ACTEWAGL DISTRIBUTION MURRUMBIDGEE ECOLOGICAL MONITORING PROGRAM

PART 3: MURRUMBIDGEE PUMP STATION

SPRING 2011

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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 Water 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 ACTEW's water abstraction licence reporting requirements. Water abstraction at the MPS, combined with a change of environmental flow releases from the Cotter Reservoir; require an assessment of the response of the river through monitoring methods that can quantify subtle impacts.

This program aims to establish the baseline river condition prior to the increased water abstraction; and then continue monitoring afterwards to determine what, if any, physicochemical and ecological changes occur.

The key aims of this sampling run were to:

1. *Collect macroinvertebrate community data, upstream and downstream of the MPS;*
2. *Provide ActewAGL with river health assessments based on AUSRIVAS protocols at the key sites that could potentially be impacted by construction works and 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 spring 2011. Sampling was completed in November 2011 and was based on the AUSRIVAS sampling protocols. Sampling was extended to include multiple replicates from each site and specimens were identified to genus level, instead of family level. The reasons for these variations were to a) establish estimates of the within–site variability prior to the commencement of pumping; and b) 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). Baseline 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. Additionally, grab samples were taken from each site for laboratory verification and nutrient analysis.

Macroinvertebrates were sampled in the riffle and edge habitats where available. 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 spring (November 8th – 10th) 2011, for macroinvertebrates and analysed in strict accordance with the ACT AUSRIVAS (Australian River Assessment System) protocols.

The key results from the spring 2011 sampling of the MPS indicate that:

1. *The results from the water quality grab samples show very low levels of site to site variation and in some case, indicators such TSS, turbidity and the nutrient concentrations are higher at the upstream sites than the downstream sites, which is probably due to flow fluctuations occurring between the 8th and 10th of November when these samples were collected. Other analytes such as pH and dissolved oxygen were probably more associated with the time of day at which the samples were collected. In the morning pH was <8.0 while the three exceedances at MUR 28, MUR 935 and MUR 29 were all collected in the afternoon when photosynthetic activity is at its highest.*

2. *Total nitrogen and Total phosphorus concentrations were above the ANZECC guidelines at four out of five sites. Concentrations tended to be higher upstream of the Cotter River confluence than they were downstream, indicating that the Cotter River is helping to dilute the nutrients. Despite this, the background levels in this section of the Murrumbidgee River remain above the recommended levels.*

3. *There is no evidence from the current study that the MPS is negatively impacting the water quality at the sites monitored for this program. However, given the limitation of not having a continuous record downstream of MPS, compensation for the limited number of grab samples should be made by intensifying the sampling frequency during periods of MPS operation and water abstractions.*

4. *There was no significant difference in either chlorophyll-a concentrations or AFDM between upstream and downstream locations suggesting no discernable impact from the Murrumbidgee Pump Station. Compared to autumn 2011 (no spring 2010 data available due to high flows), there has been up to a 6-fold decrease in the periphyton chlorophyll-a concentrations amongst all sampling sites which is likely due to a seasonal fluctuations in flows and water temperatures, although it is also likely that the standing crops were significantly reduced as a direct result of the environmental flow release.*

5. *All sites except MUR 931 (about 5km upstream of MPS) were assessed as BAND B (significantly impaired) by the AUSRIVAS model for their overall site assessment. MUR 931 is reported as BAND C (severely impaired) due to a poor edge habitat assessment. Compared to autumn 2011, the overall sites assessments are comparable to those reported here, expect that there has been an apparent decline in the edge at MUR 931. All riffle assessments dropped from BAND A to BAND B; however comparing the riffle assessments on a season by season basis, it can be seen that in spring 2009 (last spring assessment) the results for the riffle habitat are almost identical, suggesting a seasonal influence on these assessments. For example, periodic*

high flow events throughout spring may prevent the macroinvertebrate communities fully re-establishing; and during autumn, during period of more stable flow communities have a better opportunity to reach equilibrium and therefore result in higher AUSRIVAS bands.

6. *There has been an overall increase in the occurrence of sensitive mayflies and stoneflies since spring 2009, coinciding with a higher frequency of high flow events. We suggest that this is due to improvements in substrate quality, through flushing fine sediments and increased base flow, which many of these taxa require. In this sampling run we collected a genus of mayfly that has not been collected so far in this project. This could be because it was flushed downstream with the environmental flow, or because local habitat conditions have improved as a result of the environmental flow release.*

Based on the MPS sampling program to date, it is expected that the resistance and resilience of the macroinvertebrate fauna to any potential impact resulting from the approximate 150 ML/d abstraction from the MPS are likely to depend on the timing of the abstractions and the duration that flows are abstracted.

Macroinvertebrate communities are likely to be at their most vulnerable in summer and autumn when Murrumbidgee base flows are at their lowest levels and if flows are artificially lowered through ongoing water abstractions during these months we could expect to see some initial changes in water quality and loss of some of the more sensitive EPT taxa.

To achieve an improved understanding of the processes that follow water abstractions from the MPS, ALS recommends undertaking more frequent water quality monitoring upstream and downstream of the MPS prior to, during, and after operational periods, where the abstraction rate is likely to be above approximately 20% of the flow in the Murrumbidgee River. This would also require operational data from the MPS (i.e. duration and quantity) to be used for analysis.

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. It is being undertaken as part of the ACT Water Supply security infrastructure upgrade. The proposed timeline was to undertake sampling in spring and autumn over a three year period commencing in spring 2008.

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 adjacent to the Cotter Pump Station. Construction to increase the abstraction amount from the Murrumbidgee River to 150ML/d via the MPS is effectively complete. The upgraded infrastructure allows a recirculating flow from the Murrumbidgee to the base of the Enlarged Cotter Dam (ECD), providing environmental flows to the lower Cotter Reach during the construction of the ECD. This project is referred to as Murrumbidgee to Cotter (M2C) transfer. The upgraded pump station was commissioned in 2010.

Pumping will only occur when there is sufficient demand for the water (for M2C and/or potable water supply), and when there is sufficient water flow in the Murrumbidgee River. The framework for this program responds primarily to requirements of ACTEW's water abstraction licence (WU67).

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). Monitoring will eventually extend to the period after the proposed abstractions are implemented and data collected in that phase will be compared with those collected as part of this study.

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 effected by the operation and works during the upgrade of the Murrumbidgee Pump Station; under the license requirements of ActewAGL's licence to abstract water # WU67, section D6.

Specifically, the aims of the project are to:

1. Meet ActewAGL's monitoring obligations under the requirements of its licence to abstract water (Licence # WU67, section D6);

2. Provide seasonal "river health" reports in accordance with the licence requirements;

3. Obtain baseline macroinvertebrate, water quality and periphyton data for eventual use in the assessment of whether or not the proposed 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 spring 2011 sampling runs. Specifically, as outlined in the MEMP proposal to ACTEW Corporation (ALS, 2011a), this work includes:

- Sampling from autumn 2011;
- 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 ALS's NATA accredited laboratory.

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 is 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 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 M2C, 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.

To monitor for potential impacts, 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 (Smakhtin, 2001, Boulton, 2003, Dewson *et al.*, 2007), 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 (Figure 1; Table 1; Plate 1 & 2). 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 / construction point serving as 'Impacted' sites. Baseline monitoring carried out as part of this study will serve as the 'Before' period for this assessment.

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	Currently in the MPS construction zone. Grazing.	Upstream control site
MUR 935	Casuarina Sands	Recreation, construction upstream	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

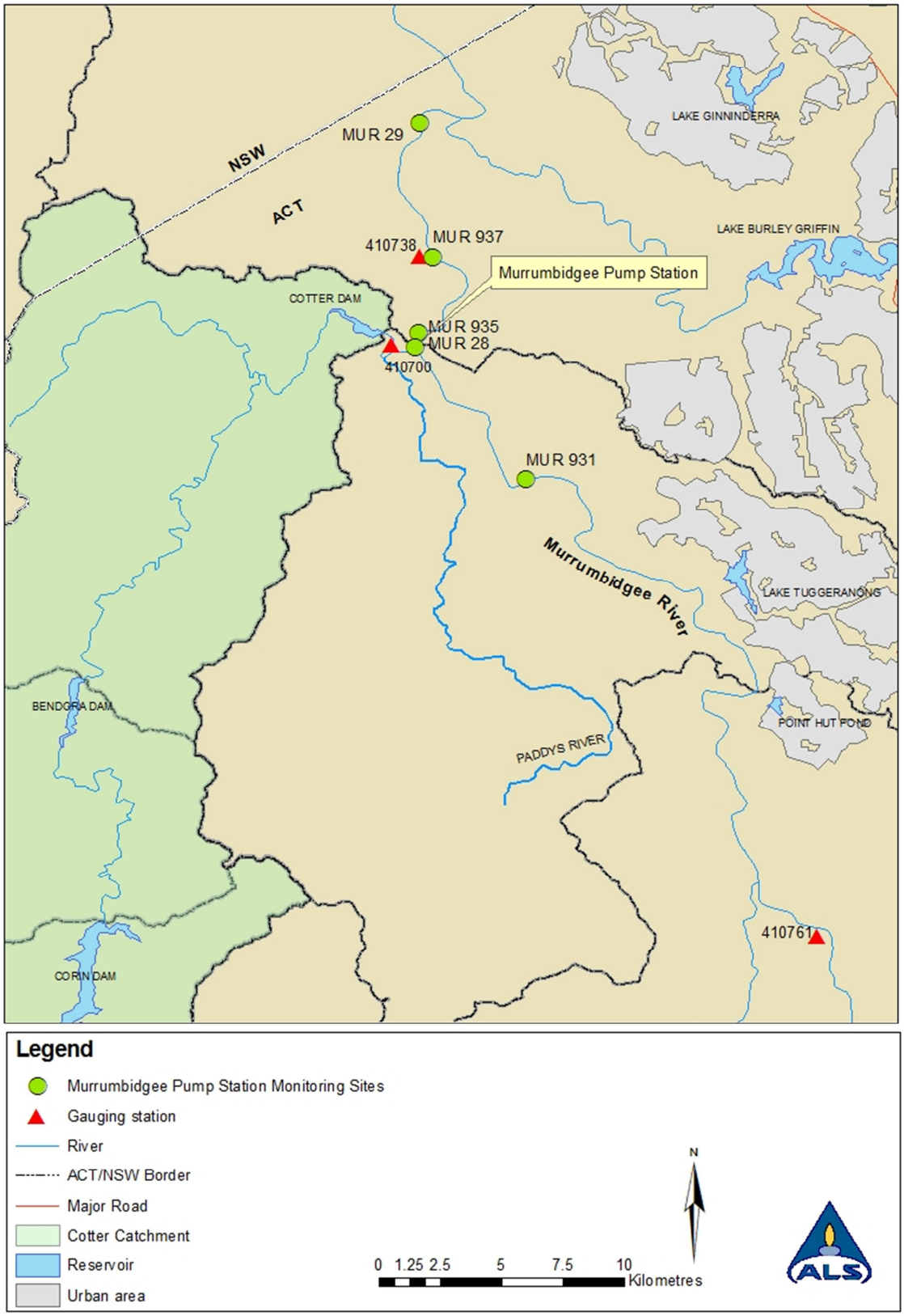

Figure 1. Location of the monitoring sites and gauging stations for the MPS monitoring program

MUR 931 Looking upstream

MUR 931 Looking downstream

MUR 28 Looking upstream

MUR 28 Looking downstream towards Cotter Bridge

Plate 1. Monitoring sites upstream of the Murrumbidgee Pump Station

MUR 935 Looking upstream to Cotter Bridge

MUR 935 Looking downstream

MUR 937 Riffle habitat, looking upstream

MUR 937 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 @ Lobb's Hole	WL, Q, pH, EC, DO, Temp, Turb, Rainfall	S -35.5381	E 149.1012

* 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 5*a* Surveyor. The Surveyor was calibrated in accordance with ALS QA procedures and the manufacturer's requirements prior to sampling. Additionally, grab samples were taken from each site in accordance with ACT AUSRIVAS protocols (Coysh *et al.*, 2000) for Hydrolab® verification and nutrient analysis. All samples were placed on ice, returned to the ALS 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 now that the MPS is operational.

2.4 Macroinvertebrate sampling

Riffle and edge habitats were sampled for macroinvertebrates (November 8th – 10th) and analysed using the ACT spring riffle and edge AUSRIVAS (Australian River Assessment System) protocols (Coysh *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; (Coysh *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 invertebrates 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 at each site. 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 10 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 spring 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 2.10.1. (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. Trend analyses of water quality parameters will be conducted at the end of the baseline collection period.

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 proposed discharge point. Sites were unable to be nested with location in the two-way design due to a lack of replication at several of the sites. Instead, a one-way analysis examined the

differences between location (up and downstream of the MPS, using site as the unit of replication).

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 4) 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 because the presence or absence of these taxa might be a function of sampling effort rather than truly reflecting ecological change.

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

Stream Invertebrate Grade Number – Average Level (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.

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

BAND	RIFFLE O/E Band width	EDGE O/E Band width	Explanation
X	> 1.14	> 1.13	More diverse than expected. Potential enrichment or naturally biologically rich.
A	0.86 – 1.14	0.87 – 1.13	Similar to reference. Water quality and / or habitat in good condition.
B	0.57 – 0.85	0.61 – 0.86	Significantly impaired. Water quality and/ or habitat potentially impacted resulting in loss of taxa.
C	0.28 – 0.56	0.35 – 0.60	Severely impaired. Water quality and/or habitat compromised significantly, resulting in a loss of biodiversity.
D	< 0.28	< 0.35	Extremely impaired. Highly degraded. Water and /or habitat quality is very low and very few of the expected taxa remain.

2.6.5 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 Licenses 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)).

ALS field staff maintain current ACT AUSRIVAS accreditation.

3 Results

3.1 Summary of sampling and river conditions

Spring sampling was completed over three days during November (8th – 10th). Mean daily flows recorded at the time of sampling at Lobb's Hole (closest upstream station to MUR 931) and 410738 (at MUR 937) were 287 ML/d and 661 ML/d respectively.

Prior to spring sampling, Snowy Hydro managed an environmental flow release from Tantangara Reservoir in the middle of October, which was maintained at 2000 ML/d over a 10 day period (Figure 2). A rainfall event at the end of November resulted in a rise in flow levels for the final week of spring. Although spring flows were moderate there was still only limited edge habitat available at site MUR 28, MUR 29 and MUR 937, resulting in the collection of only a single edge sample (Table 4). The air temperatures during the sampling period ranged between 17°C and 21°C and weather conditions were fine with partial overcast conditions.

There was an evident lack of both emergent and submergent macrophytes across all sites, in particular MUR 931 & 935. Periphyton was abundant at all sites with the exception of MUR 937 where there was little growth, in comparison to autumn where it was noted that there was "thick mats" at this site.

Table 4. Macroinvertebrate samples collected during the spring sampling run

Site	Edge	Notes	Riffle
MUR 931	2	Sub samples not possible due to limited number of macroinvertebrates in each of the two replicates collected	2
MUR 28	1	Limited habitat at site. Only 1 representative sample possible.	2
MUR 935	2		2
MUR 937	1	Limited habitat at site. Only 1 representative sample possible.	2
MUR 29	1	Limited habitat at site. Only 1 representative sample possible.	2

3.2 Hydrology and rainfall

November was the wettest month in spring with 311.2mm of rainfall recorded at Lobb's Hole (Table 5). This is the highest November rainfall on record at this site with the previous highest November rainfall in 1989 with 179.8mm (period of record: 1974-2011). While in comparison September had 24.6mm which was the 6th driest September on record. There was 33 wet days for the season averaging 11 per month. The daily rainfall for the period ranged from 0.2mm (the detectable minimum) to 87.6mm at the end of November. Two consecutive days of high rainfall in November (28th-29th) produced 85.4mm and 87.6mm respectively. This added with previous rainfall within the catchment increased flow levels dramatically, with a flow peak that was still rising at the end of November and peaked in early December (Figure 2). The highest flow recorded during November was 5420 ML/d at Lobb's Hole and 16,100 ML/d at Mt. MacDonald. These events had annual recurrence intervals of approximately 1yr and 1.2yr respectively. Rainfall and flow data are summarised in Table 5.

Flows downstream of the Cotter Dam ranged from 43.9 – 1070 ML/d during spring. This increase in flow occurred towards the end of November, with flows preceding this fluctuating between approximately 50 and 350 ML/d (Figure 3).

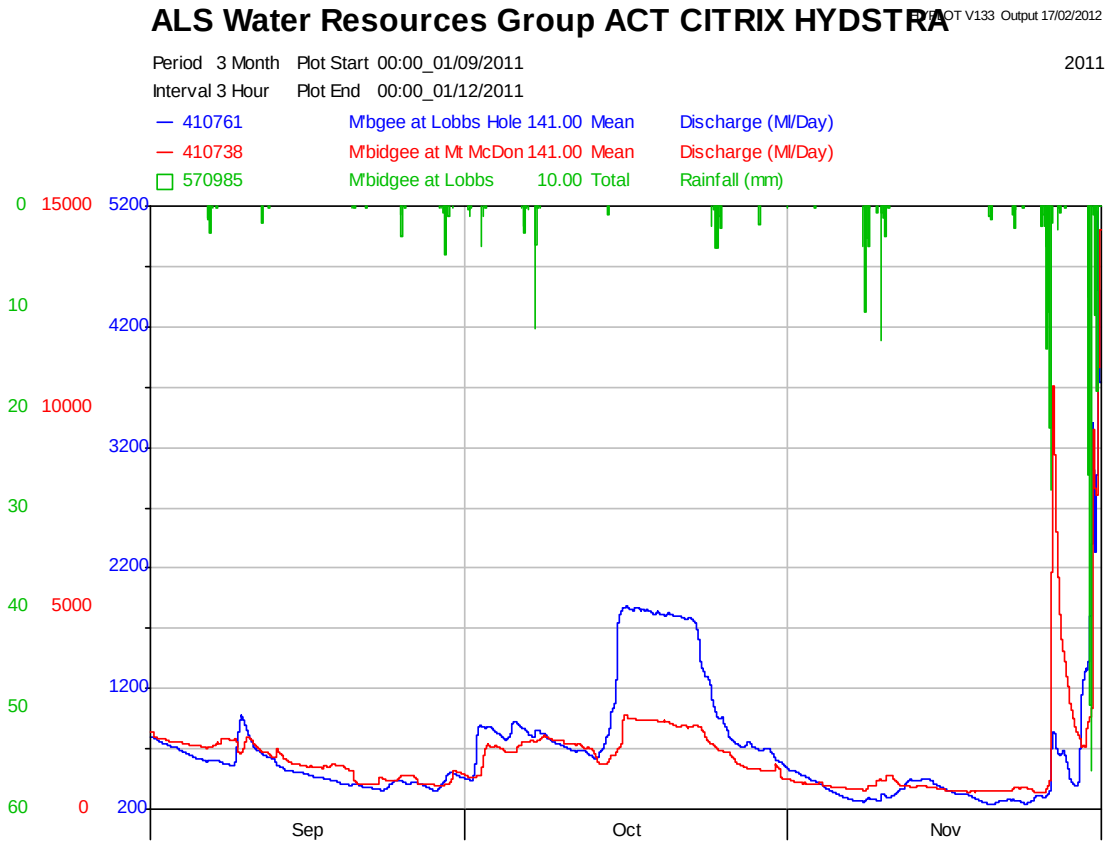

Figure 2. Spring hydrograph of the Murrumbidgee River at Lobb's Hole (410761) and Mt. MacDonald (410738). Total rainfall was recorded at the Lobb's Hole station

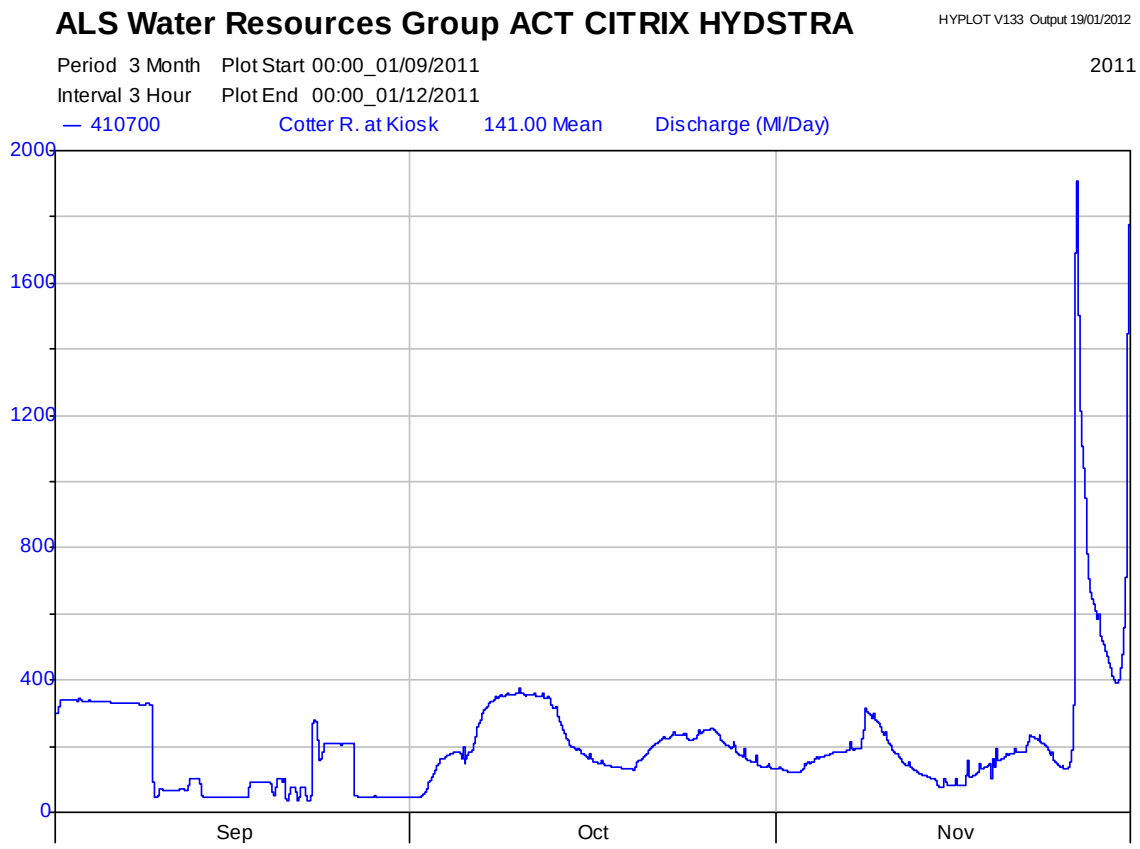

Figure 3. Hydrograph for the Cotter River downstream of Cotter Dam (410700) for spring 2011

Table 5. Monthly flow and rainfall statistics for spring 2011 at Lobb's Hole (410774) and Mount MacDonald (410761)

Station	Lobb's Hole (410761)		Mt. MacDonald (410738)
	Rainfall Total (mm)	Mean Flow (ML/d)	Mean Flow (ML/d)
September	24.6	535.0	1172
October	46.6	1051.0	1559
November	311.2	500.2	1184
Spring (mean)	382.4 (127.5)	695.4	1305

Plate 3. The Murrumbidgee River viewed from the Cotter Road bridge

Top: looking downstream and; Bottom: looking upstream with MPS on the right hand bank. Mean daily flow at the time these photographs were taken (8/11/2011) was 669 ML/d at the Mount MacDonald gauging station (410738).

3.3 Water quality

The pH probe at the Lobb's Hole continuous data logging station was down due to probe failure for a period of 24 days during September and October. Most of the logged data for the spring period was found to be within the ANZECC & ARMCANZ guidelines (2000). The exception to this was 4 days in mid-October when turbidity exceeded the guidelines and again at the end of November the turbidity readings exceeded 25 NTU for the last two days of that month. The turbidity exceedances during October coincided with the first few initial days of the environmental flow release from Tantangara Dam. The exceedance in turbidity at the end of November corresponded with a large rainfall event during the same time period.

The overall patterns displayed in the continuous water quality data show a gradual increase in water temperatures during the period (Figure 4). This increase corresponds to the increasing ambient temperatures, heading towards the beginning of summer. The turbidity was consistently low with the exception of the aforementioned spikes due to rainfall and flow events. EC was consistently low throughout the period until the end of November where there was a marked increase; despite this increaser EC remained within the ANZECC & ARMCANZ guidelines (2000) for the spring period. Monthly mean values are all within guideline limits (Table 6).

The results from the grab samples show no evidence of lasting impact on the water quality as a result of the upgrade to the pump station (Table 7). All sites with the exception of MUR 931 are showing super saturation of dissolved oxygen, although MUR 935 has exceeded the guidelines. NO_x values are all within guideline levels, other than the upstream site MUR 931. The pH readings at sites MUR 28, 935 and 29 were found to be outside guideline limits, however, this pattern does not appear to be linked with the MPS.

The total nitrogen levels increased from autumn at all sites other than MUR 937, which was the only site not to exceed the guideline levels. Sites MUR 931, 28 and 935 all showed slightly lower total phosphorus levels than during autumn, however still exceeded the guidelines. Site MUR 29 was again on the cusp of the total phosphorus guidelines while MUR 937 had decreased to below guideline levels.

Table 6. 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 mean monthly minimums and maximums

Station	Lobb's Hole (410761)				
Analyte	temp.	EC	pH*	turbidity	D.O. (% Sat.)
September	12.63	78.51	7.69	8.45 (12.13)	97.06-100.86
October	15.96	76.76	7.63	20.03 (31.48)	96.63-100.62
November	20.86	85.54	7.86	12.57 (92.28)	95.15-99.11
Spring	**16.48**	**80.27**	**7.73**	**13.68**	**95.15-100.86**

** Means exclude 11 days in September and 13 days in October (pH sensor failure)*

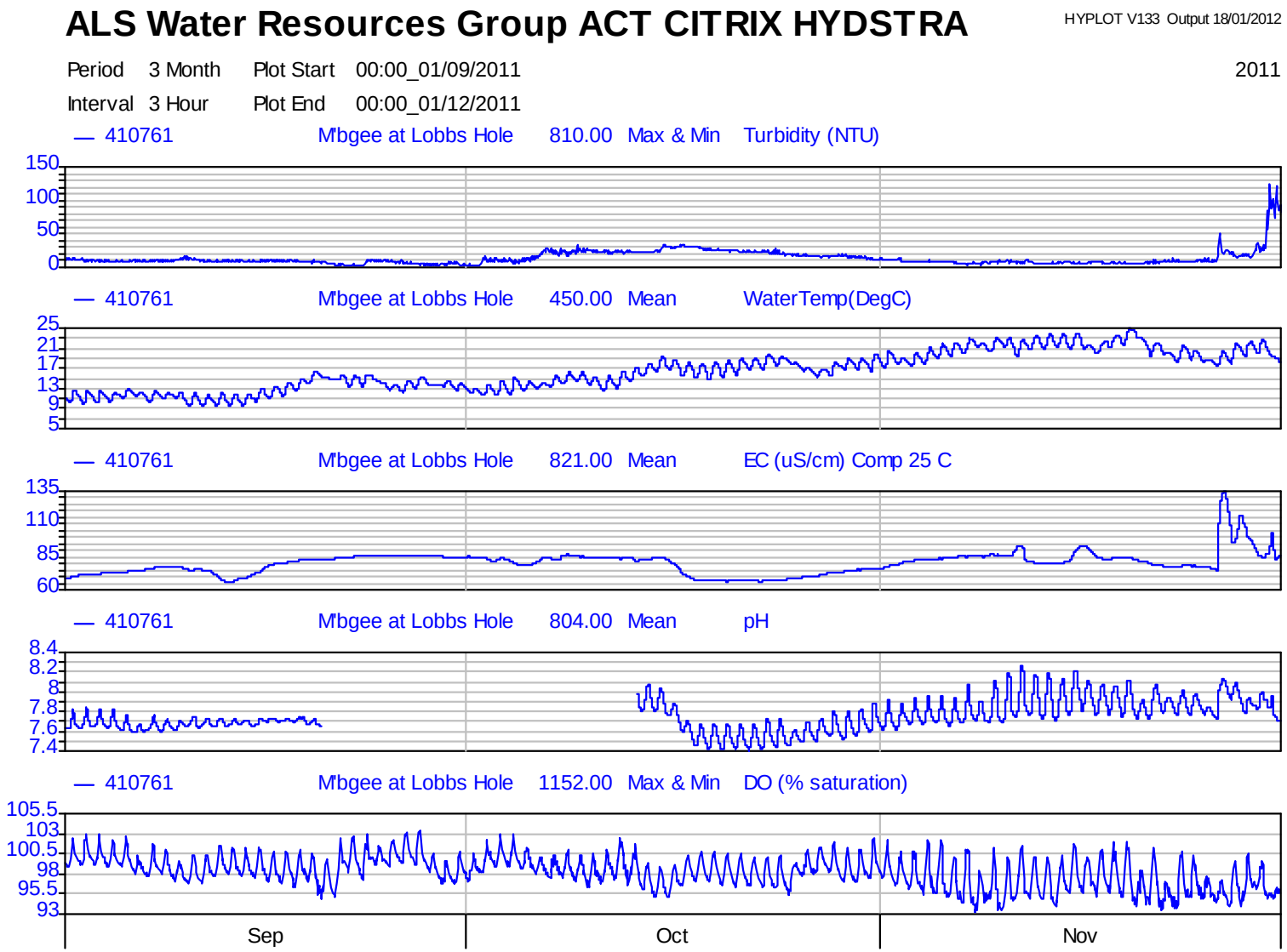

Figure 4. Continuous water quality records from Lobb's Hole (410761) for spring 2011

Table 7. Water quality results for spring 2011. ANZECC & ARMCANZ guidelines are in parentheses. Yellow cells indicate values outside guidelines. Orange cells indicate values are on the cusp of the upper limit of the guideline.

Location	Site	Time Date	Temp. (℃)	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)	Alk.	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	1000 9/11/11	21.7	77.4	11	14	7.7	99.8	8.07	33.1	0.016	0.014	<0.002	0.014	0.029	0.33
	MUR 28	1425 9/11/11	23.5	77.6	11	16	8.1	107.1	8.21	33.2	0.005	<0.002	<0.002	<0.002	0.029	0.31
Downstream	MUR 935	1250 9/11/11	23.6	75.3	13	15	8.1	110.5	8.55	32.4	0.006	0.004	<0.002	0.002	0.027	0.30
	MUR 937	0950 8/11/11	22.6	62.5	6	8	7.7	103.2	8.19	28	0.002	<0.001	<0.002	0.002	0.019	0.22
	MUR 29	1315 10/11/11	22.5	71.2	7	13	8.1	109.0	8.6	29.6	0.004	0.002	<0.002	<0.002	0.020	0.26

3.4 Periphyton

Periphyton chlorophyll-a was higher on average upstream of the Murrumbidgee Pump Station (mean=10334 ± 3192 [95% CI]) compared to the downstream sites (mean = 7906 ± 2695 [95% CI]); however, due to the high site to site variation in the data (Figure 5), these differences were not statistically significant ($F_{1,3}$ = 0.29; P=0.62; Table 8). Overall, periphyton chlorophyll-a was highest at MUR 935 and MUR 29, while the lowest values were seen at MUR 937.

Aside from MUR 935, the estimated biomass from the periphyton samples (as AFDM) displayed a fairly even distribution amongst sampling sites (Figure 6). Means ranged from 2550 mg/m^{-2} at MUR 937 to 21800 mg/m^{-2} at MUR 935 and because of the elevated mean value at MUR 935 the average for the downstream sites was slightly higher (mean=11792 ± 5778 [95% CI]) compared to the upstream sites (mean=7554 ± 8807 [95% CI]) although not statistically different ($F_{1,3}$ = 0.38; P=0.57; 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	0.29	0.62
	Site [Location]	3	7.35	0.001
	Residual	28		
AFDM (log)	Location	1	0.38	0.57
	Site [Location]	3	1.53	0.23
	Residual	27		

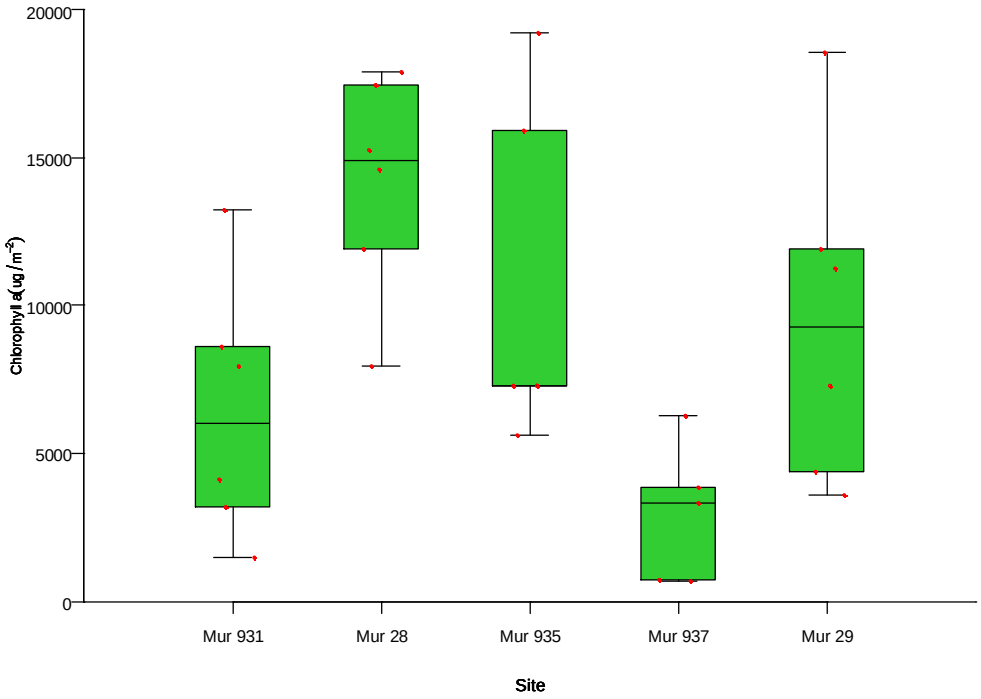

Figure 5. Periphyton chlorophyll-a concentrations from upstream and downstream of the MPS

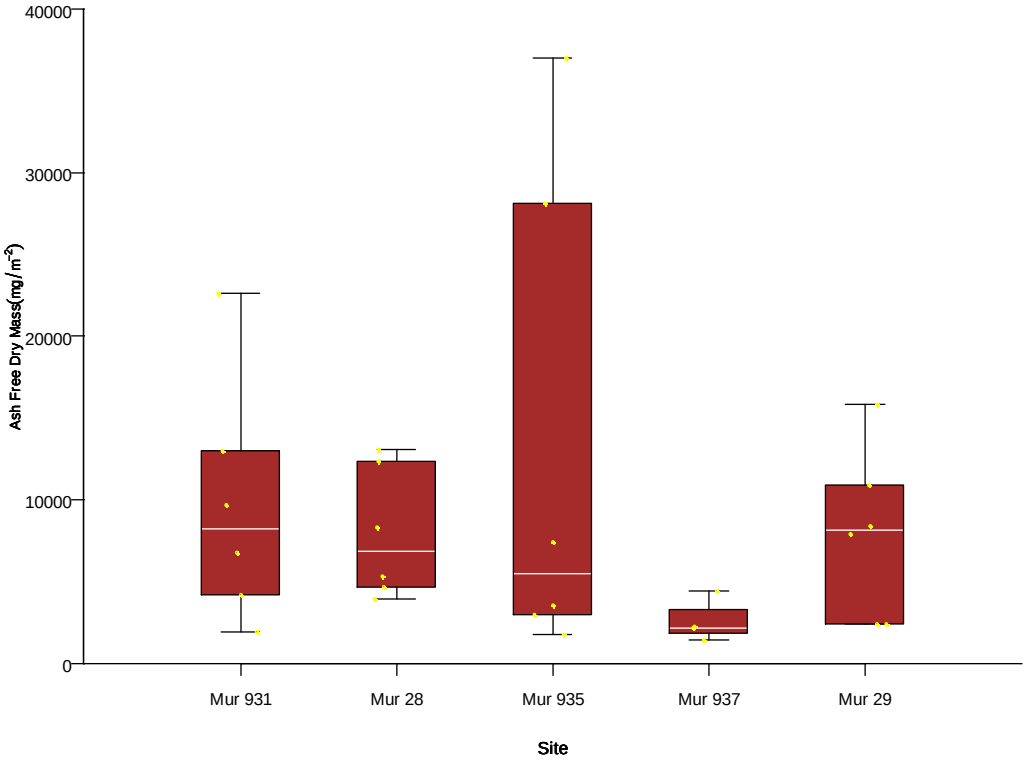

Figure 6. Periphyton Ash Free Dry Mass (AFDM) from upstream and downstream of the MPS

Strip chart values in red (above) and yellow (top) represent raw data points. See **APPENDIX E** for and explanation on how to interpret box and whisker plots

3.5 Macroinvertebrate communities

3.5.1 Patterns in community structure

3.5.1.1 Riffle

The number of macroinvertebrate families collected ranged from 17 at MUR 937 to 23 at MUR 29 (Figure 7) correspondingly the lowest and highest number of genera (25 - 33) were also collected at MUR 937 and MUR 29 respectively. Of the total number of macroinvertebrate taxa collected, there were between 7 and 10 EPT families and between 13 and 18 genera collected representing 23-25% of the total number of families and 54% of the total number of genera collected in total amongst the monitoring sites (Figure 8).

Based on the estimated abundances from the kick net samples, the highest proportion of macroinvertebrates amongst all sites come from the tolerant group of taxa which includes, Oligochaeta and Dipterans (true flies) (Figure 9). The dominant group from the tolerant taxa were Simuliidae (black flies), which accounted for as much at 70% of the assemblage. Oligiocheates and Chironomids were the next two most abundant groups. In the sensitive macroinvertebrate category, Hydropsycidae and Hydroptilidae were the two most abundant families.

The multivariate analysis of the macroinvertebrate assemblages shows a high degree of similarity amongst the riffle samples (Figure 10). All sites are within the 60% similarity groups, while at 65% MUR 931 separates out and forms its own group containing all the replicates from that site. While there is some evidence from the R value (R=0.75: P=.10) to indicate that there is a location difference in the macroinvertebrate assemblages, the P-value suggests that despite the upstream samples being closer in assemblage to one another than the downstream samples these differences are not statistically significant. All sites were characterised by 5 numerically dominant taxa including: Simuliidae (SIGNAL=5), Chironomidae (SIGNAL=3), Hydropsycidae (SIGNAL=6), Orthocladiinae (SIGNAL=4) and Hydroptilidae (SIGNAL=4).

Of note is the collection of the mayfly nymph: Coloburiscidae (SIGNAL=8) (Plate 4) at MUR 935. This particular macroinvertebrate has not been collected downstream of Colinton so far in the MEMP program. Usually, this genus of mayfly is restricted to cool water and fast currents, which can extent to torrential flows (Gooderham and Tsyrlin, 2005). Given the location of MUR 935, this taxa was not predicted (above 50%) to occur at these sites and is therefore has had no influence on the AUSRIVAS component of this study.

Plate 4. Coloburiscidae (*Coloburiscoides sp:* stream horse) collected from MUR 935

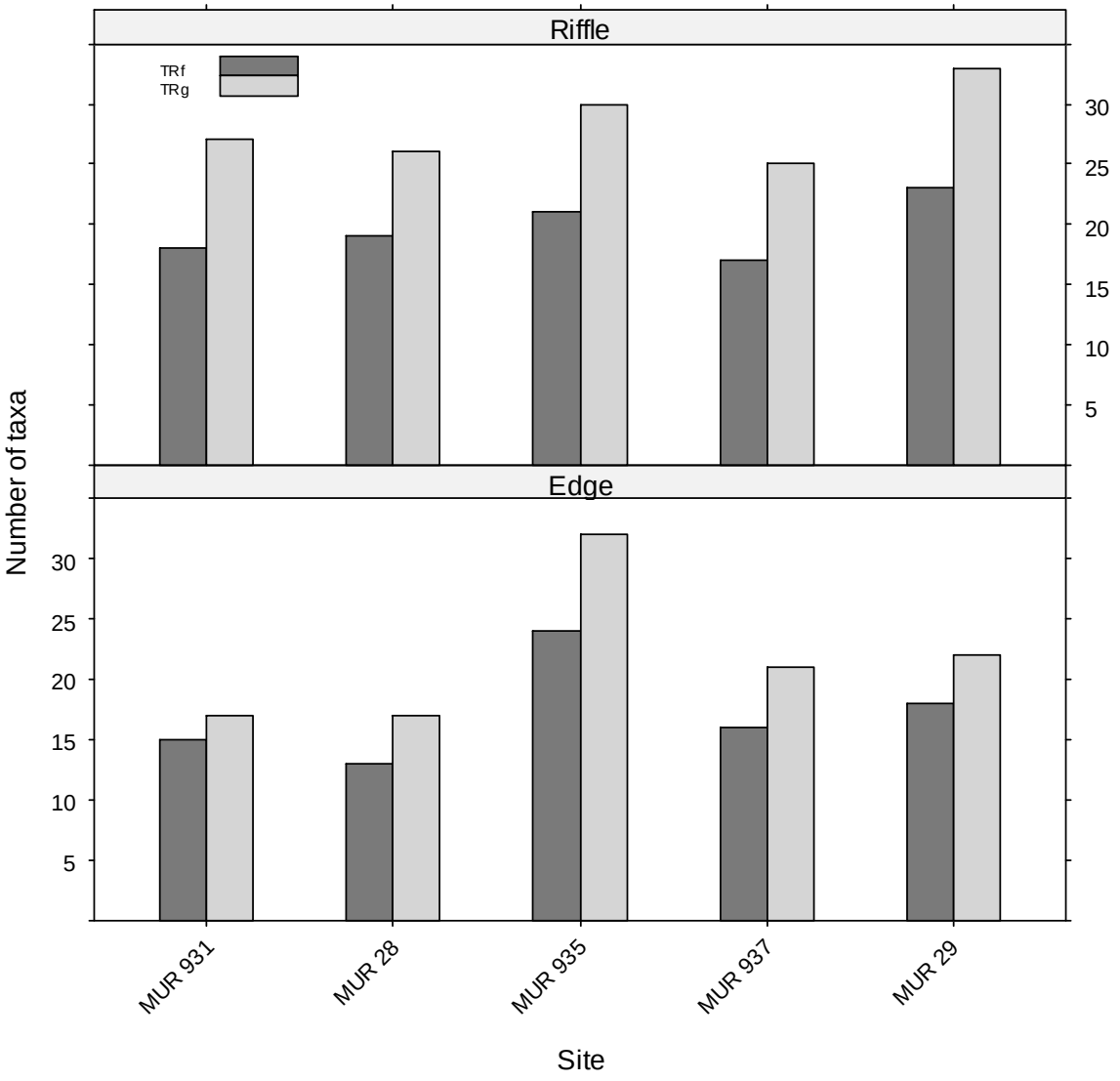

Figure 7. Family (TRf) and genus (TRg) richness from riffle and edge habitats

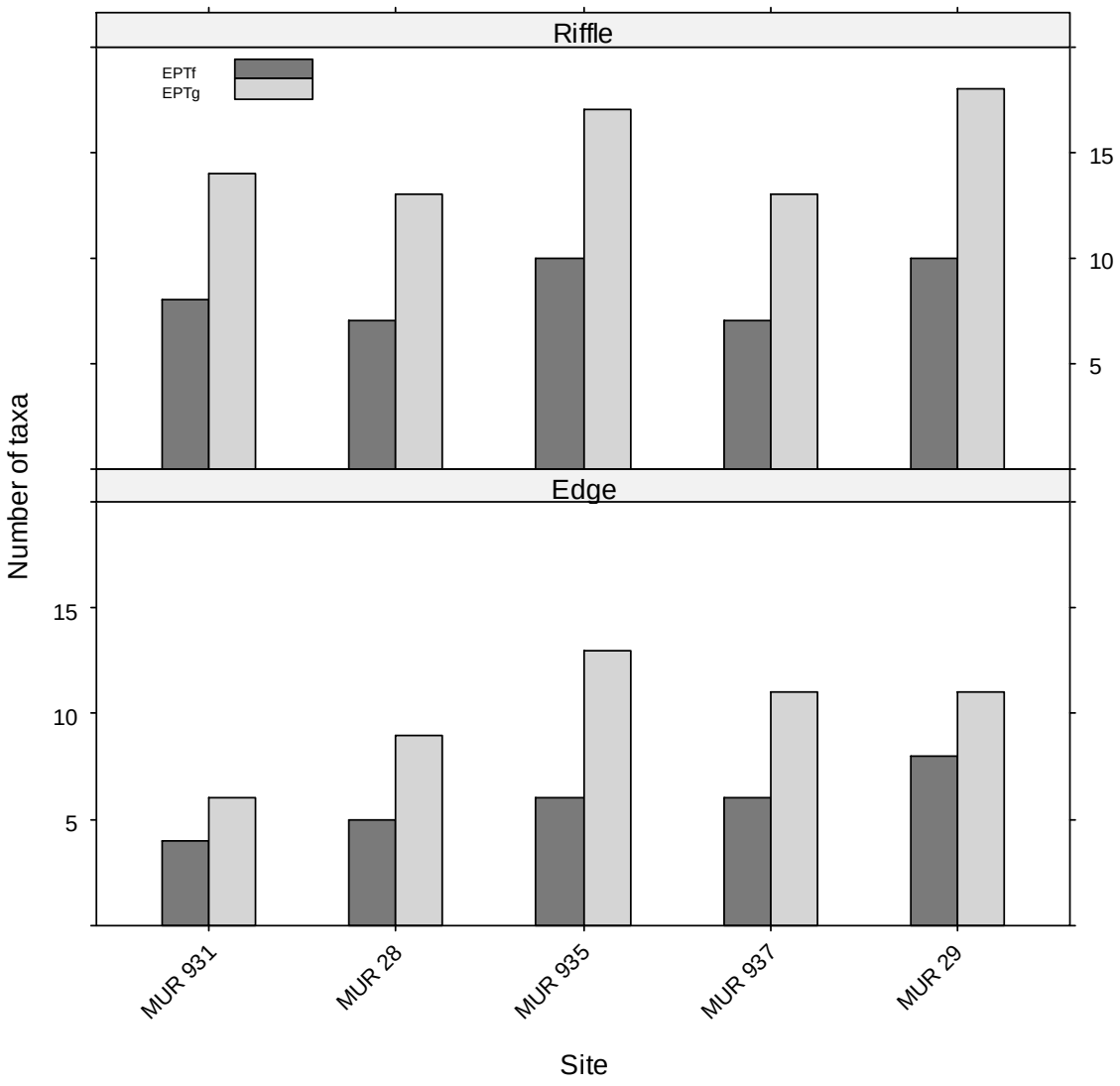

Figure 8. EPT richness in the riffle and edge habitats at the family (EPTf) and genus (EPTg) taxonomic levels

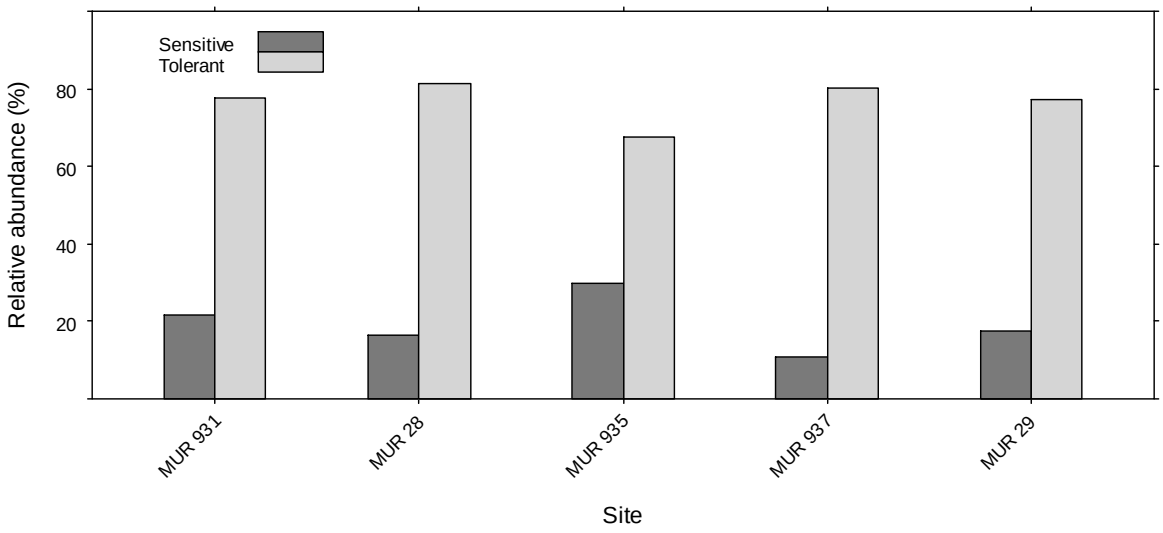

Figure 9. Relative abundance of sensitive (EPT) and tolerant taxa

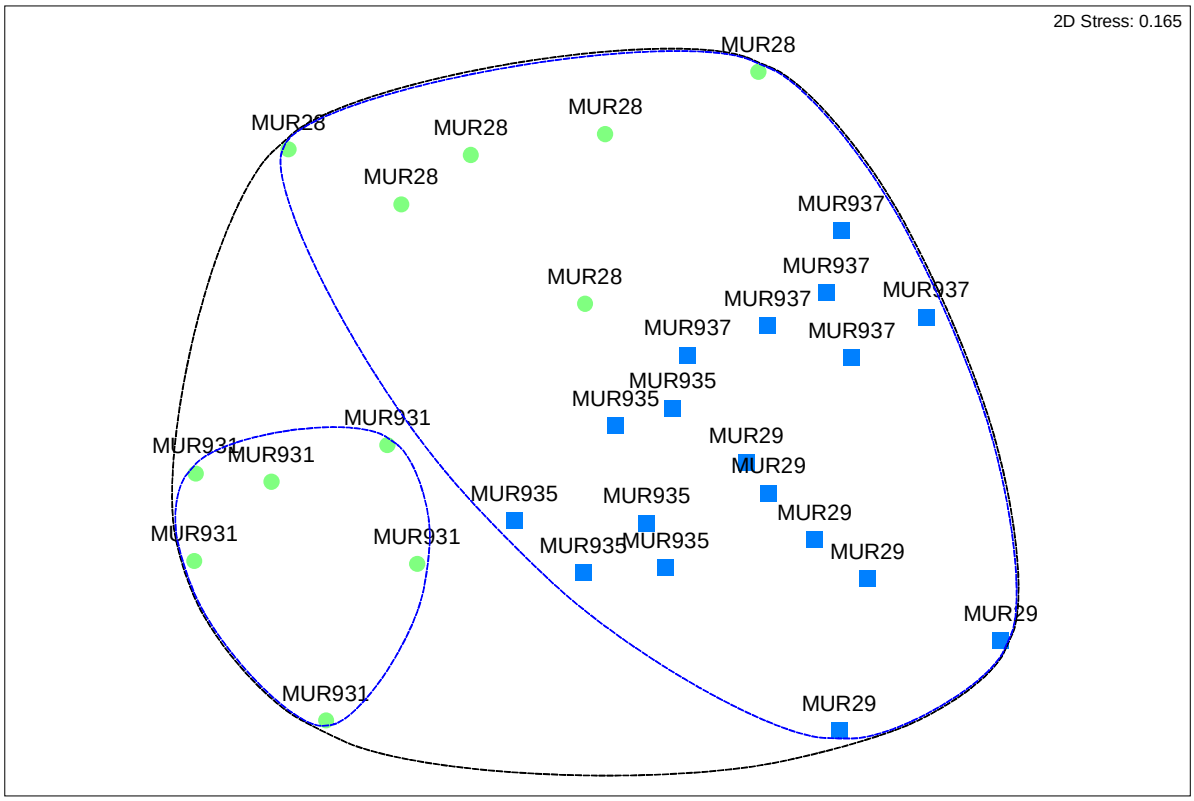

Figure 10. NMDS plot of riffle samples taken in spring 2011

Green circles are upstream of the MPS, blue squares are downstream Ellipses represent 60% similarity (black) and 65% (blue) similarity groups superimposed from the cluster analysis.

3.5.1.2 Edge

Only one edge replicate was possible from MUR 28, MUR 937, and MUR 29 (Table 4). At MUR 28 and MUR 937 the reason for this was a lack of representative habitat, while at MUR 29 only one sample was possible because of access and safety issues, resulting in reduced statistical power in the ANOSIM test.

Casuarina Sands (MUR 935) had the highest number of macroinvertebrate families (24) while the lowest number was collected at MUR 28 (13) (Figure 7). The number of genera ranged from 17 at MUR 931 and MUR 28 to 32 at MUR 935 (Figure 7). Proportionally, MUR 931 had the lowest number of EPT families compared to the total richness (25%) while MUR 29 had the highest (44%). Overall there was one unique EPT family and genus to MUR 29 (Philopotamidae: *Chimarra sp.*); all t the remaining families and genera overlapped at more than one site.

Overall the edge habitats were approximately 40 % similar to one another (Figure 11). MUR 931 is visibly different from the main group, however because MUR 28 is closer to all of the downstream sites, there is no evidence to suggest that this is driven by the MPS because of the non-significant location effect (R=0.33; P=0.20).

The macroinvertebrate community at MUR 931 was composed of many of the taxa collected with the main ordination group (Figure 11). The main difference between this site and the others appears to be differences in the number of individuals in each taxonomic group. *Micronecta sp.* (Corixidae) and Simuliidae for example were present, but were only represented by <50 individuals compared to the other sites where they were estimated to be in the thousands. Oligiocheates were missing from MUR 931.

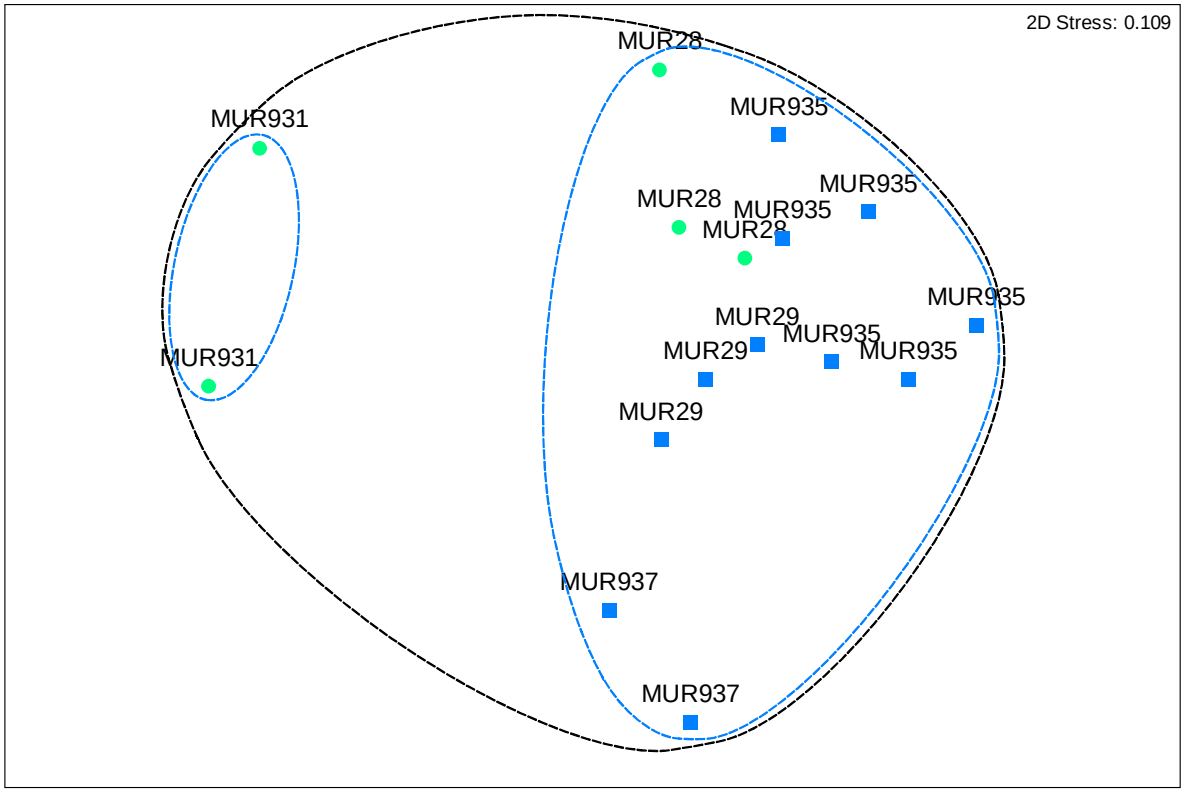

Figure 11. NMDS plot of edge samples taken in spring 2011

Green circles are upstream of the MPS, blue squares are downstream Ellipses represent 40% similarity (black) and 52% (blue) similarity groups superimposed from the cluster analysis.

3.5.2 AUSRIVAS assessment

The overall site assessment given by the AUSRIVAS model indicates no change at four of the five sites in this program – all being assessed as BAND B (Table 9). The exception was site MUR 931 which dropped a bandwidth to BAND C as a result of a poor riffle assessment. There was no change amongst all sites with respect to the edge or riffle habitat assessments (all BAND B) compared to spring 2009. However, there was no valid comparison for MUR 931 because in spring 2009, there was no reliable assessment available for this site.

The observed to expected ratio (OE/50) output from the AUSRIVAS model shows no location effect on the edge or riffle assessments. On average the upstream riffle sites had more macroinvertebrates missing than the downstream sites (upstream=8; downstream=6) however the ANOVA model of the AUSRIVAS ratios indicates no location difference ($F_{1,3}$=4.89; P=0.11: Table 10). The edge on the other hand had and equal number of taxa missing from both the upstream and downstream sites and not surprisingly the AUSRIVAS ratios did not differ statistically between locations ($F_{1,3}$=1.55; P=0.30: Table 11).

Most of the missing taxa (APPENDIX B) were shared amongst all sampling sites. There were some instances where macroinvertebrates were collected in one replicate at a given site (e.g. Leptophlebiidae at MUR 935) but were missing in the second sample and other cases where despite being collected in the majority of the samples were missing in one or two subsamples. For example, Oligochaeta at MUR 29 and Chironomidae at MUR 29; in this case, the absence of these mentioned taxa, despite being common throughout the remaining samples, has not affected the final AUSRIVAS assessment which would have remained the same had they been present.

The majority of missing macroinvertebrate families amongst all of the riffle samples were moderately to highly sensitive taxa with SIGNAL-2 scores ranging from 6-9. Macroinvertebrates at the higher end of this scale such as Glossosomatidae (SIGNAL=9) and Conoesucidae (SIGNAL=8) were missing from all of the samples. Until now, these two families have only been collected in spring 2009 and autumn 2010 at two and one site respectively (MUR 931 and MUR 29). Psephenidae (SIGNAL=6) was also missing from all of the monitoring sites and to this point has not been collected from any of the sites in this program. Other families, such as Leptophlebiidae were common upstream of MPS and then diminished with distance downstream; while Elmidae (SIGNAL=7), while not completely absent from any of the sites, were missing from at least two samples from a given site.

Macroinvertebrates that were predicted to occur in the edge samples, but were missing included the sensitive Gripopteryigidae (SIGNAL=8) which was missing from MUR 28 and Leptophlebiidae (SIGNAL=8), which was missing from MUR 931. Tolerant families such as: Oligochaeta (SIGNAL=2) was missing from MUR 931, Ceratopogonidae (SIGNAL=4) was missing completely from all sites except MUR 935 where it was collected in one sample and Tanypodine (SIGNAL=4) which was missing from MUR 937 and MUR 29 (APPENDIX B).

SIGNAL -2 scores were higher on average downstream of the MPS (upstream=4.5; downstream=4.9) which appears to be driven by a higher occurrence of Gripopteryigidae (SIGNAL=8) and Elmidae (SIGNAL=7). Location differences in the riffle SIGNAL scores accounted for 37% of the variation in the ANOVA model but were not statistically different ($F_{1,3}$ =4.64; P=0.12: Table 10); nor were they significantly different for the edge habitat samples ($F_{1,3}$ =0.42; P=0.56: Table 11) even though the mean score was higher upstream (4.3) compared to the downstream average (4.09)

Table 9. AUSRIVAS and SIGNAL-2 scores for spring 2011

Coloured cells indicate replicates that were nearly outside the experience of the model

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	4.56	4.43	0.67	0.78	B	B	C	B	C
	Mur 931	2	4.38		0.60		B				
	Mur 931	3	4.89		0.67		B				
	Mur 931	4	4.14	4.50	0.52	0.66	C	B			
	Mur 931	5	4.00		0.45		C				
	Mur 931	6	4.50		0.60		B				
	Mur 28	1	4.80	4.14	0.75	0.78	B	B	B	B	B
	Mur 28	2	4.70	3.83	0.75	0.66	B	B			
	Mur 28	3	4.44	4.22	0.68	1.00	B	A			
	Mur 28	4	4.78		0.68		B				
	Mur 28	5	4.44		0.68		B				
	Mur 28	6	5.00		0.75		B				
DOWNSTREAM	Mur 935	1	4.78	3.50	0.67	0.66	B	B	B	B	B
	Mur 935	2	5.00	4.63	0.82	0.89	B	A			
	Mur 935	3	4.25	4.14	0.59	0.78	B	B			
	Mur 935	4	4.80	4.13	0.74	0.89	B	A			
	Mur 935	5	5.09	3.86	0.82	0.78	B	B			
	Mur 935	6	4.80	4.11	0.74	1.00	B	A			
	Mur 937	1	4.73	4.50	0.82	0.89	B	A	B	B	B
	Mur 937	2	4.92	3.33	0.90	0.66	A	B			
	Mur 937	3	4.73		0.82		B				
	Mur 937	4	4.80		0.75		B				
	Mur 937	5	5.00		0.82		B				
	Mur 937	6	4.80		0.75		B				
	Mur 29	1	4.73	4.00	0.83	0.78	B	B	B	B	B
	Mur 29	2	5.27	4.25	0.83	0.89	B	A			
	Mur 29	3	5.25	4.63	0.91	0.89	A	A			
	Mur 29	4	5.20		0.76		B				
	Mur 29	5	5.00		0.83		B				
	Mur 29	6	5.13		0.60		B				

Table 10. One-way nested analysis of variance results for O/E 50 and SIGNAL scores from the riffle

Response	Source	DF	F-value	P-value
O/E 50	Location	1	4.89	0.11
	Site [Location]	3	3.85	0.02
	Residual	29		
SIGNAL - 2	Location	1	4.64	0.12
	Site [Location]	3	3.33	0.03
	Residual	29		

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

Response	Source	DF	F-value	P-value
O/E 50	Location	1	1.55	0.30
	Site [Location]	3	0.38	0.76
	Residual	15		
SIGNAL - 2	Location	1	0.42	0.56
	Site [Location]	3	0.84	0.49
	Residual	15		

4 Discussion

Construction work on the Murrumbidgee Pump Station (MPS) was completed in 2010. Biological and water quality monitoring is underway to assess any changes associated with the operation of MPS. The sampling conducted in spring 2011 is the fifth sampling run undertaken by ALS. The focus is on aquatic fauna, periphyton and water quality at five sites based on the recommendations in ACTEW's licence to take water (WU67 section D6).

4.1 Water quality

Water quality is collected in conjunction with the biological samples in the MPS project as an indicator of the effects of water abstraction. One of the limitations of this analysis is that there are no continuous water quality data downstream of the MPS, which would be representative of the downstream sites. Hall's Crossing (410777) currently logs continuous data downstream near the ACT/NSW border, however the water quality at this site is strongly influenced by the Molonglo River; which carries the effluent from the Lower Molonglo Water Quality Control Centre (LMWQCC), and is therefore not an indicator of the quality of water between the MPS and the Molonglo confluence. With that said, the data collected at Lobb's Hole (410761) does provide an indication of water quality upstream of the MPS and the indication from the spring data is that there were obvious changes to electrical conductivity and pH in response to the environmental flow release in October (Figure 4). At the end of the flow release, water temperature continued to increase throughout November which is the influence of increasing air temperatures heading into summer.

If there were lasting impacts from the MPS upgrade or impacts resulting from water abstractions taken at the MPS, it could be expected that downstream of the MPS there would be increases in turbidity following rainfall events, potentially from remanent construction roads or increases in nutrient concentrations and EC and changes in pH and dissolved oxygen resulting from lower water levels (Dewson *et al.*, 2007). The results from the grab samples show very low levels of site to site variation and in some case, indicators such TSS, turbidity and the nutrient concentrations (Table 7) are higher at the upstream sites than the downstream sites, which is probably due to flow fluctuations occurring between the 8th and 10th of November when these samples were collected. Other analytes such as pH and dissolved oxygen were probably more associated with the time of day at which the samples were collected. In the morning pH was <8.0 while the three exceedances at MUR 28, MUR 935 and MUR 29 were all collected in the afternoon when photosynthetic activity is at its highest.

The conclusion, therefore, is that the variation in the grab sample results and the gauged continuous data can be attributed to changes in flow and seasonal changes, which affected all sampling sites, not just the sites downstream of the MPS. We conclude that there is no evidence from the current study that the MPS is negatively impacting the water quality at the sites monitored for this program. However, given the limitation of not having a continuous record downstream of MPS, compensation for the limited number of grab samples should be made by intensifying the sampling frequency during periods of MPS operation and water abstractions.

4.2 Periphyton

There was no significant difference in either chlorophyll-a concentrations or AFDM between upstream and downstream locations (Table 8) suggesting no discernable impact from the Murrumbidgee Pump Station. Compared to autumn 2011 (no spring 2010 data available), there has been up to a 6-fold decrease in the periphyton chlorophyll-a concentrations amongst all sampling sites which is likely due to a combination of seasonal fluctuations in flows and water temperatures, although it is also likely that the standing crops were significantly reduced as a direct result of the environmental flow release.

On a season by season basis the spring 2009 chlorophyll-a concentrations were up to 5 time higher than spring 2011 which is probably a result of lower spring base flows pre-2010 when the drought broke in the ACT and surrounding regions and fewer high –flow events during that period.

The highest periphyton chlorophyll-mean and median values came from MUR 935 and MUR 28 which are the closet in proximity downstream and upstream respectively to the MPS. Historically, MUR 28 has shown the highest chlorophyll-a concentrations, which may relate to a gradual cumulative increase in TP and TN through the catchment, reaching a maximum at MUR 931 and MUR 28 (Table 7) before dissipating downstream of the Cotter confluence – most likely through dilution – and then increasing again downstream of the Molonglo river confluence.

Periphyton samples taken over the past three years support these patterns in nutrient concentration in general, however, owing to lag affects in the timing of nutrient uptake and growth rates, correlations between the two variables have been difficult to show. Other factors accounting for high within and between site variations include differences in substrate composition, daily fluctuations in depth and velocities and grazing rates of certain groups of macroinvertebrates (Steinman and Lamberti, 1996, Rutherford *et al.*, 2000). Isolating these factors would require more intensive assessments which are beyond the scope of this current work.

Those details aside, the key result from this analysis is that operations of the MPS appear to not be playing a role in the variation seen in the AFDM and the periphyton chlorophyll-concentrations. Other factors such as velocities, temperature, substrate and depth are certainly influencing standing stocks, but isolating which are the most important is perhaps not required for the purposes of this project.

4.3 River health and patterns in macroinvertebrate communities

Prior to the spring sampling run there was a period of ten days in mid-October when an environmental flow release was maintained at 2000 ML/d. The similarities amongst sites that were obtained from the multivariate analyses of both the riffle and edge habitats (Figures 10 and 11) are consistent with the findings of Thomaz *et al.* (2007) who suggest that floods and high flows tend to connect water bodies resulting similar water quality, hydrological and hence biological communities. Similarly, Ortiz and Puig (2007) found that after finding strong location differences in water quality, taxonomic richness and the absence of certain EPT taxa downstream of the effluent, a series of high flow events effectively homogenised the macroinvertebrate communities and water quality variables so that the effect size of the point source impact either vanished or was reduced.

This can be seen in this study – firstly by the similar physico-chemical water quality characteristics and secondly in the high similarity percentages amongst sites determined by the macroinvertebrate assemblages. The similarity amongst sites and locations is not surprising given the similarities in substrate, vegetation and land-use practices between these sites. The geographic range of these sites also substantiates these similarities given that there is little variation in altitude, geology or other physical features which influences the distribution of macroinvertebrate communities (Cummins, 1974, Hynes, 1975, Downes *et al.*, 2000, Allan, 2004, Clarke *et al.*, 2008).

The main difference among sites was variation in the estimated abundances of the main taxonomic groups rather than a complete absence of taxa at certain sites. The results from this study indicate that there were five main groups with low to moderate tolerance levels (SIGNAL-2) scores. Although, these tolerant taxa dominate the macroinvertebrate assemblages numerically, up to 54% of the genera diversity were represented by members of the EPT. The presence of these sensitive groups suggests that the water quality and habitat conditions within the limits of this study are providing a healthy environment to support such taxa albeit in relatively low numbers (Figure 9). The lower estimated

abundances of the EPT taxa may be a result of two different processes. First, taxa such as Chironomids and Simuliids are often the first to re-colonise following high flow disturbances which often results in highly uneven community assemblages because they can outcompete other taxa and proliferate rapidly (Niemi *et al.*, 1990, Miller and Gollady, 1996); while others such as Oligiocheates may be resistant to the disturbance and therefore may not have been affected to the same degree as other taxa more susceptible to high flows.

All sites except MUR 931 were assessed as BAND B (significantly impaired) by the AUSRIVAS model for their overall site assessment. MUR 931 is reported as BAND C (severely impaired) due to a poor edge habitat assessment. Compared to autumn 2011, the overall sites assessments are comparable to those reported here, expect that there has been an apparent decline in the edge at MUR 931. All riffle assessments dropped from BAND A to BAND B; however comparing the riffle assessments on a season by season basis, it can be seen that in spring 2009 (last spring assessment) the results for the riffle habitat are almost identical, suggesting a seasonal influence on these assessments. For example, periodic high flow events throughout spring may prevent the macroinvertebrate communities fully re-establishing; and during autumn, during period of more stable flow communities have a better opportunity to reach equilibrium and therefore result in higher AUSRIVAS bands.

In the case of this sampling round, although the period following the environmental flow release (Figure 2) was relatively stable, the time since the flows ceased and the samples were collected may still have not been long enough for the communities to fully re-establish. It should be pointed out that in the case of MUR 931, the BAND C assessment resulted only from one additional family being missing from the sample compared to the other sites (APPENDIX B) and that the additional missing taxa – Tanypodine (SIGNAL 5) – was missing from other sites in this study. The quality of the edge habitat at MUR 931 was high, with a deep profile, good trailing vegetation and large woody debris throughout. It is therefore unclear why the overall abundance and EPT diversity (Figure 8) at this site was low; although it may be that this site: a) is more susceptible to high flows - being at the end of a straight run there are no natural bends to buffer the impacts of high flow events or b) has naturally slow recruitment rates following high flow events.

In past sampling runs, Elmidae and Gripopterygidae in particular have been absent or very rare in the kick samples, despite being predicted with high probability by the AUSRIVAS model. Gripopterygidae, it was thought were absent due to background water quality and habitat conditions, while Elmidae it was thought, were missing because of unfavourable flow conditions during previous sampling runs. Both taxa exhibit qualities that make them useful indicators for flow and water quality related monitoring programs. Elmidae in particular are considered to be good indicators of flow variation (Brooks *et al.*, 2011) because of their affinity for fast flowing, clear and high oxygenated water (Gooderham and Tsyrlin, 2005). *Dinotoperla* spp. (Gripopterygidae) on the other hand can be found in slower moving water, but are considered to be highly sensitive to poor water quality.

These taxa have increased in frequency since spring 2009 which is probably related to the removal of fine sediment deposits in the riffle habitat from substrate mobilisation and increased base flows since the drought broke. The results from this round of sampling also uncovered the sensitive mayfly: *Coloburiscoides sp* (Coloburiscidae; SIGNAL=8) (Plate 4) at MUR 935. As noted in section 3.5.1.1 this particular macroinvertebrate has not been collected downstream of Colinton so far in the MEMP program. It is unclear whether this mayfly was brought down the system by the environmental flow release and was left stranded; or has to this point been locally rare and simply never collected previously or conditions in this section of the river have improved with more frequent high flow events. The AUSRIVAS model does not currently “expect” this family to occur in this section of the Upper Murrumbidgee River Catchment, so it will not affect the AUSRIVAS band scheme if it continues to be collected. However, like Elmidae and Gripopterygidae, if it continues to be collected it may provide another useful indicator of water quality and flow variation.

5 Conclusion and Recommendations

Water quality results from this study were highly comparable amongst all sampling sites suggesting that there has been no detectable impact from the completion of the MPS upgrade or any pumping regime itself. Small variation in the water quality parameters between sites is thought to be a result of variations in flow as a result of sampling on different days. If there were any impacts on certain water quality parameters resulting from the MPS, they appear to have dissipated; which was probably assisted by the environmental flow release.

The AUSRIVAS modelling produced BANDS B and C for the Murrumbidgee River upstream and downstream of MPS indicating 'significant' to 'severely' impacted macroinvertebrate communities. Many of the missing taxa were missing from most or all of the sites suggesting a similar influence occurring at all sites. Given the close temporal proximity to the environmental flow release, it is suggested that this was the overriding factor influencing these results.

Based on the MPS sampling program to date, it is expected that the resistance and resilience of the macroinvertebrate fauna to any potential impact resulting from the (up to) 150 ML/d abstraction from the MPS are likely to depend on:

a) the timing of the abstractions; and

b) the duration that flows are abstracted.

Macroinvertebrate communities are likely to be at their most vulnerable in summer and autumn when Murrumbidgee River base flows are usually at their lowest levels and if flows are artificially lowered through ongoing water abstractions during these months, we could expect to see some initial changes in water quality and loss of some of the more sensitive EPT taxa.

To achieve an improved understanding of the processes that follow water abstractions from the MPS, ALS recommends undertaking more frequent water quality monitoring upstream and downstream of the MPS prior to, during and after operational periods, where the abstraction rate is likely to be above ~20% of the flow in the Murrumbidgee River. This would also require operational data from the MPS (i.e. duration and quantity) to be used for analysis.

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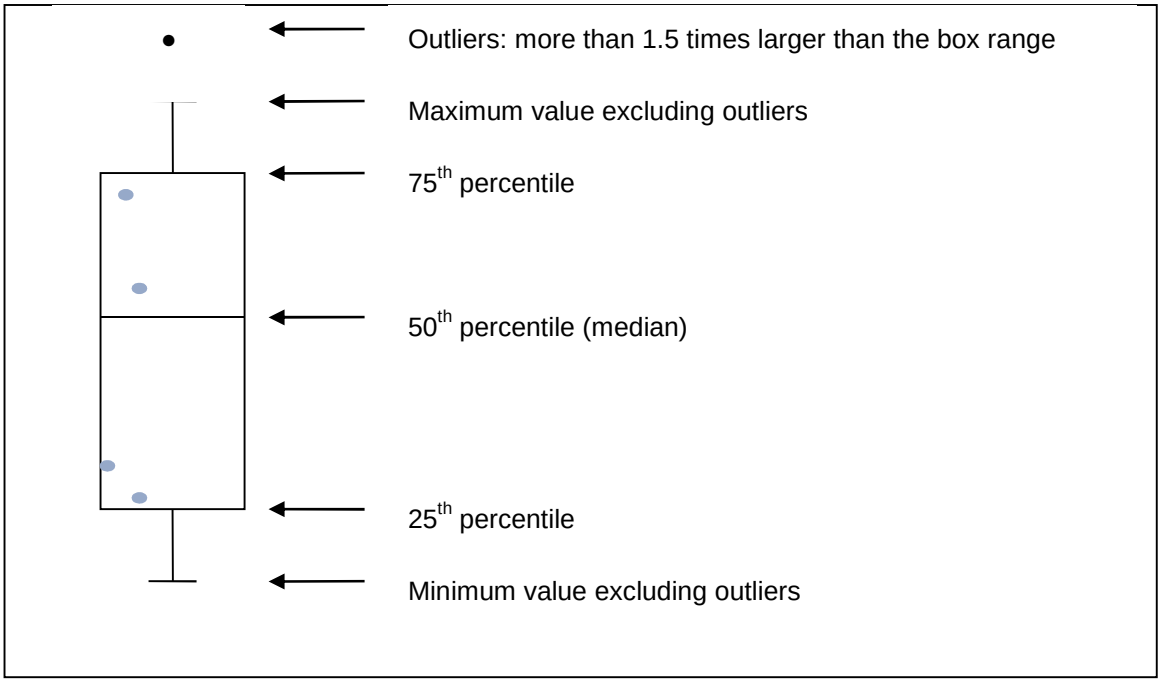
APPENDIX A –
Interpreting Box and Whisker Plots

Box and whisker plots are intended as an exploratory tool to help describe the distribution of the data. The strip chart (blue points) on the inside of the plot area indicates 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 B –

Taxa Predicted with >50% Probability, but were Missing from the Spring 2011 Samples

Appendix B Macroinvertebrates predicted to occur with >50% probability by the AUSRIVAS model but absent from edge samples. Number in cells represents their given probability of occurrence at a given site. Blank cells indicate collection at a given site.

Edge

Site	Taxa	Oligochaeta	Ceratopogonidae	Tanypodinae	Baetidae	Leptophlebiidae	Gripopterygidae	Leptoceridae	Total number of missing taxa
	SIGNAL	2	4	4	5	8	8	6	
MUR 931	Edge	*1.00*	*0.65*		*0.62*	*0.82*			4
MUR 931		*1.00*	*0.65*	*0.97*	*0.62*	*0.82*			5
MUR 28	Edge		*0.65*	*0.97*	*0.62*		*0.62*		4
MUR 28		*1.00*	*0.65*		*0*	*0.82*	*0.62*		4
MUR 28			*0.65*				*0.62*		2
MUR 935	Edge		*0.65*	*0.97*	*0.62*	*0.82*	*0.62*		5
MUR 935			*0.65*	*0.97*	*0.62*				3
MUR 935			*0.65*	*0.97*	*0.62*		*0.62*		4
MUR 935			*0.65*		*0.62*		*0.62*		3
MUR 935			*0.65*		*0.62*		*0.62*	*0.88*	4
MUR 935					*0.62*		*0.62*		2
MUR 937	Edge		*0.65*	*0.97*				*0.88*	3
MUR 937			*0.65*	*0.97*		*0.82*	*0.62*	*0.88*	5
MUR 29	Edge		*0.65*	*0.97*		*0.82*		*0.88*	4
MUR 29			*0.65*	*0.97*			*0.62*		3
MUR 29			*0.65*	*0.97*	*0.62*				3

Appendix B continued Taxa predicted to occur with ≥50% probability by the AUSRIVAS model, but not collected in the riffle habitat.

Riffle

Site	Taxa	Oligochaeta	Acarina	Elmidae	Psephenidae	Tipulidae	Tanypodinae	Chironominae	Baetidae	Leptophlebiidae	Caenidae	Gripopterygidae	Hydrobiosidae	Glossosomatidae	Conoesucidae	Total number of missing taxa
	SIGNAL	2	6	7	6	5	4	3	5	8	4	8	8	9	8	
MUR 931	Riffle		*0.83*		*0.65*		*0.60*			*0.96*		*0.96*	*0.60*	*0.76*	*0.75*	8
MUR 931				*0.97*	*0.65*		*0.60*		*0.62*	*0.96*		*0.96*	*0.60*	*0.76*	*0.75*	9
MUR 931			*0.83*		*0.65*		*0.60*		*0.62*	*0.96*			*0.60*	*0.76*	*0.75*	8
MUR 931			*0.83*	*0.97*	*0.65*		*0.60*		*0.62*	*0.96*		*0.96*	*0.60*	*0.76*	*0.75*	10
MUR 931			*0.83*	*0.97*	*0.65*	*0.70*	*0.60*		*0.62*	*0.96*		*0.96*	*0.60*	*0.76*	*0.75*	11
MUR 931			*0.83*		*0.65*		*0.60*		*0.62*	*0.96*		*0.96*	*0.60*	*0.76*	*0.75*	9
MUR 28	Riffle			*0.96*	*0.64*		*0.59*					*0.95*	*0.59*	*0.75*	*0.72*	7
MUR 28					*0.64*		*0.59*			*0.94*		*0.95*	*0.59*	*0.75*	*0.72*	7
MUR 28				*0.96*	*0.64*		*0.59*			*0.94*		*0.95*	*0.59*	*0.75*	*0.72*	8
MUR 28				*0.96*	*0.64*		*0.59*		*0.61*	*0.94*			*0.59*	*0.75*	*0.72*	8
MUR 28				*0.96*	*0.64*		*0.59*			*0.94*		*0.95*	*0.59*	*0.75*	*0.72*	8
MUR 28					*0.64*		*0.59*		*0.61*			*0.95*	*0.59*	*0.75*	*0.72*	7
MUR 935	Riffle				*0.67*		*0.58*			*0.96*	*0.89*	*0.97*	*0.61*	*0.79*	*0.77*	8
MUR 935					*0.67*		*0.58*			*0.96*		*0.97*		*0.79*	*0.77*	6
MUR 935			*0.85*	*0.97*	*0.67*		*0.58*			*0.96*		*0.97*	*0.61*	*0.79*	*0.77*	9
MUR 935				*0.97*	*0.67*		*0.58*					*0.97*	*0.61*	*0.79*	*0.77*	7
MUR 935				*0.97*	*0.67*		*0.58*						*0.61*	*0.79*	*0.77*	6
MUR 935				*0.97*	*0.67*		*0.58*					*0.97*	*0.61*	*0.79*	*0.77*	7
MUR 937	Riffle			*0.97*	*0.65*							*0.96*	*0.60*	*0.77*	*0.75*	6
MUR 937					*0.65*							*0.96*	*0.60*	*0.77*	*0.75*	5
MUR 937				*0.97*	*0.65*							*0.96*	*0.60*	*0.77*	*0.75*	6
MUR 937				*0.97*	*0.65*		*0.59*					*0.96*	*0.60*	*0.77*	*0.75*	7
MUR 937					*0.65*		*0.59*					*0.96*	*0.60*	*0.77*	*0.75*	6
MUR 937				*0.97*	*0.65*		*0.59*					*0.96*	*0.60*	*0.77*	*0.75*	7
MUR 29	Riffle			*0.96*	*0.62*					*0.94*			*0.59*	*0.73*	*0.72*	6
MUR 29					*0.62*	*0.67*	*0.62*					*0.95*		*0.73*	*0.72*	6
MUR 29					*0.62*		*0.62*						*0.59*	*0.73*	*0.72*	5
MUR 29				*0.96*	*0.62*	*0.67*		*0.90*					*0.59*	*0.73*	*0.72*	7
MUR 29					*0.62*		*0.62*					*0.95*	*0.59*	*0.73*	*0.72*	6
MUR 29		*1.00*		*0.96*	*0.62*	*0.67*	*0.62*			*0.94*			*0.59*	*0.73*	*0.72*	9