APPENDIX E

Neubecks Creek Ecological Monitoring Program Report Spring 2012-Spring 2018

Neubecks Creek Ecological Monitoring Program

Neubecks Creek EMP Spring 2012 to Spring 2018

59919010

Prepared for

EnergyAustralia NSW

24 September 2019

Cardno
Shaping the Future

Contact Information

Cardno (NSW/ACT) Pty Ltd
ABN 95 001 145 035

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

Telephone: 02 9496 7700
Facsimile: 02 9499 3902
International: +61 2 9496 7700

Document Information

Prepared for	EnergyAustralia NSW
Project Name	Neubecks Creek EMP Spring 2012 to Spring 2018
File Reference	59919010_R002_Rev0_NeubecksCreekEMPSpr2012-Spr2018.docx
Job Reference	59919010
Date	24 September 2019
Version Number	0
Effective Date	24 September 2019
Date Approved:	24 September 2019

Document History

Version	Effective Date	Description of Revision	Prepared by:	Reviewed by:
A	14/05/19	Draft for Review	Dan Pygas	Kate Reeds Alicia de Vos (EnergyAustralia)
0	24/09/19	Final	Dan Pygas	

Executive Summary

Introduction and Background

EnergyAustralia NSW (EnergyAustralia) operates Mount Piper Power Station (MPPS), near Lithgow NSW. On 16 February 2012 EnergyAustralia was granted approval for the construction and placement of ash at the Lamberts North Ash Placement Project (the Project). The Project provides a storage area for ash produced from the burning of coal after the previous storage area (Ash Area 1) reached capacity.

The 2010 Environmental Assessment for the Project identified several aspects of construction and ash placement that may affect the aquatic ecology of nearby Neubecks Creek, located just north of the Project site. The primary effect identified was that on water quality, via potential changes to Electrical Conductivity (EC) and concentrations of heavy metals. The approval conditions required an Ecological Monitoring Program (EMP) be established, aimed at detecting potential impacts to aquatic biota and habitat in Neubecks Creek and informing management decisions to mitigate, minimise and / or ameliorate any impacts. Construction of the Project commenced in February 2013 and ash placement on the Project site commenced in September 2013.

In accordance with the EMP, previous sampling was undertaken in spring (November) 2012, autumn (May) 2013, spring (December) 2013 and autumn (May) 2014 by GHD and in spring (November) 2014, spring (December) 2015, spring (December) 2016, autumn (May) 2018 and most recently in spring (December) 2018 by Cardno (NSW/ACT) Pty Ltd (Cardno)

Cardno, formerly Cardno Ecology Lab, was commissioned by EnergyAustralia to undertake the spring 2018 monitoring component of the EMP. The spring 2018 monitoring included the following sites:

> Control NCR1 on Neubecks Creek upstream of the Project area;

> Impact NCR2 on Neubecks Creek adjacent to the Project area;

> Control NCR3 on Neubecks Creek upstream of the Project area; and

> Control A16 on the Coxs River at Lidsdale downstream of the confluence with Neubecks Creek; and

> Control CR0 on the Coxs River adjacent to Ben Bullen State Forest and upstream of the confluence with Neubecks Creek, which was not sampled in autumn and spring of 2018 due to the low water level here.

The primary objectives of this monitoring were to:

> Assess whether any impacts to the aquatic ecology of Neubecks Creek occurred in spring 2018 and since the Project began and determine whether any such impacts were attributable to the Project; and,

> Provide recommendations on any actions, if any, that may be required to minimise, mitigate or ameliorate any impacts to the aquatic environment that may have occurred, and on any refinements to subsequent monitoring events that would improve the efficacy of the EMP.

Methods

Assessment of aquatic habitat, water quality and macroinvertebrate assemblages (using the AUSRIVAS protocol) was undertaken by Cardno on 12 December 2018 during the spring AUSRIVAS sampling season. Several biotic indices were derived from the macroinvertebrate data collected in previous spring surveys in 2012, 2013, 2014, 2015 and 2016 and used to determine whether any changes to macroinvertebrates due to the Project have occurred. These indices were:

> Total number of taxa;

> Number of pollution sensitive Ephemeroptera, Plecoptera and Trichoptera (EPT) taxa;

> OE50 Taxa Score (a biotic index of aquatic habitat and water quality); and

> SIGNAL2 Score (a biotic index of water pollution).

Permutational Analysis of Variance (PERMANOVA), was used to explore the difference between NCR1 and NCR2 in 2013, 2015, 2016 and 2018 and among NCR1, NCR2, NCR3 and A16 sampled in 2015, 2016 and 2018 (i.e. when replicate samples were collected). Changes in the structure of macroinvertebrate assemblages in all samples collected in spring of 2012, 2013, 2014, 2015, 2016 and 2018 were also explored using graphical multivariate techniques. In addition, long-term water quality and water discharge data from Neubecks Creek and local rainfall data sourced from EnergyAustralia, the Bureau of Meteorology, and Water NSW were examined to aid in the interpretation of macroinvertebrate data.

Findings

There was no evidence of any change in spring 2018 data that would suggest an impact due to the Project. None of the statistical tests indicated any change through time at NCR2 that could otherwise have indicated an impact. The apparent elevations in EC and concentrations of some metals that occurred in 2018 (generally following relatively low rainfall and flow) do not appear to have affected macroinvertebrate indicators sampled in spring 2018. The capture of a native mountain galaxiid in the AUSRIVAs dip net at one of the control sites in autumn and spring 2018 indicates Neubecks Creek provides habitat for at least one native species of fish.

Examination of long-term water quality data from Neubecks Creek showed variability in the location, timing and magnitude of several measures. This is likely to be related to the heavily modified catchment associated with coal mining, energy generation and other industries, local rainfall, flow and hydrology in Neubecks Creek, and the relative effect of evaporation and dilution occurring during low and high flow conditions, respectively. Background concentrations of many metals, some of which often exceed guidelines for the protection of aquatic ecosystems, would be one of the factors influencing the type and abundance of macroinvertebrates and other aquatic biota in Neubecks Creek.

The complex interactions that exist between the various types of disturbance experienced in Neubecks Creek (e.g. those affecting habitat, water quality and flow) make any changes in indicators of ecological health difficult to distinguish from those that could be due to the Project. Nevertheless, the Environmental Monitoring Program does add value to the wider monitoring program, and it is expected that any large magnitude and / or cumulative impacts to aquatic biota would be detected, allowing appropriate management actions to be implemented. Recent changes to the monitoring of aquatic ecology, including the addition of further control sites, will assist in identifying any future impacts, were they to occur, and inform future impact minimisation and remediation efforts.

Recommendations

1. Further monitoring should be undertaken annually in spring during operation of the Project and for at least five years after completion of all activities that could impact aquatic ecology.
2. There would be merit in undertaking annual sampling in autumn. Although baseline data is not available from autumn, the results of monitoring in autumn would complement that undertaken in spring and provide further confidence regarding the presence or absence of a potential impact associated with the Project.
3. Sampling should continue at the additional control site established on Neubecks Creek (NCR3). While no baseline data is available from this site, control (upstream) data collected here during future surveys would improve the power of statistical tests and aid in the detection of an impact occurring in the future.
4. Sampling should be discontinued at control Site CR0 as this site has been found dry on more than one occasion and is thus unlikely to provide suitable control data. The two control sites on Neubecks Creek (NCR1 and NCR3) will provide suitable control data during future surveys.
5. Three replicate AUSRIVAS samples should continue to be collected from each site during all future surveys. This will provide a measure of the variation present in each indicator at each site, thereby, improving the ability to detect any future impact by enabling the use of appropriate statistical analysis.
6. The use of quantitative macroinvertebrate sampling methods should be incorporated to provide more robust data and additional confidence surrounding the findings of the EMP.

Table of Contents

Appendices

Tables

Figures

1 Introduction

1.1 Background

EnergyAustralia NSW (EnergyAustralia) operates Mount Piper Power Station (MPPS), near Lithgow, NSW. MPPS comprises two 700 MW steam turbine generators and produces power through the burning of coal sourced from local coal mines. On 16 February 2012, EnergyAustralia was granted approval for the Lamberts North Ash Placement Project (the Project) by the Department of Planning and Infrastructure (DP&I). The Project provides a facility for the storage of ash produced from MPPS following Ash Area 1 reaching its ash storage capacity. The Project includes construction activities and the delivery, placement, and capping of ash, the rehabilitation of the site and ongoing management. Construction began in February 2013 and ash placement began in September 2013.

The Environmental Assessment for the Project (SKM 2010) identified several aspects of construction and ash placement that could affect the aquatic ecology of Neubecks Creek, which flows in an easterly direction just north of the Project. Potential effects included, but were not limited to:

> Impacts to water availability flowing into Neubecks Creek due to changes to on-site water usage and changes to run-off caused by reductions in catchment area;

> Changes to the flood regime of Neubecks Creek due to the modification of the landform of the area to accommodate the ash placement facility; and

> Impacts to the water quality of Neubecks Creek, such as changes to electrical conductivity and metal concentrations, due to the mobilisation of sediment and other contaminants during construction and operation.

Condition B7 of the Conditions of Approval (CoA) for the Project required that an Ecological Monitoring Program (EMP) (GHD 2014a) be designed, aimed at detecting potential impacts to the aquatic ecology of Neubecks Creek due to the Project, and informing management decisions taken to mitigate, minimise and / or ameliorate any impacts that were detected. The EMP would incorporate baseline and ongoing (for at least 5 years after ash capping) monitoring of the ecological health of Neubecks Creek, and implementation of management measures to address any ecological impacts that were identified. The EMP formed part of the Construction Environmental Management Plan (CEMP), and subsequent Operational Environmental Management Plan (OEMP) for the Project. EnergyAustralia NSW commissioned Cardno (NSW/ACT) Pty Ltd (formerly the Cardno Ecology Lab) to undertake the spring 2018 monitoring in accordance with the EMP.

1.2 Current Study

The specific objectives of the current study were to:

> Sample indicators of ecological health in Neubecks Creek potentially affected by the Project and at unaffected control sites there and on the Coxs River in spring 2018;

> Compare the findings with those of previous studies also undertaken in autumn as part of the EMP;

> Assess whether any impacts to the aquatic ecology of Neubecks Creek occurred in spring 2018 and determine whether any such impacts were attributable to the Project; and

> Provide recommendations on any actions, if any, that may be required to minimise, mitigate or ameliorate any impacts to aquatic ecology that may have occurred and on any refinements to subsequent monitoring events that would improve the efficacy of the EMP.

Following the recommendations made following the 2015 study (Cardno Ecology Lab 2015a), monitoring incorporated sampling of AUSRIVAS edge habitat only, no sampling of AUSRIVAS riffle habitat was undertaken (**Section 2.1**). Sampling also included an additional reference site on Neubecks Creek upstream of any potential impact that may be experienced due to the Project (a further control site on Coxs River was not sampled in 2018 due to low flow). In addition, this monitoring incorporated the recommendations made previously in the critical review of the EMP by Cardno Ecology Lab in 2014 (Cardno Ecology Lab 2014a) (**Section 2.2**).

2 Previous Studies

2.1 Monitoring

In accordance with the EMP, baseline aquatic ecology sampling was undertaken at two sites on Neubecks Creek in spring 2012 (GHD 2014b). Further sampling at these sites was done in autumn 2013 (GHD 2014c), spring 2013 (GHD 2014d), autumn 2014 (GHD 2014e), spring of 2014 (Cardno Ecology Lab 2015a), 2015 (Cardno 2016) and autumn 2018 (**Table 2.1**).

Table 2-1 Timing of aquatic ecology surveys undertaken for the Neubecks Creek EMP and the respective report reference. The timing of key Project activities and the respective monitoring phase is also identified.

Monitoring Phase	Sampling Date	AUSRIVAS Season	Report Reference
Preparation of EMP	n/a	n/a	GHD (2014a)
Baseline	8 Nov 2012	Spring 2012	GHD (2014b)
Commencement of Construction – February 2013			
During Construction	6 May 2013	Autumn 2013	GHD (2014c)
Commencement of Ash Placement – September 2013			
During Ash Placement	12 Dec 2013	Spring 2013	GHD (2014d)
	22 May 2014	Autumn 2014	GHD (2014e)
	19 Nov 2014	Spring 2014	Cardno Ecology Lab (2015a)
	14 Dec 2015	Spring 2015	Cardno (2016a)
	1 to 2 Dec 2016	Spring 2016	Cardno (2017)
	9 and 11 May 2018	Autumn 2018	Cardno (2018)
	11 December 2018	Spring 2018	Current study

These reports included background information on the aquatic ecology of Neubecks Creek and present the results of AUSRIVAS sampling and the assessment of aquatic habitat at these sites. The reports assessed whether impacts to the aquatic ecology of Neubecks Creek may have occurred following the baseline study. No impacts attributable to the Project were identified in data collected following the start of construction in autumn 2013 (GHD 2014c). GHD (2014d and e) suggested that impacts to macroinvertebrates may have occurred following the commencement of ash placement in spring 2013 and autumn 2014, respectively. However, Cardno's review of data between spring 2012 and autumn 2014 (Cardno 2014a) did not find any conclusive evidence of this (**Section 2.2**).

2.2 EMP Review

Cardno Ecology Lab reviewed the EMP following a request by EnergyAustralia in late 2014. The review included the EMP and monitoring undertaken from spring 2012 to autumn 2014. The aim was to examine the suitability and efficacy of the EMP and recommend any appropriate amendments to future monitoring to help ensure the objectives of the OEMP, with respect to aquatic ecology, are met. The specific objectives, scope, identified issues and detailed recommendations of the critical review are detailed in Cardno Ecology Lab (2014).

The following associated recommendations were made:

> Based on its location with respect to Project activities, NCR1 on Neubecks Creek has been re-classified as a control site;

> Results from the ongoing *in situ* and *ex situ* water quality monitoring program are used to aid in the interpretation of macroinvertebrate data;

> As construction activities commenced in February 2013 and prior to the autumn 2013 sampling event in May 2013, data from May 2013 is treated as post-baseline data;

> The statistical approach has been revised following the re-classification of NCR1 as a control site and confirmation that sampling in autumn provides post-baseline data.

These were incorporated into the current study as appropriate.

2.3 Previous Surveys

Cardno Ecology Lab (2015a) undertook the spring 2014 monitoring following the implementation of the amendments to the EMP (**Section 2.2**). This included a re-assessment of all data collected during the EMP. The findings provided limited evidence that changes in macroinvertebrates occurred at the impact site (NCR2) on Neubecks Creek in autumn 2013 that could be associated with the commencement of construction of the Project. These included a reduction in the total number of taxa and the number of relatively pollution sensitive Ephemeroptera, Plecoptera and Trichoptera (EPT) taxa, a lower OE50 Taxa Score and a change in the structure of the macroinvertebrate assemblage at this site. However, appropriate statistical tests, which would provide strong evidence of the presence or absence of an impact, could not be performed in the absence of autumn baseline data. There was also evidence of a subsequent recovery in most of these indicators, and data from NCR2 in autumn 2013 were comparable with those collected further downstream at the sites on the Coxs River sampled during this season as part of the separate Coxs River Biological Monitoring Program (Cardno Ecology Lab 2015b).

Examination of long-term water quality data provided by EnergyAustralia indicated relatively great variation in the location, timing and magnitude of several indicators. There was some indication that an elevated concentration of zinc that occurred near NCR2 prior to the autumn 2013 survey may have contributed to changes in the macroinvertebrate assemblage. However, as macroinvertebrates will almost certainly respond to the combined effect of several elevated indicators as well as several other environmental cues (such as drought and flood events) operating in the creek, it was unclear how much of the variation in macroinvertebrate data is explained by levels of zinc and other measures of water quality. The taxa absent from NCR2 in autumn 2013 (i.e. generally those that are pollution tolerant), together with the presence of some pollution sensitive taxa, suggested that other factors, such as changes to habitat quality due to habitat fragmentation following reduced flow, may also influence macroinvertebrates in Neubecks Creek. The cause of elevations in electrical conductivity (EC) in Neubecks Creek, such as those observed around the time of ash placement on the Project site (GHD 2014d) and which was unclear at the time of the review, was attributed to rainfall and flow patterns in the creek, rather than any impacts due to the Project (Aurecon 2014).

Cardno Ecology Lab (2015a), provided the following recommendations aimed at further improving the robustness and cost effectiveness of the EMP:

> As no autumn baseline data is available, sampling in spring is preferred. Though no baseline data collected in autumn is available, surveys in autumn would, however, allow assessment of any changes that may manifest in autumn only;

> Due to the paucity of AUSRIVAS data collected from riffle habitat (following frequent low flows during sampling), sampling of riffle habitat (when present) should cease and effort be re-directed to collection of two replicate AUSRIVAS edge samples at each site, thereby improving the ability to detect any future impact by enabling the use of appropriate statistical analysis; and

> Establishment of an additional control site on Neubecks Creek and on the Coxs River, upstream of any potential impact that may be experienced due to the Project. While no baseline data would be available from these sites, control data collected here during future surveys would improve the power of statistical tests and aid in the detection of an impact occurring in the future.

> Where appropriate, the more specific recommendations provided in Cardno Ecology Lab (2014a) aimed at improving the overall robustness of the study have also been implemented.

The findings of the spring 2015 monitoring did not provide any evidence of an impact due to the Project (Cardno 2016). None of the PERMANOVA tests undertaken on data collected from NCR1 and NCR2 in spring of 2013 and 2015 indicated a change that could otherwise be due to a Project related impact. There was also no conclusive evidence of any change in spring 2016 and in autumn 2018 that would suggest an impact due to the Project (Cardno 2017 and 2018). None of the statistical tests indicated any change through time at NCR2 that could be due to a Project related impact.

3 Existing Information

3.1 Environmental Context

Neubecks Creek (also known as Wangcol Creek) flows in an easterly direction north of the Project site (**Figure 3.1**). It is a naturally ephemeral creek (though it may appear perennial due to ongoing discharge from industries within its catchment). It has two main tributaries: a western arm which arises in the southwest of Ben Bullen State forest, several kilometres northwest of the Project, and a northern arm with a source in Blackmans Flat a few kilometres northwest of the Project site. These two tributaries join just north of the Castlereagh Highway and to the northwest of the Project site before joining the Coxs River at Blue Hole, a flooded historic quarry, approximately two kilometres north of Lidsdale. Other tributaries of Neubecks Creek include Lamberts Gully, which flows north into Neubecks Creek from the southeast of the Project Area. The Project includes ash placement over Huons Gully, which otherwise would have flowed into Neubecks Creek upstream of Lamberts Gully. Several un-named drainage lines also traverse the area.

Neubecks Creek is situated in a substantially disturbed catchment in which water quality, quantity and drainage patterns are influenced by surrounding historical and current mining operations (Ivanhoe Colliery, Commonwealth Open Cut Coal Mine, Angus Place Coal Mine, Kerosene Vale Mine, and Pine Dale Coal Mine), power generation (Mount Piper and Wallerawang Power Stations) and agricultural land practices. The creek has also been re-aligned several times to facilitate nearby mining practices.

3.2 Aquatic and Riparian Habitat

The riparian vegetation of the Neubecks Creek Catchment consists primarily of cleared land with some disturbed native regrowth. The section of creek in the vicinity of Blackmans Flat is almost devoid of native riparian vegetation except for scattered trees and occasional patches of *Leptospermum* sp. (Centennial Coal 2012). Some more established mixed native and invasive trees and shrubs (e.g. willow (*Salix alba*) and blackberry (*Rubus* sp.)) are present along the main channel of the creek in the vicinity of the Project.

Adjacent to the Project, Neubecks Creek consists of faster flowing riffle and deeper slower flowing pools (GHD 2014a). The substratum generally consists of sand, coarse gravel, cobbles and rock. In places there are large deposits of fine sediment.

3.3 Water Quality

3.3.1 Environmental Assessment

Water quality in Neubecks Creek was reviewed as part of the Environmental Assessment for the Project (SKM 2010). The review examined water quality data collected from four previously established water quality monitoring sites located on the creek in the vicinity of the Project (**Figure 3.1**):

> LDP01 (MPPS Licensed Discharge Point 1): located upstream of the Project and the previous ash storage area (Ash Area 1);

> WX22: Neubecks Creek gauging station, located adjacent to the Project;

> Site 2: Springvale Coal monitoring site located immediately upstream of the confluence with Lamberts Gully; and

> Site 3: Springvale Coal monitoring site located immediately downstream of the confluence with Lamberts Gully.

Data were available from LDP01 and WX22 for the period 2000 to 2009 and from Sites 2 and 3 from 2000 to 2007. Data were compared with Australian Guideline Default Trigger Values (DTVs) (ANZECC/ARMCANZ 2000) for upland rivers in south eastern NSW. The findings are summarised as follows:

> Electrical Conductivity (EC) often exceeded the upper DTV (350 µs/cm) and was recorded as high as 1333 µs/cm at LDP01 and 1200 µs/cm at Site 3;

> pH was within lower and upper DTVs (6.5 to 8.0); and

> Concentrations of metals (aluminium, silver, arsenic, cadmium, chromium, manganese, copper and zinc) were above the trigger value for 95% protection of freshwater ecosystems at one or more sites.

Additional water quality data from WX22 collected by EnergyAustralia from 2008 to 2012 were presented in GHD (2014a). These data indicated that nickel, boron, copper and lead in Neubecks Creek can also exceed DTVs at times.

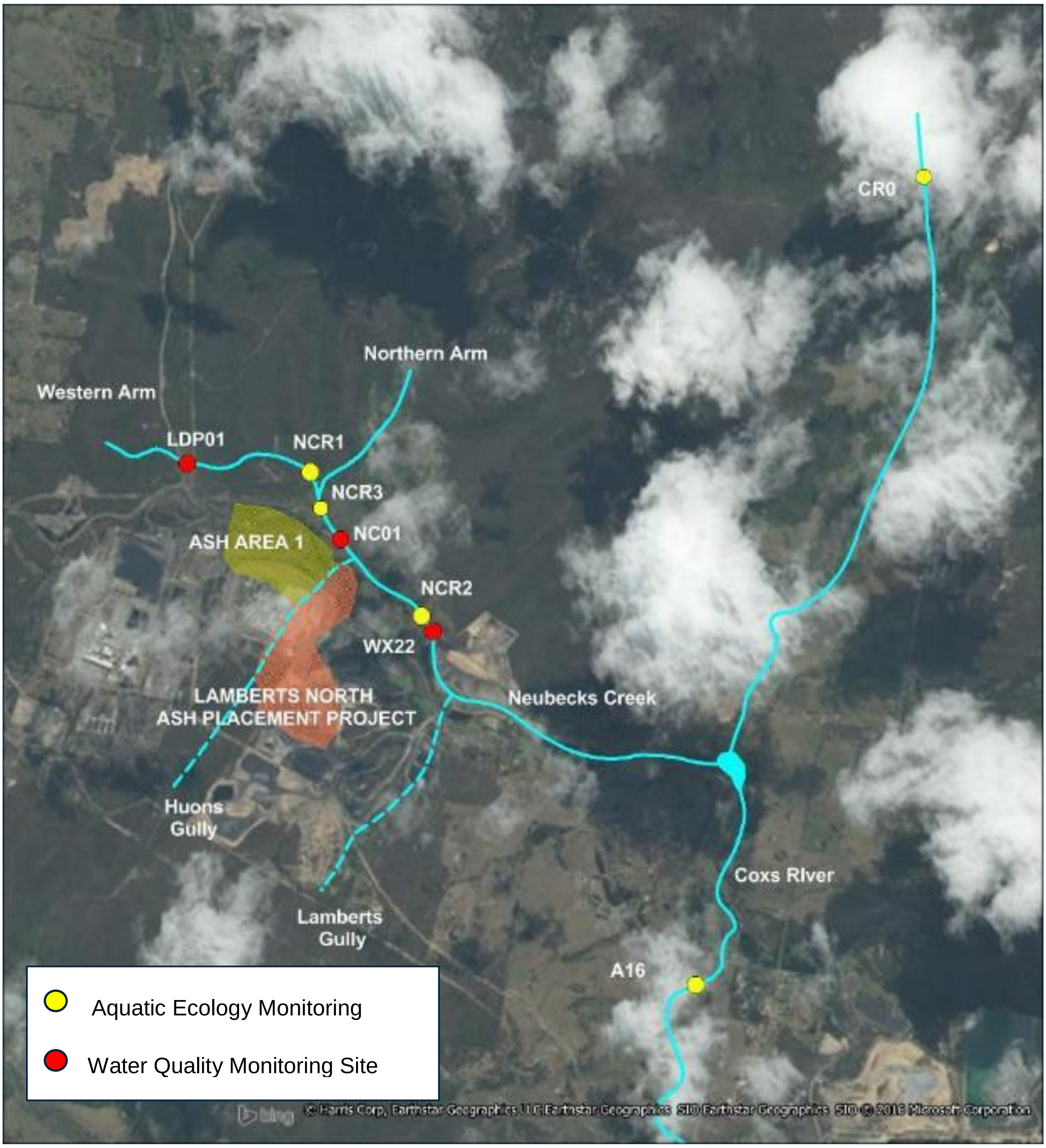


Figure 3-1 Aerial image identifying the location of the Project (Lamberts North), the previous ash depository (Ash Area 1), Neubecks Creek, the Coxs River, aquatic ecology monitoring sites and long-term water quality monitoring sites. Note CR0 was not sampled in the current study due to low water level.

3.3.2 Ash Area 1 Monitoring

Aurecon (2014) reviewed water quality data as part of the ongoing monitoring associated with Stages 1 and 2 of the previous Ash Area 1 placement area. This included surface water quality data collected at LDP01, WX22 and NC01 (on Neubecks Creek upstream of the Project site and the confluence with Lamberts Gully) prior to (October 2012 to August 2013), and following (September 2013 to August 2014) ash placement on the Project site. The findings are summarised as follows:

> Median EC ranged from 310 to 640 µs/cm and was often above the upper DTV for upland creeks (noting that Aurecon (2014) used DTVs for lowland rivers) at LDP01 and WX22 before, and after, ash placement and at NC01 following ash placement;

> pH ranged from 7.0 to 7.8 and was within the DTVs at each site before, and after, ash placement;

> Turbidity ranged from 2.3 to 26 ntu and was slightly above the upper DTV at LDP01 before ash placement; and

> Concentrations of heavy metals and indicators of water quality measured following ash placement were compared with locally derived guidelines (90th percentile of pre-placement data). While the concentrations of several metals (including barium, nickel and zinc) exceeded these local guidelines, it was noted that exceedances could not be attributed to the Project due to the confounding influence of groundwater flow from historic mine workings and Ash Area 1.

It was also noted that elevated ECs and concentrations of metals observed in Neubecks Creek were due to preceding periods of low rainfall and flow. Relatively high ECs and concentrations of nickel at WX22, compared with those at LDP01 and NC01, were attributed to inflows from MPPS via Huon Gully. Elevated concentrations of zinc at WX22 were most likely due to local mine water seepage during dry weather.

Groundwater from the Project area flows eastward towards Huons Gully, then into Neubecks Creek (Aurecon 2014). Groundwater from the Ash Area 1 area may also flow eastward through the Project area and into Neubecks Creek via Huons Gully, and potentially northeast towards Neubecks Creek. This pattern of groundwater flow prevented the identification of suitable water quality tracers that could be used to identify potential leachates from the ash deposited on the Project site and discriminate them from those associated with Ash Area 1.

3.4 Aquatic Biota

There is little publicly available information on the aquatic biota of Neubecks Creek. GHD (2014a) reviewed the findings of a 1993 aquatic flora and fauna survey of Neubecks Creek by the former Department of Water Resources (DWR 1994). The findings of this review are summarised in **Sections 3.4.1** and **3.4.2**. Additional information on macroinvertebrates in Neubecks Creek and the wider upper Coxs River Catchment is summarised from the findings of SCA Sydney Drinking Water Catchment Audits (GHD 2013). The findings of an ecotoxicology study in the northern arm of Neubecks Creek (Battaglia *et al*. 2005) are also summarised in **Section 3.4.2.1**.

3.4.1 Flora

The review of DWR (1994) provided by GHD (2014a) noted the following observations of aquatic flora in Neubecks Creek:

> Emergent aquatic flora is relatively diverse, with common species including tall spikerush (*Eleocharis sphacelata*), spikerush (*Eleocharis acuta*), jointed rush (*Juncus articulatus*), common reed (*Phragmites australis*) and cumbungi (*Typha orientalis*);

> Submerged aquatic flora was sparse and consisted of green algae (*Chara* sp., *Nitella* sp., *Spirogyra* sp. and *Rhizoclonium* sp.);

> A smothering effect due to the presence of fine sediments in the creek was offered as an explanation of the low diversity of submerged aquatic flora;

> Dense beds of tall spikerush and cumbungi were present in some sections of creek, reducing water flow in these sections.

3.4.2 Fauna

3.4.2.1 Aquatic Macroinvertebrates

The review of DWR (1994) suggested that Neubecks Creek supported a diverse macroinvertebrate community, dominated by true flies (Order: Diptera), caddisflies (Order: Trichoptera), damselflies, dragonflies (Order: Odonata) and beetles (Order: Coleoptera).

More recent surveys of AUSRIVAS edge habitat in Neubecks Creek adjacent to the Project and at other nearby sites on the Coxs River were undertaken as part of the SCA Sydney Drinking Water Catchment Audits (GHD 2013). The results of the 2009 survey on Neubecks Creek indicated the aquatic habitat here was severely impaired (AUSRIVAS Band C) relative to reference condition. The aquatic habitat at sites on the Coxs River upstream and downstream of the confluence with Neubecks Creek sampled in 2009 ranged from severely impaired to significantly impaired (AUSRIVAS Band B) relative to reference condition. Further monitoring at a subset of these sites in 2011 also indicated that the aquatic habitat was severely to significantly impaired. Long term sampling undertaken at A16 (also included in the EMP, see **Section 4.2**) on the Coxs River downstream of the confluence with Neubecks Creek from 2001 to 2012 indicated that the condition of aquatic habitat ranged generally from severely impaired to equivalent to reference condition (AUSRIVAS Band A). In 2002 the macroinvertebrate assemblage at this site was richer than expected under the AUSRIVAS model (Band X). While the habitat condition at A16 appears to have declined from 2009 to 2012, there appears to have been a general improvement across the Upper Coxs River sub-catchment through that time (GHD 2013).

It was noted in GHD (2014a) that the macroinvertebrate assemblages at most of the sites sampled in the Coxs River catchment (at least prior to 2010) were dominated by pollution-tolerant taxa, and that analyses indicated that the invertebrate assemblages and individual taxa were influenced by EC in the river.

A study by Battaglia *et al*. (2005) indicated that the abundance and diversity of macroinvertebrate fauna in Neubecks Creek was much lower than two reference creeks (Megalong Creek and Jocks Creek) and attributed this difference to acid mine drainage (AMD) from previous mining activities within the area. The study found a strong correlation between water quality (concentrations of several analytes, including nickel and zinc, were found to be greater in Neubecks Creek than in the reference creeks) and macroinvertebrate data. The study also concluded that poor water quality impacted on macroinvertebrate assemblages within the creek, rather than the quality of the sediment from the creek bed.

3.4.2.2 Fish

The DWR (1994) review indicated three species of fish occurring in Neubecks Creek during the DWR (1994) survey, these were:

> The native mountain galaxias (*Galaxius olidus*), which represented over 90 % of the fish caught;

> The native flathead gudgeon (*Philypnodon grandiceps*); and

> The non-native wild goldfish (*Carassius auratus*).

It was noted that the low diversity and abundance of the fish assemblage in Neubecks Creek compared with other nearby freshwater streams suggested fish habitat quality in the creek was poor.

Topographical maps show several crossings that may represent significant barriers to fish movement through the creek. Such structures would impact fish populations by reducing longitudinal connectivity and habitat availability, and could cause population fragmentation.

3.5 Summary

Neubecks Creek is situated in a heavily disturbed and modified catchment. It has experienced substantial environmental stress due primarily to nearby historic and current coal mining activities, power generation and land clearing practices and continues to do so. Poor water quality (primarily elevated EC and concentrations of heavy metals) due to discharged process water, groundwater flow from historic mine workings, increased sedimentation due to run-off from nearby roads and other impermeable surfaces and the removal of native vegetation are likely the major contributing factors to the generally depauperate macroinvertebrate and fish assemblages supported by the creek. SKM (2010) noted that there is sufficient data from the on-going monitoring and the modelling studies undertaken as part of previous and current studies to suggest that the main contribution to elevated water quality indicators in Neubecks Creek is historic coal mining activities rather than Ash Area 1 or the operation of MPPS. The findings of the review of water quality data collected before and after ash placement on the Project site by Aurecon (2014) suggested a complex interaction between the various water quality impacts in Neubecks Creek (Aurecon 2014), which would also be affected by local rainfall patterns and water flow in the creek.

The 2010 audit (DECCW 2010) indicated that as a whole, the Upper Coxs River sub-catchment was under a high level of stress, due to inflows from the sewage treatment plants, inflows of urban stormwater, runoff from roads and grazing lands, regulation of flows by dams, extraction of surface and ground water, occurrence of barriers to fish passage, geomorphological disturbance from past and present mining and licenced discharges from nearby power stations and coal mines. Despite these observations, Neubecks Creek does support aquatic biota and habitat of ecological value. While the riparian strip has been impacted by historic vegetation clearing and channel realignments (and includes exotic species), it is relatively intact along the main channel of the creek. It would therefore be an important source of woody debris and bank stabilisation. The creek also supports several native macrophytes which provide habitat for macroinvertebrates and fish and may also be important in nutrient cycling, limit the magnitude and duration of elevated concentrations of nutrients and help prevent eutrophication due to excess nutrients.

Monitoring programs such as that included in the EMP that aim to detect the potential impact on the aquatic ecology of Neubecks Creek due to specific activities (such as the Project) must take into consideration the cumulative impacts the creek has experienced, now and in the past, and patterns of rainfall and flow.

4 Methodology

4.1 Study Rationale

The primary aim of the EMP is to identify changes in the selected indicators of aquatic ecology at the impact site that show a different trend, or magnitude, to those at the control sites. Any such changes would be related to variation in environmental variables, such as water quality and flow, in an attempt to explain the pattern of changes and potential causative pathways.

The methods utilised in this survey and described in **Sections 4.2** to **4.6** are based on those prescribed in the EMP (GHD 2014a) and incorporate the modifications and additions described in the review of the EMP (Cardno Ecology Lab 2014a) (**Sections 2.1** and **2.2**).

4.2 Study Sites

The following sites were sampled by Cardno on 11 December 2018, which was within the spring AUSRIVAS sampling season (**Figure 3.1**):

> Control NCR1 located on Neubecks Creek upstream of Huons Gully and the Project area. While this site is situated on a section of Neubecks Creek which has, and continues to be, impacted by other disturbances, it is not expected to experience any impact due to the Project (**Section 2.2**);

> Impact NCR2 located on Neubecks Creek downstream of Huons Gully and adjacent to the Project area;

> Control NCR3 located on Neubecks Creek between the Northern Arm and Huons Gully upstream of the Project area. A control site could not be established farther upstream because the habitat there was unsuitable (consisting of a wide channel with dense aquatic vegetation or a narrow, re-sectioned channel with minimal riparian vegetation) and would not be expected to provide comparable control data for NCR2;

> Control A16 located on the Coxs River approximately 5 km downstream of the ash placement (this site is an ongoing Sydney Catchment Authority (SCA) macroinvertebrate monitoring site); and

Site Coxs River 0 (CR0) located on the Coxs River upstream of the confluence with Neubecks Creek was also visited, however, the low water levels did not provide sufficient habitat to undertake sampling using AUSRIVAS. This was also the case in May 2018. Thus, data collected from this site previously have not been included in the data analysis undertaken in this report. It is recommended that this site be removed from the monitoring program (**Section 7**). NCR3 was included from December 2015, following the recommendations in Cardno Ecology Lab (2015a) (**Section 2.1**).

Note that the control site on the Coxs River (A16) is located downstream of the impact site and could conceivably experience impacts due to the Project. It is considered unlikely that such impacts would occur because A16 is located some distance downstream and receives substantial flows from the upper Coxs River. The latitude and longitude of each site are presented in **Appendix A**.

4.3 Timing

The timing of the current and previous sampling undertaken at each site is presented in **Table 4.1**.

Table 4-1 The timing and number of AUSRIVAS edge and riffle habitat samples collected at each of the Neubecks Creek EMP aquatic ecology monitoring sites during 2012 to 2018

Date	AUSRIVAS Season	NCR1		NCR2		NCR3	A16		CR0
AUSRIVAS Habitat		Edge	Riffle	Edge	Riffle	Edge	Edge	Riffle	Edge
8 Nov 2012	Spring 2012	1	1	1	1		1	1	
6 May 2013	Autumn 2013	2		1	1				
12 Dec 2013	Spring 2013	2		2			1	1	
22 May 2014	Autumn 2014	2		2					
19 Nov 2014	Spring 2014	1		1			1	1	
14 Dec 2015	Spring 2015	2		2		2	2		2

Date	AUSRIVAS Season	NCR1		NCR2		NCR3	A16		CR0
AUSRIVAS Habitat		Edge	Riffle	Edge	Riffle	Edge	Edge	Riffle	Edge
1 to 2 Dec 2016	Spring 2016	2		2		2	2		2
9 and 11 May 2018	Autumn 2018	2		2		2	2		
11 December 2018	Spring 2018	3		3		3	3		

Note, only spring data have been examined in the current report (**Section 2.1**). Riffle habitat was not sampled due to absence of this habitat during low flows. CR0 not sampled in autumn and spring of 2018 due to low water levels.

4.4 Field Sampling

4.4.1 Aquatic Habitat

Aquatic habitat was assessed using methods in the NSW AUSRIVAS Manual (Turak *et al.* 2004). Descriptions of physical habitat included visual assessments of streambed composition, aquatic and riparian vegetation, potential disturbance and sketches of the river profiles.

The condition of aquatic habitat was assessed using the Reference Condition Selection Criteria (RCSC) categories developed by the Queensland Government (QLD DNRM 2001), as per the requirements of the EMP (**Appendix B**). This assessment rates the level of influence (from 1 to 5, with 1 being a very major impact and 5 an indiscernible impact) that a watercourse experiences from several potential anthropogenic disturbances in relation to the selection of reference aquatic ecology monitoring sites. The condition of aquatic habitat was also assessed using a modified version of the Riparian, Channel and Environmental (RCE) Inventory method (Peterson 1992; Chessman *et al.* 1997). This assessment involves evaluation and scoring of the characteristics of the adjacent land, the condition of riverbanks, channel and bed of the watercourse, and degree of disturbance evident at each site (**Appendix C**). The maximum score (52) indicates a stream with little or no obvious physical disruption and the lowest score (13) a heavily channelled stream without any riparian vegetation can be considered to be in poor condition.

Digital photographs were taken looking upstream and downstream at each site to provide a record of aquatic habitat present at the time of sampling and to aid in the site descriptions.

4.4.2 Water quality

During previous field sampling events, 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 before aquatic fauna were sampled to avoid disturbance to the waterway. The following variables were recorded:

> Temperature (°C);

> Electrical Conductivity, EC (µs/cm);

> pH;

> Dissolved oxygen, DO (mg/L and % saturation);

> Turbidity (ntu).

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

These water quality data were intended to provide information on environmental conditions at the time of sampling for aquatic ecology. Due to a probe malfunction in spring 2018 in-situ water quality data were not available from this survey. Nevertheless, long-term trends in water quality data collected by other specialists were examined (**Section 4.6.1**).

4.4.3 AUSRIVAS Macroinvertebrates

Aquatic macroinvertebrates associated with edge habitats were sampled using the AUSRIVAS rapid assessment methodology (RAM) (Turak *et al*. 2004). Edge samples were collected with dip nets (250 µm mesh) over a period of 3 to 5 mins from a total of 10 m of habitat within a 100 m reach of the river at each site. The dip net was used to agitate and scoop up material from vegetated river edge habitats. Where the habitat was discontinuous, patches of habitats with a total length of 10 m were sampled over the 100 m reach. Each RAM sample was rinsed from the net onto a white sorting tray from which live animals were removed (“picked”) using forceps and pipettes. Each tray was picked for a minimum period of forty minutes, after which they were picked at ten minute intervals either until no new specimens had been found or total of 60 minutes (i.e. the initial 40 minutes plus up to another 20 minutes) had elapsed. Care was taken to collect cryptic and fast moving animals in addition to those that were conspicuous and / or slow-moving. The animals collected at each site were placed into a labelled jar containing 70% alcohol in water. The aim of the live picking is to pick as many macroinvertebrate taxa as possible. There is no set minimum or maximum number of animals to be collected, however, at least 20 chironomids were collected where possible to help ensure that an adequate representation of all subfamilies was obtained.

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

4.5 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 (Class), Ostracoda (Subclass), Nematoda and Nemertea (Phylum), Acarina (Order) and Chironomidae (Subfamily). Up to ten animals of each family were counted, in accordance with the latest AUSRIVAS protocol (Turak *et al*. 2004).

4.6 Data Analysis

4.6.1 Water Quality and Hydrological Data

Water quality data were compared with the Australia, New Zealand Environment Conservation Council default trigger values (DTVs) for physical and chemical stressors for slightly disturbed upland rivers in southeast Australia (ANZECC/ARMCANZ 2000). The sites on Neubecks Creek and the Coxs River are at an altitude of 885 to 920 m and thus are classified as upland watercourses by ANZECC/ARMCANZ (2000). For metal data, guidelines for 95% protection of species for slightly to moderately disturbed ecosystems were utilised. While Neubecks Creek is probably more accurately described as a heavily modified system, guidelines for slightly to moderately disturbed systems are applied to these systems as a precautionary measure (ANZECC/ARMCANZ 2000).

EC and pH data collected from LDP01, NC01 and WX22 (**Figure 3.1**) by EnergyAustralia between 12 January 2014 and December 2018 were examined to aid in the interpretation of macroinvertebrate data. Concentrations of nickel and zinc (metals identified as exceeding locally derived guidelines following ash placement on the Project site (Aurecon 2014) (**Section 3.3.2**) and aluminium and boron (previous examination of these data suggested elevated concentrations of these metals occurred around the time of the aquatic ecology survey in spring 2014 (Cardno Ecology Lab 2015a)) recorded from these sites from January 2014 to September 2017 provided by EnergyAustralia were examined to aid the interpretation of macroinvertebrate data. Previous examination of data for four other metals (barium, copper (Cu-F), iron (Fe-F) and manganese (Mn-F) (Cardno Ecology Lab 2015) of potential concern suggested an increase in concentrations above background levels at one or more sites prior to the spring 2015 aquatic ecology survey (Cardno 2016). EC and the concentration of boron, nickel and zinc appeared elevated at WX22 (adjacent to the ash placement and NCR2) in early 2018 a few months prior to the current survey. Boron also appeared to be elevated at LDP1 and NC01 at this time.

Local monthly rainfall data obtained from the Bureau of Meteorology (BOM) station at Lidsdale (approximately 5 to 6 km south east of the aquatic ecology monitoring sites on Neubecks Creek) (BOM 2019) and monthly discharge data from NOW station 212055 (NOW 2016) from January 2012 to 28 February 2019 are also presented.

This cursory examination of water quality data has been undertaken in an attempt to explain any patterns in macroinvertebrate data. More detailed assessment of impacts to water quality in Neubecks Creek due to the Project will be undertaken by other specialist consultants.

4.6.2 Macroinvertebrate Indicators

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. 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. OE50Taxa 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 4.2**.

Table 4-2 AUSRIVAS Bands and corresponding OE50 Taxa Scores for AUSRIVAS edge habitat sampled in spring

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

The SIGNAL2 biotic index (Stream Invertebrate Grade Number Average Level) developed by Chessman (2003) was also used to determine the environmental quality of sites on the basis of the presence or absence of families of macroinvertebrates. This method assigns grade numbers between 1 (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 Score. The SIGNAL2 Score 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 Score was calculated using un-weighted SIGNAL2 grade data. Weighting SIGNAL2 grades according to abundance may bias the SIGNAL2 Score towards naturally more abundant taxa.

Two other biotic indicators; total taxon richness (the number of macroinvertebrate taxa collected in the sample) and Ephemeroptera, Plecoptera and Trichoptera (EPT) Taxon Richness (the combined number of mayfly, stonefly and caddis fly taxa, respectively, which are considered to be relatively pollution sensitive) were also obtained from AUSRIVAS macroinvertebrate data. The relative contribution of each of the major taxonomic groups (including Trichoptera, Diptera, Coleoptera, Hemiptera, Plecoptera, Odonata, Ephemeroptera, Crustacea and Mollusca) to the total number of taxa present in each sample was also examined visually to provide an indication of any changes that could be indicative of an impact.

4.6.3 Statistical Analysis

4.6.3.1 Interpretation and Data Presentation

The objective of the statistical analyses was to identify differences in the macroinvertebrate indicators at the Impact sites that may differ from those at the Control sites. Statistically significant differences associated with an interactive effect of Survey and Site could provide evidence that an impact may have occurred. Evidence is assessed by examining differences between pairs of Surveys and Sites.

Two PERMANOVA designs were utilised according to the availability of replicate sampling (i.e. two or more AUSRIVAS samples per site). The first included data collected from NCR1 and NCR2 in spring of 2013, 2015, 2016 and 2018 and the second, data from NCR1, NCR2, NCR3 and A16 sampled in 2015, 2016 and 2018 (**Section 4.6.3.2**). The first design enabled changes since 2013 (albeit following commencement of the Project) at NCR1 and NCR2 to be examined, the second design also included control sites NCR3 and A16 also (albeit only from 2015 onwards) to help place any changes at NCR2 in the context of the wider catchment area.

Differences in univariate indicators among AUSRIVAS macroinvertebrate assemblages sampled in edge habitat at each site in spring of each year sampled (2012, 2013, 2014, 2015, 2016 and 2018) were also explored.

4.6.3.2 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 may be examined by *Post-hoc* permutational t-tests. Only statistical differences with a significance level of $P \leq 0.05$ are considered. Significant differences between groups may arise due to differences between group means, differences in dispersion (equivalent to variance) among groups or a combination of both. Either outcome could be indicative of an impact. Moreover, only significant statistical interactions are potentially indicative of an impact, hence significant main effects are not considered in detail.

Two analytical designs were utilised:

1. Comparison among sites sampled in spring of 2013, 2015, 2016 and 2018:

> Year: A fixed factor with four levels: 2013, 2015, 2016 and 2018; and

> Site: A fixed factor with two levels: NCR1 and NCR2.

2. Comparison among all sites sampled in spring of 2015, 2016 and 2018:

> Year: A fixed factor with three levels: 2015, 2016 and 2018; and

> Site: A fixed factor with four levels NCR1, NCR2, NCR3 and A16.

Multivariate patterns in data collected from each site during spring of 2012, 2013, 2014, 2016 and 2018 were examined using the Principal Coordinates Analysis (PCO) routine in PERMANOVA+. This is a generalised form of Principal Components Analysis (PCA) in which samples are projected onto linear axes based on their dissimilarities in a way that best describes the patterns among them using as few dimensions as possible (Clarke and Gorley 2006). The amount of variation 'explained' by each principal axis is indicated and the dissimilarity between data points can be determined from their distances apart on the axes (Anderson *et al*. 2008). Relative differences among samples were also examined using Hierarchical Clustering in PERMANOVA+ in Primer v6.

4.6.3.3 Univariate Analyses

PERMANOVA + was used to examine spatial differences and temporal changes in the number of taxa, OE50 Taxa Scores, SIGNAL2 Indices and the number of EPT taxa. These analyses were based on a Euclidean distance matrix of all possible pairs of samples of the variable of interest and with $P \leq 0.05$. The analytical designs described in **Section 4.6.3.2** were utilised.

As is the case with multivariate analyses, significant differences between groups (e.g. NCR1 and NCR2) 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 would be 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.

4.6.3.4 QA/QC Procedures

Data generated in the field were checked for accuracy and completeness before leaving each site. On return to the laboratory, field data sheets were photocopied, entered into spreadsheet format and checked. Spreadsheet 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 animals were missed. A Cardno staff member with appropriate training and experience checked the identifications and counting of samples. These activities were recorded on the Laboratory Management Sheet. Data were entered into an electronic spreadsheet and data for each sample were printed and checked by a second staff member.

5 Results

5.1 Aquatic Habitat

5.1.1 NCR1

As for previous surveys undertaken by Cardno, the aquatic habitat at control location NCR1 upstream of the Project in 2018 appeared relatively undisturbed (**Plate 1a** and **b**). There was no evidence of recent channel re-alignments or re-sectioning, and several mature trees, albeit including some invasive willows, were present on both banks. This vegetation would help stabilise banks, thereby minimising erosion and associated increases in sedimentation. It would also be a source of woody debris which provides habitat for fish and macroinvertebrates. The upstream section of the site consisted of a large pool which was bordered by dense beds of cumbungi. The downstream section consisted of a channel approximately 1 m in width with loose cobble and pebble substratum. Some flow was present at the time of sampling. Rushes (*Juncus* sp.) were common along this section.

5.1.2 NCR2

While the section of Neubecks Creek at the impact site NCR2 (**Plate 1c** and **d**) also did not appear to have been subject to recent modification, the banks just downstream of the site had been re-sectioned and reinforced. Riparian vegetation consisted primarily of grasses and a few isolated trees. The absence of substantial bank stabilising vegetation likely explains the bank slumping and erosion present throughout the site. The channel consisted of loose material covered with fine sediment / diatom layer. A concrete gauging station / ford situated through the centre of the site acted as a small weir. Bank slumping was evident, though bank material was somewhat stabilised by grasses. The channel consisted primarily of loose cobbles and pebbles and moderate water flow was present at the time of sampling.

5.1.3 A16

The relatively steep banks, uniform bank profile and absence of any trees and other substantial riparian vegetation at A16 (**Plate 1e** and **f**) suggest that this section of the Coxs River has been re-aligned and / or re-sectioned. Bank slumping was present, though bank material was somewhat stabilised by grasses. The channel consisted primarily of loose cobbles and pebbles and moderate water flow was present at the time of sampling.

5.1.4 NCR3

The aquatic habitat at NCR3 (**Plate 2a** and **b**) was very similar to that at NCR2. The riparian vegetation within a few metres of the creek was relatively undisturbed with several large trees and grasses. There was no evidence of bank or channel modifications.

5.1.5 CR0

CR0 (**Plate 2c**) was located on the edge of Ben Bullen State Forest approximately 8 km upstream of A16. The riparian vegetation was far less disturbed than that at A16, with several large trees on both banks. Bankside vegetation consisted primarily of grasses which would stabilise banks to some extent. No flow was observed at the time of sampling during 2015 and 2016 and a large proportion of the bed material consisted of silt and other loose material. During 2018 there was substantially less water than in previous years, with only a small pool present that was too shallow for collection of an AUSRIVAS macroinvertebrate sample.

5.1.6 RCE Scores

General observations of aquatic habitat at each site were supported by the results of the RCE inventory. The total RCE scores for Sites NCR1, NCR2, NCR3, A16 and CR0 were 36, 25, 36, 33 and 38, respectively (**Appendix D**). These scores were the same as those recorded for these sites in 2015 and 2016. The low score for NCR2 was due primarily to the relatively poor condition of the riparian vegetation, unstable banks and the absence of in-stream habitat (e.g. large woody debris). A16 also scored relatively low in categories associated with the condition of riparian vegetation, compared with NCR1 and NCR2, though it did score relatively high in categories associated with channel form, riffle / pool sequence and channel substratum. The greater score for CR0 reflected its relatively undisturbed nature.

The results of the Reference Condition Selection Criteria (RCSC) assessment reflected the disturbed nature of the local and catchment wide environment (**Appendix D**). Apart from CR0, each site scored 1 to 2 (indicative of major influences) in categories associated with the influence of major extractive industry,

Plate 1: Photographs of NCR1 looking a) upstream and b) downstream, NCR2 looking c) upstream and d) downstream and A16 looking e) upstream and f) downstream in spring 2018

Plate 2: Photographs of NCR3 looking a) upstream and b) downstream in spring 2018

alteration of riparian vegetation, and point-source waste water discharge. Influence from intensive agriculture and major dams / weirs was not apparent at any site. CR0 scored highly (4 to 5, i.e. little evidence of disturbance) in each category. This reflects its location upstream of any major disturbance (e.g. mining, abstraction, water discharge).

5.2 Water Quality and Hydrology

Daily discharge and water level data from NOW station 212055 (WX22) from January 2012 to 28 February 2019 on Neubecks Creek (Sydney Water 2018) are presented in **Figure 5.1a** and **b**. Examination of rainfall from BOM station 063132 at Lidsdale (**Figure 5.1c**) indicated that greater discharge events in Neubecks Creek followed periods of greater rainfall. EC data (**Figure 5.2a**) suggests that EC measured at WX22 was more variable than that at NC01 and LDP01 and that it appears associated with the amount of local rainfall and thus discharge experienced in Neubecks Creek with elevated ECs tending to occur following periods of low rainfall and discharge, and low ECs tending to occur following periods of high rainfall and discharge. The high EC recorded at WX22 in April 2017 and January 2018 followed relatively low rainfall. The EC measured further upstream at LDP01 and NC01 (100 µS/cm to 700 µS/cm) was far lower, and less variable, than at WX22 (approximately 300 µS/cm to 1300 µS/cm) and does not appear to be influenced by rainfall and discharge. This pattern was similar, but less pronounced, in EC data prior to January 2014 (Cardno Ecology Lab 2015a). The EC at each site was often above the upper DTVs (350 µS / cm).

The spring 2012 to 2015 surveys were undertaken following several months of low to moderate rainfall and discharge, and show correspondingly low ECs at WX22 (approximately 200 µS/cm to 700 µS/cm) (**Figure 5-2b**). The December 2016 survey was undertaken following a relatively greater amount of rainfall and discharge in Neubecks Creek and lower ECs at WX22 (200 µS/cm to 500 µS/cm). The December 2018 survey was undertaken approximately 2 weeks following a rainfall event in late November 2018, also during correspondingly low ECs. pH at LDP01, NC01 and WX22 largely remained within DTVs (pH 6.5 to 8.0) (**Figure 5-2b**). On occasion, there was relatively great difference among the pH measured at each site, sometimes close to 1 pH unit. The pH at LDP01 was generally greater than that at NC01 and WX22.

Figure 5-2c and **Figure 5-3a-c** present the concentrations of a selection of heavy metals (those identified previously as exceeding local guidelines or identified as potentially elevated prior to the aquatic ecology surveys (**Section 4.6.1**)) measured at LDP01, NC01 and WX22 on Neubecks Creek between January 2014 and December 2018. Concentrations of boron, nickel and zinc appeared to be elevated at site WX22 adjacent to the ash placement area in early 2018. Boron also appeared to be elevated upstream of here at NC01 and LDP1 at this time. Concentrations of zinc, aluminium and copper (not graphed) were elevated above guidelines at LDP1 and NC01 on occasion, while concentrations of boron and nickel at these sites were relatively low and within guidelines. Aluminium was elevated at WX22 in late November / early December 2018 around the time of the spring 2018 aquatic ecology survey.

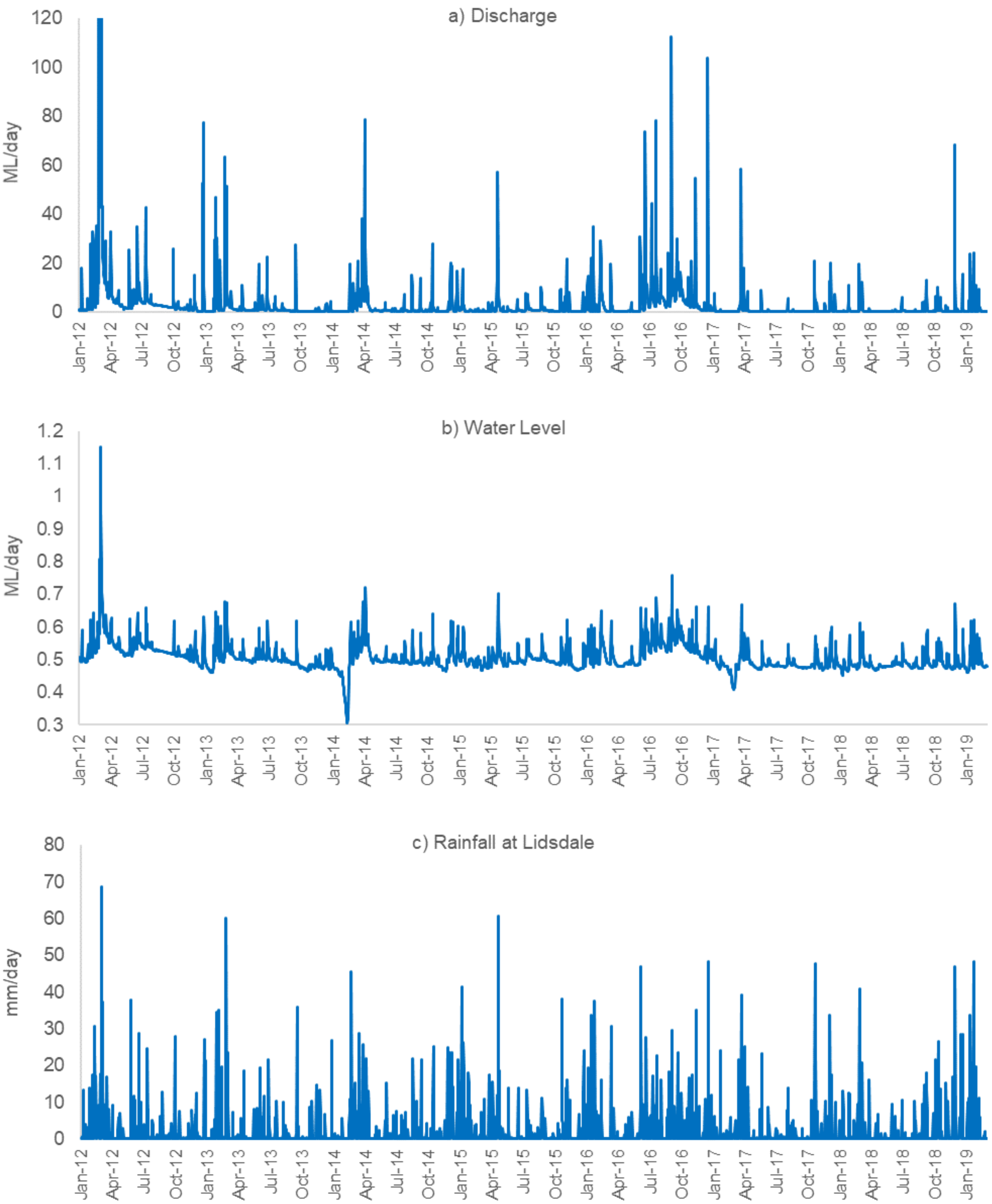
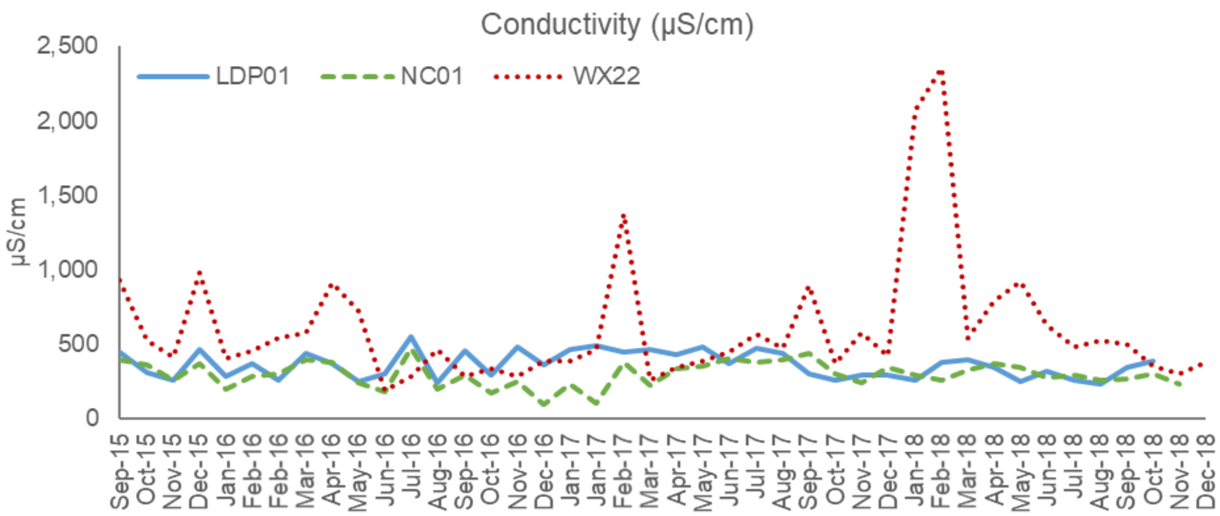
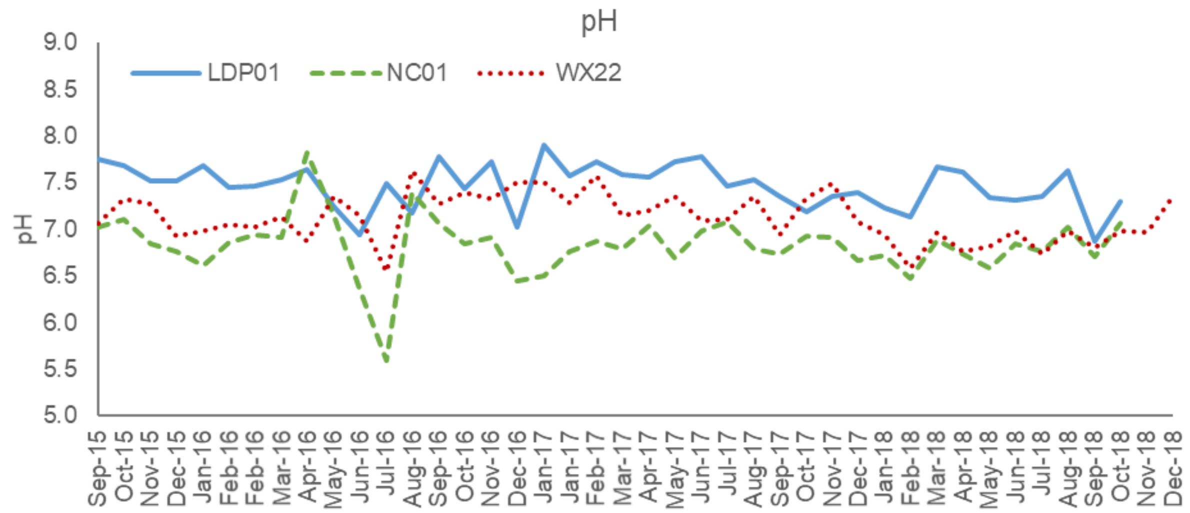


Figure 5-1 a) Daily discharge and b) water level at NSW DPI (Water) station 212055 at WX22 on Neubecks Creek, January 2012 to 28 Feb 2019. The peak discharge in March 2012 was reported as 2,841 ML/day (NOW 2015). To enable easy interpretation of the other discharge data, the Y axis scale is limited to 120 ML/day. c) Daily rainfall at BOM Lidsdale station 063132

a) Electrical Conductivity



b) pH



c) Boron (ANZECC/ARMCANZ (2000) 95 % Species Protection Trigger Value = 0.37 mg / L)

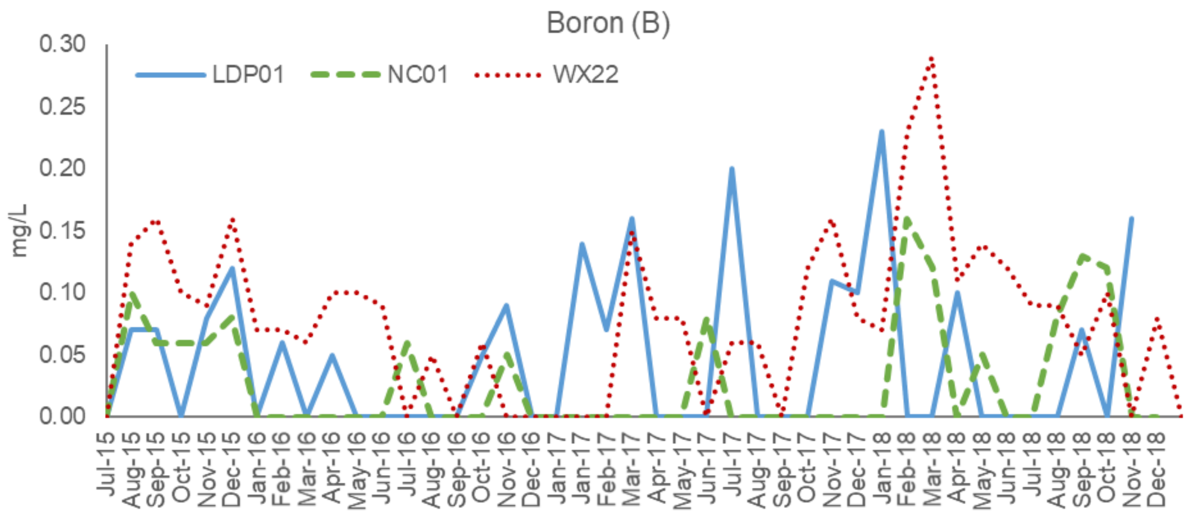
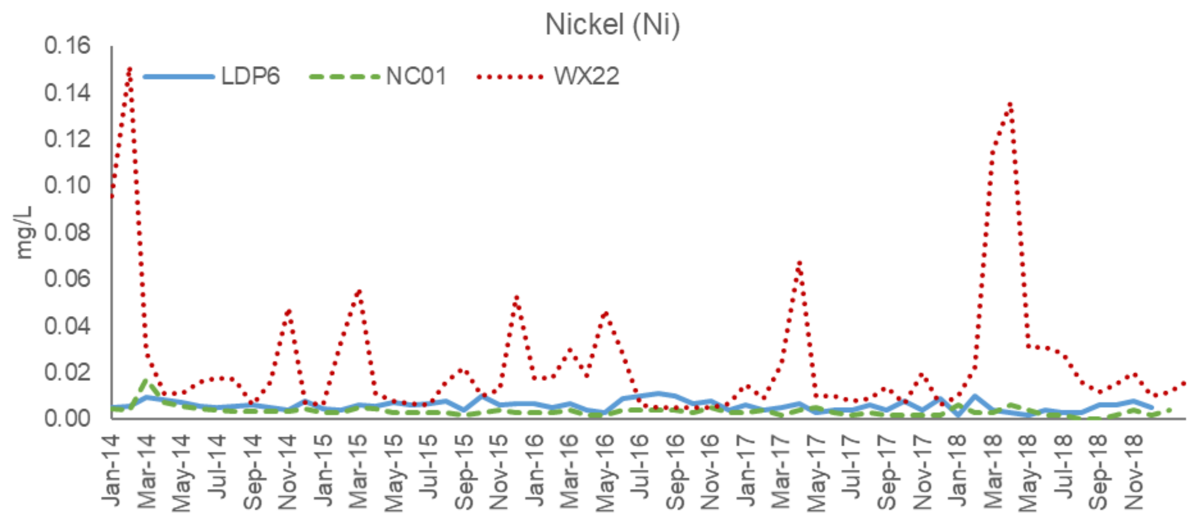
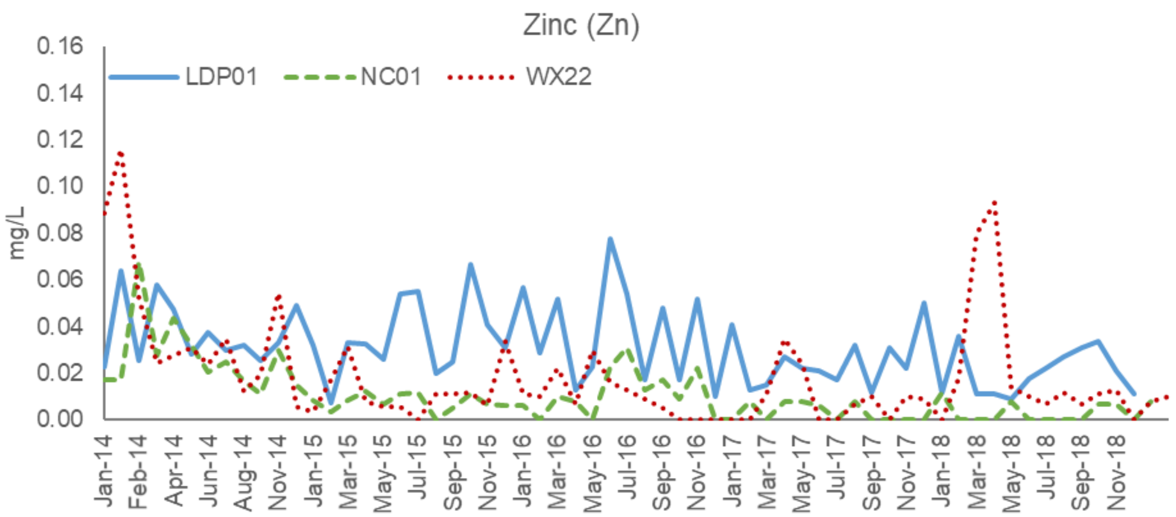


Figure 5-2 a) Electrical conductivity (EC), b) pH and c) concentration (mg / L) of boron measured at LDP01, NC01 and WX22 on Neubecks Creek by EnergyAustralia from January 2014 to July 2018.

a) Nickel (ANZECC/ARMCANZ (2000) 95 % Species Protection Trigger Value = 0.011 mg / L)



b) Zinc (ANZECC/ARMCANZ (2000) 95 % Species Protection Trigger Value = 0.008 mg / L)



c) Aluminium (ANZECC/ARMCANZ (2000) 95 % Species Protection Trigger Value = 0.055 mg / L)

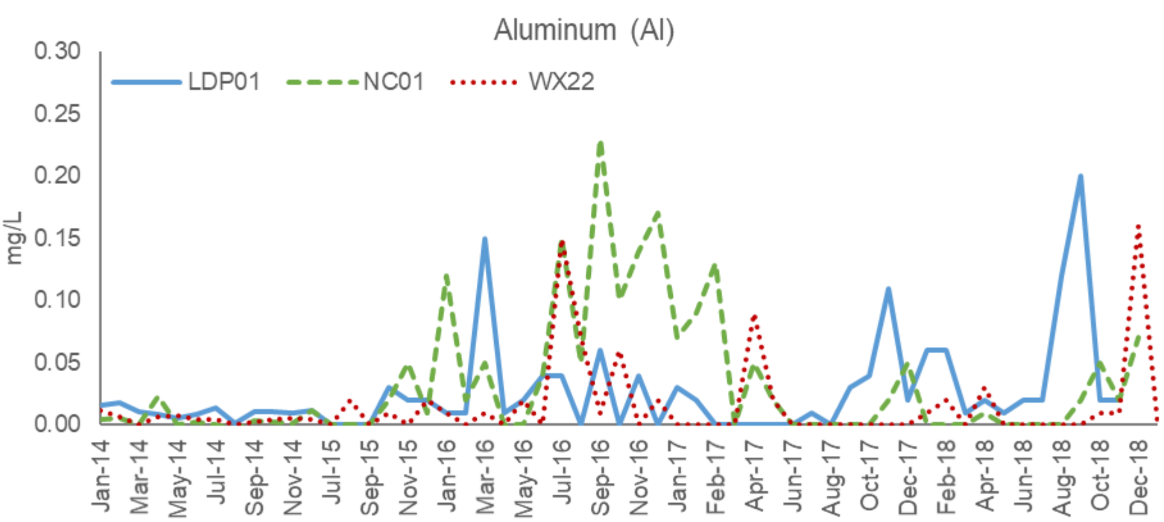


Figure 5-3 Concentrations (mg / L) of a) nickel, b) zinc and c) aluminium measured at LDP01, NC01 and WX22 on Neubecks Creek by EnergyAustralia from January 2014 to July 2018.

5.3 AUSRIVAS Macroinvertebrates

5.3.1 General Findings

5.3.1.1 Identified Taxa

A total of 54 taxa were identified from the 12 samples collected in spring 2018 (Appendix E). Over the course of the EMP, a total of 89 macroinvertebrate taxa have been identified from the 43 edge samples collected in spring from sites NCR1, NCR2, NCR3, A16 and CR0 (not sampled in 2018). Out of the 78 assigned a SIGNAL2 grade, 59 were assigned a grade of 5 or lower, indicating that the majority of taxa are moderately to very tolerant of pollution. Seven taxa (Athericidae, Gripopterygiidae, Hydrobiosidae, Leptophlebiidae, Telephlebiidae, Glossosomatidae and Philopotamidae) have a SIGNAL2 grade of 8 to 9, indicating they are sensitive to pollution. Leptophlebiidae were found at the majority of samples collected from NCR1 and NCR2.

The most common taxa identified from edge samples (those identified in over half all samples from Neubecks Creek and Coxs River) included Dytisidae (diving beetles), Leptophlebiidae (mayflies), Chironomidae (non-biting midge) (consisting of the subfamilies: Chironominae, Orthocladiinae and Tanypodinae) and Corixidae (backswimmers). Leptophlebiidae are pollution sensitive, however, most of the other taxa are pollution tolerant (SIGNAL2 grade 2 to 4). Few taxa appeared to be restricted to individual sites or separate watercourses. There was some evidence to suggest that Caenidae, may not occur, or are uncommon at NCR1, and that Atyidae, may not occur, or are uncommon at A16. These taxa have been assigned SIGNAL2 Grades of 1 to 4. It should be noted, however, that the presence of pollution tolerant taxa does not necessarily indicate poor water quality, as these taxa would be expected to occur in watercourses with good water quality also.

A mountain galaxiid was caught in the AUSRIVAS dip net at NCR3 in autumn and spring of 2018.

5.3.1.1 Number of Taxa

The number of macroinvertebrate taxa identified from edge samples collected at NCR1 has ranged from 14 to 25, 14 to 29 at NCR2, 13 to 25 at NCR3 and 7 to 24 at A16 (**Appendices F** and **G**). No site had consistently more or fewer taxa and there was no strong evidence of trends in these data, though fewer taxa were identified at NCR2 in spring 2013 to spring 2018 (following commencement of ash placement on the Project site), than in spring 2012 (prior to construction and ash placement).

5.3.1.2 Number of EPT Taxa

The number of EPT taxa identified from edge samples collected from NCR1 has ranged from 1 to 4, 2 to 6 at NCR2, 0 to 3 at NCR3 and 1 to 8 at A16 (**Appendices F** and **G**). The number of EPT taxa sampled at NCR1 and NCR2 has been relatively consistent, except a larger number were sampled at NCR2 in spring 2012. Overall, more EPT taxa have been sampled at A16 than at the other sites sampled, particularly NCR3.

5.3.1.3 OE50 Taxa Score

The OE50 Taxa Score at NCR1 has ranged from 0.47 to 0.95, 0.43 to 1.04 at NCR2, 0.38 to 0.85 at NCR3 and 0.36 to 0.91 at A16 (**Appendices F** and **G**). OE50 Scores from 0.20 to 0.51 indicate severely impaired habitat (Band C), those from 0.52 to 0.83 indicate significantly impaired habitat (Band B) and those from 0.84 to 1.16 indicate habitat equivalent to reference condition (Band A). These results indicated that on all but one occasion (NCR2 in spring 2012) the macroinvertebrate assemblages sampled were less diverse than predicted (i.e. OE50 Taxa Score < 1.0). There was limited evidence to suggest a decrease in OE50 Taxa Score between spring 2012 and spring 2016 at NCR2, however, the OE50 Taxa Score in Spring 2018 was relatively high.

5.3.1.4 SIGNAL2 Score

The SIGNAL2 Score at NCR1 ranged from 3.3 to 4.2 (indicative of severe to moderate pollution), 3.7 to 4.9 (indicative of severe to moderate pollution) at NCR2, 2.9 to 4.1 (indicative of severe to moderate pollution) at NCR3 and 3.6 to 5.0 (Indicative of severe to mild pollution) at A16 (**Appendices F** and **G**). The SIGNAL2 Score at NCR3 in 2015 was 2.9 and 3.2 (indicative of severe pollution). These results suggest that Neubecks Creek and the Coxs River at these sites experience some degree of environmental stress due to poor water quality. There were no obvious trends in SIGNAL2 data.

5.3.2 Relative Contribution of Taxonomic Groups

The relative contribution of taxonomic groups in edge samples was relatively consistent among sites and surveys, and there was little evidence of any substantial changes in the relative contribution of taxonomic groups occurring at NCR2 that could be indicative of an impact (**Figure 5-4**). Oligochaetes and hydracarina were absent from one of the samples collected at NCR2 in spring 2016, however, neither is sensitive to water pollution.

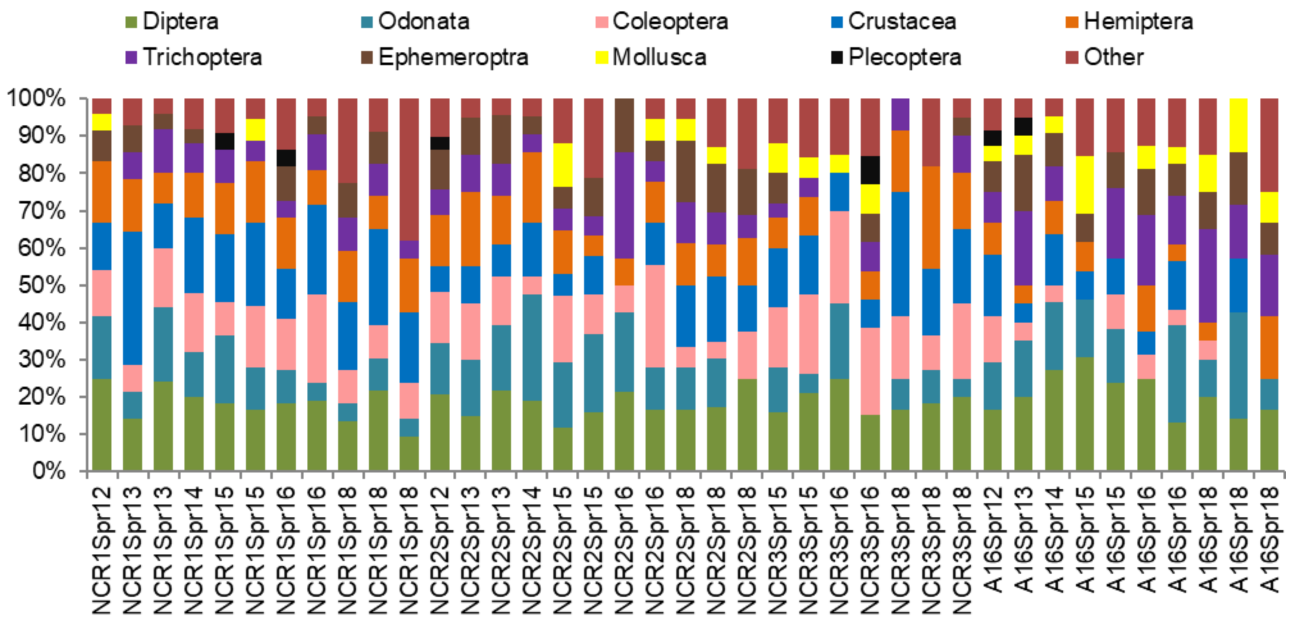


Figure 5-4 Relative contribution of major taxonomic groups identified from AUSRIVAS edge samples collected at NCR1, NCR2 and NCR3 on Neubecks Creek and A16 on the Coxs River during spring of 2012, 2013, 2014, 2015, 2016 and 2018. Based on data averaged across sites when more than 1 replicate were collected. 'Other' includes taxa in the Families Pyralidae and Dugesiidae, the Order Temnocephalida, Subclasses Oligochaeta and Collembola and the taxonomic group Hydracarina.

5.3.3 Statistical Analyses

None of the PERMANOVA tests indicated a statistically significant interaction between Survey and Site (**Table 5-1** and **Table 5-2**) that could be indicative of a project related impact. The only statistically significant sources of variation were the main effects of Survey and Site for multivariate assemblage structure evident in both analyses. Main effects do not indicate an impact.

The PCO undertaken for all edge assemblages sampled (except at CR0) during spring of 2012, 2013, 2014, 2015, 2016 and 2018 is presented in **Figure 5-5a**. There is evidence to suggest that assemblages at A16 differed from those at each other sites. This is evident in assemblages from A16 tending to group towards the left of the PCO away from those at the other sites. There was little evidence of other distinct groupings. The results of the CLUSTER diagram (**Figure 5-5b**) are reflective of the PCO, with generally little evidence of distinct groupings of samples from particular Surveys and Sites. The only exception evident in the PCO was two of the samples from A16 in spring 2018, which were relatively dissimilar from each other and all other assemblages sampled.

Replicate samples tended to be most similar to each other (e.g. those from NCR3 in spring 2015), though several replicate samples were also relatively dissimilar (e.g. NCR2 in spring 2015). Differences among replicates could indicate relatively great natural variation in macroinvertebrate assemblages at the time of sampling.

Table 5-1 Summary of results of PERMANOVA analyses undertaken using AUSRIVAS data collected from NCR1 and NCR2 in spring of 2013, 2015, 2016 and 2018. * = P ≤ 0.05, ** = P ≤ 0.01, *** = P ≤ 0.001, ns = not statistically significant. See **Appendix H** for full results

Indicator			Source of Variation
	Survey	Site	Survey x Site
Number of Taxa	ns	ns	ns
Number of EPT Taxa	ns	ns	ns
OE50 Taxa Score	ns	ns	ns
SIGNAL2 Score	ns	ns	ns
Assemblage	**	**	ns

Table 5-2 Summary of results of PERMANOVA analyses undertaken using AUSRIVAS data collected from NCR1, NCR2, NCR3 and A16 in spring of 2015, 2016 and 2018. * = P ≤ 0.05, ** = P ≤ 0.01, *** = P ≤ 0.001, ns = not statistically significant. See **Appendix H** for full results

Indicator			Source of Variation
	Survey	Site	Survey x Site
Number of Taxa	ns	ns	ns
Number of EPT Taxa	ns	ns	ns
OE50 Taxa Score	ns	ns	ns
SIGNAL2 Score	ns	ns	ns
Assemblage	***	***	ns

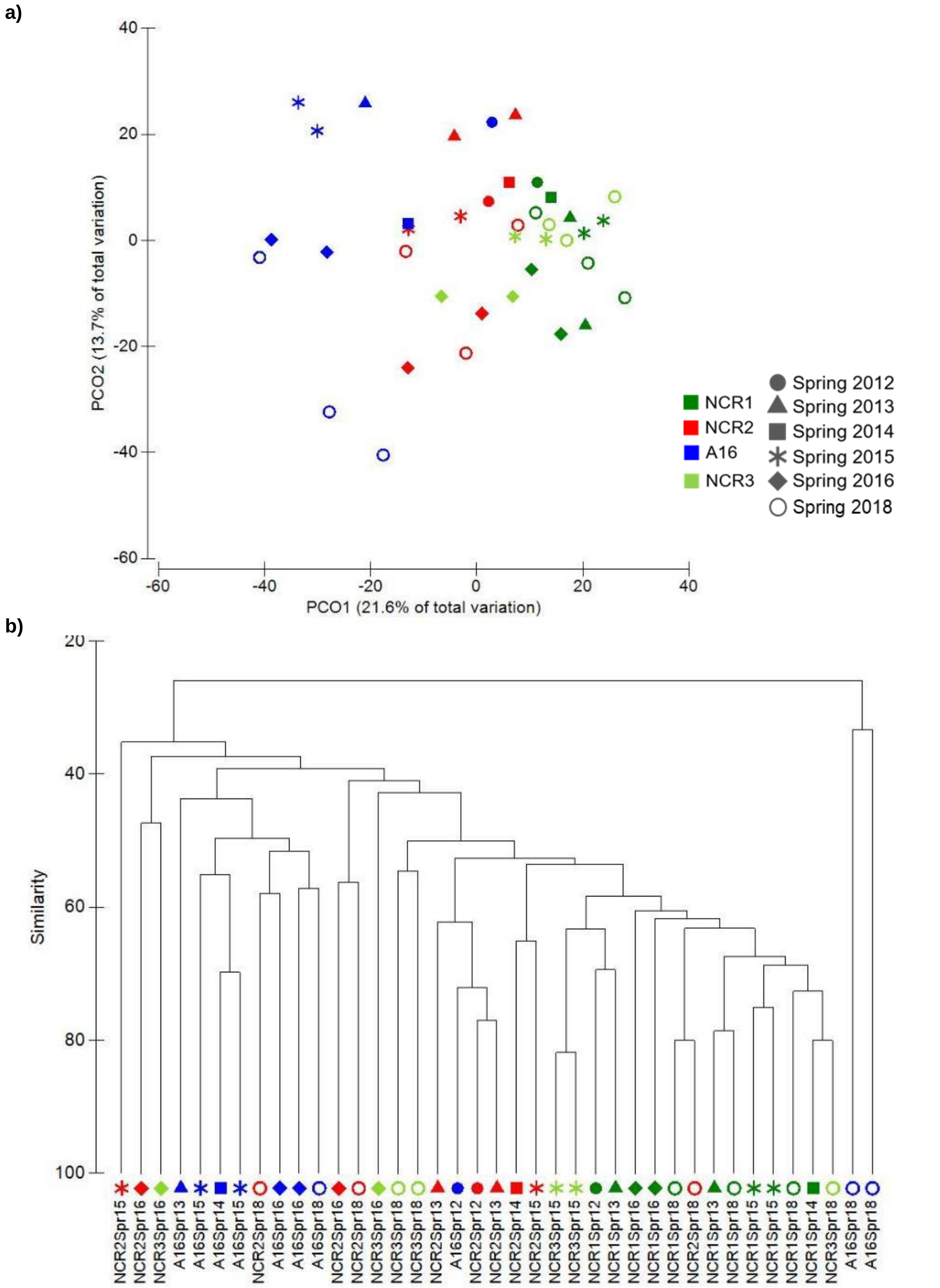


Figure 5-5 a) Principal Coordinates Analysis (PCO) and b) CLUSTER diagram of AUSRIVAS edge macroinvertebrate assemblages sampled using AUSRIVAS at NCR1, NCR2 and NCR3 on Neubecks Creek and at A16 on Coxs River in spring of 2012 to 2016 and 2018.

6 Discussion

6.1 Aquatic Habitat

The findings of this and previous investigations indicate that aquatic habitat in Neubecks Creek has experienced past degradation due primarily to local industry and historic land clearing. This appears to have been more severe at NCR2, where the condition of the riparian vegetation, creek banks and streambed were poorer compared with that upstream at NCR1 and NCR3. While these sites have experienced impacts in the past, no further direct impacts to aquatic habitat in Neubecks Creek (e.g. creek realignment, vegetation clearing) due to the Project were predicted or have been detected. Although the current condition of aquatic habitat in Neubecks Creek is not attributable to the Project, the differences in habitat observed between NCR2 and monitoring sites further upstream in Neubecks Creek (NCR1 and NCR3) and the upstream monitoring site in the Coxs River could be expected to influence the number and type of macroinvertebrate taxa (and other aquatic biota) found in samples at these sites. There was greater abundance of riparian and aquatic vegetation at NCR1 and NCR3 compared with NCR2 and A16. The additional food and habitat this would afford may partly explain any differences in the structure of macroinvertebrate assemblages sampled at these sites, and why assemblages sampled at NCR2 and A16 were similar, despite being on different watercourses (at least in spring data collected up until 2016). The presence of the mountain galaxiid in the dip net at NCR3 in autumn of 2017 and spring of 2018 also indicates that the creek is providing habitat for at least one native species of fish.

6.2 Water Quality and Hydrology

Water quality in Neubecks Creek is influenced by various types of anthropogenic disturbance. This is evident in several indicators (e.g. EC and concentrations of several metals) being in excess of default guidelines for the protection of aquatic life. Aurecon (2014) attributed these impacts to previous and current coal mining and power generation activities, among others. While the Project may also be influencing water quality in Neubecks Creek, it has not been possible to discriminate potential changes in water quality associated with the Project from the effects of other pre-existing influences (e.g. groundwater seepage from Ash Area 1 and LDP 01). The duration and magnitude of elevated measures of some water quality indicators in Neubecks Creek appear to be influenced by flow, which in turn is influenced by patterns in local rainfall (no major flow controlling impoundments are present on Neubecks Creek). During periods of low rainfall and flow, water in Neubecks Creek likely consists of a series of disconnected pools where evaporation results in increased EC and concentrations of metals (Aurecon 2014). Periods of high rainfall and flow will have a diluting effect, thereby reducing the EC and the concentrations of metals. This process likely explains the variation in measures of water quality observed in Neubecks Creek. Differences in the location, duration and magnitude of elevated measures of water quality in Neubecks Creek will depend on a complex interaction between the characteristic and source of each impact to water quality in Neubecks Creek (e.g. historic and current coal mining activities, power generation and historic land clearing etc.) and local rainfall, discharge and hydrology.

While the relative influence of impacts to water quality from multiple sources in Neubecks Creek remains unclear at this time, the changes that have been observed during the course of the EMP, and variation among sites, would be expected to influence macroinvertebrates (and other aquatic flora and fauna) in the creek. This may have explained the apparent change in biotic indices and structure of the macroinvertebrate assemblage sampled at NCR2 in autumn 2013 following the commencement of construction on the Project site (Cardno Ecology Lab 2015a). In any case, elevations in EC at this time were attributed to rainfall and flow patterns in the creek, rather than any impacts due to the Project (Aurecon 2014) (**Section 2.3**). The depauperate macroinvertebrate assemblage sampled in Neubecks Creek by Battaglia *et al*. (2005) was attributed to reduced pH (measured at pH 5.1 in Neubecks Creek compared with pH 6.5 to 6.7 in reference creeks), high concentrations of metals, or a combination of these, associated with acid mine drainage (AMD). pH data collected by EnergyAustralia suggest that, while somewhat variable, pH in Neubecks Creek is currently largely within DTVs for the protection of aquatic life.

Measures of water quality sampled in November 2014 (Cardno Ecology Lab 2015a), December 2015 (Cardno Ecology Lab 2016), in December 2016 (Cardno 2017) and in May 2018 (Cardno 2018) were generally comparable to those measured previously as part of the EMP (GHD 2014b to e). In 2014 and 2015 the EC at NCR2 and A16 was greater than that sampled previously (255 to 694 µS/cm and 350 to 826 µS/cm at NCR2 and A16, respectively). Although the EC recorded in Neubecks Creek during the course of the EMP was often well in excess of the upper DTV (350 µS/cm), this does not necessarily mean that this poses a threat to aquatic life. The relatively lower EC recorded in Neubecks Creek in December 2016 was likely a result of a diluting effect of recent rainfall and higher flows, whereas the elevated EC at WX22 in early 2018 appeared to be associated with low rainfall. A review of the sensitivity of Australian freshwater biota to salinity undertaken by Hart *et al*. (1991) indicates that adverse effects on freshwater macroinvertebrates are likely to become apparent when salinity rises to around 1,000 mg/L (approximately 1,562 µS/cm). Aquatic macrophytes and riparian plants are slightly more tolerant, being sensitive to salinities from 1,000 to 2,000 mg/L (1,562 to 3,134 µS/cm) and above 2,000 mg/L (>3,134 µS/cm), respectively. Adult fish are tolerant of salinities up to 10,000 mg/L (15,620 µS/cm). A subsequent review of the effects of increasing salinity on freshwater ecosystems in Australia undertaken by Nielsen *et al*. (2003) indicates the following:

> Majority of algae do not tolerate salinities > 10,000 mg/L (15,620 µS/cm);

> Diatoms decrease in abundance and richness as salinity increases;

> Freshwater plants tolerate salinities up to 4,000 mg/L (6,250 µS/cm), but adverse effects on growth and development of roots and leaves become apparent above 1,000 mg/L (1,562 µS/cm);

> Macroinvertebrate fauna of rivers appear to be tolerant and fairly resilient to increasing salinity;

> Structurally simple macroinvertebrates such as soft-bodied hydra, insect larvae and molluscs are more sensitive to increased salinity;

> Salinity tolerance testing of 59 macroinvertebrate taxa indicated tolerance ranged from 5,000 to 50,000 mg/L (7,810 to 78,100 µS/cm), with baetid mayflies and macrocrustaceans being the least and most tolerant, respectively; and

> A majority of native and introduced fish appear to be tolerant of salinities in excess of 3,000 mg/L (4,686 µS/cm).

These findings would suggest that the ECs measured in Neubecks Creek during the course of the EMP (i.e. approximately 100 to 2,000 µS/cm), while not ideal (i.e. within guidelines), should not have substantial detrimental effects on most macroinvertebrates. Baetid mayflies, which were found to be particularly sensitive to EC, occurred in nine of the twenty spring edge samples collected from Neubecks Creek (Cardno 2017) and at NCR2 in the current study.

Elevated concentrations of some metals were detected at WX22 adjacent to the ash placement area in 2018. Clear elevations in the concentrations of some metals were also detected around March 2015, though by the time of the 2015 survey, concentrations of these were longer elevated. Elevations in the concentrations of barium, nickel, aluminium, and zinc in Neubecks Creek have also been previously detected, and prior to previous aquatic ecology investigations. However, no clear association with water quality and macroinvertebrate data was found during this or in previous surveys (Cardno Ecology Lab 2015a and Cardno 2016). Prior to the spring 2018 survey, concentrations of aluminium, boron, nickel and zinc were elevated at some sites on Neubecks Creek (**Section 5.2**), although this was not reflected in the macroinvertebrate assemblage (**Section 6.3.2**).

Due to the historic and current coal mining, power generation and historic land clearing activities (among others) it is difficult to isolate Project related impacts on water quality from background conditions. Nevertheless, the collection and interpretation of water quality data during monitoring of aquatic ecology will help identify the most likely causes of any changes detected in macroinvertebrate data indicative of an impact. This information would help target any future impact minimisation and remediation efforts.

6.3 Macroinvertebrates

6.3.1 General Findings

The findings of the current study support those of previous investigations. The macroinvertebrate assemblage supported by Neubecks Creek appears to experience some degree of environmental stress. This is evident in OE50 Taxa Scores and Bands generally indicative of macroinvertebrate assemblages that are less diverse than predicted by the AUSRIVAS model, and thus relatively poor aquatic habitat and / or water quality. Low individual taxon SIGNAL2 grades and SIGNAL2 Scores are also indicative of severe to moderate pollution.

Despite this, some pollution sensitive taxa were also identified. This suggests that while the macroinvertebrate assemblage does experience some degree of environmental stress due to poor habitat and water quality, conditions are not as severe as what might be expected considering the sometimes degraded water quality of Neubecks Creek. The ecological health of Neubecks Creek also does not appear to be particularly poor in a regional context. AUSRIVAS data collected from Neubecks Creek were comparable to those collected from A16 on the Coxs River, which has, and continues to, experience a similar level of disturbance (i.e. impacts to water quality and the condition of riparian vegetation). These results were also comparable to those of the ongoing Coxs River Biological Monitoring Program, where the AUSRIVAS Bands at sites on the Coxs River downstream of Neubecks Creek during 2011 to 2015 ranged from Band C to Band B, with most sites on most occasions assigned Band B (Cardno Ecology Lab 2015b).

The presence of a sensitive family of mayfly (Leptophlebiidae) in edge samples collected from Neubecks Creek indicates that impaired water quality is having a limited effect. Previously, fewer leptophlebiids have been associated with elevated ECs due to mine water discharge in the Georges River (Cardno Ecology Lab 2010a and references therein). This study, and the findings of an Australian Coal Industry Research Program (ACARP) funded study into the effects of saline water discharge on aquatic biota in the Southern and Hunter Coalfields of NSW (Cardno Ecology Lab 2010b), also suggested that elevated EC can influence the abundance of aquatic macroinvertebrates.

While low pH was suggested as a possible cause of depauperate macroinvertebrate assemblages in Neubecks Creek in an earlier study by Battaglia *et al*. (2005), this was not the case during the course of the EMP. pH measured during the EMP was above that measured in Neubecks Creek (pH 5.1) by Battaglia *et al*. (2005) and largely within DTVs. The findings here are similar to those of Soucek *et al*. (2000), where the abundance and diversity of macroinvertebrates was found to be reduced in streams affected by acid mine discharge (albeit not an impacting process in this instance), irrespective of pH, suggesting other factors such as metal toxicity were responsible.

Any inferences regarding the role of water quality in influencing macroinvertebrates in Neubecks Creek must be made with caution as several other measures of water quality not considered here, such as concentrations of nutrients, or a combination of these, may be influencing macroinvertebrates in Neubecks Creek. It is also possible that the macroinvertebrate fauna present in Neubecks Creek has, over time, become tolerant to impaired water quality and that any short-term elevations in otherwise already elevated measures may have a limited observable effect.

6.3.2 Changes in Macroinvertebrates

None of the PERMANOVA tests indicated a change in spring 2018 that could be attributed to a Project related impact. Likewise, there was no evidence of any trends in data collected in spring that could be indicative of an impact occurring. This is consistent with the findings of previous investigations in spring (**Section 2.3**). Overall, data collected over the course of the EMP does not suggest any impact to macroinvertebrates in Neubecks Creek has occurred due to the Project. There were also no changes in macroinvertebrate indicators sampled from autumn 2013 to autumn 2018 that indicate an impact (Cardno 2018). Although the total number of taxa and number of EPT taxa at NCR2 was lower in autumn 2018 than in autumn of 2013 and 2014, similar changes were also observed at the control location NCR1 (Cardno 2018).

7 Conclusion and Recommendations

There was no conclusive evidence to suggest a change in macroinvertebrate indicators occurred at NCR2 in spring 2018 that could be associated with the Project. Furthermore, the condition of aquatic habitat and biota at NCR2 did not differ substantially from the habitat upstream of the Project.

The complex interaction that exists between the various types of disturbances experienced in Neubecks Creek make any changes in water quality, and thus associated changes in macroinvertebrates, difficult to distinguish from those that could be due to the Project. Nevertheless, the Environmental Monitoring Program adds value to the wider monitoring program, and it is expected that any large magnitude and / or cumulative impacts to aquatic biota would be detected, allowing appropriate management actions to be implemented. Recent changes to the monitoring of aquatic ecology, including the addition of two further macroinvertebrate control sites, will assist in identifying any future impacts, were they to occur, and help inform future impact minimisation and remediation efforts as necessary.

The following recommendations will help to ensure the robustness of the EMP and the detection of potential impacts on aquatic ecology due to the Project:

1. Further monitoring should be undertaken annually in spring during operation of the Project and for at least five years after completion of all activities that could impact aquatic ecology.
2. There would be merit in undertaking annual sampling in autumn. Although baseline data is not available from autumn, the results of monitoring in autumn would complement that undertaken in spring and provide further confidence regarding the presence or absence of a potential impact associated with the Project.
3. Sampling should continue at the additional control sites established on Neubecks Creek (NCR3). While no baseline data is available from this site, control data collected here during future surveys would improve the power of statistical tests and aid in the detection of an impact occurring in the future.
4. Sampling should be discontinued at control Site CR0 as this site has been found dry on more than one occasion and is thus unlikely to provide suitable control data. The two control sites on Neubecks Creek (NCR1 and NCR3) will provide suitable control data during future surveys.
5. Three replicate AUSRIVAS samples should continue to be collected from each site during all future surveys. This will provide a measure of the variation present in each indicator at each site, thereby, improving the ability to detect any future impact by enabling the use of appropriate statistical analysis.
6. The use of quantitative macroinvertebrate sampling methods should be incorporated to provide more robust data and additional confidence surrounding the findings of the EMP.

At this stage no Project specific mitigation, impact minimisation or ameliorate actions are recommended. Such actions may be appropriate and may be recommended following more definitive assessments of the presence or absence of an impact that will be undertaken in subsequent monitoring reports and following the recommendations described above.

8 References

ANZECC and ARMCANZ (2000). Australian and New Zealand Guidelines for Fresh and Marine Water Quality, National Water Quality Management Strategy No. 4, Australian and New Zealand Environment and Conservation Council and the Agriculture and Resource Management Council of Australia and New Zealand, October 2000.

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

Aurecon (2014). Lamberts North Water Conditioned Fly Ash Placement Water Quality Monitoring. Annual Update Report 2013/14.

Aurecon (2015). Lamberts North Water Conditioned Fly Ash Placement Water Quality Monitoring. Annual Update Report for 2014/15.

Battaglia, M., Hose, G. C., Turak, E., & Warden, B. (2005). Depauperate macroinvertebrates in a mine affected stream: clean water may be the key to recovery. *Environmental Pollution*, **138(1)**, 132-141.

BOM (2019). Website. Bureau Home. Climate. Climate Data Online. http://www.bom.gov.au/climate/data/

Cardno (2016a). Neubecks Creek EMP Spring 2012 to Spring 2015. Prepared for EnergyAustralia NSW

Cardno (2016b). Coxs River Biological Monitoring Program. 2011 to 2015. Prepared for EnergyAustralia NSW

Cardno (2017). Neubecks Creek EMP Spring 2012 to Spring 2016. Prepared for EnergyAustralia NSW

Cardno (2018). Neubecks Creek EMP Autumn 2012 to Autumn 2018. Prepared for EnergyAustralia NSW

Cardno Ecology Lab (2010a). West Cliff Colliery. Pollution Reduction Program 10 – Discharge of Water from Brennans Creek Dam. PRP 10.1 Report. Prepared for BHP Billiton Illawarra Coal.

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

Cardno Ecology Lab (2014). Neubecks Creek EMP. Critical Review. Prepared for EnergyAustralia NSW.

Cardno Ecology Lab (2015a). Neubecks Creek EMP Spring 2012 to Spring 2014. Prepared for EnergyAustralia NSW

Cardno Ecology Lab (2015b). Coxs River Biological Monitoring 2014. Prepared for EnergyAustralia.

Chessman, B.C Growns, J.E and Kotlash, A.R. (1997). Objective derivation of macroinvertebrate family sensitivity grade numbers for the SIGNAL biotic index: Application to the Hunter River system, New South Wales. Marine and Freshwater Research, 48, pp. 159-172.

Chessman (2003). SIGNAL2.iv. A Scoring System for Macroinvertebrates ('Water Bugs') in Australian Rivers. User Manual. September 2003.

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

DECCW (2010). 2010 Audit of the Sydney Drinking Water Catchment. Volume 1 – Main report.

DWR (1994). Aquatic Flora and Fauna Survey of Neubecks Creek. Consultancy Report prepared for Pacific Power by the Environmental Studies Unit, Department of Water Resources, Parramatta, NSW. June 1994. pp. 25.

SCA (2010). Audit of the Sydney Drinking Water Catchment, Volume 1 – Main Report, pp. 227. (http://www.environment.nsw.gov.au/resources/water/10973AuditSDWCvol1.pdf.)

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

Centennial Coal (2012). The Neubeck Coal Project. Briefing Paper.

GHD (2013). 2013 Audit of the Sydney Drinking Water Catchment.

GHD (2014a). Neubecks Creek – Ecological Monitoring Program. Report Prepared for Delta Electricity. Rev 2 - July 2014.

GHD (2014b). Neubecks Creek – Ecological Monitoring Program. Aquatic Ecosystem Baseline Survey – Spring 2012. Rev 2 – July 2014.

GHD (2014c). Neubecks Creek – Ecological Monitoring Project. Aquatic Ecosystem Annual Report 2012-2013. Rev 3 – July 2014.

GHD (2014d). Neubecks Creek – Ecological Monitoring Project. Aquatic Ecosystem Report Spring 2013. Final - March 2014.

GHD (2014e) Neubecks Creek – Ecological Monitoring Project. Aquatic Ecosystem Report Autumn 2014. Rev 1 - September 2014.

Hart, B.T., Bailey, P., Edwards, R., Hortle, K., James, K., McMahon, A., Meredith, C., and Swadling, K. (1991). A review of the salt sensitivity of the Australian freshwater biota. *Hydrobiologia* **210**: pp. 105-144.

Nielsen, D.L., Brock, M.A., Rees, G.N. and Baldwin, D.S. (2003). Effects of increasing salinity on freshwater ecosystems in Australia. *Australian Journal of Botany* **51**: pp. 655-665.

Peterson, R.C. (1992). The RCE: a Riparian, Channel, and Environmental Inventory for small streams in the agricultural landscape. Freshwater Biology, 27, pp. 295-306.

QLD Department of Natural Resources and Mines (DNRM) (2001). National River Health Program. Australia-Wide Assessment of River Health: Queensland AUSRIVAS Sampling and Processing Manual. Monitoring River Health Initiative Technical Report. Report Number 12.

SKM (2010). Mt Piper Power Station Ash Placement Project. Environmental Assessment. Sinclair Knight Mertz. Prepared for EnergyAustralia NSW.

Sydney Water (2016). Website. Real Time Data. Rivers and Streams. https://realtimedata.waternsw.com.au/

Soucek, D.J., Cherry, D.S., Currie, R.J., Latimer, H.A., Trent, G.C. (2000). Laboratory to Field Validation in an Intergrative Assessment of an Acid Mine Drainage – Impacted Watershed. *Environmental Toxicology and Chemistry,* **19**: pp. 1036-1043.

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

APPENDIX

A

GPS COORDINATES OF AQUATIC ECOLOGY MONITORING SITES FOR THE NEUBECKS CREEK EMP

Site	Latitude	Longitude
NCR1	-33.35061	150.04753
NCR2	-33.35822	150.05704
NCR3	-33.35205	150.04852
A16	-33.38001	150.07990
CR0	-33.32678	150.09817

Datum: WGS 84, Zone 56H

APPENDIX B

REFERENCE CONDITION SELECTION CRITERIA

No.	Reference Condition Selection Criteria Category	Comment
1	Influence of intensive agriculture upstream	Intensive agriculture is that which involves irrigation, widespread soil disturbance, use of agrochemicals and pine plantations. Dry-land grazing does not fall into this category.
2	Influence of major extractive industry (current or historical) upstream	This includes mines, quarries and sand/gravel extraction.
3	Influence of major urban area upstream	This will be relative to population size, river size and distance between the site and the impact.
4	Influence of significant point-source waste water discharge upstream	Exceptions can be made for small discharges into large rivers.
5	Influence of dam or major weir	Sites within the ponded area of impoundments also fail.
6	Influence of alteration to seasonal flow regime	This may be due to abstraction or regulation further upstream than the coverage by Criterion 5. Includes either an increase or decrease in seasonal flow.
7	Influence of alteration to riparian zone	Riparian vegetation should be intact and dominated by native species.
8	Influence of erosion and damage by stock on riparian zone and banks	Stock damage to the stream bed may be included in this category.
9	Influence of major geomorphological change on stream channel	Geomorphological change includes bank slumping, shallowing, braiding and unnatural aggradation or degradation.
10	Influence of alteration to in-stream conditions and habitats	This may be due to excessive algal and macrophyte growth, by sedimentation and siltation, by reduction in habitat diversity by drowning or drying out of habitats (e.g. riffles) or by direct access of stock into the river

APPENDIX C

RIVER, CHANNEL AND ENVIRONMENTAL (RCE) CATAGORIES

Descriptor and category	Score
1. Land use pattern beyond the immediate riparian zone	
Undisturbed native vegetation	4
Mixed native vegetation and pasture/exotics	3
Mainly pasture, crops or pine plantation	2
Urban	1
2. Width of riparian strip of woody vegetation	
More than 30 m	4
Between 5 and 30 m	3
Less than 5 m	2
No woody vegetation	1
3. Completeness of riparian strip of woody vegetation	
Riparian strip without breaks in vegetation	4
Breaks at intervals of more than 50 m	3
Breaks at intervals of 10 - 50 m	2
Breaks at intervals of less than 10 m	1
4. Vegetation of riparian zone within 10 m of channel	
Native tree and shrub species	4
Mixed native and exotic trees and shrubs	3
Exotic trees and shrubs	2
Exotic grasses / weeds only	1
5. Stream bank structure	
Banks fully stabilised by trees, shrubs etc.	4
Banks firm but held mainly by grass and herbs	3
Banks loose, partly held by sparse grass etc.	2
Banks unstable, mainly loose sand or soil	1
6. Bank undercutting	
None, or restricted by tree roots	4
Only on curves and at constrictions	3
Frequent along all parts of stream	2
Severe, bank collapses common	1
7. Channel form	
Deep: width / depth ratio < 7:1	4
Medium: width / depth ratio 8:1 to 15:1	3
Shallow: width / depth ratio > 15:1	2
Artificial: concrete or excavated channel	1

Descriptor and category	Score
8. Riffle / pool sequence	
Frequent alternation of riffles and pools	4
Long pools with infrequent short riffles	3
Natural channel without riffle / pool sequence	2
Artificial channel; no riffle / pool sequence	1
9. Retention devices in stream	
Many large boulders and/or debris dams	4
Rocks / logs present; limited damming effect	3
Rocks / logs present, but unstable, no	2
Stream with few or no rocks / logs	1
10. Channel sediment accumulations	
Little or no accumulation of loose sediments	4
Some gravel bars but little sand or silt	3
Bars of sand and silt common	2
Braiding by loose sediment	1
11. Stream bottom	
Mainly clean stones with obvious interstices	4
Mainly stones with some cover of algae / silt	3
Bottom heavily silted but stable	2
Bottom mainly loose and mobile sediment	1
12. Stream detritus	
Mainly un-silted wood, bark, leaves	4
Some wood, leaves etc. with much fine	3
Mainly fine detritus mixed with sediment	2
Little or no organic detritus	1
13. Aquatic vegetation	
Little or no macrophyte or algal growth	4
Substantial algal growth; few macrophytes	3
Substantial macrophyte growth; little algae	2
Substantial macrophyte and algal growth	1

APPENDIX D

RESULTS OF RCSC AND RCE ASSESSMENTS

River, Channel and Environmental (RCE) Category					Site
	NCR1	NCR2	NCR3	A16	CR0
Land use pattern beyond the immediate riparian zone	3	2	3	2	3
Width of riparian strip of woody vegetation	3	2	3	1	4
Completeness of riparian strip of woody vegetation	2	1	2	1	3
Vegetation of riparian zone within 10 m of channel	3	2	3	1	4
Stream bank structure	3	1	3	2	3
Bank undercutting	4	1	4	3	4
Channel form	3	3	3	4	3
Riffle / pool sequence	2	2	2	4	2
Retention devices in stream	3	1	3	2	2
Channel sediment accumulations	2	2	2	4	2
Stream bottom	3	3	3	4	2
Stream detritus	3	2	3	2	3
Aquatic vegetation	2	3	2	3	3
Total	36	25	36	33	38

Reference Condition Selection Criteria Category					Site
	NCR1	NCR2	NCR3	A16	CR0
Influence of intensive agriculture upstream	5	5	5	5	5
Influence of major extractive industry (current or historical) upstream	1	1	1	1	5
Influence of major urban area upstream	3	3	3	5	5
Influence of significant point-source waste water discharge upstream	2	2	2	2	5
Influence of dam or major weir	5	5	5	5	5
Influence of alteration to seasonal flow regime	3	3	3	3	5
Influence of alteration to riparian zone	1	1	1	1	4
Influence of erosion and damage by stock on riparian zone and banks	5	5	5	3	5
Influence of major geomorphological change on stream channel	3	1	3	2	4
Influence of alteration to in-stream conditions and habitats	3	3	3	3	5

1 = Very major impact

2 = Major impact

3 = Moderate impact

4 = Minor impact

5 = Indiscernible impact

APPENDIX E

RAW AUSRIVAS DATA DECEMBER 2018

Taxon	NCR1			NCR2			NCR3			A16		
Rep:	1	2	3	1	2	3	1	2	3	1	2	3
Dugesiidae										2		
Nematoda	1					1						1
Corbiculidae/ Sphaeriidae										3	3	1
Lymnaeidae				1								
Physidae					1					2		
Glossiphoniidae		1										
Oligochaeta					2							2
Cladocera	10	3	1	1	1		1	1			1	
Copepoda	10	10	10	3	7	3			10			
Ostracoda	10	6	8		1	1	1		2			
Atyidae	2	2	3	2			2	2	1			
Parastacidae		1			1		1		1			
Decapoda larvae		2										
Hydracarina	3	1	8			2		2	1			
Entomobryidae					1							
Caenidae	1			3	2	2						
Baetidae		1		3	6					4	3	1
Leptophlebiidae	1	1		10	3	10			1	10		
Coenagrionidae										2		
Protoneuridae				1								
Megapodagrionidae		3			1			3				
Diphlebiidae (=Amphipterygidae)					1							
Gomphidae					1						2	
Aeshnidae	2	2	2	1					1		1	
Hemicorduliidae							1			5		
Libellulidae												1
Veliidae	3		10	7		1	3	8	3			1
Gelastocoridae					1					3		1
Corixidae	4	2	10		1	3	1	2	2			
Notonectidae	10	3	3					1	1			
Pleidae				3								
Corydalidae	1											
Sialidae				1								
Haliplidae	3		1			1			10			
Dytiscidae	9	2	3		1	2	10	4	8	1		
Hydrochidae		1										
Hydrophilidae				5								
Scirtidae							2		3			
Elmidae									1			
Dixidae		1										
Culicidae		1							2			
Chironominae	4	5	7	2	4	10	1	3	3	1	1	
Tanypodinae	2	8	2	10	10	10	3		2	4		2
Ceratopogonidae	5	4		1	9	2		1	1	2		1
Simuliidae										2		
Tipulidae						2						
Sciomyzidae					1							
Glossosomatidae										2		
Hydroptilidae	1	2		1	7	1	1		7	2		
Hydropsychidae										1		
Ecnomidae										5		1
Calamoceratidae	1											
Leptoceridae		1	1	3	1				1	10	1	2
Pyralidae										1		

Note: a maximum of 10 individuals were counted per sample

APPENDIX F

BIOTIC INDICES RAW DATA

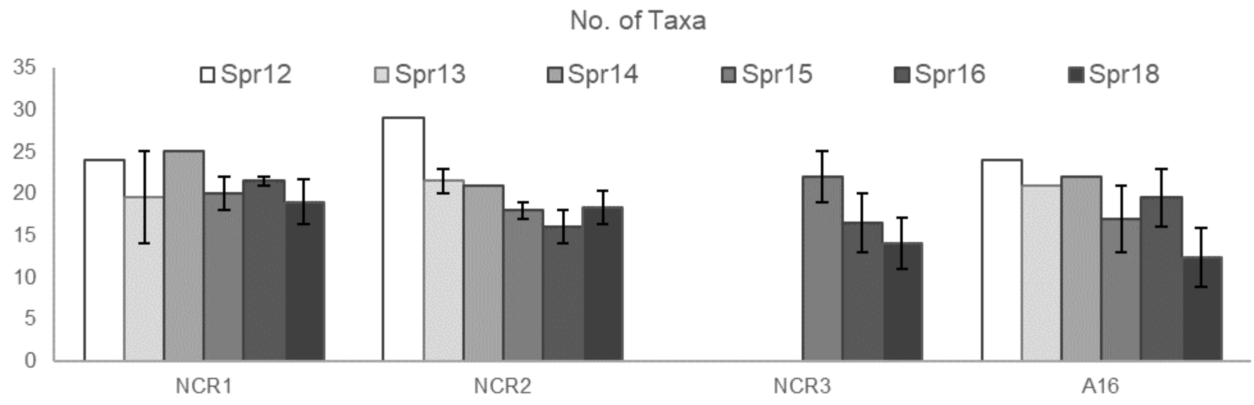
Date	AUSRIVAS Season	No. of Taxa	No. of EPT Taxa	OE50 Taxa Score	AUSRIVAS Band	SIGNAL2 Score
NCR1						
8 Nov 2012	Spring 2012 Rep 1	24	2	0.75	B	3.3
12 Dec 2013	Spring 2013 Rep 1	14	2	0.48	C	3.5
12 Dec 2013	Spring 2013 Rep 2	25	4	0.76	B	3.9
19 Nov 2014	Spring 2014 Rep 1	25	3	0.95	A	3.9
14 Dec 2015	Spring 2015 Rep 1	22	3	0.57	B	3.9
14 Dec 2015	Spring 2015 Rep 2	18	1	0.57	B	3.2
1-2 Dec 2016	Spring 2016 Rep 1	22	4	0.85	A	3.6
1-2 Dec 2016	Spring 2016 Rep 2	21	3	0.72	B	4.2
11 Dec 2018	Spring 2018 Rep 1	20	4	0.75	B	3.9
11 Dec 2018	Spring 2018 Rep 2	23	4	0.63	B	3.9
11 Dec 2018	Spring 2018 Rep 3	14	1	0.47	C	3.3
NCR2						
8 Nov 2012	Spring 2012 Rep 1	29	6	1.04	A	4.0
12 Dec 2013	Spring 2013 Rep 1	20	4	0.57	B	3.7
12 Dec 2013	Spring 2013 Rep 2	23	5	0.94	A	4.0
19 Nov 2014	Spring 2014 Rep 1	21	2	0.86	A	3.9
14 Dec 2015	Spring 2015 Rep 1	17	2	0.43	C	3.4
14 Dec 2015	Spring 2015 Rep 2	19	3	0.77	B	4.3
1-2 Dec 2016	Spring 2016 Rep 1	14	6	0.52	B	4.9
1-2 Dec 2016	Spring 2016 Rep 2	18	2	0.43	C	3.5
11 Dec 2018	Spring 2018 Rep 1	18	5	0.69	B	3.9
11 Dec 2018	Spring 2018 Rep 2	22	5	0.78	B	4.1
11 Dec 2018	Spring 2018 Rep 3	15	3	0.78	B	4.0
NCR3						
14 Dec 2015	Spring 2015 Rep 1	25	3	0.85	A	3.2
14 Dec 2015	Spring 2015 Rep 2	19	1	0.66	B	2.9
1-2 Dec 2016	Spring 2016 Rep 1	20	0	0.47	C	4.2
1-2 Dec 2016	Spring 2016 Rep 2	13	3	0.57	C	4.1
11 Dec 2018	Spring 2018 Rep 1	12	1	0.38	C	3.8
11 Dec 2018	Spring 2018 Rep 2	10	0	0.38	C	3.2
11 Dec 2018	Spring 2018 Rep 3	20	3	0.85	A	3.9
A16						
8 Nov 2012	Spring 2012 Rep 1	24	5	0.91	A	3.9
12 Dec 2013	Spring 2013 Rep 1	20	8	0.73	B	5.0
19 Nov 2014	Spring 2014 Rep 1	22	4	0.73	B	4.6
14 Dec 2015	Spring 2015 Rep 1	13	1	0.52	B	3.6
14 Dec 2015	Spring 2015 Rep 2	21	6	0.73	B	4.4
1-2 Dec 2016	Spring 2016 Rep 1	16	5	0.84	A	3.7
1-2 Dec 2016	Spring 2016 Rep 2	23	5	0.63	B	3.9
11 Dec 2018	Spring 2018 Rep 1	19	7	0.64	B	4.4
11 Dec 2018	Spring 2018 Rep 2	7	2	0.36	C	4.7
11 Dec 2018	Spring 2018 Rep 3	11	3	0.36	C	4.1
CR0						
14 Dec 2015	Spring 2015 Rep 1	19	2	0.75	B	3.6
14 Dec 2015	Spring 2015 Rep 2	24	2	0.92	A	4.0
1-2 Dec 2016	Spring 2016 Rep 1	7	0	0.33	C	2.3
1-2 Dec 2016	Spring 2016 Rep 2	9	0	0.33	C	2.8
Not sampled, site dry						

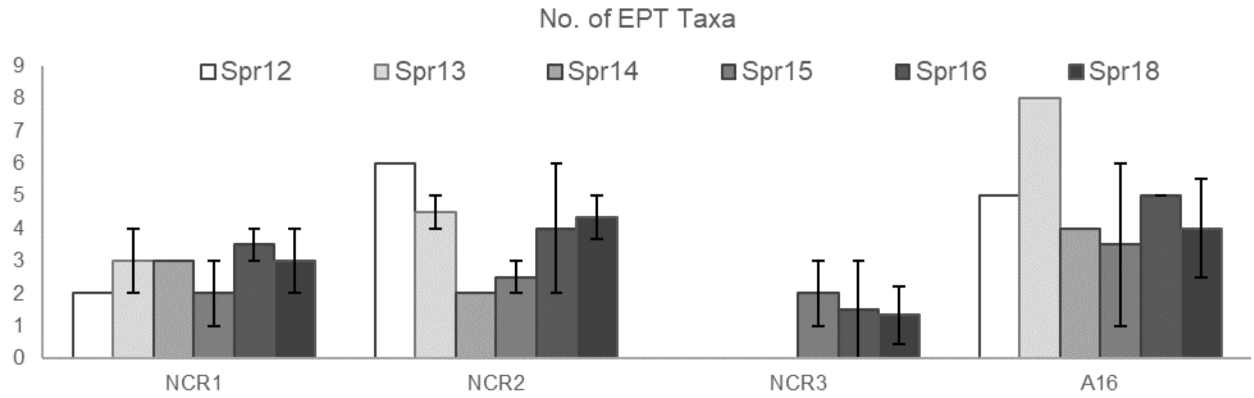
EPT = Ephemeroptera, Plecoptera and Trichoptera

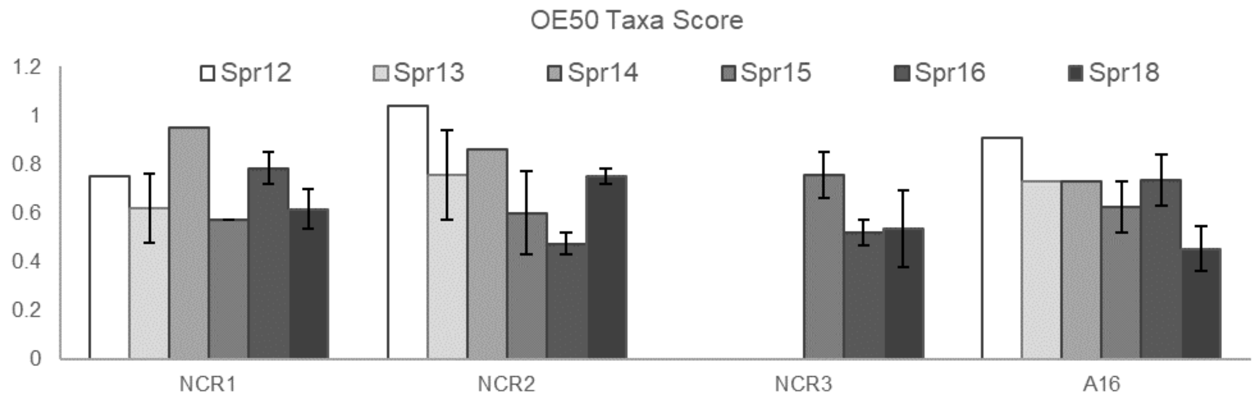
Neubecks Creek EMP Spring 2012 to Spring 2018

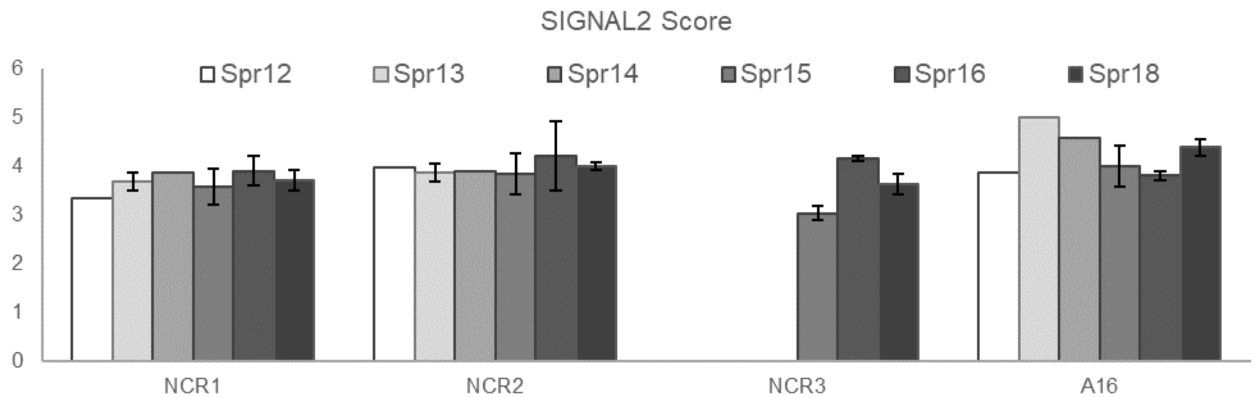
APPENDIX G

BIOTIC INDICES









Standard error bars are displayed where n = 2 (pre-spring 2018) or 3 (spring 2018), otherwise n = 1.

APPENDIX H

RESULTS OF PERMANOVAS

A) Comparison between NCR1 and NCR2 sampled in spring of 2013, 2015, 2016 and 2018:

i) No. of Taxa

Source of Variation	df	SS	MS	*F*	*P*
Survey	3	9.4	3.1	0.209	0.880
Site	1	10.4	10.4	0.691	0.419
Survey x Site	3	29.5	9.8	0.655	0.586
Residual	10	150.2	15.0		
Total	17	198.5			

ii) No. of EPT Taxa

Source of Variation	df	SS	MS	*F*	*P*
Survey	3	6.7	2.2	1.007	0.422
Site	1	4.0	4.0	1.808	0.205
Survey x Site	3	0.9	0.3	0.138	0.939
Residual	10	22.2	2.2		
Total	17	34.3			

iii) SIGNAL2 Score

Source of Variation	df	SS	MS	*F*	*P*
Survey	3	0.255	0.085	0.372	0.778
Site	1	0.304	0.304	1.330	0.288
Survey x Site	3	0.010	0.003	0.015	0.997
Residual	10	2.286	0.229		
Total	17	2.873			

iv) OE50 Taxa Score

Source of Variation	df	SS	MS	*F*	*P*
Survey	3	0.030	0.010	0.594	0.633
Site	1	0.020	0.020	1.211	0.300
Survey x Site	3	0.127	0.042	2.548	0.122
Residual	10	0.166	0.017		
Total	17	0.332			

v) Assemblage

Source of Variation	df	SS	MS	*F*	*P*
Survey	**3**	**6179.1**	**2059.7**	**2.081**	**0.005**
Site	**1**	**3744.7**	**3744.7**	**3.784**	**0.005**
Survey x Site	3	2309.4	769.8	0.778	0.754
Residual	10	9895.7	989.6		
Total	17	22069.0			

B) Comparison among NCR12, NCR2, NCR3 and A16 sampled in spring of 2015, 2016 and 2018

i) No. of Taxa

Source of Variation	df	SS	MS	*F*	*P*
Survey	2	60.6	30.3	1.539	0.241
Site	3	54.8	18.3	0.929	0.452
Survey x Site	6	97.7	16.3	0.828	0.563
Residual	16	314.8	19.7		
Total	27	540.9			

ii) No. of EPT Taxa

Source of Variation	df	SS	MS	*F*	*P*
Survey	2	4.2	2.1	0.585	0.568
Site	3	24.8	8.3	2.310	0.110
Survey x Site	6	5.3	0.9	0.248	0.956
Residual	16	57.3	3.6		
Total	27	93.9			

iii) SIGNAL2 Score

Source of Variation	df	SS	MS	*F*	*P*
Survey	2	0.702	0.351	1.873	0.187
Site	3	1.013	0.338	1.802	0.186
Survey x Site	6	1.177	0.196	1.047	0.430
Residual	16	2.999	0.187		
Total	27	6.1			

iv) OE50 Taxa Score

Source of Variation	df	SS	MS	*F*	*P*
Survey	2	0.092	0.046	1.396	0.277
Site	3	0.054	0.018	0.547	0.651
Survey x Site	6	0.264	0.044	1.339	0.300
Residual	16	0.525	0.033		
Total	27	0.949			

v) Assemblage

Source of Variation	df	SS	MS	*F*	*P*
Survey	**2**	**6652.6**	**3326.3**	**2.838**	**<0.001**
Site	**3**	**14273.0**	**4757.6**	**4.059**	**<0.001**
Survey x Site	6	9131.1	1521.8	1.298	0.101
Residual	16	18754.0	1172.1		
Total	27	49166.0			