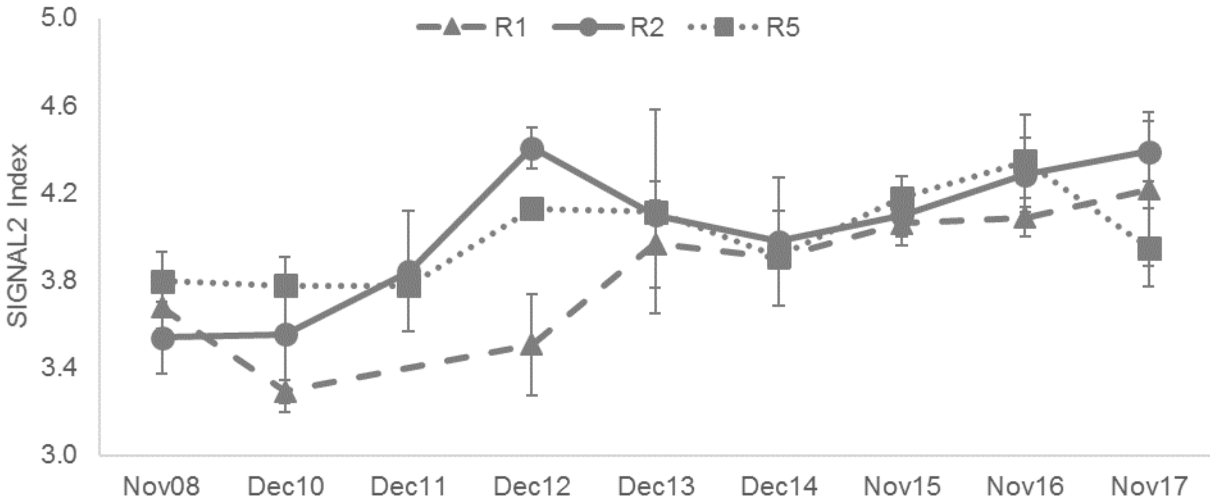
i) Number of Taxa



ii) OE50 Taxa Score



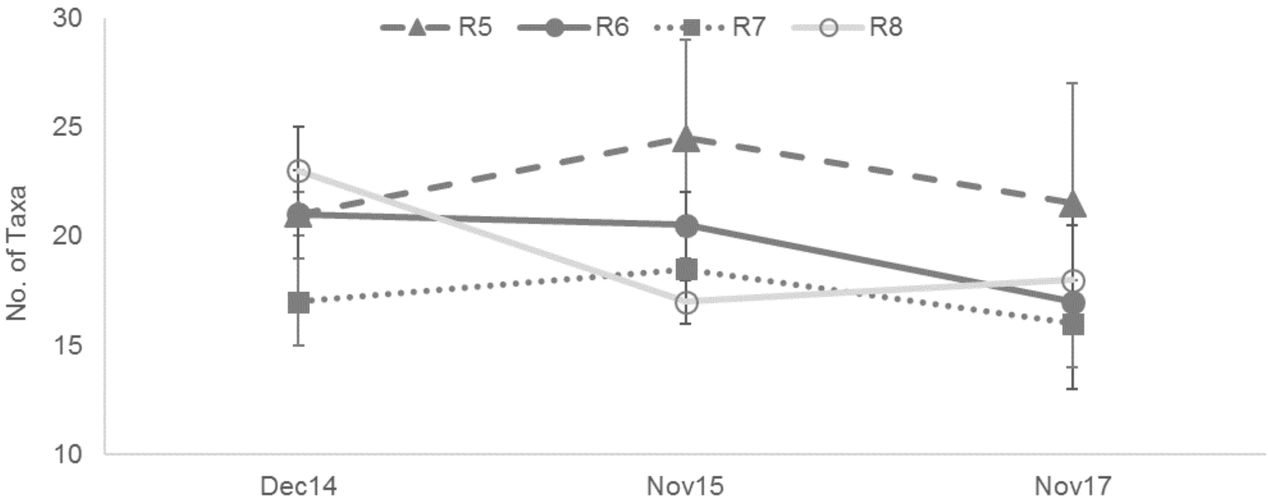
iii) SIGNAL2 Index



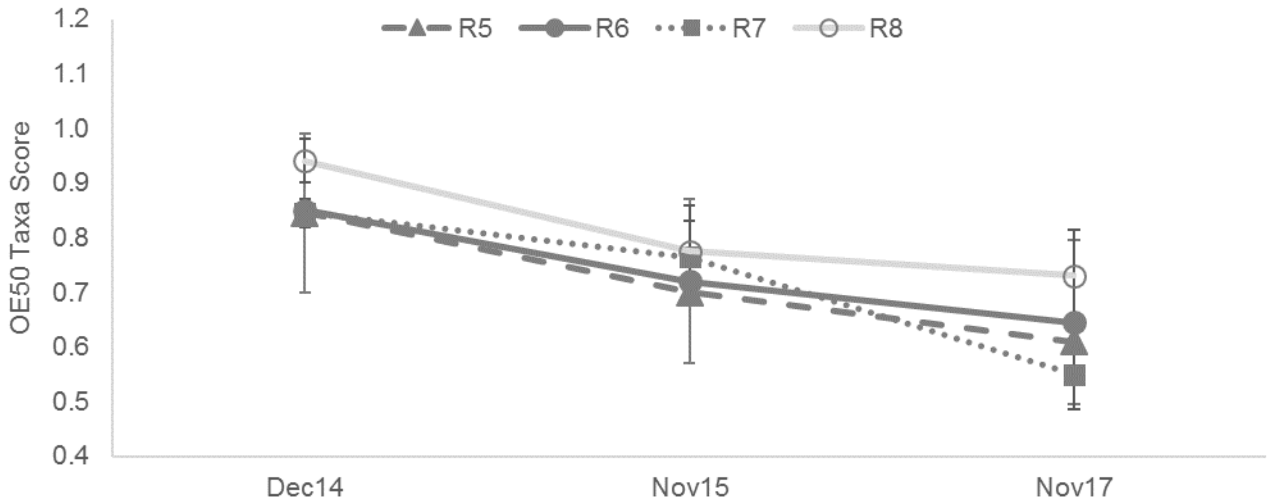
R2: Impact Reach, R1 and R5: Control Reaches. Bars are standard errors.

B) Appin Area 9

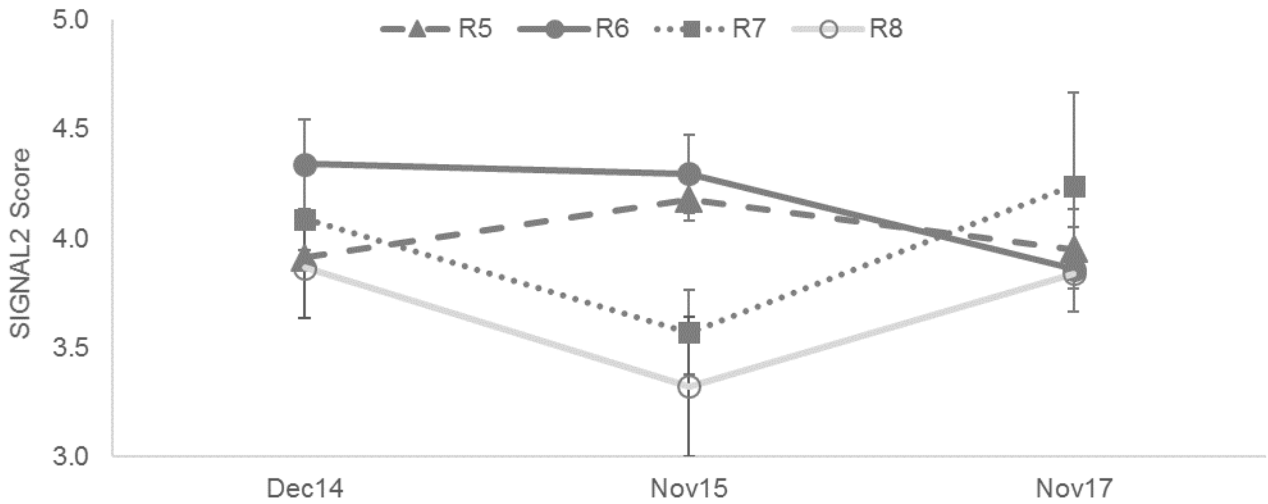
i) Number of Taxa



ii) OE50 Taxa Score



iii) SIGNAL2 Index



R6: Impact Reach, R5, R7 and R8: Control Reaches. Bars are standard errors.

Aquatic Ecology Monitoring 2003 to 2017

APPENDIX

E

PERMANOVAS COMPARING MACROINVERTEBRATE ASSEMBLAGES, NUMBER OF TAXA, OE50 TAXA SCORESAND SIGNAL2 INDICES FOR A) APPIN AREA 7 AND B) 9

A) Appin Area 7

Assemblage

Source of Variation	df	SS	MS	*F*	*P*
Survey	**8**	**18264**	**2283**	**3.466**	**0.000**
Reach	**2**	**3248**	**1624**	**2.465**	**0.001**
Survey x Reach	15	9210	614	0.932	0.676
Residual	26	17125	659		
Total	51	47746			

Number of Taxa

Source of Variation	df	SS	MS	*F*	*P*
Survey	**8**	**410.340**	**51.292**	**4.187**	**0.004**
Reach	2	34.538	17.269	1.410	0.255
Survey x Reach	15	235.050	15.670	1.279	0.286
Residual	26	318.500	12.250		
Total	51	994.830			

OE50 Taxa Score

Source of Variation	df	SS	MS	*F*	*P*
Survey	8	0.186	0.023	1.497	0.204
Reach	2	0.082	0.041	2.631	0.094
Survey x Reach	15	0.289	0.019	1.238	0.311
Residual	26	0.404	0.016		
Total	51	0.960			

SIGNAL2 Score

Source of Variation	df	SS	MS	*F*	*P*
Survey	**8**	**2.728**	**0.341**	**4.326**	**0.003**
Reach	2	0.414	0.207	2.623	0.096
Survey x Reach	15	1.061	0.071	0.898	0.573
Residual	26	2.050	0.079		
Total	51	6.167			

B) Appin Area 9

Assemblage

Source of Variation	df	SS	MS	*F*	*P*
Survey	**2**	**5190**	**2595**	**3.180**	**0.001**
Reach	**3**	**5462**	**1821**	**2.231**	**0.003**
Survey x Reach	6	5384	897	1.100	0.348
Residual	12	9793	816		
Total	23	25829			

Number of Taxa

Source of Variation	df	SS	MS	*F*	*P*
Survey	2	13.58	6.79	0.402	0.677
Reach	3	81.46	27.15	1.609	0.237
Survey x Reach	6	62.42	10.40	0.616	0.710
Residual	12	202.50	16.88		
Total	23	359.96			

OE50 Taxa Score

Source of Variation	df	SS	MS	*F*	*P*
Survey	**2**	**0.224**	**0.112**	**8.325**	**0.005**
Reach	3	0.037	0.012	0.929	0.453
Survey x Reach	6	0.017	0.003	0.214	0.961
Residual	12	0.161	0.013		
Total	23	0.440			

SIGNAL2 Score

Source of Variation	df	SS	MS	*F*	*P*
Survey	2	0.180	0.090	1.012	0.393
Reach	3	0.754	0.251	2.835	0.075
Survey x Reach	6	1.057	0.176	1.986	0.140
Residual	12	1.065	0.089		
Total	23	3.056			

Aquatic Ecology Monitoring 2003 to 2017

APPENDIX

F

TOTAL NUMBERS OF FISH CAUGHT USING A) BAIT TRAPS AND B) BACKPACK ELECTROFISHING IN NOVEMBER 2017

A) Bait Traps

Site	Flathead gudgeon (*Philypnodon grandiceps*)	Dwarf flathead gudgeon (*Philypnodon macrostomus*)	Eastern gambusia (*Gambusia holbrooki*)	Firetail gudgeon (*Hypseleotris galii*)
Site 1*				
Site 2		1		1
Site 5			10	
Site 6	1		10	12
Site 7				3
Site 8	1			10
Site X3				*No fish*
Site X4				*No fish*
Site X5				*No fish*
Site X6				*No fish*
Site X7*				*No fish*
Site X8*				*No fish*

*Freshwater catfish (*Tandanus tandanus*) were observed in nests and ornamental carp (C*yprinus carpio*) were observed amongst submerged macrophytes

B) Backpack Electrofishing

Site	Flathead Gudgeon (*Philypnodon grandiceps*)	Longfinned eel (*Anguilla reinhardtii*)	Australian smelt (*Retropinna semoni*)	Coxs gudgeon (*Gobiomorphus coxii*)	Eastern gambusia (*Gambusia holbrooki*	Dwarf flathead gudgeon (*Philypnodon macrostomus*	Carp gudgeon (*Hypseleotris* sp.)
Site 1	2	1					
Site 2							3
Site X3			4	4			3
Site X4				12		1	
Site X5		1			4		
Site X6				1	10		
Site X7*	1						2
Site X8*		1					11

Four approximate 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

APPENDIX G

SPECIES OF AQUATIC MACROPHYTES OBSERVED AT SITES ON THE NEPEAN RIVER IN 2017

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Common Name	Scientific Name	Site 1	Site 2	Site 5	Site 6	Site 7	Site 8	Site X3	Site X4	Site X5	Site X6	Site X7	Site 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	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	x						
Watercress	*Rorippa nasturtium-aquaticum*									x	x		x