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ACTEW Water

Murrumbidgee Ecological Monitoring Program

Part 3: Murrumbidgee Pump Station

Autumn 2012

INFRASTRUCTURE | MINING & INDUSTRY | DEFENCE | PROPERTY & BUILDINGS | ENVIRONMENT

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List of Abbreviations

ACT	Australian Capital Territory
ACTEW	ACTEW Corporation Limited
AFDM	Ash Free Dry Mass (periphyton)
ALS	Australian Laboratory Services
ANZECC	Australian and New Zealand Environment and Conservation Council
ANOVA	Analysis of Variance (statistics)
APHA	American Public Health Association
ARMCANZ	Agriculture and Resource management Council of Australia and New Zealand
ARI	Average Recurrence Interval
AUSRIVAS	Australian River Assessment System
BACI	Before-After-Control-Impact
CI	Confidence Interval
CMA	Catchment Management Authority
EC	Electrical Conductivity
ECD	Enlarged Cotter Dam
EIS	Environmental Impact Statement
EPA	Environmental Protection Authority
GL/a	Gigalitres per annum
GPS	Global positioning system
IBT	Inter-Basin Water Transfer
M2G	Murrumbidgee to Googong
MEMP	Murrumbidgee Ecological Monitoring Program
ML/d	Megalitres per day
NATA	National Association of Testing Authorities
NMDS	Non-metric Multidimensional Scaling (statistics)
NSW	New South Wales
NTU	Nephlelometric Turbidity Units
QA	Quality Assurance
QC	Quality Control
SD	Standard Deviation
TN	Total Nitrogen
TP	Total Phosphorus

Executive Summary

The Murrumbidgee Pump Station (MPS) is located just downstream of the Cotter River confluence with the Murrumbidgee River. The Murrumbidgee Pump Station has recently undergone a significant upgrade which increased its pumping capacity to Stromlo Treatment plant from 50ML/d to approximately 150ML/d.

The upgraded infrastructure also provides a separate recirculating flow from the Murrumbidgee River to the base of the Enlarged Cotter Dam (ECD) with a capacity of over 40ML/d. This provides environmental flows to the Cotter reach below the dam during construction and afterwards when releases from ECD are not desirable. The reticulation program is referred to as the Murrumbidgee to Cotter (M2C) project. This program (MEMP) does not monitor the effects of M2C, as this is being undertaken by others.

The framework for this program responds primarily to the ACTEW water abstraction licence reporting requirements. Water abstraction at the MPS, requires an assessment of the response of the river through monitoring methods that can quantify subtle impacts.

This program aims to establish the river condition prior to increased water abstraction levels; and then continue monitoring afterwards to determine what, if any, physicochemical and ecological changes occur. Due to the increase in river flows over the last two years, with water storage levels near capacity, the desire to abstract water from the MPS is likely to be significantly reduced for the near future.

The key aims of this sampling run were to:

1. *Collect macroinvertebrate community data, upstream and downstream of the MPS;*
2. *Provide ACTEW Water with river health assessments based on AUSRIVAS protocols at the key sites that could potentially be impacted by operation of the MPS upgrade;*
3. *Collect baseline periphyton data to assist in the characterisation of seasonal and inter-annual temporal variability; and*
4. *Report on water quality upstream and downstream of the MPS.*

This report presents the results from biological sampling of the Murrumbidgee River for the monitoring of the MPS in autumn 2012. Sampling was completed in May 2012 and was based on the AUSRIVAS sampling protocols. Specimens were identified to genus level, instead of family level as per standard AUSRIVAS protocols. The reason for this variation is to improve the ability of the monitoring program to detect subtle changes in the macroinvertebrate assemblages in response to water abstraction impacts.

Macroinvertebrate community composition, periphyton assemblages and water quality were monitored from five sites on the Murrumbidgee River, two upstream and three downstream of the Murrumbidgee Pump Station (MPS). River flows and rainfall for the sampling period were recorded at ALS gauging stations located at Lobb's Hole (upstream of the MPS: 410761) and Mt. MacDonald (410738). Physico-chemical water quality parameters including temperature, pH, electrical conductivity, turbidity and dissolved oxygen were recorded at each of the five sites at the time of the biological sampling. Macroinvertebrates were sampled in the riffle and edge habitats from all sites. Both habitats were sampled to provide a more comprehensive assessment of each site and potentially allow the program to isolate flow-related impacts from other disturbances. Riffle and edge habitats were sampled during autumn (May 7th – 9th) 2012, for macroinvertebrates and analysed in strict accordance with the ACT AUSRIVAS (Australian River Assessment System) protocols.

The key results from the autumn 2012 MPS sampling run were:

1. *All sites sampled were assessed as BAND B (significantly impaired) by the AUSRIVAS model for both edge and riffle habitat assessments, except for the riffle habitat at MUR 935 which resulted in no reliable assessment being made due to the range of band scores within the sites replicates. When these results are compared to those of autumn 2011 it appears that the edge habitat is consistent with BAND B representing all sites for consecutive years. All riffle habitat results have changed with all sites going from Band A (similar to reference), while all sites in autumn 2012 were assessed as Band B, with the exception of MUR 935 (NRA). This drop in riffle bands is likely due to the large flow event during March which are not usually associated with autumn but usually spring.*
2. *The water quality data shows no sign that activities related to the MPS upgrade project has resulted in changes to the background water quality parameters in the Murrumbidgee River. Elevated nutrient levels (TN & TP) and pH levels slightly elevated above the recommended guideline values occurred across all sampling sites and not specific to one location. This suggests that the preceding hydrological conditions coupled with the high base flows at the time of sampling are the likely factors responsible for these observed values. The fact that TP and TN tend to be higher at the farthest upstream site (MUR 931) and dissipate downstream, indicates that the nutrient source is upstream of the study reaches. As a result the nutrient levels dissipate downstream indicating no significant inputs within the study area.*
3. *The periphyton results also indicate there is no detectable difference between sites upstream of the MPS when compared to those downstream. The results indicate that MUR 28, 935 and 937 have lower chlorophyll-a concentrations compared to the farthest upstream and downstream sites suggesting that the ongoing inflows from the Cotter River and the Bendora Scour may be keeping new growth at these sites to a minimum following the high flow event in March; while the elevated chlorophyll-a and AFDM concentrations at MUR 931 are likely a result of increased nutrient inputs from farther upstream. The farthest downstream site MUR 29 had higher chlorophyll-a concentrations than MUR 28, 935 & 937. It has not been confirmed, but one likely explanation for this is that because the riffle at MUR 29 is shallower (increased width) and at lower velocity compared to the other sites, there is higher light penetration and a higher growth rate respectively. There was also an increased amount of detrital matter at MUR 29 from previous high flow events, which may also contribute to increased chlorophyll-a levels.*
4. *At the downstream sites within the riffle habitat there has been a distinct increase in the number of Simuliidae sampled and a distinct decrease in the number of Baetidae sampled. The family Elmidae was absent from the majority of replicates from MUR 935 & 29, while they are completely absent from MUR 937. This is likely due to the large March flow event scouring habitat and changing food availability which has increased some species dominance, while other species are yet to recover fully.*
5. *Considering the water quality and biological indicators in this study, there is no indication that the health assessments of each of the study sites is being compromised by the MPS project and related activities. However there is some evidence to suggest that changes in flow downstream of the Cotter River confluence, driven by high flows in the Cotter itself by the overtopping of the Cotter Dam wall and some additional input from the Bendora Scour value, that the estimated abundances of some mayflies and blackfly larvae are increasing downstream of these points. In the case of this study, this has resulted in a significant location difference being found in the riffle*

habitat, owing to the much higher number at the downstream sites. However, there was no location differences based on the AUSRIVAS results because AUSRIVAS relies on presence / absence (compositional) information rather than abundances.

1. Introduction

The Murrumbidgee Ecological Monitoring Program was set up by ACTEW Corporation to evaluate the potential impacts of water abstraction from the Murrumbidgee River The proposed timeline is to undertake sampling in spring and autumn over a four year period commencing in autumn 2009

There are four component areas being considered:

Part 1: Angle Crossing

Part 2: Burra Creek (discharge point for Angle Crossing abstraction)

Part 3: Murrumbidgee Pump Station

Part 4: Tantangara to Burrinjuck

This report focuses on Part 3: Murrumbidgee Pump Station.

The Murrumbidgee Pump Station (MPS) is located just downstream of the Cotter River confluence with the Murrumbidgee River. It is adjacent to the original Cotter Pump Station which abstracted up to 50 ML/d, contributing to the water supply for the ACT. New infrastructure has increased the abstraction amount from the Murrumbidgee River to approximately 150 ML/d via the MPS. The upgraded infrastructure also provides a recirculating flow from the Murrumbidgee to the base of the Enlarged Cotter Dam (ECD), providing environmental flows to the lower Cotter Reach below the dam especially during the construction of the ECD. This project is referred to as Murrumbidgee to Cotter (M2C) transfer. The MEMP project does not aim to monitor the effects of the M2C transfer, but rather provides a characterisation of the Murrumbidgee River condition upstream and downstream of the MPS.

The upgraded pump station was commissioned in 2010. Pumping is dependent on demand, licence requirements, and water quality. The framework for this program responds primarily to requirements of ACTEW's water abstraction licence.

The increase in abstraction at the Murrumbidgee Pump Station (MPS) may place additional stress on the downstream river ecosystem. This monitoring program has been established to monitor the condition of the Murrumbidgee River in terms of water quality and ecological condition at key sites both upstream and downstream of the extraction point (MPS).

The information derived from this program will support ACTEW's and the ACT Environmental Protection Authority's (EPA) adaptive management approach to water abstraction and environmental flow provision in the ACT.

1.1 Project Objectives

The objectives of the MPS monitoring program are to provide ACTEW with seasonal assessments of river health affected by the operation and works during the upgrade of the Murrumbidgee Pump Station, and under the license requirements of ACTEW Water's licence to abstract water (WU67, 2012).

Specifically, the aims of the project are to:

1. Meet ACTEW Water's monitoring obligations under the requirements of its licence to abstract water;
2. Provide seasonal "river health" reports in accordance with the licence requirements;
3. Collect macroinvertebrate, water quality and periphyton data for eventual use in the assessment of whether or not abstractions from the MPS are impacting the ecology and ecological "health" of the Murrumbidgee System downstream of the MPS. This study will also provide ACTEW with river health assessments based on AUSRIVAS protocols at the key sites concerning the operation and the works concerned with the upgrade of the MPS.

1.2 Project Scope

The current ecological health of the sites monitored as part of the Murrumbidgee Pump Station (MPS) monitoring program is estimated using AUSRIVAS protocols for macroinvertebrate community data; combined with a suite of commonly used biological metrics and descriptors of community composition. The scope of this report is to convey the results from the autumn 2012 sampling runs. Specifically, as outlined in the MEMP proposal to ACTEW Corporation (GHD, 2012), this work includes:

- Sampling in autumn 2012;
- Macroinvertebrate sampling from riffle and edge habitats;
- Riffle and edge samples collected as per the ACT AUSRIVAS protocols;
- Macroinvertebrates counted and identified to the taxonomic level of genus;
- Riffle and edge samples assessed through the appropriate AUSRIVAS model;

  Some water quality measurements to be measured in-situ, and nutrient samples to be collected and analysed in Australian Laboratory Services (ALS) NATA accredited laboratory in Canberra.

1.3 Rationale for using biological indicators

Macroinvertebrates and periphyton are two of the most commonly used biological indicators in river health assessment. Macroinvertebrates are commonly used to characterise ecosystem health because they represent a continuous record of preceding environmental, chemical and physical conditions at a given site. Macroinvertebrates are also very useful indicators in determining specific stressors on freshwater ecosystems because many taxa have known tolerances to heavy metal contamination, sedimentation, and other physical or chemical changes (Chessman, 2003). Macroinvertebrate community assemblage, and two indices of community condition; the AUSRIVAS index and the proportions of three common taxa (the Ephemeroptera, Plecoptera, and Trichoptera, or EPT index), are used during this survey to assess river health.

Periphyton is the matted floral and microbial community that resides on the river bed. The composition of these communities are dominated by algae but the term "periphyton" also includes fungal and bacterial matter (Biggs and Kilroy, 2000). Periphyton is important to maintaining healthy freshwater ecosystems as it absorbs nutrients from the water, adds oxygen to the ecosystem via photosynthesis, and provides a food source for higher order animals. Periphyton communities respond rapidly to changes in water quality, light penetration of the water column and other disturbances, such as floods or low flow, and this makes them a valuables indicator of river health.

2. Materials and Methods

The types of impacts that may arise during the implementation of MPS, depends on the pumping regime and the environmental flow rules adopted. Potential effects may include modification to the stream substrate through altered sedimentation processes, loss or reduced quality of riffle zones, changes in water chemistry and periphyton biomass accumulation. These processes in turn may influence the composition of macroinvertebrate and periphyton communities downstream of the abstraction point.

Macroinvertebrates were sampled in two meso-habitats (riffle and pool edges) at each site and organisms identified to family or genus level. Periphyton was sampled in the riffle zones at each site and analysed for chlorophyll-a and Ash Free Dry Mass (AFDM), which will provide estimates of the algal (autotrophic) biomass and total organic mass respectively (Biggs and Kilroy, 2000).

Sampling of riffle and edge habitats was carried out in order to provide a comprehensive assessment of each site. The monitoring of both habitats potentially allows the program to isolate flow related impacts from other disturbances. The reasoning behind this is that each habitat is likely to be effected in different ways. Riffle zones, for example, are likely to be one of the first habitats affected by low flows and water abstractions (Boulton, 2003; Dewson et al., 2007; Smakhtin, 2001), as water abstraction will result in an immediate reduction in flow velocities and inundation level over riffle zones downstream of the abstraction point. Impacts on edge habitat macroinvertebrate assemblages might be less immediate as it may take some time for the reduced flow conditions to cause loss of macrophyte beds and access to trailing bank vegetation habitat. Therefore, monitoring both habitats will allow the assessment of the short-term and longer-term impacts associated with water abstraction.

2.1 Study Sites

Site selection was based upon the recommendations outlined in ACTEW's Licence to take water WU67 section D6. Prior to sampling, comprehensive site assessments were carried out, including assessments of safety, suitability and granted access from landowners. As outlined in this document, there are no suitable reference sites in the proximity for this assessment, so a before – after / control – impact (BACI) design (Downes *et al.,* 2002) was adopted based on sites upstream of the abstraction point serving as Control sites and sites downstream of the abstraction point serving as 'Impacted' sites. Site locations are presented in Figure 1, site details in Table 1, and photos of each site in Plates 1 & 2.

Table 1. Sampling site locations and details

Site Code	Location	Land use	Purpose
MUR 931	"Fairvale" approximately 4km upstream of the Cotter River confluence	Cattle grazing	Upstream control site
MUR 28	~100m upstream of the Cotter River confluence	Grazing	Upstream control site
MUR 935	Casuarina Sands	Recreation	Downstream impact site
MUR 937	"Huntly" ~3km downstream of the Cotter River confluence. Near Mt. MacDonald gauging station	Sheep and cattle grazing	Downstream impact site
MUR 29	U/S Uriarra Crossing	Recreation, sheep and cattle grazing, some pine forest	Downstream impact / recovery site

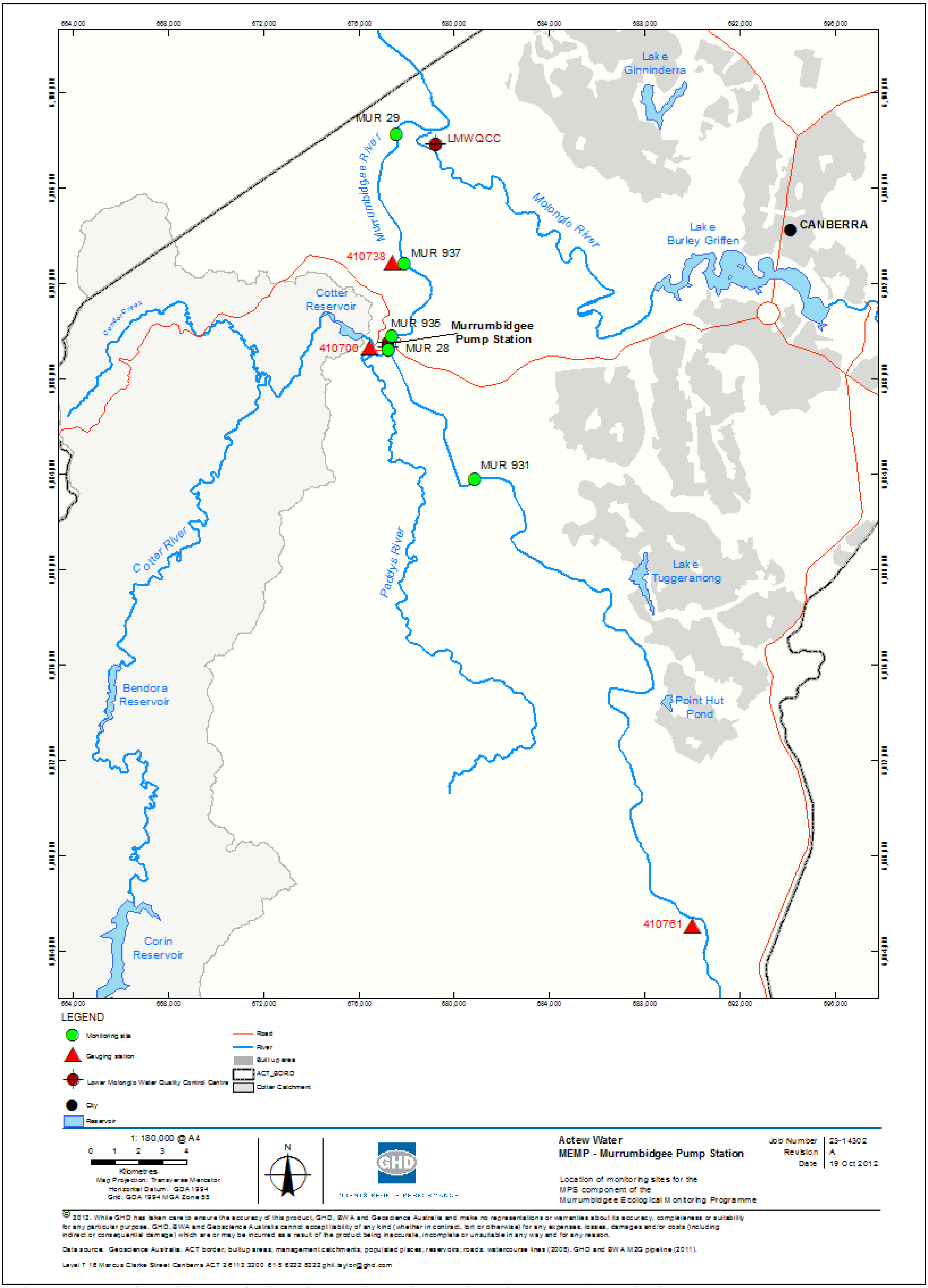
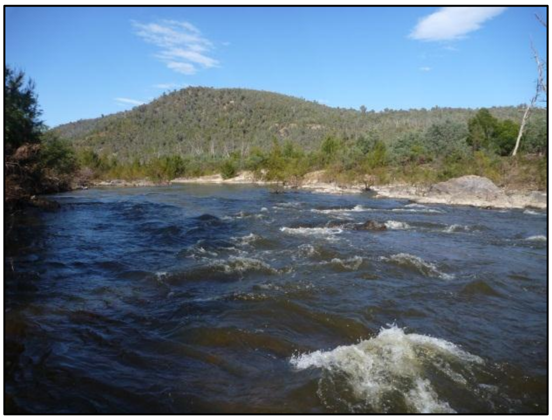


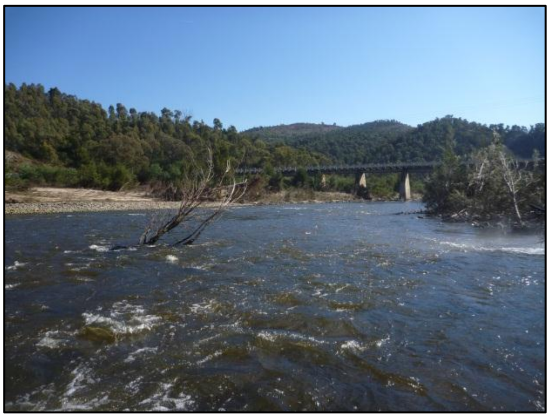
Figure 1. Location of the monitoring sites and gauging stations for the MPS monitoring program

MUR 931 Looking upstream

MUR 931 Looking downstream



MUR 28 Looking upstream



MUR 28 Looking downstream towards the Cotter Road Bridge

Plate 1. Monitoring sites upstream of the Murrumbidgee Pump Station

MUR 935 Looking upstream to Cotter Bridge

MUR 935 Riffle habitat

MUR 937 Riffle habitat, looking upstream

MUR 937 Riffle habitat, looking downstream

MUR 29 Looking upstream towards Uriarra Rd.

MUR 29 Looking downstream

Plate 2. Monitoring sites downstream of the Murrumbidgee Pump Station

2.2 Hydrology and Rainfall

River flows and rainfall for the sampling period were recorded at ALS gauging stations at Lobb's Hole (410761: upstream of MUR 931), Mt. MacDonald (410738: downstream of the MPS) and the Cotter River at Kiosk (410700: downstream of the Cotter Dam). Site locations and codes are given in Table 2 (below).

Table 2. Stream flow and water quality monitoring site locations

Site Code	Location/Notes	Parameters*	Latitude	Longitude
410700	Cotter @ Kiosk	WL, Q	S -35.3240	E 148.9417
570985	Lobb's Hole	Rainfall	S -35.2917	E 148.9565
410738	M'bidgee River @ Mt. MacDonald	WL, Q	S -35.2917	E 148.9565
410761	M'bidgee River upstream of Angle Crossing	WL, Q, pH, EC, DO, Temp, Turb, Rainfall	S -35.5398	E 149.1015

** WL = Water Level; Q = Rated Discharge; EC = Electrical Conductivity; DO = Dissolved Oxygen; Temp = Temperature; Turb = Turbidity*

2.3 Water Quality

Baseline physico-chemical parameters including temperature, pH, electrical conductivity, turbidity and dissolved oxygen were recorded at each sampling site using a multiprobe Hydrolab® Minisonde 5a Surveyor. The Surveyor was calibrated in accordance with GHD QA procedures and the manufacturer's requirements prior to sampling. Additionally, grab samples were taken from each site in accordance with ACT AUSRIVAS protocols (Nichols et al., 2000) for Hydrolab® verification and nutrient analysis. All grab samples were placed on ice, returned to the ALS Canberra laboratory and analysed for nitrogen oxides (total NOx), total nitrogen (TN) and total phosphorus (TP) in accordance with the protocols outlined in APHA (2005). Collectively, this information on the water quality parameters will assist in the interpretation of the biological data and in its own right provide a basis on which to gauge ecosystem changes linked to changes in flow at these sites.

2.4 Macroinvertebrate Sampling

Riffle and edge habitats were sampled for macroinvertebrates on the 7th and 9th May 2012 and analysed using the ACT autumn riffle and edge AUSRIVAS (Australian River Assessment System) protocols (Nichols et al., 2000). At each site, two samples were taken from the riffle habitat (flowing broken water over gravel, pebble, cobble or boulder, with a depth greater than 10 cm; (Nichols et al., 2000) using a framed net with 250 µm mesh size. Sampling began at the downstream end of each riffle. The net was held perpendicular to the substrate with the opening facing upstream. The stream bed directly upstream of the net opening was agitated by vigorously kicking, allowing dislodged macroinvertebrates to be carried into the net by the current. The process continued, working upstream over 10 metres of riffle habitat. Samples were then preserved in 70% ethanol, clearly labelled with site code and date, then stored on ice and placed in a refrigeration unit until laboratory sorting commenced. The edge habitat was also sampled according to the ACT AUSRIVAS protocols. Two samples were taken from the edge habitat. The nets and all other associated equipment were washed thoroughly between sampling events to remove any macroinvertebrates retained on them. Samples were collected by sweeping the collection net along the edge habitat at the sampling site; the operator worked systematically over a ten metre section covering overhanging vegetation, submerged snags, macrophyte beds, overhanging banks and areas with trailing vegetation. Samples were preserved on-site as described for the riffle samples.

2.5 Periphyton

Estimates of algal biomass were made using complimentary data from both chlorophyll-a (which measures autotrophic biomass) and ash free dry mass (AFDM; which estimates the total organic matter in periphyton samples and includes the biomass of bacteria, fungi, small fauna and detritus in samples) measurements (Biggs, 2000).

The five sampling sites selected for this project (Table 1) were sampled for periphyton in autumn in conjunction with the macroinvertebrate sampling. All periphyton (i.e. adnate and loose forms of periphyton, as well as organic/inorganic detritus in the periphyton matrix) samples were collected using the in-situ syringe method similar to Loeb (1981), as described in Biggs and Kilroy (2000). A 1m wide transect was established across riffles at each site. Along each transect, twelve samples were collected at regular intervals, using a sampling device of two 60 ml syringes and a scrubbing surface of stiff nylon bristles covering an area of ~637 mm^2. The samples were divided randomly into two groups of six samples to be analysed for Ash Free Dry Mass (AFDM), and chlorophyll-a. Samples for Ash Free Dry Mass and chlorophyll-a analysis were filtered onto glass filters and frozen. Sample processing followed the methods outlined in APHA (2005).

2.6 Data Analysis

Data were analysed using both univariate and multivariate techniques using R 2.15.1. (R Development Core Team, 2011), and PRIMER v6 (Clarke and Gorley, 2006). Details of these analyses are provided below.

2.6.1 Water Quality

Water quality parameters were examined for compliance with ANZECC & ARMCANZ (2000) water guidelines for healthy ecosystems in upland streams.

2.6.2 Macroinvertebrate Communities

The macroinvertebrate data were examined separately for riffle and edge habitats. Replicates were examined individually (i.e. not averaged) at all sites because the aim is to examine within site variation as much as it is to describe patterns among sites at this stage. All multivariate analyses were performed using PRIMER version 6 (Clarke and Gorley, 2006).

Processing of the aquatic macroinvertebrate samples followed the ACT AUSRIVAS protocols. Briefly, in the laboratory, the preserved macroinvertebrate samples were placed in a sub-sampler, comprising of 100 (10 X 10) cells (Marchant, 1989). The sub-sampler was then agitated to evenly distribute the sample and the contents of randomly selected cells removed. Macroinvertebrates from each selected cell were identified to genus level. Specimens that could not be identified to the specified taxonomic level (i.e. immature or damaged taxa) were removed from the dataset prior to analysis.

For the ACT AUSRIVAS model, all taxa were analysed at the family level except Chironomidae (identified to sub-family), Oligochaeta (class) and Acarina (order). Animals were identified using taxonomic keys listed in Hawking (2000). All animals within the cell were identified. Data was entered directly into electronic spread sheets to eliminate errors associated with manual data transfer.

Non-metric multidimensional scaling (NMDS) was performed on the macroinvertebrate community data following the initial cluster analysis. NMDS is a multivariate procedure that reduces the dimensionality of multivariate data by describing trends in the joint occurrence of taxa and aids with interpretation. The initial step in this process was to calculate a similarity matrix for all pairs of samples based on the Bray-Curtis similarity coefficient (Clarke and Warwick, 2001). For the macroinvertebrate data collected during this survey, the final number of dimensions is reduced to two. How well the patterns in the 2 dimensional NMDS plot represents the multivariate data is indicated by the stress value of each plot. The stress level is a measure of the distortion produced by compressing multidimensional data into a reduced set of dimensions and will increase as the number of dimensions is reduced. Stress can be considered a measure of "goodness of fit" to the original data matrix (Kruskal, 1964), and when near zero suggests that NMDS patterns are very representative of the multidimensional data. Stress greater than 0.2 indicates a poor representation (Clarke and Warwick 2001).

An analysis of similarities (ANOSIM) was performed on the data to test whether macroinvertebrate communities were statistically different upstream and downstream of the Murrumbidgee Pump Station. Sites were nested within location in a two-way design.

The similarity percentages (SIMPER) routine was carried out on the datasets only if the initial ANOSIM test was significant (i.e. $P<0.05$), to examine which taxa were responsible for, and explained the most variation among statistically significant groupings. This procedure was also used to describe groups (i.e. which taxa characterised each group of sites) (Clarke and Warwick, 2001).

2.6.3 AUSRIVAS Assessment

AUSRIVAS is a prediction system that uses macroinvertebrates to assess the biological health of rivers and streams. Specifically, the model uses site-specific information to predict the macroinvertebrate fauna expected (E) to be present in the absence of environmental stressors. The expected fauna from sites with similar sets of predictor variables (physical and chemical characteristics influenced by non-human characters, e.g. altitude) are then compared to the observed fauna (O) and the ratio derived is used to indicate the extent of any impact (O/E). The ratio derived from this analysis is compiled into bandwidths (i.e. X, A-D; Table 3) which are used to gauge the overall health of particular site (Coysh et al., 2000). Data is presented using the AUSRIVAS O/E 50 ratio (Observed/Expected score for taxa with a >50% probability of occurrence) and the previously mentioned rating bands (Tables 3).

Site assessments are based on the results from both the riffle and edge samples. The overall site assessment was based on the furthest band from reference in a particular habitat at a particular site. For example, a site that had a Band A assessment in the edge and a Band B in the riffle would be given an overall site assessment of Band B (Coysh et al., 2000). In cases where the bands deviate significantly between habitat (e.g. D – A) an overall assessment is avoided due to the unreliability of the results.

The use of the O/E 50 scores is standard in AUSRIVAS. However it should be noted that this restricts the inclusion of rare taxa and influences the sensitivity of the model. Taxa that are not predicted to occur more than 50% of the time are not included in the O/E scores produced by the model. This could potentially limit the inclusion of rare and sensitive taxa and might also reduce the ability of the model to detect any changes in macroinvertebrate community composition over time (Cao et al., 2001). However, it should also be noted that the presence or absence of rare taxa does vary over time and in some circumstances the inclusion of these taxa in the model might indicate false changes in the site classification since the presence or absence of these taxa might be a function of random processes rather than truly reflecting ecological change.

2.6.4 SIGNAL-2 (Stream Invertebrate Grade Number – Average Level)

Stream **I**nvertebrate **G**rade **N**umber – **A**verage **L**evel (SIGNAL) is a biotic index based on pollution sensitivity values (grade numbers) assigned to aquatic macroinvertebrate families that have been derived from published and unpublished information on their tolerance to pollutants, such as sewage and nitrification (Chessman, 2003). Each family in a sample is assigned a grade between 1 (most tolerant) and 10 (most sensitive). Sensitivity grades are also given in the AUSRIVAS output which can then be used as complimentary information to these assigned bandwidths to aid the interpretation of each site assessment.

2.6.5 EPT index

The EPT index is the total number of families within the generally pollution-sensitive insect orders of **E**phemeroptera (mayflies), **P**lecoptera (stoneflies) and **T**richoptera (caddisflies). Any loss of families in these groups usually indicates disturbance of some kind (EPA 2004). A higher relative abundance of EPT taxa against all other taxa collected can therefore be indicative of increased river health.

Table 3. AUSRIVAS band-widths and interpretations for the ACT autumn riffle and edge models

	RIFFLE	EDGE	
BAND	O/E Band width	O/E Band width	Explanation
X	> 1.12	> 1.17	More diverse than expected. Potential enrichment or naturally biologically rich.
A	0.88 – 1.12	0.83 – 1.17	Similar to reference. Water quality and / or habitat in good condition.
B	0.64 – 0.87	0.49 – 0.82	Significantly impaired. Water quality and/ or habitat potentially impacted resulting in loss of taxa.
C	0.40 – 0.63	0.15 – 0.48	Severely impaired. Water quality and/or habitat compromised significantly, resulting in a loss of biodiversity.
D	< 0.40	< 0.15	Extremely impaired. Highly degraded. Water and /or habitat quality is very low and very few of the expected taxa remain.

2.6.6 Periphyton

The raw Chlorophyll-a and Ash Free Dry Mass data were converted to estimates of concentrations and biomass per square metre respectably following the methodology outlined in Biggs and Kilroy (2000).

These data were used to test for differences between upstream-control locations versus downstream impact locations. Log transformed Chlorophyll-a and raw ash free dry mass data were fitted to a mixed effects, nested analysis of variance (ANOVA). Site was nested within location and was treated as a random effect and location was considered a fixed effect. For the purposes of graphical visualisation, raw data are presented.

2.7 Macroinvertebrate quality control procedures

A number of Quality Control procedures were undertaken during the identification phase of this program including:

- Organisms that were heavily damaged were not selected during sorting. To overcome losses associated with damage to intact organisms during vial transfer, attempts were made to obtain significantly more than 200 organisms;
- Identification was performed by qualified and experienced aquatic biologists with more than 100 hours of identification experience;
- When required, taxonomic experts confirmed identification. Reference collections were also used when possible;
- ACT AUSRIVAS QA/QC protocols were followed;
- An additional 10% of samples were re-identified by another senior taxonomist;
- Very small, immature, or damaged animals or pupae that could not be positively identified were not included in the dataset.

All procedures were performed by AUSRIVAS accredited staff.

2.8 Licences and Permits

All sampling was carried out with current NSW scientific research permits under section 37 of the Fisheries Management Act 1994 (permit number P01/0081(C)).

GHD field staff maintain current AUSRIVAS accreditation.

3. Results

3.1 Summary of sampling and river conditions

Heavy rainfall throughout the catchment resulted in a high flow event at the beginning of March (Figure 2) and a second, smaller event occurred in the middle of April. Flows were stable during the sampling period. The weather was overcast on the 7th, but fine on the 9th, while temperatures were varied between days with a maximum of 12°C and 22°C respectively.

Sampling was completed on the 7th and 9th of May. Quick reference site summaries are shown in Appendix A. The farthest upstream site (MUR 931) and farthest downstream site (MUR 29) were sampled on the 7th of May, while the three remaining sites were sampled on the 9th. This delay in sampling was due to the Bendora Scour Valve being operational and preventing access to MUR 28. This was turned down (but not completely off) for a short period on the 9th of May at which point we were able to gain access to the site and complete the required sampling. The scour valve had been operating for over a week prior to the time of sampling, with the intention of releasing water from the valve continuously for a month. The number of samples collected at each site is presented in Table 4.

All sites showed evidence of the high flows from the event during early March. All sites had remnants of logs and wood debris throughout the areas, while some showed patches of dead vegetation due to inundation during the event. All sites showed a patchy presence of both periphyton and filamentous algae, with denser areas found in the slower moving sections of sites, which is to be expected.

Table 4. Macroinvertebrate samples collected during the autumn sampling run

Site	Riffle	Edge	Notes
MUR 931	2	2	Large woody debris throughout reach
MUR 28	2	1	Limited edge habitat. Delay in sampling due to the scour valve
MUR 935	2	2	
MUR 937	2	2	
MUR 29	2	2	

3.2 Hydrology and Rainfall

The hydrograph for autumn 2012 indicates the large high flow event which came through the Murrumbidgee catchment at the beginning of March (Figure 2). Peak flow at the Lobb's Hole gauging station exceeded 63,000 ML/d representing a 1 in 8 year Average Recurrence Interval flood event for that site; while at the Mt. MacDonald gauging station, peak flow exceeded 130,000 ML/d, which represents a 1 in 10 year ARI event for that site.

Throughout the rest of the period there were a couple of small rainfall events with only one resulting in a small peak in the hydrograph. This meant that flows for most of the remaining period were steady including during sampling. Monthly flow and rainfall summaries are shown in Table 5.

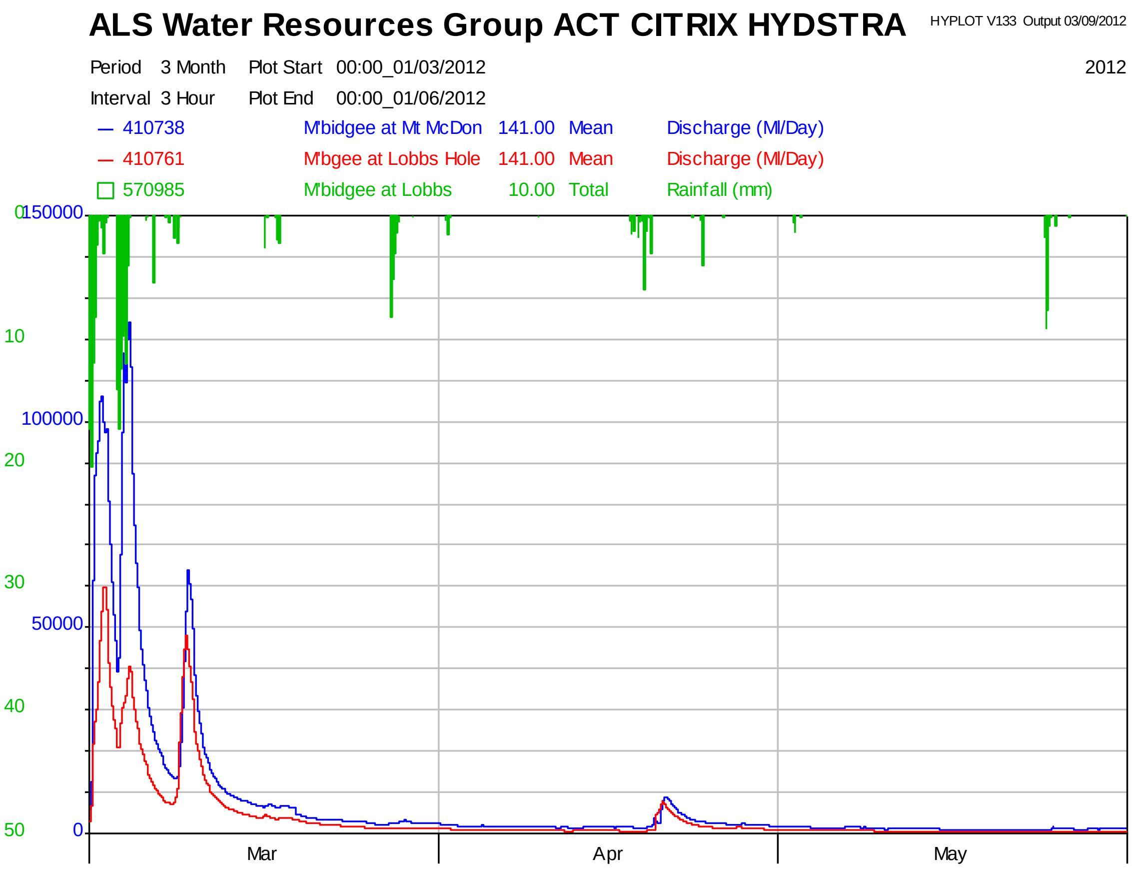


Figure 2. Autumn hydrograph of the Murrumbidgee River at Lobb's Hole (410761) and Mt. MacDonald (410738) Total rainfall is shown for the Lobb's Hole station (570985)

Figure 3 shows the flow in the Cotter River below the Enlarged Cotter Dam (ECD) for the autumn period. Flows in the the Cotter River were much higher during this season in comparison to previous sampling runs. This higher flow is due to the recent high levels of rain in the region, as well as the advanced stages of the ECD construction. The overtopping of the ECD during the March event was captured by ACTEW's Cotter Dam Cam (Plate 3). The operation of the Bendora Scour Valve for an extended period during the autumn period is also a contributing factor to the increased flow levels downstream of MUR 28. The scour valve can be seen operational in Plate 4.

Point Hut Pond (upstream of MUR 931) has been referenced in previous reports (ALS, 2011c), but not in relation to the MPS. It is believed that due to the high level of rainfall immediately prior and during the season that the inflow from the pond has had a larger impact upon the MPS sites which are all located downstream of the pond outlet, with potential for increased nutrient levels. The Point Hut Pond level can be found in Appendix B.

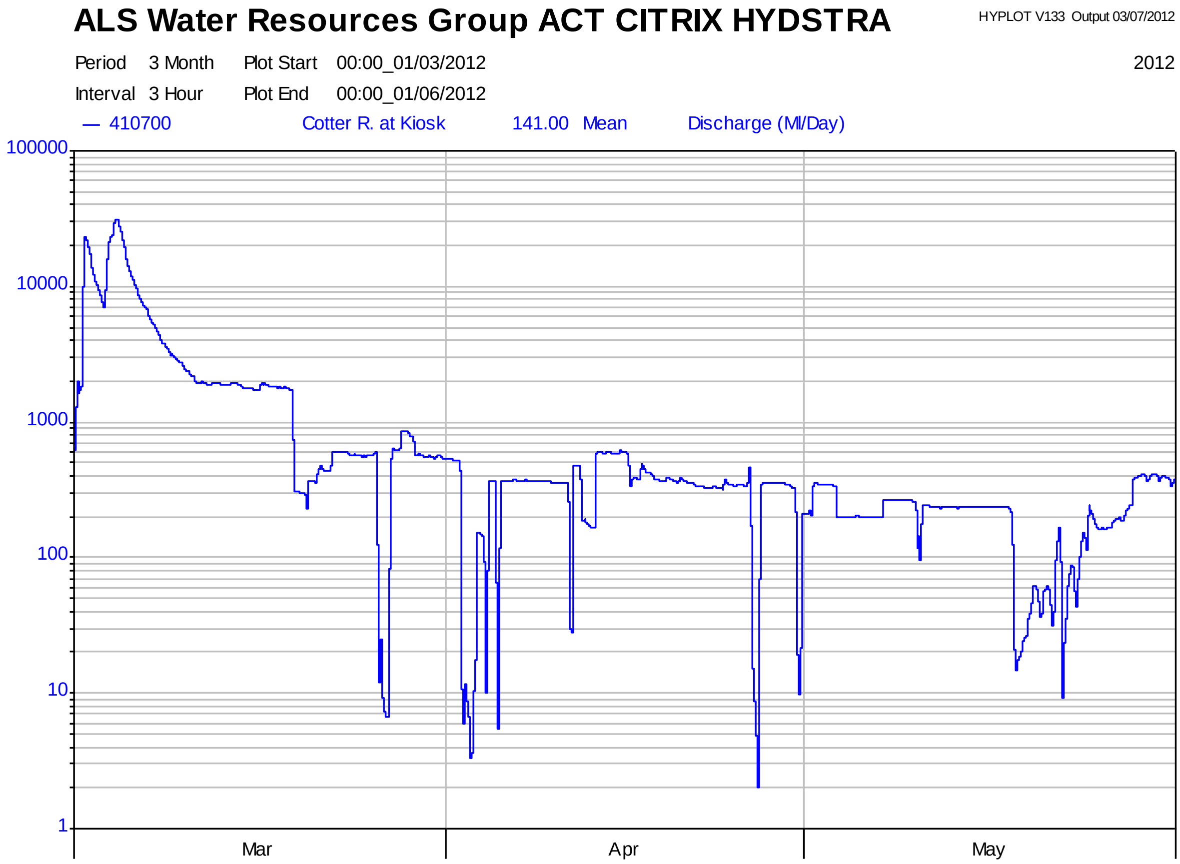


Figure 3. Hydrograph for the Cotter River downstream of Cotter Dam (410700) for autumn 2012

Plate 3. Enlarged Cotter Dam construction during March event, 2/5/2012

(Source: www.actew.com.au)

Table 5. Monthly flow and rainfall statistics for autumn 2012 at Lobb's Hole (410761) and Mount MacDonald (410738)

Station	Lobb's Hole (410761)		Mt. MacDonald (410738)
	Rainfall Total (mm)	Mean Flow (ML/d)	Mean Flow (ML/d)
March	204.2	10,400	20,347
April	24.2	1,330	2,240
May	22.8	527	1,118
Autumn (mean monthly)	251.2 (83.7)	4,090	7902

Plate 4. The Murrumbidgee River viewed from the Cotter Road Bridge.

Top: looking upstream with the Bendora scour valve operating and; Bottom: looking downstream with MPS on the right hand bank Mean daily flow at the time these photographs were taken (3/5/2012) was 1,598 ML/d at the Mount MacDonald gauging station (410738).

3.3 Water Quality

The results from grab sample taken at the sampling sites can be found in Table 6. There were only a small number of exceedances of the ANZECC & ARMCANZ (2000) guidelines. The pH values at MUR 931 and 29 are on the cusp of the guideline level with all other sites exceeding the guideline. All sites exceeded the guidelines levels for total nitrogen with levels decreasing downstream. Total phosphorus guideline levels were exceeded at the three most upstream sites only, with values again decreasing downstream. This pattern indicates that the source and/or sources of the elevated phosphorus and nitrogen is located upstream of MUR 931.

The pH sensor at Lobb's Hole (410761) was not operational in autumn until April due to the delay in parts supply from a component failure (the spare unit having been used at one of the other MEMP sites), but all other parameters were operational and logging correctly (Figure 4).

Evidence of the variation in flows can be seen in the continuous water quality parameters at Lobb's Hole. During the start of March turbidity, electrical conductivity (EC), temperature and dissolved oxygen (DO) % saturation are all variable as a result of the multiple events, however most readings were still found to be within the ANZECC & ARMCANZ (2000) guidelines. Smaller variations are also present in mid-April during the small increased flow event.

Dissolved oxygen displayed a natural diurnal trend while water temperature decreased throughout the season, corresponding to decreasing ambient temperatures towards the beginning of winter. EC remained within the guidelines for the whole period while turbidity was stable after the high flow conditions with all daily means within the guidelines. Once the pH sensor was installed and logging it was stable, remaining within the guideline limits.

Monthly mean values for the five water quality parameters are displayed in Table 7 and show some values outside the ANZECC and ARMCANZ (2000) guidelines.

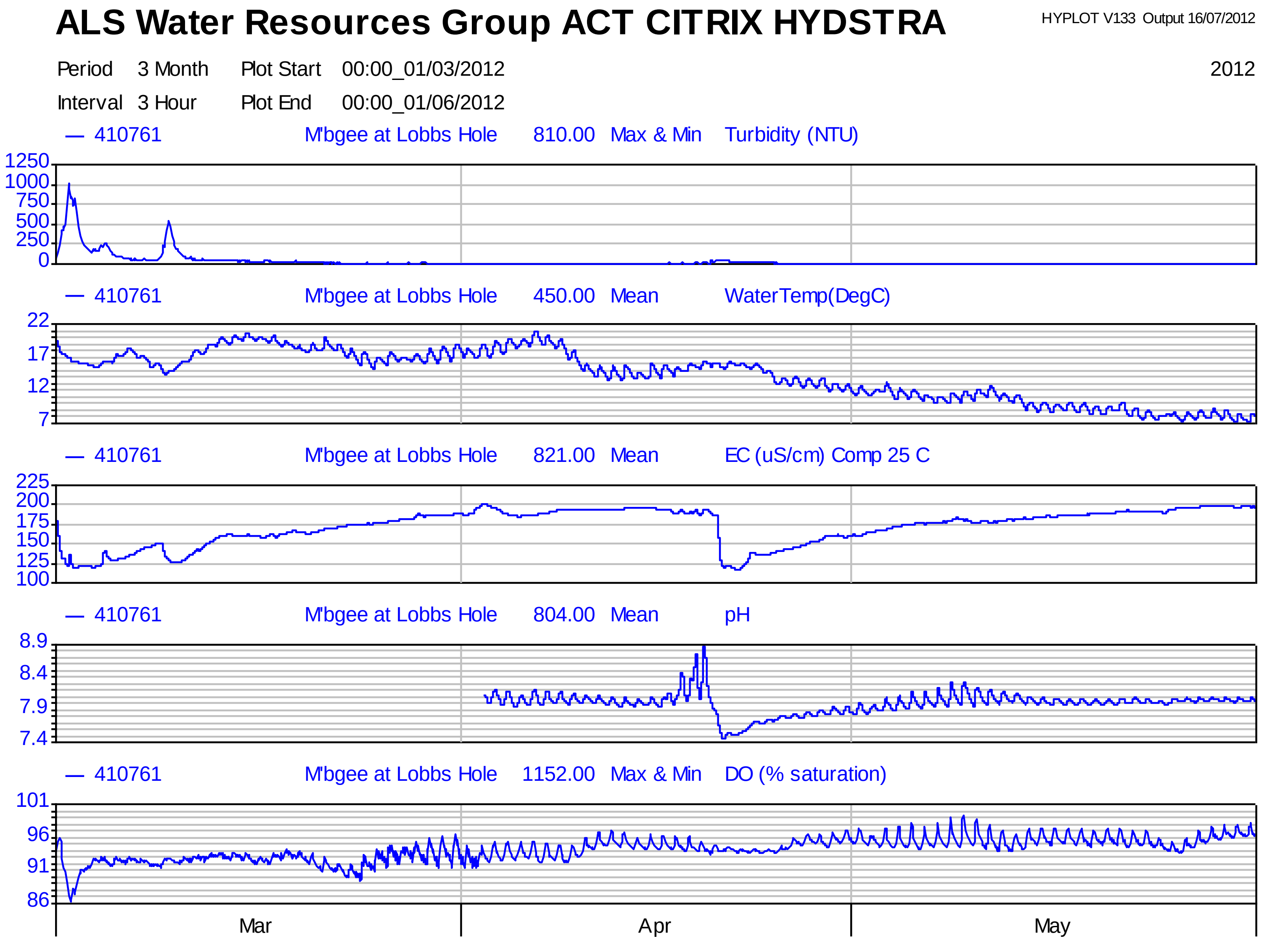


Figure 4. Continuous water quality records from Lobb's Hole (410761) for autumn 2012

Table 6. Water quality results for autumn 2011

ANZECC & ARMCANZ guidelines are in parentheses, yellow cells indicate values outside guidelines, light orange cells indicate values are on the cusp of the upper limit of the guideline.

	Site	Date	Time	Temp. (°C)	EC (µs/cm) (30-350)	Turbidity (NTU) (2-25)	TSS mg/L	pH (6.5-8)	D.O. (% Sat.) (90-110)	D.O. (mg/L)	Alkalinity (mg/L)	NOX (mg/L) (0.015)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia(mg/L)	TP (mg/L) (0.02)	TN (mg/L) **(0.25)**
Upstream	MUR 931	7/5	10.15	10.7	160	5.6	4	8.0	103.7	10.8	65	0.008	0.006	<0.002	0.006	0.026	0.34
	MUR 28	9/5	10.00	10.2	160	4.3	3	8.1	105.7	11.0	64	0.004	0.002	<0.002	0.005	0.022	0.33
Downstream	MUR 935	9/5	11.40	10.9	160	4.3	3	8.1	109.1	11.5	62	0.004	0.002	0.002	0.006	0.021	0.32
	MUR 937	9/5	14.10	12.0	130	4.4	2	8.2	113.5	11.4	55	0.003	0.001	<0.002	0.003	0.018	0.29
	MUR 29	7/5	13.15	11.0	130	4.6	<2	8.0	109.1	11.2	53	0.004	0.004	<0.002	0.004	0.019	0.28

Table 7. Monthly water quality statistics from Lobb's Hole (410761)

All values are means. Monthly maximum turbidity values are in parentheses. Dissolved oxygen is expressed as average monthly minimum and maximum values.

Station	Lobb's Hole (410761)				
Analyte	temp.	EC	pH	turbidity	D.O. (% Sat.)
March	17.5	157.3	-	88.0 (660)	88.58 – 93.79
April	15.8	175.1	7.96	8.9 (38.5)	92.84 – 95.86
May	9.8	184.5	8.03	4.3 (7.03)	94.34 – 96.79
Autumn	**14.4**	**172.3**	**8.00**	**33.7 (660)**	**88.58 – 96.79**

3.4 Periphyton

The distribution of the chlorophyll-a data shows a fairly distinct "U" shaped pattern with values at MUR 931 exceeding 200,000 ug/m$^{\mathbf{-2}}$ and 85,000ug/m^{-2} at the farthest downstream site, MUR 29 (Figure 5). Mean concentrations upstream of the Murrumbidgee Pump Station were 37,265 ± 29,254 ug/m^{-2} compared to downstream with an average of 28,780 ± 14,776ug/m^{-2}. Owing to these extreme values at the upstream and downstream extents of this study, there was no significant location effect in chlorophyll-a concentrations ($F_{\mathbf{1,29}}$ = 0.71; P=0.81; Table 8). Compared to the chlorophyll–a data the Ash Free Dry Mass (AFDM) distribution was more evenly spread across sampling sites (Figure 6), although the concentrations were slightly higher at MUR 931, which corresponds to the elevated chlorophyll-a concentrations at that site. The average concentration upstream of MPS was 4,825 ± 2,721 mg/m^{-2} compared to 3,908 ± 1,637 mg/m^{-2} downstream of the pump station. These mean values where not statistically different from one another ($F_{1,29}$ = 0.63; P=0.49; Table 8).

Table 8. One-way nested analysis of variance results for chlorophyll-a and ash free dry mass densities

Response	Source	DF	F-value	P-value
Chlorophyll-*a* (log)	Location	1	0.71	0.80
	Site [Location]	3	4.89	0.008
	Residual	28		
AFDM (log)	Location	1	0.63	0.49
	Site [Location]	3	2.46	0.08
	Residual	29		

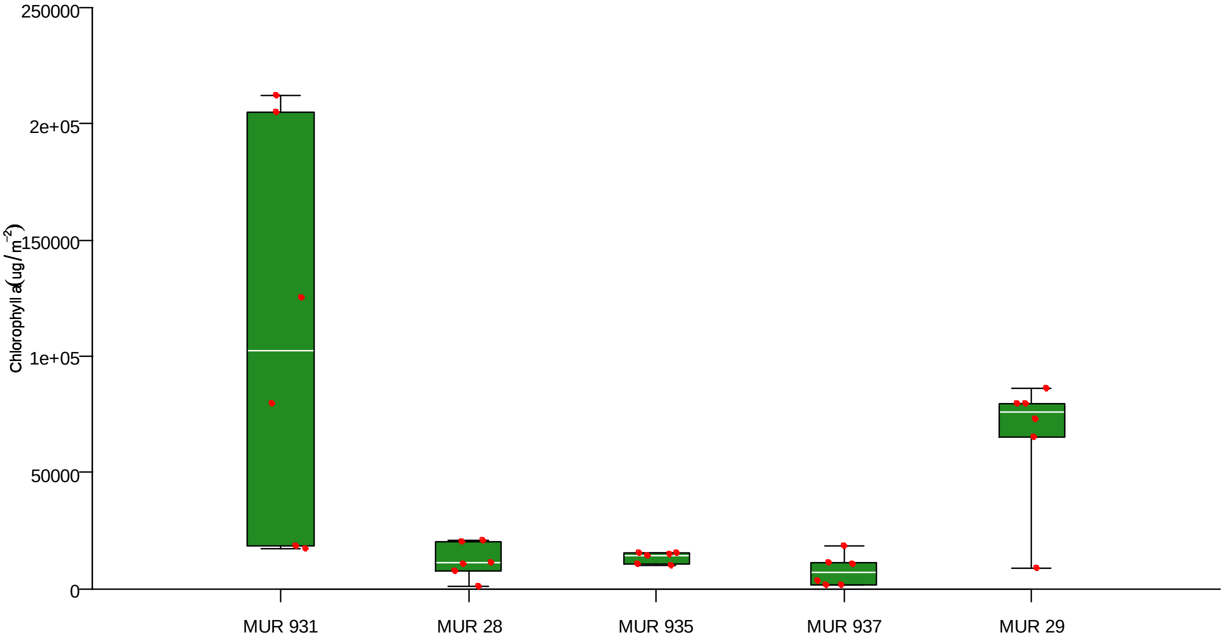


Figure 5. Periphyton chlorophyll-a concentrations from upstream and downstream of the MPS

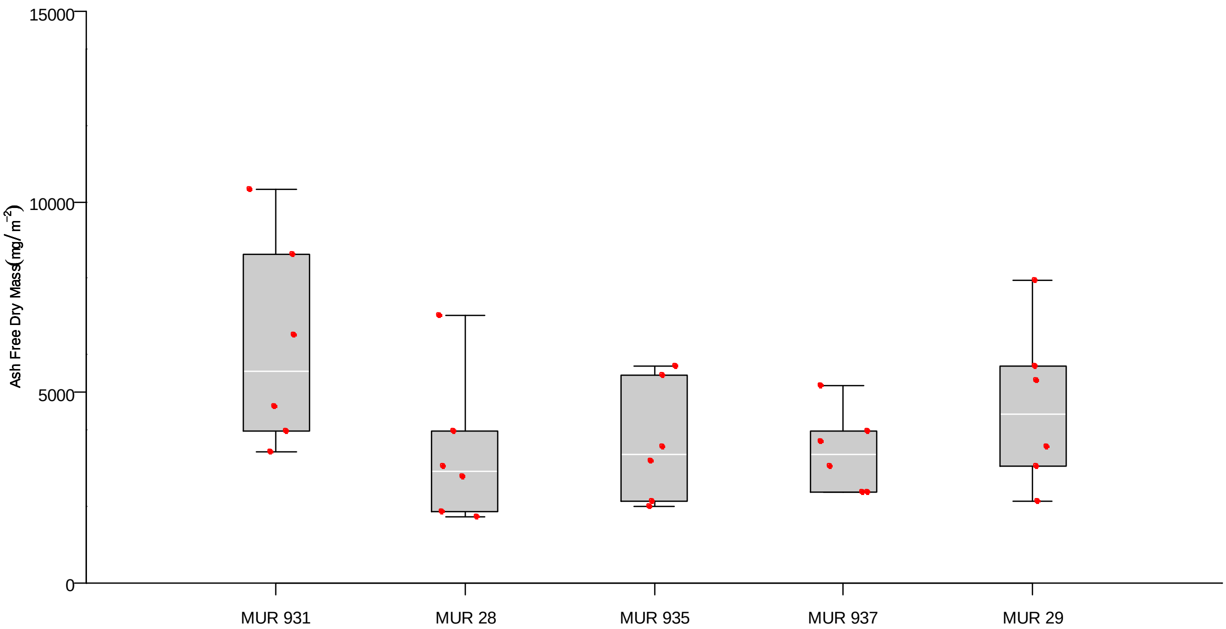


Figure 6. Periphyton Ash Free Dry Mass (AFDM) from upstream and downstream of the MPS

Strip chart values in red represent raw data points in Figures 5 & 6. See APPENDIX C for an explanation on how to interpret box and whisker plots.

3.5 Macroinvertebrate Communities

3.5.1 Univariate Metrics

The total estimated abundances of macroinvertebrates for the samples collected indicated that there were significantly higher estimated densities of macroinvertebrates at downstream sites compared to the upstream sites (Figure 7). This pattern was clearly evident in both habitats but more pronounced in the riffle habitat.

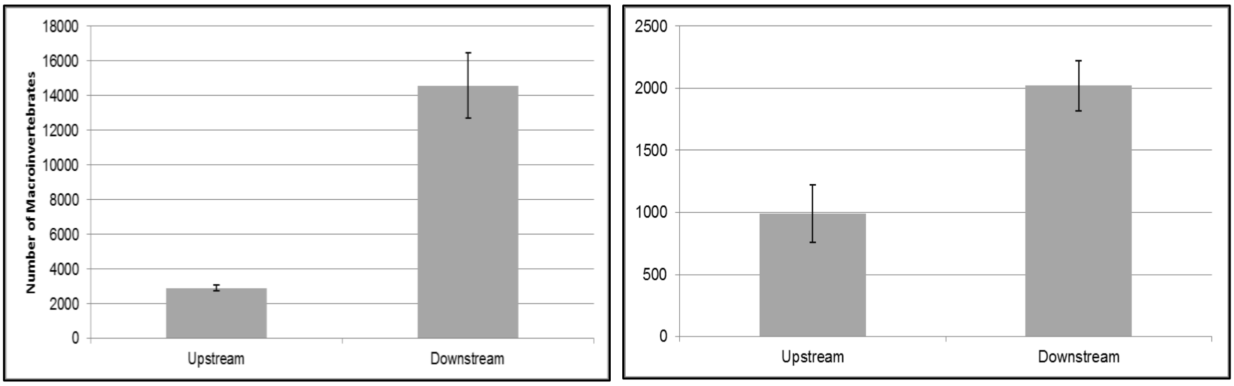


Figure 7. Total estimated abundance of macroinvertebrates averaged over upstream and downstream sites for riffle (left) and edge (right)

No significant differences were found between upstream and downstream sites in terms of taxa richness or number of EPT taxa collected from edge habitats (Figures 8 and 9). Within the edge habitat the highest number of macroinvertebrate families collected in a sample was 23 families at site MUR 931 compared to the lowest count of 11 families at site MUR 935. The highest and lowest number of genera were collected from site MUR 931 (32) and site MUR 29 (14). The highest and lowest number of EPT taxa collected was 8 families at site MUR 931 and 4 families at site MUR 29; highest and lowest numbers of genera corresponded with family data with 15 and 7 genera collected respectively.

Significant differences were found between upstream and downstream sites in terms of taxa richness and number of EPT taxa collected from riffle habitats. Within the riffle habitat the highest number of macroinvertebrate families collected in a sample was 17 at site MUR 931 compared to the lowest count of 7 families at site MUR 935, which also corresponded to the highest and lowest number of genera with 23 and 10 respectively. The highest and lowest number of EPT families collected was 8 families at MUR 931 and 2 families at MUR 935, while corresponding highest and lowest genus values were 14 and 4 genera respectively.

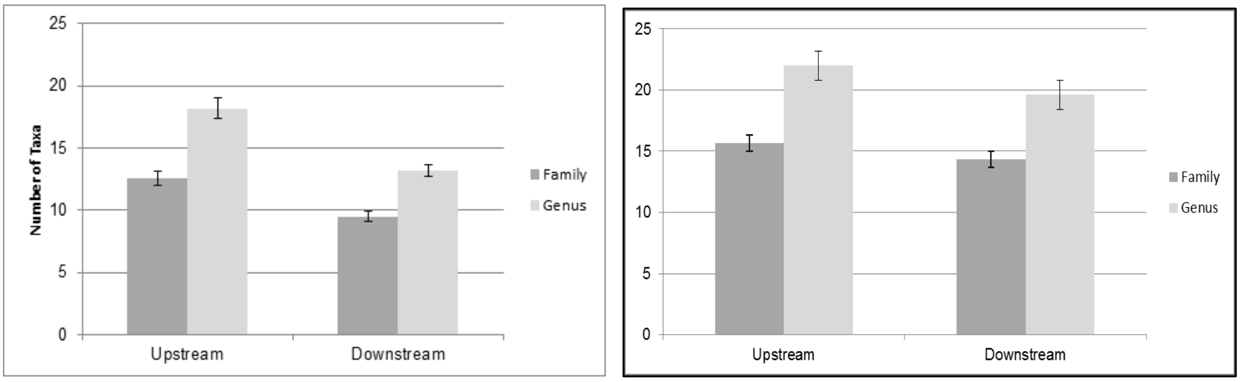


Figure 8. Taxonomic richness of macroinvertebrates averaged over upstream and downstream sites for riffle (left) and edge (right)

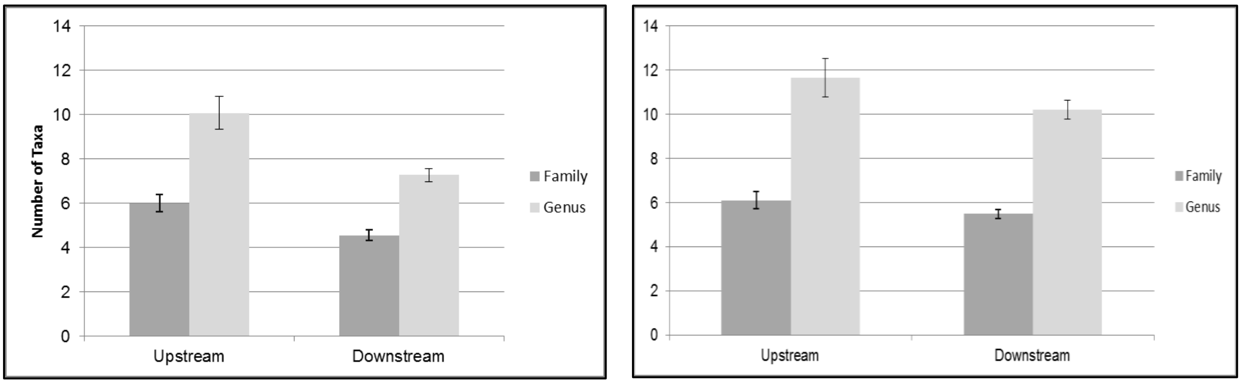


Figure **9**. EPT richness of macroinvertebrates averaged over upstream and downstream sites for riffle (left) and edge (right)

The relative abundance of EPT families in relation to other taxa is presented in Figure 10. The contribution that tolerant taxa (Oligochaeta, Chironomidae and Diptera) make to the community composition at each location is presented in Figure 11. As stated, an increased number of riffle EPT taxa were collected from sites upstream from the MPS.

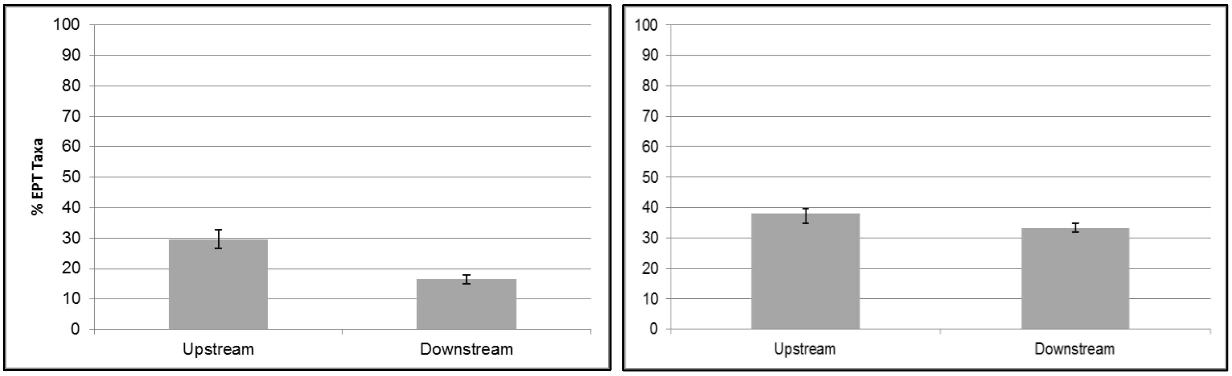


Figure 10. EPT abundance percentage averaged over upstream and downstream sites for riffle (left) and edge (right)

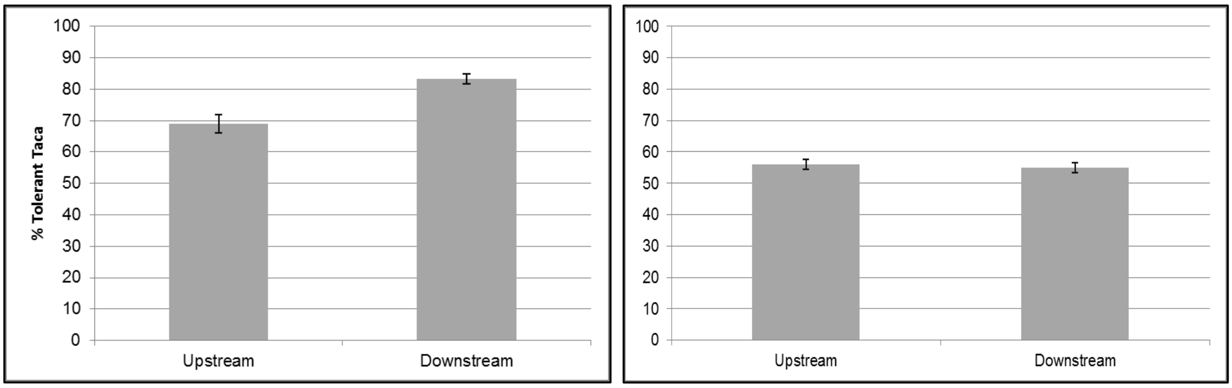


Figure 11. Percentage of tolerant taxa averaged over upstream and downstream sites for riffle (left) and edge (right)

3.5.2 Patterns in community structure

Riffle habitat

Macroinvertebrate communities collected from riffle habitat show distinct grouping by location in the ordination plot (Figure 12). All sites, regardless of location, are grouped within a 60% similarity ellipse, with the upstream and downstream groups divided into separate 70% similarity ellipses. However, the subsequent nested ANOSIM results do not indicate significant assemblage differences based on location (R=0.92; *p*=0.1)[1].

[1] This is because the ANOSIM relies on permutations to generate *P*-values for the rank similarities (Clarke and Warwick, 2001) With five sites in this sampling programme, the smallest attainable *P*-value is 0.10, which is what was found in this study. However, we can infer significance from the high R-value (0.92) (Bob Clarke, *pers. comms*. 2011).

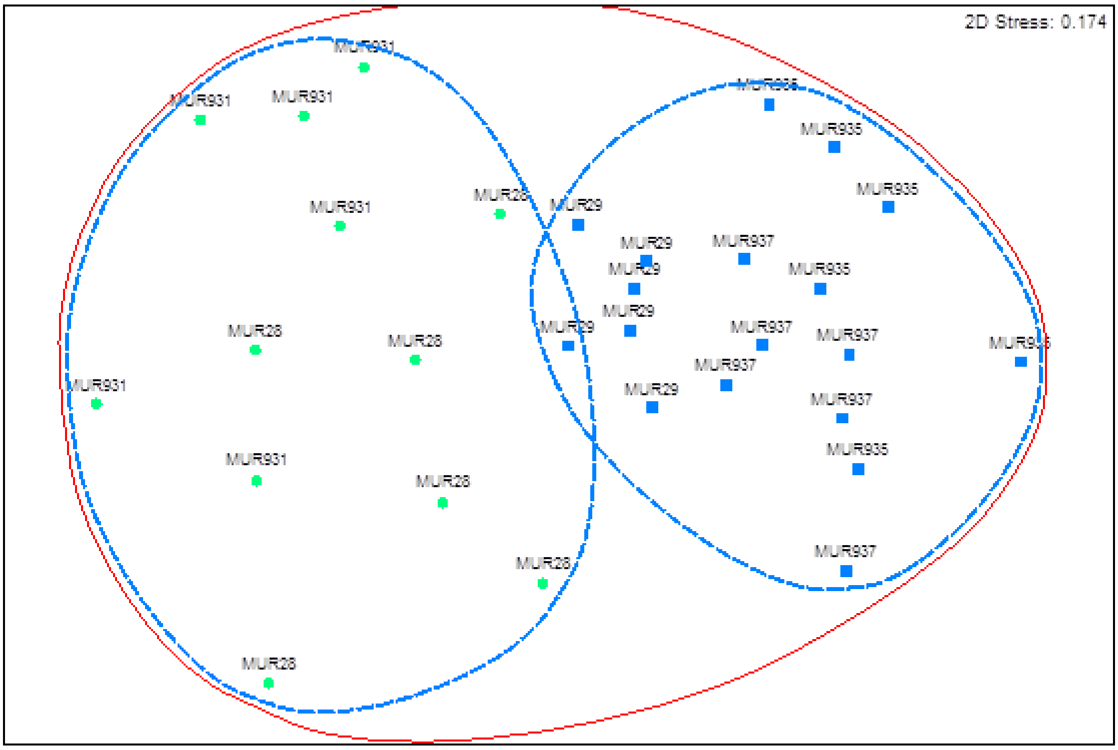


Figure 12. MDS Ordination plot displaying autumn 2012 riffle macroinvertebrate data

Red ellipse represents 60% similarity group and blue ellipse represents 70% similarity groups based on cluster analysis output

The SIMPER routine indicates that the principal contributors to these observed differences is the greater abundances of blackfly larvae (family: Simuliidae) and to a lesser extent chironomid larvae (family: Orthocladiinae) and Baetidae mayflies collected from the downstream sites (Table 9).

As stated in Section 3.5.1, significantly increased total abundances were observed at downstream sites. Much of this variation can be attributed to increased abundances of Simuliidae larvae at these sites. Mean estimated abundances upstream were 8,636 ± 3,339 and downstream were 66,797 ± 48,568. A decrease in Simuliidae numbers was also found at the downstream sites, with the greatest abundance being collected from MUR 935 (19,492±4,520), followed by MUR 937 (10,575±2,090) and then MUR 29 (3,332±1,037).

Overall, there were five dominant taxonomic groups collected from both upstream and downstream sites. These groups included a combination of tolerant and sensitive taxa. The dominant families included Oligochaetes (SIGNAL=2), Hydropsychidae (SIGNAL=6), Baetidae (SIGNAL=5), Orthocladiinae (SIGNAL=3) and Simuliidae (SIGNAL=5).

The relative abundances of EPT taxa were lower at all sites compared to the autumn 2011 results. Mean relative abundances at the upstream sites ranged from 24% to 36% and at the downstream sites from 11% to 24%. During autumn 2011, relative abundances ranged between 40% and 60% across all sites.

Table 9. Discriminating taxa between zones based on the SIMPER analysis of riffle samples

Comparison	Discriminating taxa	SIGNAL-2	Comments
Upstream vs. Downstream	Simuliidae	5	Characterises both upstream and downstream sites but is present in higher abundances downstream
	Baetidae	5	Characterises both upstream and downstream sites but is present in higher abundances downstream
	Orthocladiinae	4	Characterises both upstream and downstream sites but is present in higher abundances downstream

Edge habitat

The nested ANOSIM results do not indicate significant differences between locations based on the macroinvertebrate assemblages (R=0; *p*=0.7). The similarity of the edge habitat both upstream and downstream of the MPS presented in Figure 13, is due to the dominance of the same taxa which were present in both locations. The main taxa driving these similarities were Orthocladiinae (SIGNAL=4), Caenidae (SIGNAL=4), Oligochaeta (SIGNAL=2), Chironominae (SIGNAL=3), Baetidae (SIGNAL=5) and Leptophlebiidae (SIGNAL=8).

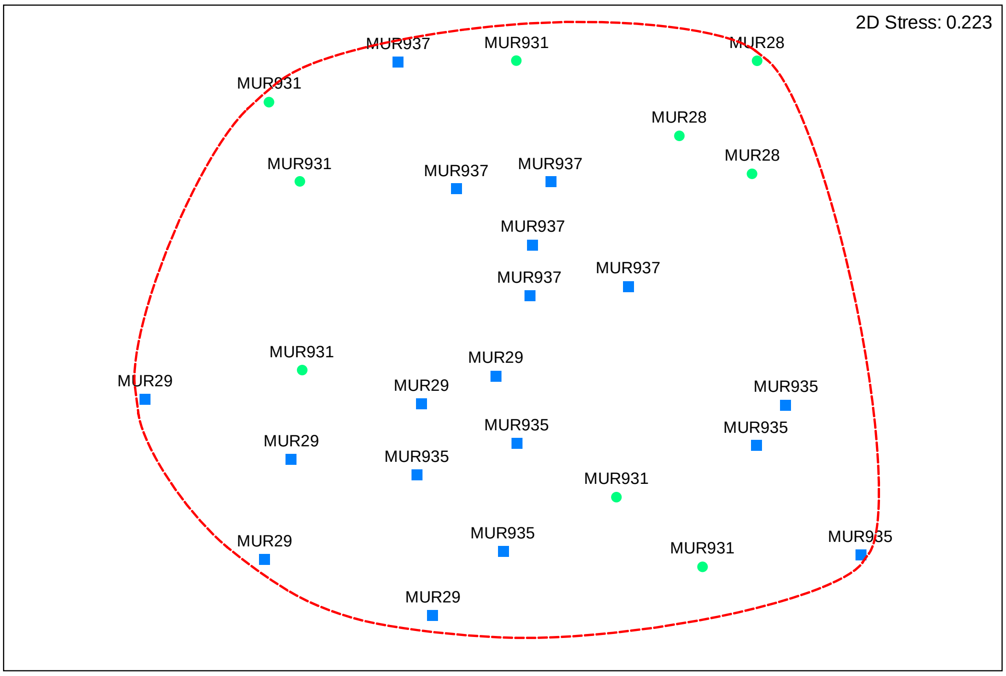


Figure 13. MDS Ordination plot displaying autumn 2012 edge macroinvertebrate data

Red ellipse represents 60% similarity grouping based on the cluster analysis output.

3.5.3 AUSRIVAS Assessment

Within the riffle habitat average O/E 50 scores were not significantly higher (*p*=0.06) (Table 11) upstream than downstream. Within the upstream sites 83% of the replicates were banded 'A' and 17% a banding of 'B' and within the downstream sites 20% of sites were banded 'A', 70% banding 'B' and 10% banding 'C' (Table 10). Elmidae beetles (SIGNAL = 7) were identified in 17% of downstream replicates and 75% of upstream replicates; Tipulidae larvae (SIGNAL = 5) from 6% of downstream and 42% upstream and Gripopterygidae stoneflies (SIGNAL = 8) from 6% downstream and 25% upstream replicates. The lowest banding was produced for site MUR 935 (Band C, O/E 0.56), where Chironominae larvae and the mayfly Caenidae were not collected (along with the absence of Elmidae, Tipulidae and Gripopterygidae). The results for this site also highlight the variability within sites, with bandings of between 'A' and 'C' produced by the model.

Within the edge habitat average O/E 50 scores were not significantly different (Table 12) upstream when compared to downstream means. Within the upstream sites 56% of the replicates were banded 'A' and 44% a banding of 'B' and within the downstream sites 11% of sites were banded 'A' and the remaining 86% Band-B (Table 10). All of the edge habitats were therefore considered to be significantly impaired (Band-B), suggesting fewer taxa collected than were expected by the model, based on the habitat and physico-chemical variables. These results are comparable with those collected during autumn 2011, when all sites were also assessed as Band-B. Reasons for the Band-B result at most replicates include the absence of hydroptilidae caddisflies (SIGNAL=6) and gripopterygidae stoneflies (SIGNAL=7). As in previous years the missing taxa from all edge samples, regardless of location in relation to the MPS, included Conoesucidae caddisflies (SIGNAL =7), Synlestidae damselflies (SIGNAL =7) and Planorbidae snails (SIGNAL=2) (Appendix D). In the case of Conoesucidae, this family has yet to be collected in the lower reaches of the Murrumbidgee River during the course of the MEMP and Synlestidae has rarely been collected. For the complete list of collected taxa refer to Appendix E.

With regards to SIGNAL-2 score, in the riffle habitat mean scores of 4.53 were calculated for upstream sites and 4.29 for downstream sites. SIGNAL-2 scores for the riffle habitat decreased upstream and increased downstream of the MPS when compared to autumn 2011 results. The autumn 2011 riffle results averaged 4.60 upstream and 4.48 downstream. ANOVA results indicate that there is a significant difference between the SIGNAL-2 scores upstream compared to downstream (*p*=0.02). This is a result of the increased abundances of tolerant to moderately tolerant taxa found at the downstream sites.

In the edge habitat, mean SIGNAL-2 scores of 4.42 were calculated from upstream sites and 4.28 for downstream sites. SIGNAL-2 scores for the edge habitat also slightly increased upstream of the MPS when compared to autumn 2011 results with downstream sites again slightly lower, on average. The autumn 2011 edge results averaged 4.30 upstream and 4.43 downstream. No significant differences in SIGNAL-2 scores between upstream and downstream locations were found within the edge habitat.

The overall health assessments determined by the AUSRIVAS modelling (based on the lowest grade within each habitat) therefore indicated that all sites other than MUR 935 were graded a Band-B. MUR 935 was given no reliable assessment, due to banding scores of A, B and C in the riffle replicates. This illustrates that at the majority of sites the lowest graded replicate indicated that fewer taxa were collected than were expected by the model, based on the habitat and physico-chemical variables.

Table 10. AUSRIVAS and SIGNAL-2 scores for autumn 2012

Location to MPS	SITE	Rep.	SIGNAL-2		AUSRIVAS O/E score		AUSRIVAS band		Overall habitat assessment		Overall site assessment
			Riffle	Edge	Riffle	Edge	Riffle	Edge	Riffle	Edge	
UPSTREAM	Mur 931	1	5.20	4.36	1.00	0.62	A	B	B	B	B
	Mur 931	2	5.24	4.57	1.11	0.85	A	A			
	Mur 931	3	4.73	4.15	0.78	0.85	B	A			
	Mur 931	4	4.67	4.56	1.00	0.85	A	A			
	Mur 931	5	5.00	4.53	0.89	0.93	A	A			
	Mur 931	6	5.07	4.48	1.11	0.93	A	A			
	Mur 28	1	4.91	4.63	0.78	0.78	B	B	B	B	B
	Mur 28	2	4.90	4.50	0.89	0.70	A	B			
	Mur 28	3	4.92	4.58	1.00	0.62	A	B			
	Mur 28	4	5.17	NS	0.89	NS	A	NS			
	Mur 28	5	5.08	NS	0.89	NS	A	NS			
	Mur 28	6	5.25	NS	0.89	NS	A	NS			
DOWNSTREAM	Mur 935	1	4.13	4.71	0.78	0.70	B	B	NRA	B	NRA
	Mur 935	2	4.75	4.64	0.78	0.54	B	B			
	Mur 935	3	4.29	4.67	0.67	0.70	B	B			
	Mur 935	4	5.44	4.07	0.56	0.78	C	B			
	Mur 935	5	5.20	4.25	0.89	0.78	A	B			
	Mur 935	6	4.86	4.71	0.67	0.78	B	B			
	Mur 937	1	4.50	4.62	0.67	0.70	B	B	B	B	B
	Mur 937	2	5.38	4.27	0.67	0.78	B	B			
	Mur 937	3	5.00	4.26	0.78	0.78	B	B			
	Mur 937	4	5.00	4.18	0.89	0.85	A	A			
	Mur 937	5	5.00	4.53	0.78	0.78	B	B			
	Mur 937	6	5.00	4.00	0.78	0.70	B	B			
	Mur 29	1	5.38	4.07	0.78	0.78	B	B	B	B	B
	Mur 29	2	4.63	3.64	0.78	0.78	B	B			
	Mur 29	3	4.91	4.42	0.78	0.78	B	B			
	Mur 29	4	4.55	4.08	0.78	0.70	B	B			
	Mur 29	5	5.27	4.06	1.00	0.85	A	A			
	Mur 29	6	4.80	3.83	0.89	0.62	A	B			

NS: Not sampled as limited edge habitat available.

NRA: No reliable assessment as band range is greater than one level (AUSRIVAS protocol).

Table 11. One-way analysis of variance results for O/E 50 and SIGNAL-2 scores from the riffle

Response	Source	DF	F-value	P-value
O/E 50	Location	1	9.01	0.06
	Site [Location]	3	2.09	0.13
	Residual	29		
SIGNAL- 2	Location	1	21.83	0.02
	Site [Location]	3	0.35	0.79
	Residual	29		

Table 12. One-way analysis of variance results for O/E 50 and SIGNAL-2 scores from the edge

Response	Source	DF	F-value	P-value
O/E 50	Location	1	0.92	0.41
	Site [Location]	3	2.03	0.14
	Residual	26		
SIGNAL- 2	Location	1	2.07	0.25
	Site [Location]	3	1.88	0.16
	Residual	26		

Discussion

3.6 Water Quality and periphyton

The water quality results indicate that neither the Murrumbidgee Pump Station nor the inflows from the Cotter River confluence are having any impacts downstream.

The water quality data shows no sign that activities related to the MPS have resulted in changes to the background water quality parameters in the Murrumbidgee River. Elevated nutrient levels (TN & TP) and pH levels slightly elevated above the recommended guideline values occurred across all sampling sites and not specific to one location. This suggests that the preceding hydrological conditions coupled with the high base flows at the time of sampling are the likely factors responsible for these observed values.

The fact that TP and TN tend to be higher at the furthest upstream site (MUR 931) and dissipate downstream, indicates that the main nutrient source is upstream of the study area and therefore outside the scope of this study. The trend indicates that the nutrients are being taken up by the system slowly as they continue downstream (TP dropping below guideline levels at MUR 937), showing there are no significant inputs within the study area.

The pH data shows MUR 28, MUR 935, and MUR 937 are exceeding guideline levels with MUR 931 and MUR 29 (the most upstream and most downstream site respectively) on the cusp of the guideline value. The change is small and likely to be a function of groundwater contributions and may also be a response to elevated levels of photosynthesis.

The periphyton results indicate that there was no detectable impact from the completed MPS upgrade or pumping schedule. There was no statistical difference identified between the upstream and downstream mean chlorophyll-a or AFDM concentrations due to the 'U' pattern present showing higher concentrations at the furthers upstream and downstream sites and reduced values in between.

There is some evidence of a negative relationship between the high flow levels downstream of the Cotter River confluence and the chlorophyll-a and AFDM concentrations. The persisting higher flows since the March event from the Cotter River, with assistance from the Bendora Scour valve, may have prevented the periphyton communities at MUR 28, MUR 935, and MUR 937, from full recovery after the impact from the March event.

The furthest downstream site MUR 29 had higher chlorophyll-a concentrations than MUR 28, MUR 935 and MUR 937. It has not been confirmed, but one likely explanation for this is that because the riffle at MUR 29 is shallower (increased width) and at lower velocity compared to the other sites, there is higher light penetration and a higher growth rate respectively. There was also an increased amount of detrital matter at MUR 29 from previous high flow events, which may also contribute to increased chlorophyll-a levels.

MUR 931, which showed the highest levels of chlorophyll-a and AFDM is located upstream of the Cotter River confluence and was therefore not affected by the persisting high flows. This site has the most canopy coverage of all MPS sites, and should have a reduced capacity for primary production than the other sites. However, the periphyton results are not consistent with this which could be caused by a number of factors. The canopy layer could be providing allochthonous input to the system, which other sites would not be experiencing due to their reduced canopies. There is also the potential that excess nutrients could be entering the system from Point Hut Pond which overtopped a number of times during the autumn period during the periods of high rainfall. These additional nutrients are then potentially dissipating before reaching sites further downstream.

3.7 River health and patterns in macroinvertebrate communities

The results of the autumn 2012 round indicate that variations in the macroinvertebrate communities at sites downstream from the MPS were detected. This variation was detected in terms of reduced taxa richness and number of EPT taxa collected, increased total abundance and decreased AUSRIVAS banding and O/E scores. Significant variation was not detected using multivariate techniques due to the high degree of intra-site variation. No significant differences between the upstream and downstream locations within the edge habitat communities were detected.

The most obvious point to note regarding the changes in community composition at the downstream sites is the high abundances of Simuliidae (black fly larvae) and to a lesser extent an increase in Baetidae mayflies. The increased abundances of these families are suggestive of increased flow conditions. Simuliidae larvae are filter-feeding rheophilous species - usually occurring in fast flowing water. They require flow to aid in respiration and to effectively strain fine particulates from the water (Merritt and Cummins, 1996). With regards to Baetidae mayflies, Brittain and Saltveit (1989) showed that under high flow conditions, Baetids increased in abundance compared to sites with lower base-flows while Malmqvist and Englund (1996) investigated the impacts of flow alterations on Mayflies and found that abundances of mayflies in general were significantly lower at sites with lower flow and that Baetids became sparser in response to flow reductions. The observed increase in Baetids at downstream sites has been reported previously (ALS, 2011b) but the increase in Simuliidae larvae has not. The riffle habitat at MUR 935 displayed variable results and supported the greatest number of Simuliidae larvae. The absence of a number of previously collected taxa from only certain replicates again indicates the high degree of intra-site variability within the Murrumbidgee River.

It would be expected that an increase in flows would result in an increase of the rheophilic Elmidae beetle. However, an absence of Elmidae beetles from downstream site MUR 937 and from the majority of replicates from downstream sites MUR 29 and MUR 935 was observed. Elmidae beetles are considered to be good indicators of flow variation (Brooks *et al*. 2011) because of their affinity for fast flowing, clear and highly oxygenated water (Gooderham and Tsyrlin 2005) but it may be that autumn conditions favoured the proliferation of Simuliidae larvae on available habitat. SIGNAL-2 scores were not significant between upstream and downstream sites in the edge habitat, but were in the riffle habitat. As previously discussed this significance is due to differences in abundance, rather than diversity, which is likely being affected by increased flows downstream of the Cotter confluence and Bendora Scour valve. Average SIGNAL-2 scores in comparison to autumn 2011 for the riffle habitat decreased upstream and increased downstream, while in the edge habitat increased upstream and decreased downstream. A reduction in SIGNAL-2 score is generally reflective of water quality issues and AUSRIVAS scores are more indicative of habitat quality.

There are potentially three reasons for the differences in community composition during the autumn 2012 round. These are likely related to a number of flow events observed during (and prior to) the autumn survey. Firstly, at a local scale, the Bendora Scour Valve (located directly downstream of the upstream site MUR 28) had been operational for over a week prior to the sampling event, releasing additional water into the sampling sites and increasing flow rate at these sites. Secondly, additional flow entering the Murrumbidgee River from the Cotter Confluence may be facilitating a higher number of these taxa by increasing food resources and creating more favourable habitat conditions for selected taxa. Thirdly, at a catchment level, there was a large flood event in early March, with all sites still displaying evidence of the event in terms of damage to the physical habitat. All sites had remnants of logs and wood debris throughout the reach, while some showed patches of dead vegetation due to inundation during the event. Sudden increases in flow can cause catastrophic downstream drift of macroinvertebrate communities resulting from increased shear stress and bed movement (Bunn & Arthington 2002). Therefore, the scouring impact during the flooding event in March likely resulted in an initial loss of diversity and abundances. Taxa richness appears to have returned to comparable levels to the pre-flood conditions (based on comparisons with the autumn 2011 data), however at the upstream sites the abundances of those taxa are taking a little longer to recover relative to the downstream sites; which appear to be benefiting from the increased flows from the Cotter River and Bendora scour operation.

4. Conclusions and Recommendations

The results from the autumn 2012 sampling program indicate that there has been no detectable impact upon the Murrumbidgee River system from the MPS pumping activity undertaken. The water quality results show that all sites are relatively similar with no location patterns indicating relation to the MPS, with elevated nutrient levels present originating from upstream of the study area.

The periphyton results also indicated there was no detectable impact from the MPS pumping schedule. However, there was some evidence that increased flows, downstream of the Cotter River confluence, were having some influence on the periphyton communities. Chlorophyll-a and AFDM showed reduced levels at MUR 28, 935 & 937, possibly resulting from increased levels of scour compared to the upstream (MUR 931) being unaffected and furthest downstream site (MUR 29) experiencing reduced impacts from these flows. While the elevated levels of chlorophyll-a and AFDM at MUR 931 are potentially originating from excess nutrients entering the system from overtopping at Point Hut Pond.

The AUSRIVAS modelling resulted in all sites being assessed as BAND B indicating that all sites are ‘significantly’ impaired. However, there were a number of replicates which were assessed as BAND A or ‘similar to reference’ while a single replicate was assessed as BAND C being ‘severely’ impaired. A number of the missing taxa were absent across all or most sites which suggests that all sites have been similarly impaired by a disturbance. This is likely to be the large flood event experienced at the beginning of March, with the macroinvertebrate communities at all sites still in a recovery phase following these high flows.

While changes in estimated abundances seem likely in response to changes in flow, the resilience and/or resistance that seems to be inherent of the macroinvertebrate communities in the Murrumbidgee River means (based on the current data record), that permanent changes in the community composition may be unlikely as long as there is a sufficient period of time to allow recovery. This should allow community assemblages to return a pre-disturbance state – although abundances of slow recovering taxa (i.e. Stoneflies and caddisflies) may take longer.

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Appendix A

Site Summaries

MUR931

Fairvale
7/5/2012 10:15am

Temp. (°C)	EC (µs/cm)	Turb. (NTU)	TSS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
10.7	160	5.6	4	8.0	103.7	10.8

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
65	0.008	0.006	< 0.002	0.006	0.026	0.34

Daily Flow: 750 ML/day

Recorded at the closest station (410761), located on the Murrumbidgee River at Lobb's Hole.

Compared to current flow:

Spring 2011:  Autumn 2011: 

Riffle Habitat

- Dominant substrate was cobble

Dominant Taxa

- Simuliidae
- Hydropsychidae

Sensitive Taxa (SIGNAL-2 ≥ 8)

- Leptophlebiidae
- Hydrobiosidae

Edge Habitat

- Dominant trailing bank vegetation was wood, blackberries and native tree's and shrubs

Dominant Taxa

- None

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae
- Gripopterygidae

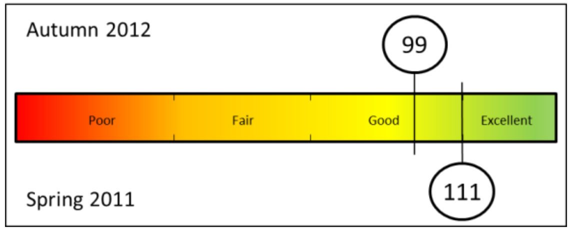
AUSRIVAS Results

	Autumn 2011	Spring 2011	Autumn 2012
Riffle Habitat	A	B	B
Edge Habitat	B	B	B
Overall Site Assessment	B	B	B

Additional Comments

- New periphyton growth
- Filamentous algae in thick mats, but patchy
- Very few macrophytes
- Some small isolated areas of erosion
- A number of tree's have been pushed over by the March event
- Large amounts of logs and wood debris deposited along the right hand bank
- Upstream riffle was sampled due to better looking habitat

Site Quality Assessment



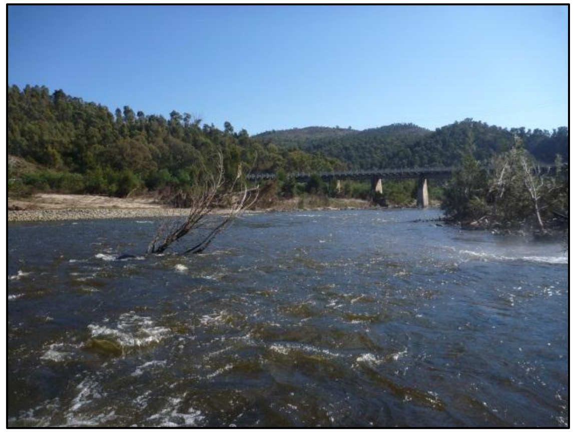
MUR28

Upstream Cotter River Confluence

9/5/2012 10:00am

Temp. (°C)	EC (µs/cm)	Turb. (NTU)	TSS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
10.2	160	4.3	3	8.1	105.7	11.0

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
64	0.004	0.002	< 0.002	0.005	0.022	0.33



Daily Flow:

750 ML/day

Recorded at station 410761, located on the Murrumbidgee River at Lobb's Hole.

1200 ML/day

Recorded at station 410738, located on the Murrumbidgee River at Mt. MacDonald.

250 ML/day

Recorded at station 410700, located on the Cotter River at Cotter Kiosk (below the Enlarged Cotter Dam).

The high flows down the Cotter River limit the comparability of this seasons flow to that of other seasons, which is further complicated by the operation of the Bendora Scour Valve.

AUSRIVAS Results

	Autumn 2011	Spring 2011	Autumn 2012
Riffle Habitat	A	B	B
Edge Habitat	B	B	B
Overall Site Assessment	B	B	B

Riffle Habitat

- Dominant substrate was bedrock and boulder

Dominant Taxa

- Hydropsychidae

Sensitive Taxa (SIGNAL-2 ≥ 8)

- Leptophlebiidae
- Gripopterygidae
- Hydrobiosidae

Edge Habitat

- Limited edge habitat available due to scour valve, resulting in a single edge sample
- Dominant trailing bank vegetation was wood

Dominant Taxa

- Chironomidae
- Baetidae
- Leptoceridae

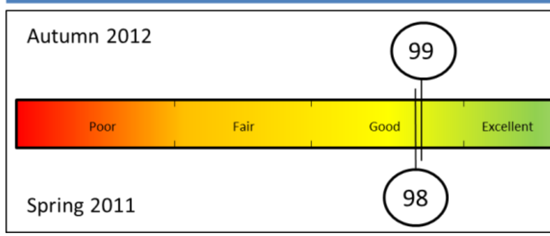
Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae

Additional Comments

- Bendora Scour Valve has been on for over a week, was turned down, but not completely off, for sampling
- The Murrumbidgee Pump Station is currently recirculating water down the Cotter River, downstream of the Enlarged Cotter Dam

Site Quality Assessment



MUR935

Casuarina Sands
9/5/2012 11:40am

Temp. (°C)	EC (µs/cm)	Turb. (NTU)	TSS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
10.9	160	4.3	3	8.1	109.1	11.5

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
62	0.004	0.002	0.002	0.006	0.021	0.32

Daily Flow:

750 ML/day
Recorded at station 410761, located on the Murrumbidgee River at Lobb's Hole.

1200 ML/day
Recorded at station 410738, located on the Murrumbidgee River at Mt. MacDonald.

250 ML/day
Recorded at station 410700, located on the Cotter River at Cotter Kiosk (below the Enlarged Cotter Dam).

The high flows down the Cotter River limit the comparability of this seasons flow to that of other seasons, which is further complicated by the operation of the Bendora Scour Valve.

AUSRIVAS Results

	Autumn 2011	Spring 2011	Autumn 2012
Riffle Habitat	A	B	N
Edge Habitat	B	B	B
Overall Site Assessment	B	B	N

Riffle Habitat

- Dominant substrate was boulder

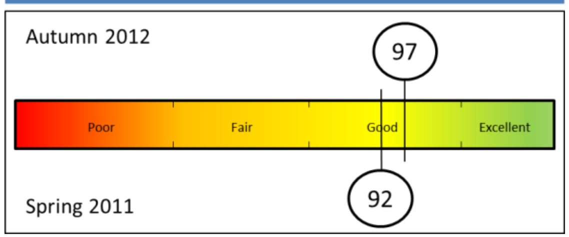
Dominant Taxa

- Chironomidae
- Simuliidae
- Baetidae
- Hydrobiosidae
- Hydropsychidae

Sensitive Taxa (SIGNAL-2 ≥ 8)

- Leptophlebiidae
- Hydrobiosidae
- Philopotamidae

Site Quality Assessment



Edge Habitat

- Limited edge habitat due to inability to cross the channel
- Dominant trailing bank vegetation was wood and *Casuarina sp.*

Dominant Taxa

- Baetidae
- Leptophlebiidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae
- Gripopterygidae

Additional Comments

- Large dense mats of filamentous algae along the edges of the channel in the slower moving waters
- Some erosion on the left hand bank
- Sand has been scoured out from the edge of the riffle section
- Deposition of wood debris on the left hand bank
- Large amounts of sand and cobble material deposited on the right hand bank, possible shifting of some material also

MUR937

Mt. MacDonald
9/5/2012 2:10pm

Temp. (°C)	EC (µs/cm)	Turb. (NTU)	TSS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
12.0	130	4.4	2	8.2	113.5	11.4

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
55	0.003	0.001	< 0.002	0.003	0.018	0.29

Daily Flow: 1200 ML/day

Recorded at the closest station (410738), located on the Murrumbidgee River at Mt. MacDonald.

Compared to current flow:

Spring 2011: 

Autumn 2011: 

AUSRIVAS Results

	Autumn 2011	Spring 2011	Autumn 2012
Riffle Habitat	A	B	B
Edge Habitat	B	B	B
Overall Site Assessment	B	B	B

Riffle Habitat

- Dominant substrate was cobble

Dominant Taxa

- Chironomidae
- Simuliidae
- Baetidae
- Hydrobiosidae
- Hydropsychidae

Sensitive Taxa (SIGNAL-2 ≥ 8)

- Leptophlebiidae
- Hydrobiosidae

Edge Habitat

- Dominant trailing bank vegetation was wood and shrubs

Dominant Taxa

- Baetidae
- Corixidae
- Leptoceridae

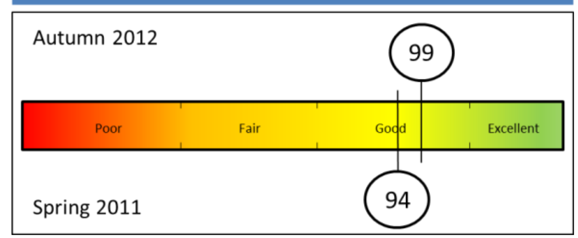
Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae
- Gripopterygidae
- Hydrobiosidae

Additional Comments

- Substrate is reasonably clean with some dense patches of periphyton
- Periphyton and filamentous algae is much more abundant in slow flowing areas
- Small areas of erosion on the left hand bank
- Wood debris is strewn throughout the edges of the channel
- Areas of dead grass and weeds along both banks due to inundation during higher flows

Site Quality Assessment



MUR29

Uriarra Crossing
7/5/2012 1:15pm

Temp. (°C)	EC (µs/cm)	Turb. (NTU)	TSS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
11.0	130	4.6	< 2	8.0	109.1	11.2

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
53	0.004	0.004	< 0.002	0.004	0.019	0.28

Daily Flow: 1400 ML/day

Recorded at the closest station (410738), located on the Murrumbidgee River at Mt. MacDonald.

Compared to current flow:

Spring 2011: 

Autumn 2011: 

AUSRIVAS Results

	Autumn 2011	Spring 2011	Autumn 2012
Riffle Habitat	A	B	B
Edge Habitat	B	B	B
Overall Site Assessment	B	B	B

Riffle Habitat

- Dominant substrate was cobble

Dominant Taxa

- Chironomidae
- Baetidae
- Oligochaeta

Sensitive Taxa (SIGNAL-2 ≥ 8)

- Hydrobiosidae

Edge Habitat

- Limited edge habitat available
- Dominant trailing bank vegetation was wood and *Casuarina sp.*

Dominant Taxa

- Corixidae
- Leptoceridae

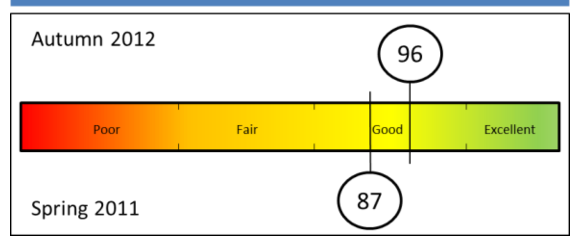
Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae

Additional Comments

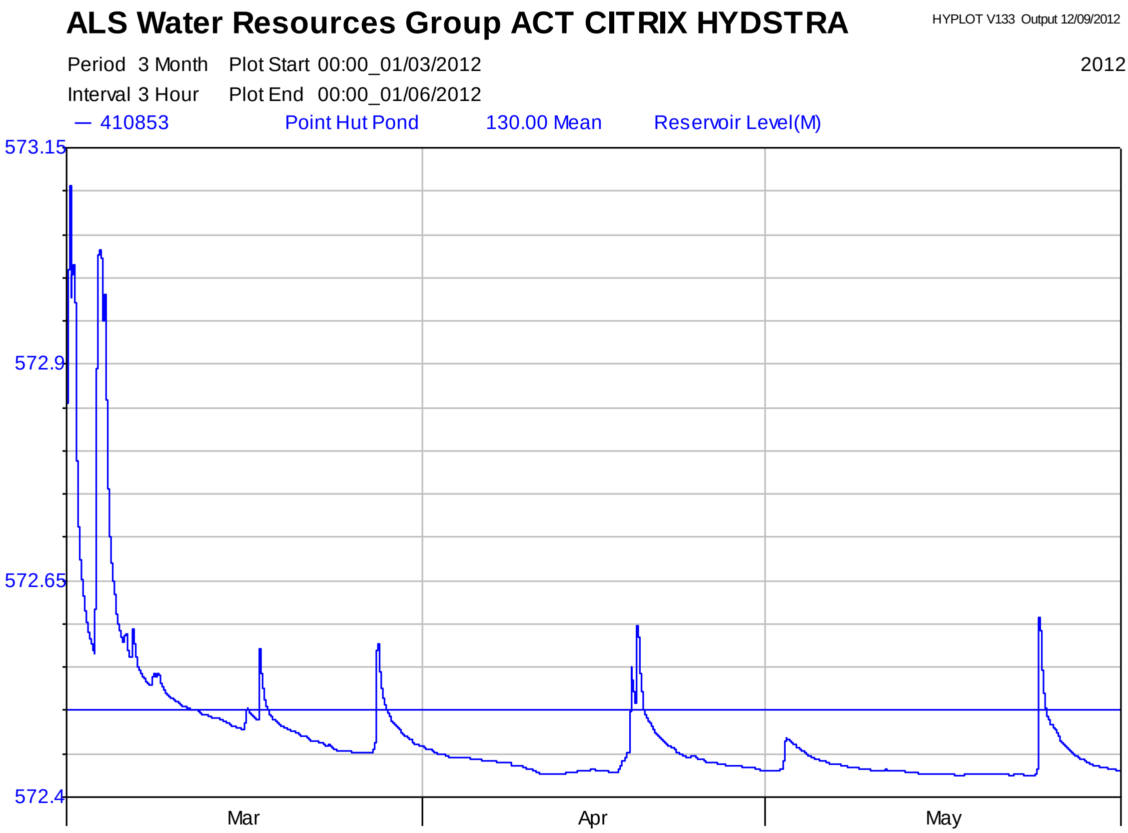
- Tree's have been pushed over by high flows (mainly *Casuarina sp.*)
- Large dense mats of filamentous algae in shallow pooling areas
- Grasses and weeds have been scoured off the left hand bank leaving bare patches

Site Quality Assessment



Appendix B

Point Hut Pond Hydrograph

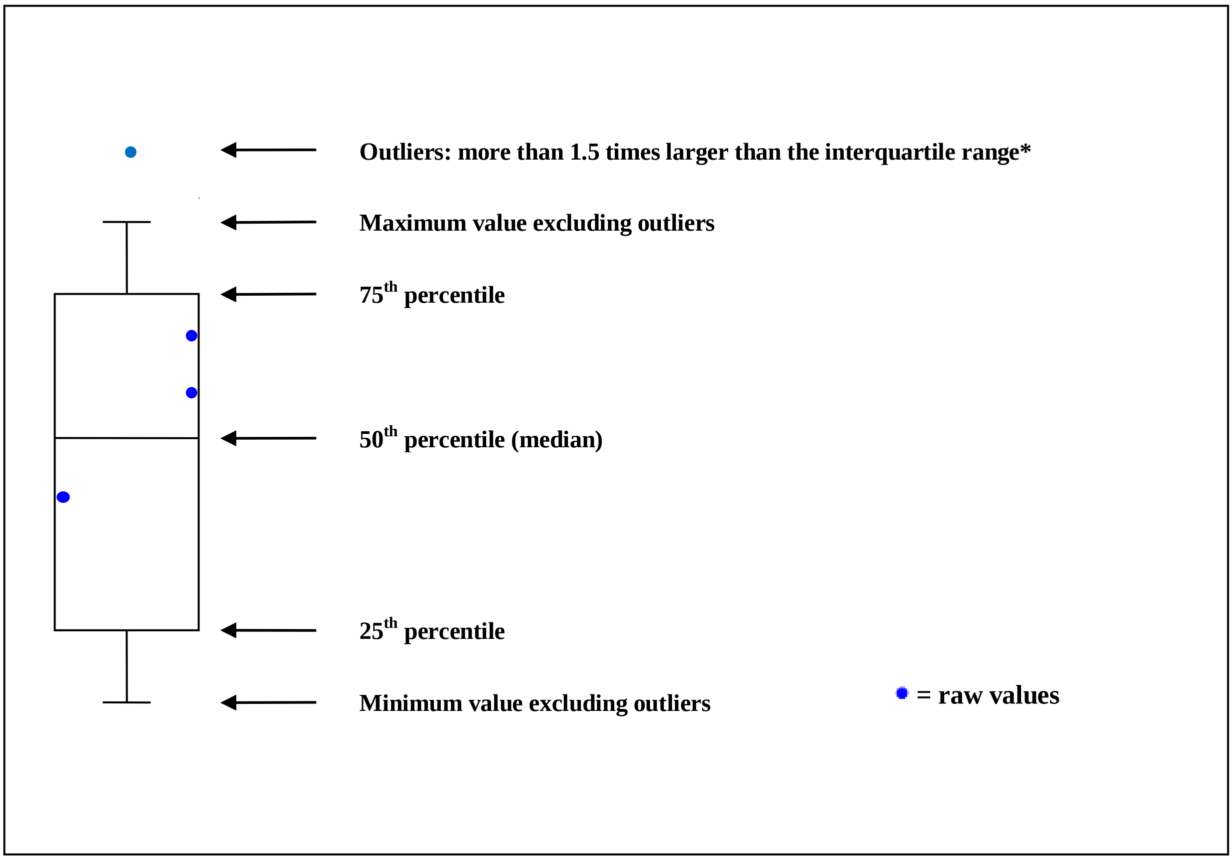


Appendix B. Point Hut Pond hydrograph during autumn 2012 (410853)

Appendix C

Interpreting box and whisker plots

Box and whisker plots are intended as an exploratory tool to help describe the distribution of the data. The blue points on the inside of the plot area indicate the raw data values that make up the distribution portrayed in the boxplot. The plot below explains how the box and whisker plots should be read.



* The interquartile (IQR) range is the difference between the 25th and 75th percentile. This value is important when two sets of data are being compared. The closer the values are to the median, the smaller the IQR. Conversely, the more spread out the values are, the larger the IQR.

Appendix D

Taxa predicted with >50% probability, but were missing from the autumn 2012 samples

Number in cells represents their given probability of occurrence at a given site. Blank cells indicate collection at a given site.

Appendix D. Macroinvertebrates predicted to occur with >50% probability by the AUSRIVAS model but absent from edge samples

Site	Taxa	Planorbidae	Elmidae	Tanypodinae	Corixidae	Synlestidae	Gripopterygidae	Hydroptilidae	Ecnomidae	Conoesucidae	Leptoceridae	Total number of missing taxa
	SIGNAL	2	7	4	2	7	8	4	4	7	6	
MUR 931	Edge	*0.55*	*0.62*	*0.90*		*0.65*	*0.69*	*0.93*	*0.59*	*0.59*		8
MUR 931		*0.55*	*0.62*			*0.65*			*0.59*	*0.59*		5
MUR 931		*0.55*	*0.62*			*0.65*	*0.69*			*0.59*		5
MUR 931		*0.55*				*0.65*	*0.69*	*0.93*		*0.59*		5
MUR 931		*0.55*	*0.62*			*0.65*				*0.59*		4
MUR 931		*0.55*				*0.65*	*0.69*			*0.59*		4
MUR 28	Edge	*0.55*			*0.62*	*0.65*	*0.69*	*0.93*		*0.59*		6
MUR 28		*0.55*	*0.62*		*0.62*	*0.65*	*0.69*		*0.59*	*0.59*		7
MUR 28		*0.55*	*0.62*	*0.90*		*0.65*	*0.69*	*0.93*	*0.59*	*0.59*		8
MUR 935	Edge	*0.55*	*0.62*		*0.62*	*0.66*		*0.93*		*0.59*	*0.97*	7
MUR 935		*0.55*	*0.62*	*0.90*	*0.62*	*0.66*	*0.69*	*0.93*	*0.59*	*0.59*		9
MUR 935		*0.55*	*0.62*		*0.62*	*0.66*	*0.69*		*0.59*	*0.59*		7
MUR 935		*0.55*	*0.62*			*0.66*	*0.69*		*0.59*	*0.59*		6
MUR 935		*0.55*	*0.62*			*0.66*	*0.69*		*0.59*	*0.59*		6
MUR 935		*0.55*	*0.62*			*0.66*	*0.69*	*0.93*		*0.59*		6
MUR 937	Edge	*0.55*		*0.90*		*0.66*	*0.69*	*0.93*	*0.59*	*0.59*		7
MUR 937		*0.55*	*0.62*			*0.66*	*0.69*	*0.93*		*0.59*		6
MUR 937		*0.55*	*0.62*			*0.66*	*0.69*	*0.93*		*0.59*		6
MUR 937		*0.55*		*0.90*		*0.66*	*0.69*			*0.59*		5
MUR 937		*0.55*	*0.62*			*0.66*	*0.69*	*0.93*		*0.59*		6
MUR 937		*0.55*	*0.62*	*0.90*		*0.66*	*0.69*	*0.93*		*0.59*		7
MUR 29	Edge	*0.55*	*0.62*			*0.66*	*0.69*	*0.93*		*0.59*		6
MUR 29		*0.55*	*0.62*			*0.66*	*0.69*	*0.93*		*0.59*		6
MUR 29		*0.55*	*0.62*			*0.66*	*0.69*	*0.93*		*0.59*		6
MUR 29		*0.55*	*0.62*			*0.66*	*0.69*	*0.93*	*0.59*	*0.59*		7
MUR 29		*0.55*	*0.62*			*0.66*	*0.69*			*0.59*		5
MUR 29		*0.55*	*0.62*	*0.90*		*0.66*	*0.69*		*0.59*	*0.59*	*0.97*	8

Appendix D (cont.). Taxa predicted to occur with ≥50% probability by the AUSRIVAS model, but not collected in the riffle habitat

Site	Taxa	Oligochaeta	Elmidae	Tipulidae	Chironominae	Caenidae	Gripopterygidae	Total number of missing taxa
	SIGNAL	2	7	5	3	4	8	
MUR 931	Riffle		*1.00*				*0.60*	2
MUR 931								0
MUR 931				*0.80*			*0.60*	2
MUR 931							*0.60*	1
MUR 931				*0.80*			*0.60*	2
MUR 931								0
MUR 28	Riffle		*1.00*	*0.80*			*0.60*	3
MUR 28				*0.80*			*0.60*	2
MUR 28			*1.00*					1
MUR 28				*0.80*			*0.60*	2
MUR 28				*0.80*			*0.60*	2
MUR 28				*0.80*			*0.60*	2
MUR 935	Riffle		*1.00*	*0.80*			*0.60*	3
MUR 935			*1.00*	*0.80*			*0.60*	3
MUR 935			*1.00*	*0.80*		*1.00*	*0.60*	4
MUR 935			*1.00*	*0.80*	*1.00*	*1.00*	*0.60*	5
MUR 935				*0.80*			*0.60*	2
MUR 935			*1.00*	*0.80*	*1.00*		*0.60*	4
MUR 937	Riffle	*0.80*	*1.00*	*0.80*			*0.60*	4
MUR 937		*0.80*	*1.00*	*0.80*			*0.60*	4
MUR 937			*1.00*	*0.80*			*0.60*	3
MUR 937			*1.00*				*0.60*	2
MUR 937			*1.00*	*0.80*			*0.60*	3
MUR 937			*1.00*	*0.80*			*0.60*	3
MUR 29	Riffle		*1.00*	*0.80*			*0.60*	3
MUR 29			*1.00*	*0.80*			*0.60*	3
MUR 29			*1.00*	*0.80*			*0.60*	3
MUR 29			*1.00*	*0.80*			*0.60*	3
MUR 29				*0.80*				1
MUR 29				*0.80*			*0.60*	2

Appendix E

Taxonomic inventory

Appendix E. Taxonomic inventory of the macroinvertebrate taxa collected for the riffle habitat

CLASS / Order	Family / Subfamily	Genus	MUR 28	MUR 931	MUR 935	MUR 937	MUR 29
ACARINA			■	■	■		■
Coleoptera	Elmidae	*Austrolimnius*		■			
		Coxelmis	■				
		Simsonia	■		■		
		sp.	■	■			■
		Stetholus	■				
	Scirtidae					■	■
Diptera	Ceratopogonidae	*Ceratopoginae*		■			
	Chironominae		■	■	■	■	■
	Empididae		■	■	■	■	■
	Orthocladiinae		■	■	■	■	■
	Simuliidae	*Austrosimulium*	■	■	■	■	■
		sp.	■	■	■	■	■
	Tanypodinae						■
	Tipulidae		■	■		■	
Ephemeroptera	Baetidae	*Baetidae Genus 2*	■	■	■	■	■
		sp.	■	■	■	■	■
	Caenidae	*Genus C*	■	■	■		
		sp.	■	■	■	■	■
		Tasmanocoenis	■	■	■	■	■
	Coloburiscidae	*Coloburiscoides*	■				■
	Leptophlebiidae	*Atalophlebia*	■				
		Jappa	■	■		■	■
		sp.	■	■	■	■	■
Hemiptera	Corixidae	*Micronecta*					■
Megaloptera	Corydalidae	*Archichauliodes*		■			
OLIGOCHAETA			■	■	■	■	■
Plecoptera				■			
	Gripopterygidae	*Dinotoperla*		■			
		Illiesoperla	■	■			■
		sp.		■			
Trichoptera	Ecnomidae	*Ecnomus*	■	■			
		sp.		■	■	■	■
	Glossosomatidae	*Agapetus*			■		
	Hydrobiosidae	*sp.*	■	■	■	■	■
		Taschorema	■	■	■	■	
	Hydropsychidae	*Asmicridea*		■	■		
		Cheumatopsyche	■	■	■	■	■
		sp.	■	■	■	■	■
	Hydroptilidae	*Hydroptila*		■			
		Oxyethira		■		■	
		sp.	■	■			
	Leptoceridae			■			

Appendix E (cntd.). Taxonomic inventory of the macroinvertebrate taxa collected for the edge habitat

CLASS / Order	Family / Subfamily	Genus	MUR28	MUR931	MUR935	MUR937	MUR29
ACARINA			■	■	■	■	
BIVALVIA	Corbiculidae	*Corbicula*		■			
Coleoptera	Elmidae	*Austrolimnius*				■	
		Coxelmis		■			
		Simsonia	■				
		sp.		■			
		Stetholus	■			■	
	Hydraenidae	*Hydraena*		■		■	■
	Hydrophilidae	*Berosus*					■
	Scirtidae			■			
Decapoda	Atyidae	*Paratya*	■	■	■	■	■
	Parastacidae	*Cherax*					■
Diptera	Ceratopogonidae	*Ceratopoginae*		■	■	■	
		Forcipomyiinae		■			
	Chironominae		■	■	■	■	■
	Empididae		■	■	■	■	■
	Orthocladiinae		■	■	■	■	■
	Psychodidae		■	■	■	■	■
	Simuliidae	*Austrosimulium*	■	■	■	■	■
		sp.	■	■	■	■	■
	Stratiomyidae	*Odontomyia*					■
	Tanypodinae		■	■	■	■	■
	Tipulidae		■	■	■	■	■
Ephemeroptera	Baetidae	*Baetidae Genus 1*				■	
		Baetidae Genus 2	■	■	■	■	■
		Cloeon	■				
		sp.	■	■	■	■	■
	Caenidae	*Genus C*	■	■	■	■	■
		sp.	■	■	■	■	■
		Tasmanocoenis	■	■	■	■	■
	Leptophlebiidae	*Atalophlebia*	■	■	■	■	■
		Jappa	■	■	■		
		sp.	■	■	■	■	■
GASTROPODA	Physidae	*Physa*				■	■
	Planorbidae/physidae				■		
Hemiptera	Corixidae	*Micronecta*	■	■	■	■	■
	Gerridae			■	■		
	Notonectidae	*Enithares*			■		
	Veliidae	*Microvelia*		■			■
Hirudinea	Glossiphoniidae						■
Nematoda						■	■
Odonata	Aeshnidae	*Brevyistyla*			■		
OLIGOCHAETA			■	■	■	■	■
Plecoptera	Gripopterygidae	*Dinotoperla*		■			
		sp.		■	■		
			■			■	
Trichoptera	Ecnomidae	*Ecnomus*	■	■	■	■	■
		sp.		■	■		■
	Hydrobiosidae	*Taschorema*				■	
	Hydropsychidae	*Asmicridea*	■				
		Cheumatopsyche	■	■	■	■	■
		sp.	■	■	■	■	■
	Hydroptilidae	*Hellyethira*	■		■	■	■
		Hydroptila		■	■		■
		Oxyethira		■	■		
		sp.		■			
	Leptoceridae	*Notalina*		■	■	■	■
		Oecetis	■	■		■	
		sp.	■	■	■	■	■
		Triaenodes		■	■	■	■
		Triplectides		■	■	■	■
	Philopotamidae				■		

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