ACTEW Corporation

Murrumbidgee Ecological Monitoring Program

Part 1: Angle Crossing

Spring 2009

Brisbane - Canberra - Melbourne - Sydney - Regional offices

CERTIFICATE OF APPROVAL FOR ISSUE OF DOCUMENTS

Report Title: Angle Crossing assessment Spring 2009

Document Status: Final

Document No: CN211063/2009/001

Date of Issue: 30/06/2010

Project Title: Murrumbidgee Ecological Monitoring Program

Client: ACTEW Cooperation

Cover Photograph: Looking southeast: Angle Crossing, March 2009

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Document Revision Control

Version	**Description of Revision**	**Person Making Issue**	**Date**	**Approval**
1	FINAL	NM	30/06/2010	

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Executive Summary

To improve the ACT water security for the future, ACTEW Corporation is proposing to construct an additional pumping structure and pipeline to abstract water from the Murrumbidgee River near Angle Crossing (southern border of the ACT).

The proposed pumping system will transfer water from Angle Crossing through an underground pipeline into Burra Creek, and then transfer the water by run of river flows into the Googong Reservoir. The system is being designed to pump up to 100 ML/d, and is expected to be in operation in 2011. Abstraction will be dictated by the level of demand for water, and by the availability of water in the Murrumbidgee River. The proposal is referred to as Murrumbidgee to Googong project (M2G).

This program aims to determine the baseline river condition prior to the additional water abstraction and then continue monitoring after commencement to determine what changes are taking place that are attributable to abstraction from Angle Crossing.

The key aims of this sampling run were to:

- *Collect current baseline condition macroinvertebrate community data, up- and downstream of Angle Crossing;*
- *Provide ACTEW with river health assessments based on AUSRIVAS protocols at key sites potentially affected by the construction and operation of pumping infrastructure at Angle Crossing;*
- *Collect current condition periphyton community baseline data to help monitor seasonal and temporal change and;*
- *Report on water quality up and downstream of Angle Crossing.*

This report presents the results from biological sampling and monitoring of the Murrumbidgee River upstream and downstream of Angle Crossing in spring 2009. Sampling was completed in November 2009. Sampling was based on the AUSRIVAS sampling protocols, but was extended to include replicated sampling at each site and genus level for particular taxa, in order to: a) establish within-site variability prior to the commencement of pumping; and

b) improve the potential ability of the monitoring program to detect subtle changes in the macroinvertebrate community in response to water abstraction impacts.

The key results from the spring 2009 sampling of Angle Crossing show that:

All sites were classified as "significantly impaired" (BAND B) by the AUSRIVAS assessment. This assessment has not changed since autumn 2009, although there were a higher proportion of sub-samples with BAND A assessments in spring compared to autumn. This has resulted in higher average AUSRIVAS O/E scores across most sires, except immediately downstream of Angle Crossing.

Continuous water quality data show seasonal and high flow related fluctuations over the course of spring. Turbidity exceeded recommended levels (25 NTU) for approximately 40% of the spring monitoring period due to steady rainfall and high flows. Nutrient guideline levels were exceeded at all sampling sites, as they were in autumn, however, in this round of sampling they were up to 6 times higher than levels recorded in autumn. We believe this was due to increased runoff from agricultural land further up the catchment (in the Numeralla sub-catchment). Most other analytes remained within ANZECC and ARMCANZ (2000) recommended limits for the spring period

Macroinvertebrate taxonomic richness and density were lower in spring compared to autumn. This could be related to seasonal variation; however, it is more likely that it was due to hydrological disturbance associated with the high flow event. Trends in community composition are consistent with those reported in the literature with respect to responses to hydrological disturbance. For example, high flow tolerant taxa such as Oligochaetes were more prevalent in spring post the November high flow event and there were fewer EPT taxa, which tend to have a high propensity to drift under high flow conditions.

The high within-site variation in observed in autumn was again apparent in the spring sampling program. This suggests that a single sample is not representative of the macroinvertebrate composition at a given site. We recommend maintaining the current regime to best describe macroinvertebrate communities at a given site.

Recovery in taxa from the November high flow event should be rapid, and there should be noticeable increases in taxa diversity and abundances in the next round of sampling, notwithstanding further hydrological disturbance and seasonal influences. The high flow event in spring had an homogenising effect in terms of over-riding the influences of other factors on macroinvertebrate community structure. In the absence of further hydrological disturbance, we would expect to see between-site similarities decrease as the influences of other factors (e.g. water quality, habitat quality) exert greater influence on macroinvertebrate communities.

List of abbreviations

ACT – Australian Capital Territory
ACTEW – ACTEW Corporation Limited
AFDM – Ash Free Dry Mass (periphyton)
ANOSIM – Analysis of similarities
ANOVA – Analysis of Variance (statistics)
ANZECC –Australian and New Zealand Environment and Conservation Council
APHA – American Public Health Association
ARMCANZ – Agriculture and Resource management Council of Australia and New Zealand
AUSRIVAS – Australian River Assessment System
BACI – Before After Control Impact
CMA – Catchment Management Authority
CRCFE – Cooperative Research Centre for Freshwater Ecology
EC – Electrical Conductivity
EIS – Environmental Impact Statement
EPA – Environmental Protection Authority
EPT – Ephemeroptera, Plecoptera and Trichoptera taxa
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
SIMPER – Similarity Percentages
TN – Total Nitrogen
TP – Total Phosphorus

1 Introduction

The Murrumbidgee Ecological Monitoring Program (MEMP) 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 is to undertake sampling in spring and autumn over a three year period that commenced 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 1: Angle Crossing.

To improve ACT water security for the future, ACTEW Corporation is proposing to construct an additional pumping structure and pipeline to abstract water from the Murrumbidgee River near Angle Crossing (southern border of the ACT).

The proposed pumping system will transfer water from Angle Crossing through an underground pipeline into Burra Creek, and then transfer the water by run of river flows into the Googong Reservoir. The system is being designed to pump up to 100 ML/d, and to be in operation in late 2011. Abstraction will be dictated by the level of demand for the water, and by the availability of water in the Murrumbidgee River. The proposal is referred to as Murrumbidgee to Googong project (M2G).

Due to the combined effects of climate change and increased demands from industry and households, the impacts of water abstraction on aquatic ecosystems, river health and water quality have been extensively researched (see Dewson *et al.*, 2007 for a recent review). It is expected there will be changes to the aquatic ecosystem within the Murrumbidgee River and Burra Creek as a result of M2G. Some of these effects include, but are not limited to: changes to water chemistry; and changes to channel morphology, velocity and depth. All of these changes have potential knock-on effects to the biota within the river's ecosystem (**APPENDIX A**). This current monitoring program will form the basis of an Ecological Monitoring Program to satisfy EIS requirements.

1.1 Background: The Upper Murrumbidgee River

The Murrumbidgee River flows for 1,600 km from its headwaters in the Snowy Mountains to its junction with the Murray River. The catchment area to Angle Crossing is 5096 km^2. As part of the Snowy Mountains Scheme, the headwaters of the Murrumbidgee River were constrained by the 252 GL Tantangara Dam, which was completed in 1961. The reservoir collects water and diverts it outside the Murrumbidgee catchment to Lake Eucumbene. This has reduced base flows and the frequency and duration of floods in the Murrumbidgee River downstream. The Murrumbidgee River is impounded again at Burrinjuck Dam, after the river passes through the ACT. This region above Burrinjuck Dam is generally known as the Upper Murrumbidgee.

Land-use varies from National Park in the high country to agriculture and farming in the valley regions. Annual rainfall varies from greater than 1400 mm in the mountains, to 620 mm at Canberra, and down to around 300mm in the west.

Drought has had the most significant impact on catchment quality within the upper Murrumbidgee catchments in recent times. More than 80% of catchments have been drought-*a*ffected since late 2002. Drought-induced land degradation in the upper Murrumbidgee catchments has been significant across all areas and adverse effects include increased stress on surface and groundwater resources, increased soil erosion and a shift from mixed farming and cropping to grazing, and reduced stock numbers. Drought has also led to increased pressure on native vegetation in the catchments, a heightened risk of fire in native forests, and an increase in the abundance of several weed species.

1.2 Project objectives

There are two key phases to this project, which incorporates two sets of objectives, representing long and short term aims, i.e. before and after abstraction (Table 1). Phase 1 of this monitoring program involves the establishment of baseline macroinvertebrate community composition at selected sites up- and downstream of the proposed abstraction point. The focus of Phase 1 will be on the documentation of spatial and seasonal changes in macroinvertebrate and periphyton assemblages as well as monitoring water quality patterns. This will also include monitoring potential effects associated with (either directly or indirectly) the construction of the new pump station at Angle Crossing.

Phase 2, incorporates long term objectives, which aim to delineate potential ecological effects that are related specifically to the abstraction of water from the Murrumbidgee River at Angle Crossing, outside of what is considered natural, temporal and spatial variation.

The specific aims of this monitoring program are:

1. To determine seasonal and annual variation in the composition and abundance of periphyton at control and test sites before water abstractions commence, and to assist in the monitoring of river ecosystem health once the abstractions begin.

2. To determine baseline macroinvertebrate communities at test and control sites before the water abstractions commence, and to assist in the monitoring of riverine ecosystem health once the abstractions begin.

Table 1. Project objectives and estimated time frames

	Key objectives	Time frame	Outcomes
Phase 1	Obtain baseline information to include: hydrological, biological and physico-chemical water quality information. Establish spatial and temporal trends up and downstream of the existing low-level crossing that is Angle Crossing.	2-3 years	Help establish flow rules for the operation of the pump in the M2G project Establish biological signatures and inventories as references for changes over time
Phase 2	Monitor the ecological responses related specifically to water abstractions from Angle Crossing. The ability to do this depends on establishing a comprehensive data set of spatial and temporal variability at all concerned sites.	3+ years	Help minimise ecological impacts by better understanding biological responses to water abstraction.

1.3 Project scope

The current ecological health of the sites monitored as part of the Murrumbidgee to Googong (M2G) monitoring program was 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 2009 sampling. Specifically, as outlined in the MEMP proposal to ACTEW Corporation (Ecowise, 2009) this work includes:

- Sampling conducted in spring 2009;
- Macroinvertebrate communities collected from riffle and edge habitats using AUSRIVAS protocols;
- Macroinvertebrate samples counted and identified to the taxonomic level of genus;
- Riffle and edge samples assessed through the appropriate AUSRIVAS model;
- *In-situ* water quality measurements collected and samples analysed for nutrients in Ecowise's NATA accredited laboratory.

1.4 Rationale for using biological indicators

Macroinvertebrates and periphyton are two of the most common biological indicators used in river bio-assessment. Macroinvertebrates provide a general characterisation of the health of a stream ecosystem because they represent a continuous record of preceding environmental, chemical and physical conditions at a given site; they are also very useful indicators in determining specific stressors on freshwater ecosystems because many taxa have known tolerances to certain impacts such as: heavy metal contamination, sedimentation and other physical or chemical changes that might exist (Chessman, 2003).

Periphyton is the matted community that resides on the surfaces of the river bed. The composition of these communities is dominated by algae but the term "periphyton" also includes fungal and bacterial matter (Biggs & 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 source of 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 flows, and this makes them a valuable indicator of river health.

Changes in total periphyton biomass and/or the live component of the periphyton (as determined by chlorophyll-*a*) can vary with changes in flow volume, so these variables are often used as indicators of river condition in relation to monitoring the effects of flow regulation, environmental flow releases or water abstraction impacts (Talsma & Hallam, 1982; Biggs, 1989;; Whitton & Kelly, 1995; Biggs *et al.*, 1999;). Water abstractions from Angle Crossing will not affect the timing or magnitude of higher flows, but it could affect conditions during the seasonal low flow period, such as increasing the nutrient availability through increased residence time, reducing scouring impacts on benthic organism and reducing surface flows over riffle habitats and thus decreasing habitat quality and availability. As changes in flow volume are expected with the proposed changes in the Murrumbidgee River water abstraction regime, periphyton biomass and chlorophyll-*a* are included as biological indices.

2 Materials and Methods

2.1 Study sites

Macroinvertebrate community composition, periphyton assemblages and water quality were monitored from replicate sites on the Murrumbidgee River, up- and downstream of Angle Crossing (~2km west of Williamsdale) with the aim of obtaining baseline ecological condition information following the ANZECC guidelines for ecological monitoring (ANZECC & ARMCANZ, 2000).

The upper Murrumbidgee River is impacted by activities in its large catchment, which includes a large array of land-use practices. As such, it was important to select a sufficiently large number of sites to enable the program to provide a reasonable snap-shot of the current status of the macroinvertebrate community in the study area. Sites were chosen based on several criteria, which included:

Safe access and approval from land owners;

Sites have representative habitats (i.e. riffle / pool sequences). If both habitats were not present then riffle zones took priority as the they are the most likely to be affected by abstractions;

Sites which have historical ecological data sets (e.g. Keen, 2001) took precedence over "new sites" –allowing comparisons through time to help assess natural variability through the system. This is especially important in this program because there is less emphasis on the reference condition, and more on comparisons between and among sites of similar characteristics in the ACT and surrounds over time.

Potential sites were identified initially from topographic maps, they were visited prior to sampling and their suitability was subsequently considered. Six sites suited the criteria mentioned above (Table 3; Figures 1 and 2). These sites include three sites upstream of Angle Crossing (in NSW) and three sites downstream (all in the ACT).

2.2 Hydrology and rainfall

River flows and rainfall for the sampling period were recorded at ECOWISE gauging stations located at Lobb's Hole (downstream of Angle Crossing: 410761) and Mount MacDonald (410738: ~5.2 km downstream of the Cotter River Confluence). A new water quality site has been installed upstream of Angle Crossing (MURWQ09).

Site locations and codes are given in Table 2. Stations are calibrated monthly and data is downloaded and verified before storage on the database where it is quality coded. Water level data is verified manually by comparing the logger value to staff gauge value. If there are differences between logger and staff, the logger is adjusted accordingly. Rain gauges are calibrated and adjusted as required. Records are stored on the HYDSTRA© database software and downloaded for each sampling period.

Table 2. Location and details of continuous water quality and flow stations

Site Code	Location/Notes	Parameters*	Latitude	Longitude
MURWQ09	M'bidgee River U/S Angle Crossing	WL, Q, pH, EC, DO, Temp, Turb, Rainfall	S 35.3533	E 149.0705
410761	M'bidgee River @ Lobb's Hole (D/S of Angle Crossing)	WL, Q, pH, EC, DO, Temp, Turb, Rainfall	S 35.5398	E 149.1015
410738	M'bidgee River @ Mt. MacDonald	WL, Q	S 35.2917	E 148.9553

* WL = Water Level; Q = Rated Discharge; EC = Electrical Conductivity; DO = Dissolved Oxygen; Temp = Temperature; Turb = Turbidity; Rainfall = Rainfall (0.2 mm increments).

2.3 Water quality

Baseline in-situ physico-chemical parameters including temperature, pH, electrical conductivity, turbidity and dissolved oxygen were recorded using a multiprobe Hydrolab® minisonde 5a at sites indicated in Table 3. The Hydrolab® was calibrated following QA procedures and the manufactures requirements prior to sampling. Additionally, grab samples were taken from each site in accordance with the AUSRIVAS protocols (Coysh *et al.*, 2000b) for Hydrolab verification and nutrient analysis. All samples were placed on ice, returned to the ECOWISE laboratory, and analysed for nitrogen oxides (total NOx), total nitrogen and phosphorus in accordance with the protocols outlined in APHA (2005). Collectively, this information on the water quality parameters will assist in the interpretation of biological data and provide a basis on which to gauge ecosystem changes potentially linked to flow reductions at these key sites following water abstractions.

Table 3. Sampling site locations and details

Site Code	Location	Landuse	Habitat sampled
MUR 15	Near Colinton - Bumbalong Road	Grazing / Recreation	Riffle and Edge
MUR 16	The Willows - Near Michelago	Grazing	Riffle and Edge
MUR 18	U/S Angle Crossing	Grazing	Riffle and Edge
MUR 19	D/S Angle Crossing	Grazing / Recreation	Riffle and Edge
MUR 23	Point Hut Crossing	Recreation / Residential	Riffle and Edge
MUR 28	U/S Cotter River confluence	Grazing	Riffle and Edge

2.4 Macroinvertebrate sampling and processing

At each site, macroinvertebrates were sampled in the riffle and edge habitats where available. Both habitats were sampled to provide a more comprehensive assessment of each site (Coysh *et al.*, 2000a); and potentially allow 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 by changes in flow conditions. Riffle zones, for example, are likely to be one of the first habitats affected by low flows and water abstractions 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..

Riffle and edge habitats were sampled for macroinvertebrates and analysed in strict accordance with the ACT spring riffle and edge AUSRIVAS (Australian River Assessment System) protocols (Coysh *et al.*, 2000b) during spring (October 24 – November 11th) 2009. 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 10cm; (Coysh *et al.*, 2000b) using a framed net (350mm wide) 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 directly upstream of the net opening was disturbed by vigorously kicking and agitating the stream bed, allowing any dislodged material to be carried into the net. The process continued, working upstream over 10 metres of riffle habitat. The samples were then preserved in the field using 70% ethanol, clearly labelled with site codes and date then stored on ice and refrigerated until laboratory sorting commenced.

The edge habitat was also sampled in strict accordance with 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 and sites 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.

Processing of the 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. The contents of randomly selected cells were removed and the macroinvertebrates within each cell were identified to genus level except for Chironomids (sub-family) and Oligochaeta (class) Specimens that could not be identified to the specified taxonomic level (i.e. immature or damaged taxa) were removed from the data set prior to analysis. For the AUSRIVAS model, taxa were analysed at family level except for: Chironomidae (sub-family), Oligochaeta (class) and Acarina (order) until 200 animals were identified (identification followed taxonomic keys published by Hawking, (2000)). If 200 animals were identified before a cell had been completely analysed, identification continued until the animals in the entire cell were identified. Data were entered directly into electronic spreadsheets to eliminate errors associated with manual data transfer.

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) of the periphyton samples (Biggs, 2000).

The six sites shown in Table 2, were sampled for periphyton in spring in conjunction with the macroinvertebrate sampling. All periphyton - adnate and loose forms of periphyton, as well as organic/inorganic detritus in the periphyton matrix, 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. Transects were marked using flagging tape and GPS coordinates were be taken. Along each transect, twelve samples were collected at regular intervals, using a syringe sampling device, based on two 60 ml syringes and a scrubbing surface of stiff nylon bristles, covering an area of ~637 mm^2. The samples were then divided randomly into two groups of six samples to be analysed for Ash Free Dry Mass (AFDM gm^{-2}), and chlorophyll-*a*. Samples for Ash Free Dry Mass (gm^{-2}) and chlorophyll-*a* analysis were filtered onto glass filters and frozen. Sample processing follows the methods outlined in APHA (2005).

2.6 Data analysis

2.6.1 Water quality

Water quality parameters were examined for compliance with ANZECC water guidelines for healthy ecosystems in upland streams (ANZECC, 2000). 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. All multivariate analyses were performed using PRIMER version 6 (Clarke & Gorley, 2006). Univariate statistics were performed using R version 2.9.2 (R Development Core Team, 2009).

To test for differences in univariate metrics (SIGNAL-2 scores and AUSRIVAS OE50 ratios) upstream and downstream of Angle Crossing, mixed effect, nested ANOVA models were conducted (Quinn & Keough, 2002). Sites were considered random effects representing the river condition upstream and downstream of the proposed abstraction point; while location (up- and downstream) was considered a fixed, constant effect. Data transformations were not necessary because the model assumptions were met on all accounts. For all analyses, alpha was set to 5%.

Several additional metrics to the AUSRIVAS and SIGNAL-2 were used. The number of taxa (taxa richness) was counted for each site and other descriptive metrics such as the relative abundances of pollution-sensitive taxa (Ephemeroptera, Plecoptera and Trichoptera- EPT) and, pollution-tolerant taxa, (i.e. Oligochaeta and Chironomids) were examined at family and genus levels.

Taxa richness was monitored as a means of assessing macroinvertebrate diversity. In assessing the taxonomic richness of a site, it is important to keep in mind that high taxa richness scores can, but does not always indicate better ecological condition at a given location. In certain instances high taxa richness may indicate a response to the provision of new habitat or food resources that might not naturally occur as a result of anthropogenic activities.

Non-metric multidimensional scaling (NMDS) was also performed on the macroinvertebrate community data following the initial cluster analysis. NMDS is a multivariate procedure that reduces the dimensionality of multivariate data and aids interpretation. It reduces the dimensionality of the data by describing trends in the joint occurrence of taxa. 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 & Warwick, 2001). For the macroinvertebrate data collected during this survey, the final number of dimensions was reduced to two. Stress values for each NMDS plot were examined before results were interpreted. 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 and can be considered a measure of "goodness of fit" to the original data matrix (Kruskal, 1964). Stress near zeros suggests that NMDS patterns are very representative of the multidimensional data, while stresses greater than 0.2 indicate a poor representation (Clarke and Warwick 2001).

The analysis of similarities test (ANOSIM) was performed on the data to test whether macroinvertebrate communities were statistically different up and downstream of the MPS. Sites were nested within location for the analysis. 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 (Clarke & Warwick, 2001). This process was also used to determine which taxa characterised particular groups of sites).

2.6.3 AUSRIVAS assessment

In addition to assessing the composition and calculating biometrics from the macroinvertebrate data, riffle and edge samples, river health assessments based the ACT AUSRIVAS spring riffle and edge models were conducted. AUSRIVAS is a prediction system that uses macroinvertebrate communities 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 which can not be influenced due to human activities, 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 4 and 5).

The 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 an A assessment in the edge and a B Band in the riffle would be given an overall site assessment of B (Coysh *et al.*, 2000b). In cases where the bands deviate significant between habitat (e.g. D – A) then an overall assessment was 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 be noted that the presence or absence of rare taxa does vary naturally 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 or the effects of a recent hydrological disturbance rather than truly reflecting ecological change.

Table 4. AUSRIVAS band-widths and interpretations for the ACT spring riffle and edge models

	RIFFLE	EDGE	
BAND	O/E Band width	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	0-0.27	0-0.34	Extremely impaired. Highly degraded. Water and /or habitat quality is very low and very few of the expected taxa remain.

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.

2.6.5 Periphyton

To test whether estimated biomass (AFDM) and live content (Chlorophyll-*a*) were different between sites upstream and downstream of Angle Crossing, a mixed effects, nested analysis of variance was fitted to the Log-transformed data for AFDM and Chlorophyll-a. Site was nested within location (upstream or downstream of the abstraction point); Consequently, site and location were treated as random and fixed effects, respectively in the ANOVA. Log-transformation was necessary to meet the assumptions of normality. For the purposes of graphical visualisation, however, raw data are presented.

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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. Attempts were made to obtain significantly more than 200 organisms, to overcome losses associated with damage to intact organisms during vial transfer.
- Identification was performed by qualified and experienced aquatic biologists with more than 100 hours of identification experience.
- When required, taxonomic experts performed confirmations of 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)).

Ecowise field staff maintains current ACT and NSW AUSRIVAS accreditation.

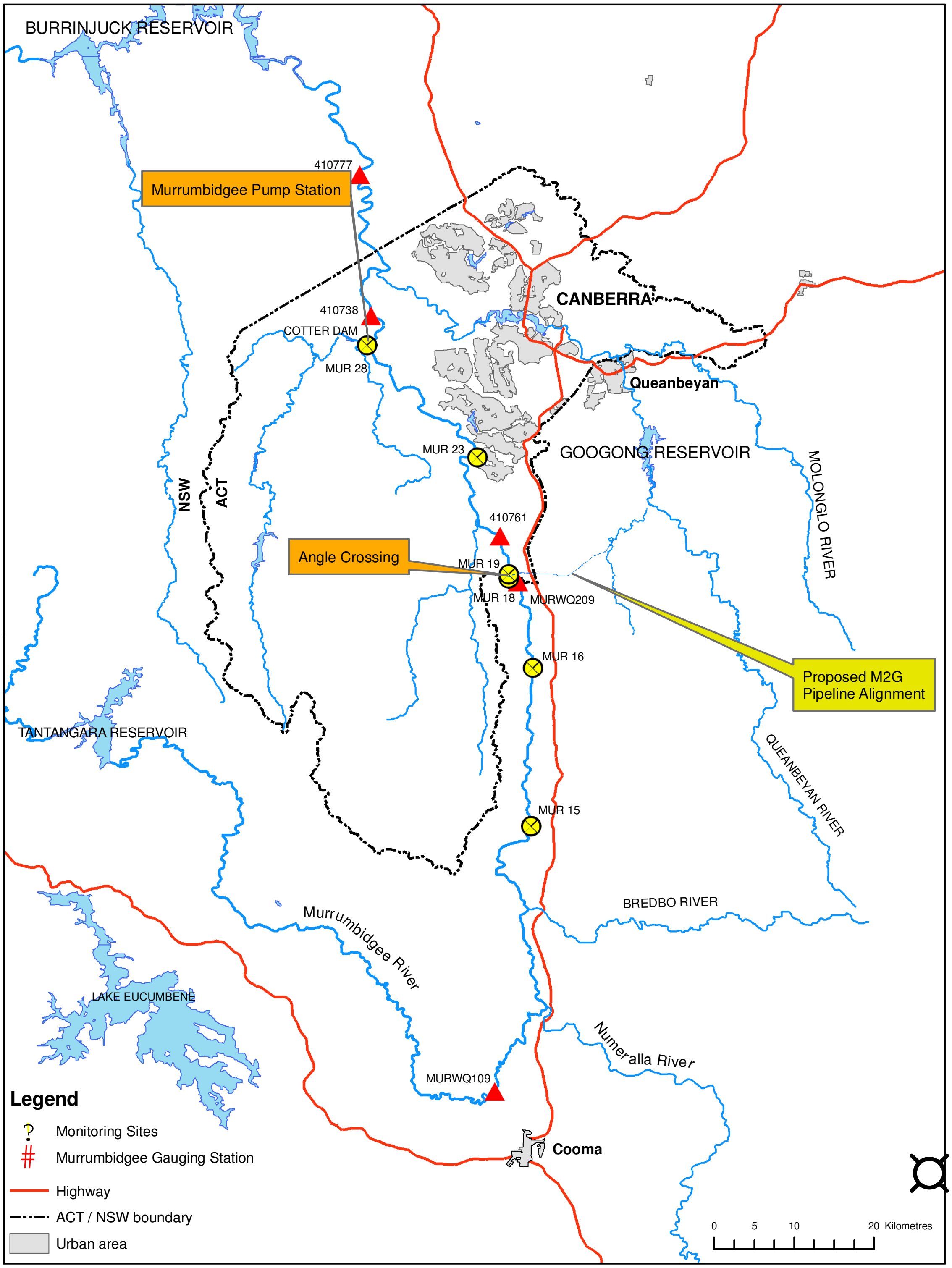

Figure 1. Angle Crossing sampling locations

Mur 18. ~800m Upstream of Angle Crossing

MUR 15. Near Colinton
(205ML/d)

MUR 15. 13th November 2009

MUR 16. “The Willows” near Michelago
(205ML/d)

MUR 16. 13th November 2009

Figure 2. Photographs of sampling sites

Mur 19. Downstream Angle Crossing

Mur 23. Point Hut Crossing

Mur 28. Upstream Cotter River confluence

Figure 2 cntd. Sampling site photographs

3 Results

3.1 Hydrology and rainfall

The average flow during the three months of spring was 278 ML/d. Average flows in the Murrumbidgee River were more than 15 times those recorded during the autumn period ranging from a daily mean of 53.ML/d in late November to 1605 ML/d following a high flow-event in early November (Figure 2; Table 5).

Monthly rainfall was highest in October, with 90.6 mm and lowest in November with 11mm (recorded at Lobb's Hole: 410761). There were 38 wet days in spring (compared to 19 in autumn), with 16 days recorded in October, 13 in September and 9 in November. Total daily rainfall ranged from the detectable minimum of 0.2mm to 28 mm. There were four days in which the daily total exceeded 15mm two days in late October and two days in September. The two days in October (28mm and 17.8mm) occurred within three days of each other and triggered a high flow event that affected all sites downstream of MUR 15 (Figure 1).

Sampling in spring was conducted in late October/early November to correspond to the same sampling period in 2008. A week into the sampling program(i.e. on November 2nd). however, the high flow event described above occurred, making it unsafe to sample. Sampling was reconvened when the river had subsided to safe, wadable levels just over a week later and concluded on the 12th and 13th of November *.

At the time of sampling, the new gauging site upstream of Angle Crossing (MURWQ09) had only just been installed (APPENDIX B) and calibrations and final checks were being conducted.

** Ecowise recognise that there is a stand down period of four weeks following floods (Coysh et al., 2000b), however in this case the timing of the sampling program meant that, if the obligatory 4 week waiting period was adhered to sampling would have extended into summer, for which AUSRIVAS predictive models do not apply. Further, the majority of sampling was completed before the high flow event occurred. It was felt that by sampling over one continuous sampling period, rather in two disrupted periods, the potential biasing influence of other sources of variation (e.g. seasonal changes in water temperatures, light incidence, recruitment, etc) might be avoided.*

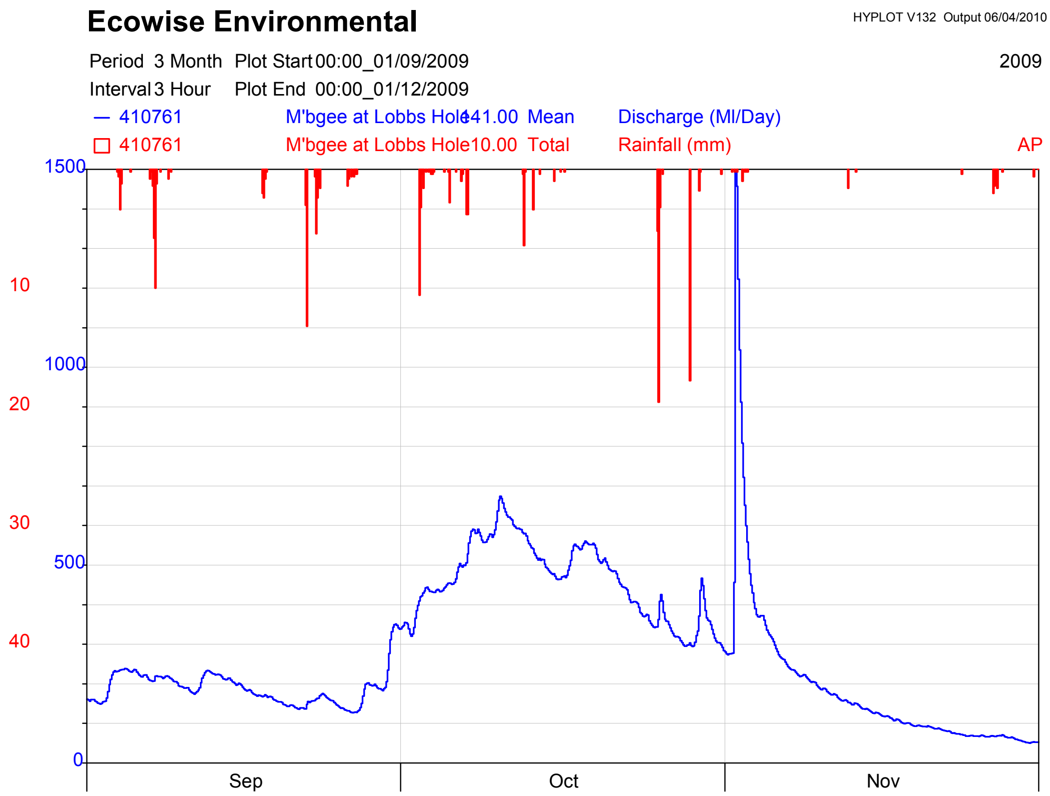

Figure 2. Spring hydrograph of the Murrumbidgee River at Lobb's Hole. Total rainfall (mm) is shown in red**.**

Table 5. Spring rainfall and flow summary for upstream of Angle Crossing and downstream at Lobb's Hole (410761)

Flow values are daily means. Rainfall is total (mm).

Site	Lobb's Hole (410761)	
	Rainfall (total)	Mean Flow (ML/d)
September	63.4	189.8
October	90.6	459.5
November	11.0	184.3
Spring mean	164.4	277.8

3.2 Water quality

Continuous water quality data are reported here from stream flow station 410761 (Lobb's Hole; Figure 1). As mentioned in section 3.1, data from MUR WQ 09 are not available at this stage, but should be for the next round of sampling.

The continuous water quality data obtained from Lobb's Hole for the period 1/09/09-30/11/09 are presented in Figure 3. The four week gap in the pH data series is due to a lightning strike in late September. Electrical conductivity and turbidity were the most variable parameters throughout spring.

Turbidity exceeded the ANZECC and ARMCANZ (2000) guidelines (based on daily means) for 40 % of the spring monitoring period. Early September was only marginally over the 25 NTU upper limits for healthy ecosystems, with daily means reaching a maximum of 45 NTU. Later that month NTU recordings ranged form 1.8-3.3 NTU. These low values continued for most of October, but with the arrival of heavier rainfalls in the catchment, turbidity spiked to a daily mean of 1463 NTU and remained over the guideline limits, fluctuating between 26 -1660 NTU until mid-December, when the weather stabilised.

Temperature, electrical conductivity and dissolved oxygen saturation fluctuated in conjunction with variations in river flow (Figure 3). Water temperature was most influenced by ambient temperate and increased steadily over the coarse of spring from September (mean = 13.5) to November (mean=22.4). EC was lowest during periods of high flow (Figure 3), but increased following the high flow event from ~45 µs/cm in October to a monthly average of 91 µs/cm in November with daily means peaking at 104 µs/cm. There was very little variation in pH at Lobb's Hole, though there was a loss of data through October due to sensor damage.. Monthly means in pH at this site ranged from 7.7-7.9,

The nutrient levels recorded in spring exceeded ANZECC and ARMCANZ (2000) recommendations, as they did in autumn. The highest levels were recorded at MUR 15, 16 and 23 (Table 6) and were up to 6 times higher than the levels recorded in autumn. Nitrogen oxides (NOx) also exceeded guideline values by 14% to >100% (0.19 mg/L – 31mg/L). EC levels were lower than the minimum limits of the guidelines at all but one site (Mur 16), while turbidity exceeded the recommended upper limit of 25 NTU at all of the sites sampled over this period.

3.3 Periphyton

Chlorophyll-*a* concentrations were up to four times higher than the autumn estimates at Point Hut crossing (MUR 23) (Ecowise, 2009), while the levels of within-site variability in Ash Free Dry Mass (AFDM) were similar to autumn, on average AFDM was ~ 60% lower than recorded in autumn.

On average, Chlorophyll-*a* estimates were higher downstream of Angle Crossing (mean=28830 ug/m^{-2}) compared to the upstream sites (mean = 5907 ug/m^{-2}). These differences were not significantly different ($F_{1,30}$ = 4.74; P=0.09; Figure 4a).. Similarly, AFDM was not different between upstream and downstream locations ($F_{1,30}$ = 0.00; P0.98; Figure 4b).

As noted in the autumn sampling report (Ecowise, 2009), AFDM tended to be more evenly distributed than the chlorophyll-*a* estimates from the periphyton, suggesting a less patchy distribution across the transects (Figure 4b). Patches of filamentous algae were not restricted to the margins in spring as they were in autumn

Average chlorophyll-*a* concentrations were negatively correlated to current velocity (R^2=0.77; n=36) (velocity readings ranged from 0.49 m/s^{-1} – 0.91 m/s^{-1}). There were no correlations between water quality variables (specifically nutrient data and temperature) and AFDM or Chlorophyll-*a*, but as noted in Ecowise (2009) this was not surprising since there are no clear differences in the water quality parameters between sites or locations (Table 6). The reason for the lack of correlation between water quality and periphyton biomass is that periphyton is a cumulative response to antecedent WQ conditions. In this study however, instantaneous nutrient test samples at the time periphyton biomass samples were collected. Therefore, there would not necessarily be a correlation because of the potential lag-effect.

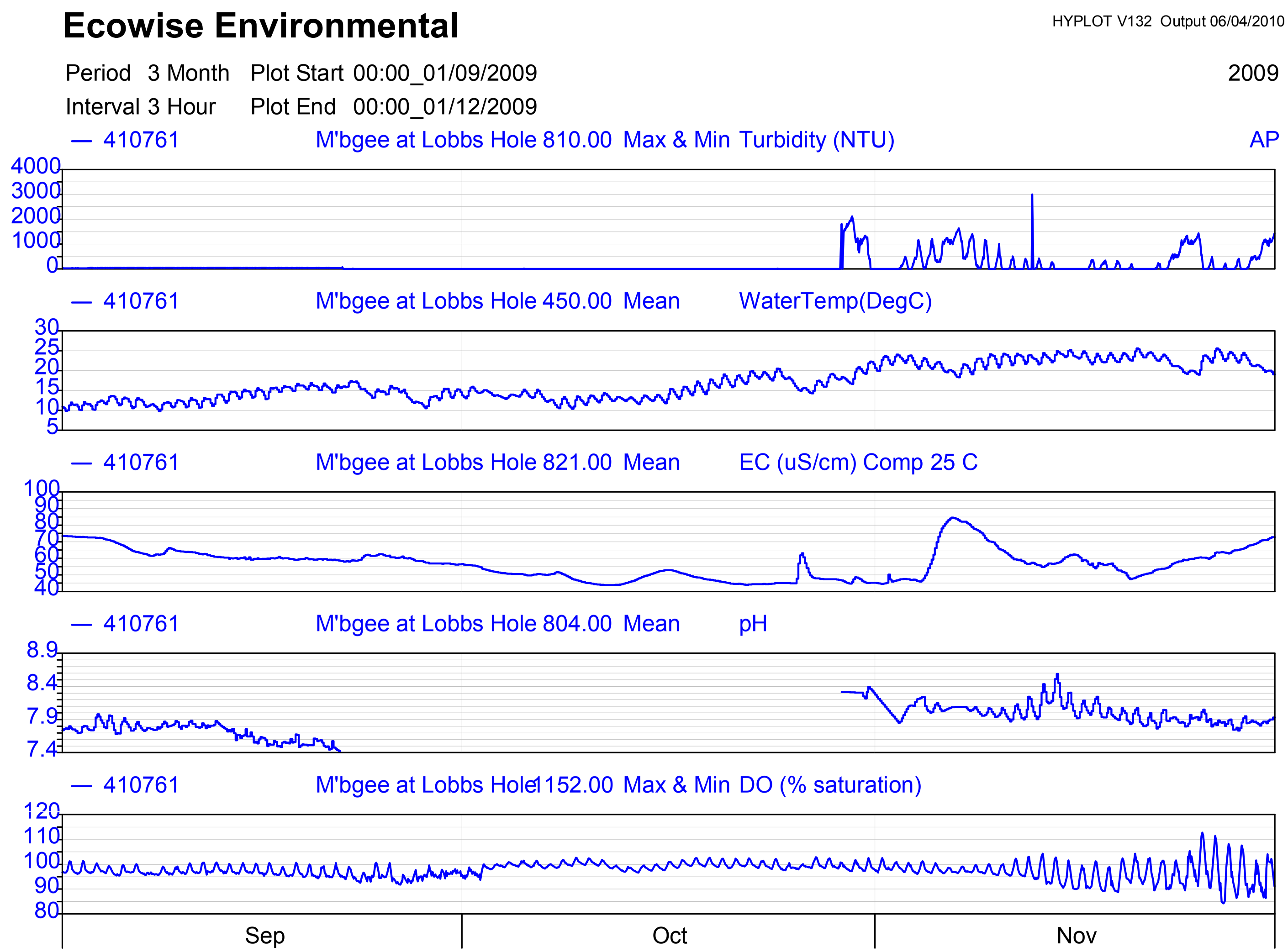

Figure 3. Water quality records from Lobb's Hole during spring 2008

The break in pH data series was due to lightening damage to the sensor in late September.

Table 6. In-situ water quality and nutrient results from Spring 2009. (ANZECC guideline values are in red). Yellow cells indicate values outside of ANZECC and AMRCANZ (2000) guidelines for slightly disturbed upland streams in South Eastern Australia.

Location	Site	Time	Temp. (°C)	EC (µs/cm) (30-350)	Turbidity (NTU) (2-25)	pH (6.5-8)	D.O. (% Sat.) (90-110)	Dissolved Oxygen (mg/L)	Alkalinity	NOX (mg/L) (0.015)	Nitrate (mg/L)	Nitrite (mg/L)	Total Phosphorus (mg/L) (0.02)	Total Nitrogen (mg/L) (0.25)
Control sites	MUR 15	09.00	20.1	23.5	200	7.08	88.9	7.3	35	0.19	0.17	0.02	0.18	1.4
	MUR 16	13.05	21.6	31.1	220	6.8	95.3	7.8	28.7	0.31	0.05	0.05	0.19	1.1
	MUR 18	08.00	22.1	23.4	87	7.4	93.5	8.7	30.1	0.10	0.10	<0.01	0.14	0.78
Downstream sites	MUR 19	10.00	23.1	23.4	87	7.4	100.5	8.02	30.6	0.10	0.10	<0.01	0.15	0.73
	MUR 23	12.05	24.7	27.1	130	7.3	105.3	8.15	33.3	0.20	0.18	0.02	0.18	1.00
	MUR 28	14.00	24.7	19.1	60	7.7	107.4	8.3	26	<0.01	<0.01	<0.01	0.07	0.57

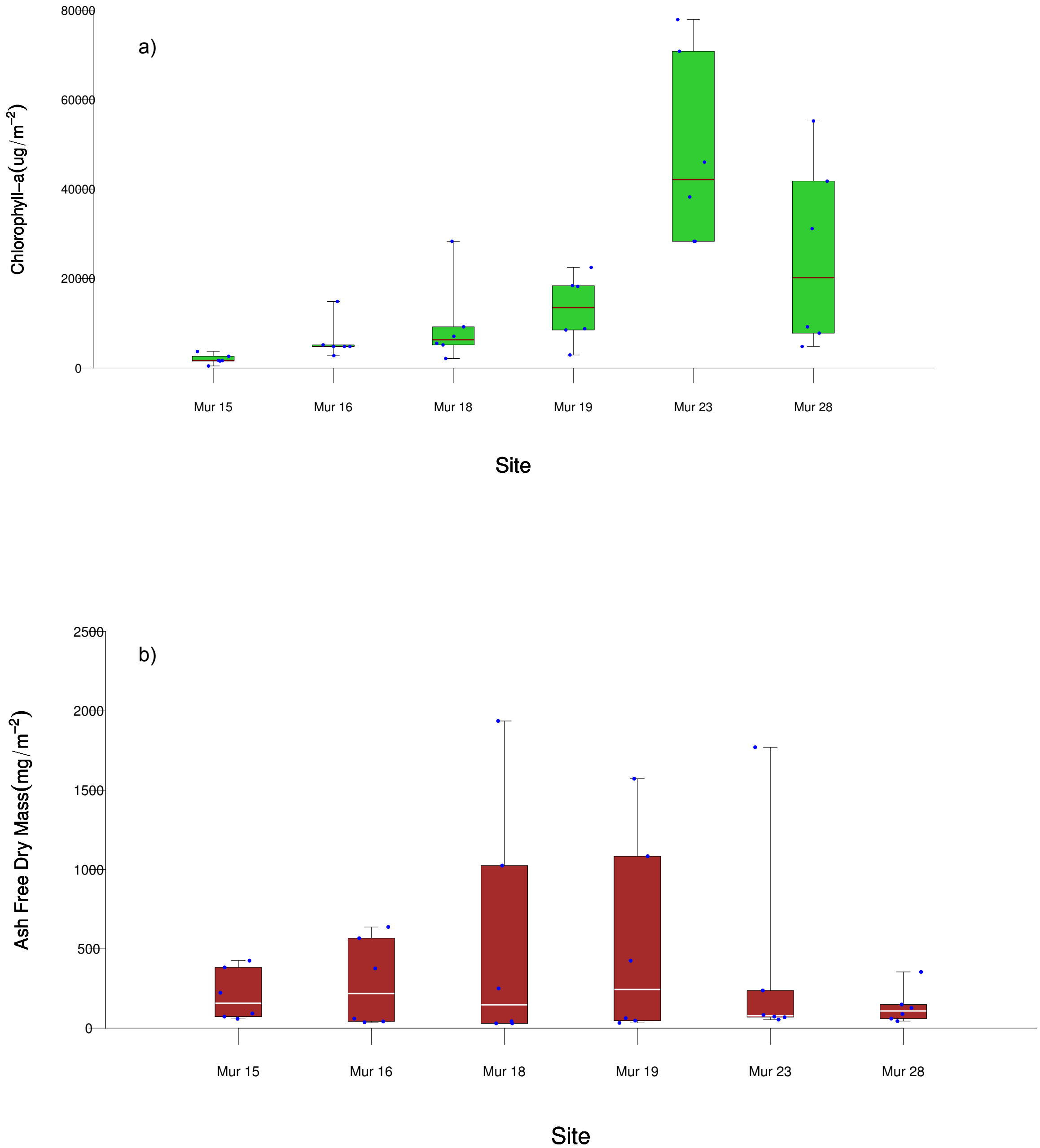

Figure 4. The distribution of a) Chlorophyll-*a*; and b) Ash Free Dry Mass (AFDM) upstream and downstream of Angle Crossing.

Strip chart values (in blue) represent the raw data values for each site. See **APPENDIX C** for an explanation of how to interpret box and whisker plots.

3.4 Macroinvertebrate communities

Macroinvertebrate communities collected in the riffles did not vary significantly between upstream and sites downstream of Angle Crossing (R=0.37; P=.10; Figures 5 & 6). Similarly, there were no significant differences in edge community structure at sites upstream and downstream of Angle Crossing (R= -0.29; P=0.90: Figure 7 and 8). Infact the negative R-value indicate that some samples taken downstream of Angle crossing were more similar to those communities upstream of the crossing (e.g. MUR 23 and 15 and MUR 23 and 18; Figure 8). Pair-wise comparisons between site-groups for upstream and downstream of Angle Crossing were not carried out because of the non-significant global R-values recorded for both habitats.

3.4.1 Riffles

Taxa richness was highest at MUR 23 (Point Hut Crossing) with 18 families and 26 genera, but genus and family richness was relatively even across all sites (taxa richness range: families: 15-18; genera: 18-26) (Figure 9),. The lowest number of families (14) recorded was at MUR 19 (downstream of Angle Crossing), which also recorded the lowest number of genera (18). These richness values were up to 30% lower than those recorded in autumn, though the even distribution across sites is almost identical to those seen in autumn (Ecowise, 2009).

All sites in this sampling program were dominated by the same five taxa: *Austrosimulium* sp. and *Simulium* sp. (Simuliidae; black flies); Chironominae spp. (Chironomidae: midges); Oligochaeta (worms) and Orthocladiinae (Chironomidae). These five taxa contributed up to 60% of the total sample. MUR 15 and MUR 16 differed slightly in that, *Oxyethira* sp. (Hydroptilidae: Trichoptera) also featured as a dominant taxa, while MUR 18 (upstream of Angle Crossing) featured a relatively high abundance of *Caenis* sp. (Caenidae: Ephemeroptera). These results are reflected in Figure 10, where all sites can be seen to be comprised of 65 – 87% tolerant taxa, while sensitive (EPT) taxa only accounted for 9-30% of the total abundance at the various monitoring sites. The latter figure represents a decline of approximately 70% since autumn across all sites. On average the upstream sites had a higher relative abundance of EPT taxa (mean=23.7%) compared to downstream (14.6%) and a slightly lower relative abundance of tolerant taxa [upstream: tolerant = 74.7%; downstream = 80.1%].

Despite having a higher abundance of *Diplectrona* sp. (Hydropsychidae; Trichoptera) than many of the upstream sites, MUR 19 recorded the lowest relative abundance score for EPT taxa of 9.7%, due to the very high abundances Chironomids, Simulids and Oligochaetes.

At 60% similarity, the NMDS solutions revealed 1 main group containing four of the sites, while the remaining two sites were distributed in the NMDS plot such that MUR 19 was grouped with replicate 1 from MUR 23, while replicate 2 from MUR 23 formed the final group. The main group included the same sites which formed the main group in autumn (Figure 6), with the addition of MUR 15 (i.e. MUR 15 became more similar to MUR 16, 18, 28 and 18).

The macroinvertebrate assemblages collected in spring showed more within-site variation than in autumn. Across all sites there was a decrease by 7-11 % group average similarity. In other words, similarities between replicates collected from the same sites decreased such that some replicates and subsamples were more similar to other sites than to replicates from the same site (Figure 6). This is most obvious at sites MUR 23, 28 and 19 – all downstream of Angle Crossing. These same sites were also the most variable in the autumn sampling program.

3.4.2 Edges

Family richness was highest at MUR 28 (22), while genus richness was highest at MUR 23 (32) (Figure 9). MUR 19 (downstream of Angle Crossing) recorded the least number of families (10).

Similar to observations made in relation to riffle-habitat above (section 3.4.1), edge samples were dominated by pollution-tolerant taxa with low to intermediate SIGNAL scores, such as Oligochaeta (SIGNAL = 2), Simulids (SIGNAL =5), two dominant sub-families of Chironomids: Orthocladiinae (SIGNAL = 4) and Chironominae, *Physa acuta* (Gastropoda: introduced snail) and *Micronecta sp* (Corixidae; SIGNAL = 2). These taxa all featured as the five most dominant across these sites, but in different orders of relative abundance. Sites MUR 23 and 28 (Point Hut Crossing and upstream of the Cotter confluence respectively) differed slight to the other sites in that they also had high abundances of *Micronecta sp*. (Corixidae) in their community assemblages. The edge habitat at MUR 28 had particularly high numbers of Corixidae.

Caddisflies (Trichoptera) were present in high numbers and relatively diverse upstream of Angle Crossing at sites MUR 15 and 16 (>150 individuals per site) but declined by an order of magnitude downstream of MUR 16 to MUR 23, where numbers increased, then declined sharply again at MUR 28. Mayflies (Ephemeroptera) were depauperate both numerically and in terms of diversity across all of the sites. Common taxa such as genera in the Baetidae and Leptophlebiidae families were missing at from >90% of the samples. At the sites where they were present (i.e. MUR 23 and 28) they were present with individual numbers ranging from 4 to 23. Mayflies in the family Caenidae (SIGNAL=4) were common, particularly the genus: *Tasmanocoenis spp.* which were present in all of the samples. However the number of individuals of this family were still low (<100 per site).

3.5 AUSRIVAS assessment

Taxa predicted to occur with ≥50% probability, but were absent from each habitat and site are presented in **APPENDIX E**.

AUSRIVAS results for spring 2009 indicate that there are no differences in the observed to expected ratios (which the AUSRIVAS BANDS are based on) between the sites upstream and downstream of Angle Crossing for both the riffle ($F_{1,30}$=0.122; P=0.75; Figure 11) and edge ($F_{1,30}$=0.008; P=0.93; Figure 12) habitats. SIGNAL-2 scores, which are in indication of the degree of pollution at given site showed that while riffles upstream had slightly higher SIGNAL scores on average (mean=5.13) compared to the downstream sites (mean=4.87), these differences were not statistically different ($F_{1,30}$=1.72; P=0.26; Figure 12). Similar results are also seen for the edge habitat: upstream (mean=3.98), downstream (mean =3.85) ($F_{1,30}$=0.11; P=0.79; Figure 12).

All of the sites were assessed as BAND B ("*significantly impaired*") for their final assessment (Table 7), which is consistent with observations made in relation to the autumn 2009 sampling event. Only one site (MUR 15) did not have a reliable assessment due to BAND A's and BAND C's resulting from the different samples taken from riffle habitat at this site. The edge habitat at MUR 15 was comprised of 50% BAND A subsamples and 50% BAND B subsamples indicating that in certain areas of this site at least, there were communities close to reference condition.

Unlike the samples in autumn, there were no clear patterns in terms of missing taxa that were predicted to occur (**APPENDIX E**). Overall there were four taxa that were absent from >90% of all riffle samples, these taxa were: Psephenidae (SIGNAL=6); Tanypodinae (SIGNAL=4); Glossosomatidae (SIGNAL=9) and Conoesucidae (SIGNAL=7). Other taxa that were absent in the majority of the samples included: Elmidae (SIGNAL=7) and Tipulidae (SIGNAL=5).,Gripopterygidae (SIGNAL =8) were absent from certain sub-samples at some sites). This is a shift from autumn, when they were only recorded at MUR 16 and in very limited numbers. Baetidae were completely missing from the samples taken from MUR 15.

The edge samples were less variable than the riffle samples in that taxa missing from a site were entirely absent rather than only missing from one or more subsamples. MUR 15 and 16 had the most missing but expected taxa (**APPENDIX D**) of the edge samples. Two important families of mayfly (Baetidae and Leptophlebiidae) were notably missing from MUR 15, while common, tolerant taxa such as Corixidae (SIGNAL=2) and Tanypodinae (SIGNAL=4) were absent from MUR 16, as well as the stick caddis (Leptoceridae: SIGNAL=6).

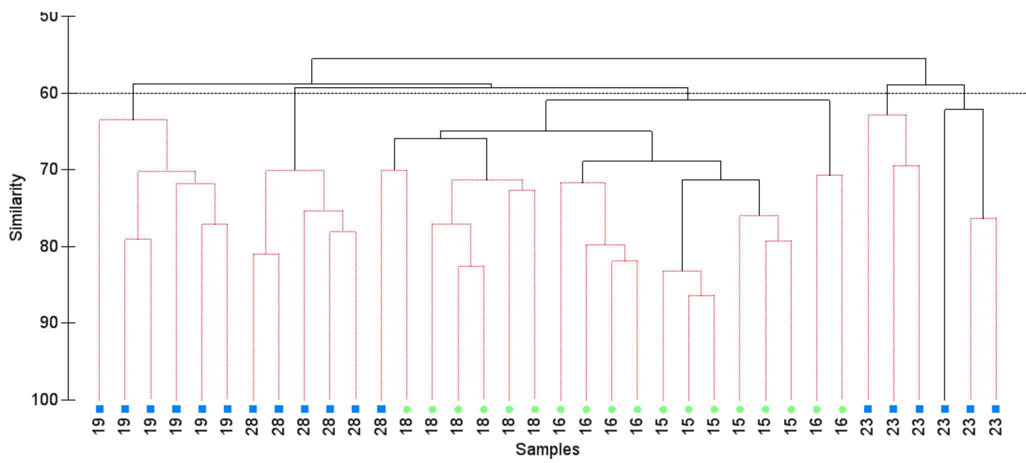

Figure 5. Cluster analysis based on genus level data for spring riffle samples.

Blue squares indicate sites downstream of Angle Crossing; green circles are upstream of Angle Crossing.

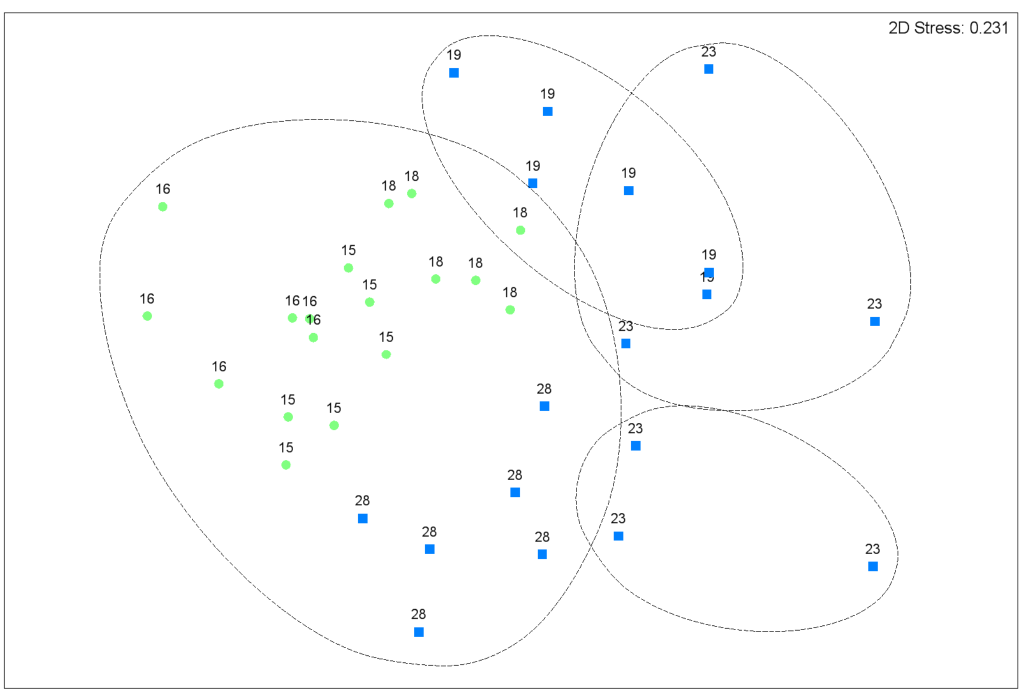

Figure 6. Non-metric multidimensional scaling of genus data from spring riffle samples.

Ellipses represent the 60% similarity groups superimposed from the cluster analysis (above)

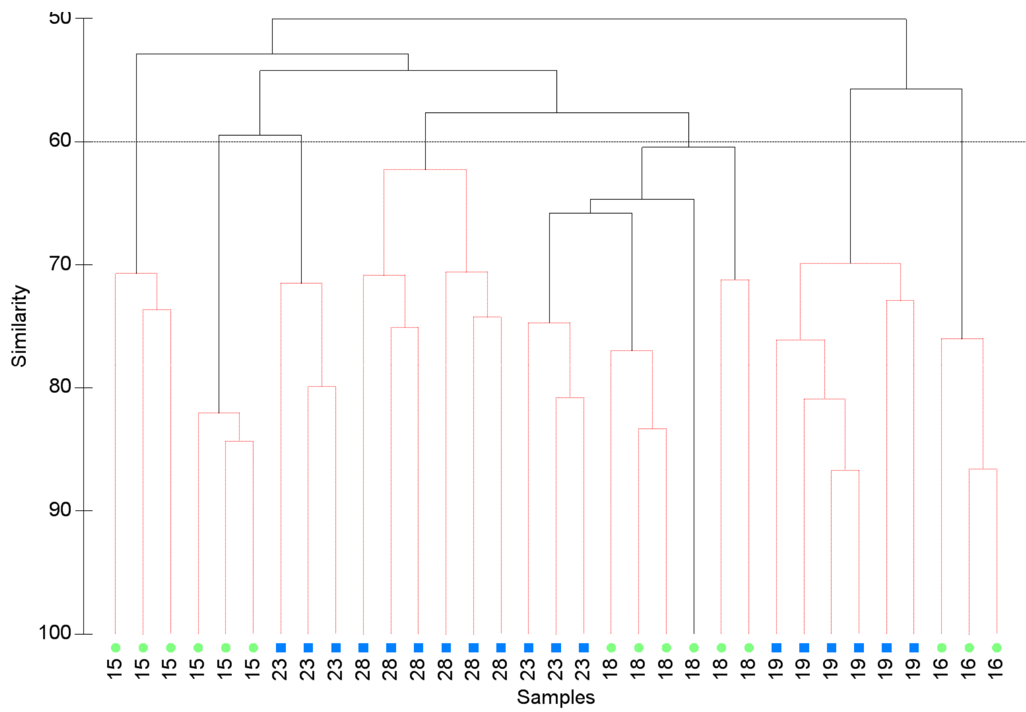

Figure 7. Cluster analysis based on genus level data for spring edge samples.

Blue squares indicate sites downstream of Angle Crossing; green circles are upstream of Angle Crossing.

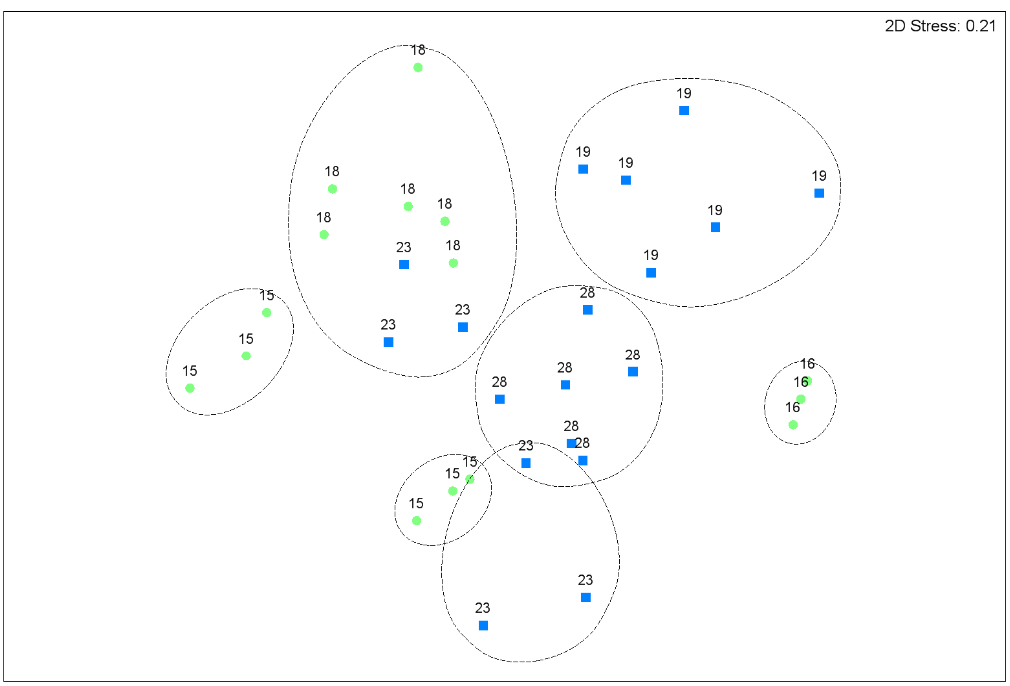

Figure 8. Non-metric multidimensional scaling of genus level data from spring edge samples.

Ellipses represent the 50% similarity groups superimposed from the cluster analysis (above)

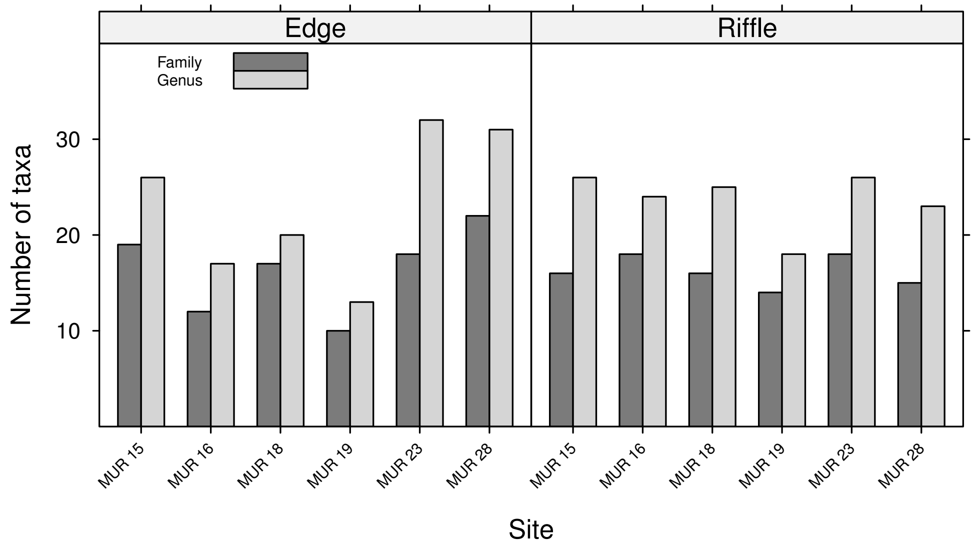

Figure 9. Total number of taxa at genus and family levels in the riffle and edge habitats.

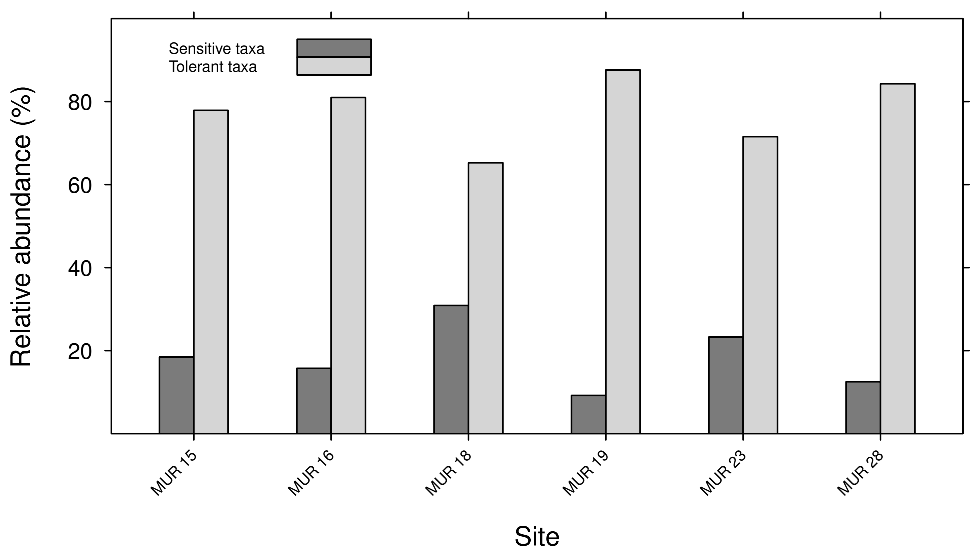

Figure 10. Average relative abundances of sensitive and tolerant taxa from sites upstream and downstream of Angle Crossing.

Table 7. AUSRIVAS and SIGNAL scores for spring 2009. *NRA = No Reliable Assessment.

SITE	Rep.	SIGNAL-2		AUSRIVAS O/E score		AUSRIVAS band		Overall habitat assessment		Overall site assessment
		Riffle	Edge	Riffle	Edge	Riffle	Edge	Riffle	Edge	
Mur 15	1	5	3.17	0.64	0.66	B	B	NRA	B	NRA
Mur 15	2	5.45	3.17	0.88	0.66	A	B			
Mur 15	3	5.22	3.29	0.72	0.78	B	B			
Mur 15	4	4.57	4	0.56	1	C	A			
Mur 15	5	4.57	3.88	0.56	0.89	C	A			
Mur 15	6	4.88	4.11	0.64	1	B	A			
Mur 16	1	4.7	4.83	0.77	0.66	B	B	B	B	B
Mur 16	2	5.13	4.86	0.62	0.78	B	B			
Mur 16	3	4.91	4.83	0.85	0.66	B	B			
Mur 16	4	5	-	0.85	-	B	-			
Mur 16	5	5	-	0.85	-	B	-			
Mur 16	6	5.31	-	1.01	-	A	-			
Mur 18	1	5.67	3.5	0.92	0.66	A	B	B	B	B
Mur 18	2	5.4	4.13	0.76	0.89	B	A			
Mur 18	3	5.54	4.11	0.99	1	A	A			
Mur 18	4	5.55	3.17	0.84	0.66	B	B			
Mur 18	5	5.27	4.11	0.84	1	B	A			
Mur 18	6	5.25	4.38	0.92	0.89	A	A			
Mur 19	1	5.22	3.33	0.69	0.66	B	B	B	B	B
Mur 19	2	4.78	3.33	0.69	0.66	B	B			
Mur 19	3	5.56	3.33	.69	0.66	B	B			
Mur 19	4	5.3	3.33	0.77	0.66	B	B			
Mur 19	5	4.63	3.33	0.61	0.66	B	B			
Mur 19	6	5	3.67	0.69	0.66	B	B			
Mur 23	1	5.2	4.56	0.88	1	A	A	B	B	B
Mur 23	2	4.91	3.57	0.97	0.78	A	B			
Mur 23	3	4.67	4.13	0.79	0.89	B	A			
Mur 23	4	4.91	3.63	0.97	0.89	A	A			
Mur 23	5	4.91	4.13	0.97	0.89	A	A			
Mur 23	6	4.67	4.14	0.79	0.78	B	B			
Mur 28	1	4.7	3.78	0.75	1	B	A	B	B	B
Mur 28	2	4.4	4.67	0.75	1	B	A			
Mur 28	3	4.67	4.56	0.67	1	B	A			
Mur 28	4	4.75	3.88	0.6	0.89	B	A			
Mur 28	5	4.38	4.13	0.6	0.89	B	A			
Mur 28	6	5.1	3.86	0.75	0.78	B	B			

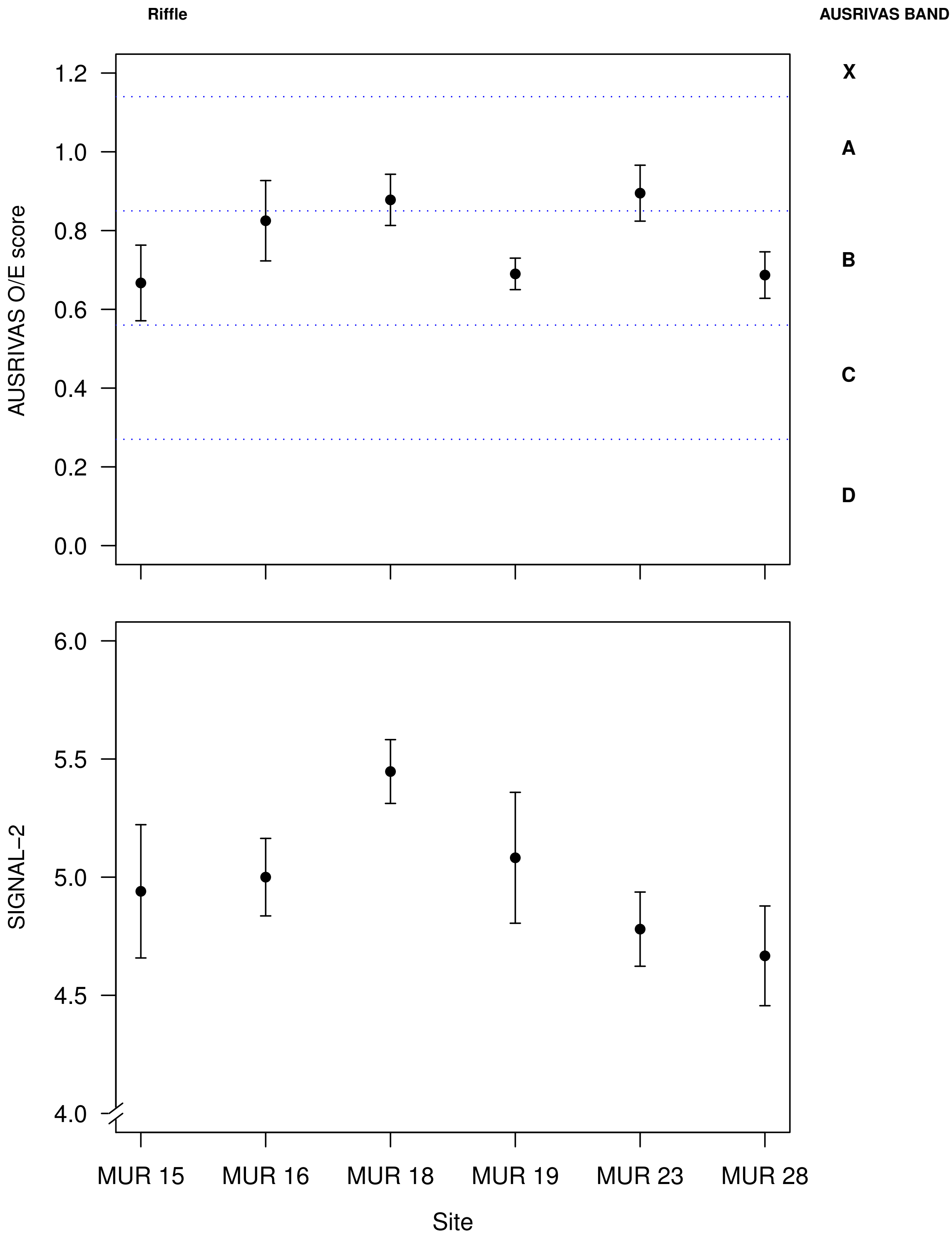

Figure 11. Average AUSRIVAS OE50 scores (top) and average SIGNAL-2 scores for RIFFLE samples upstream and downstream of Angle Crossing. Error bars are 95% confidence intervals.

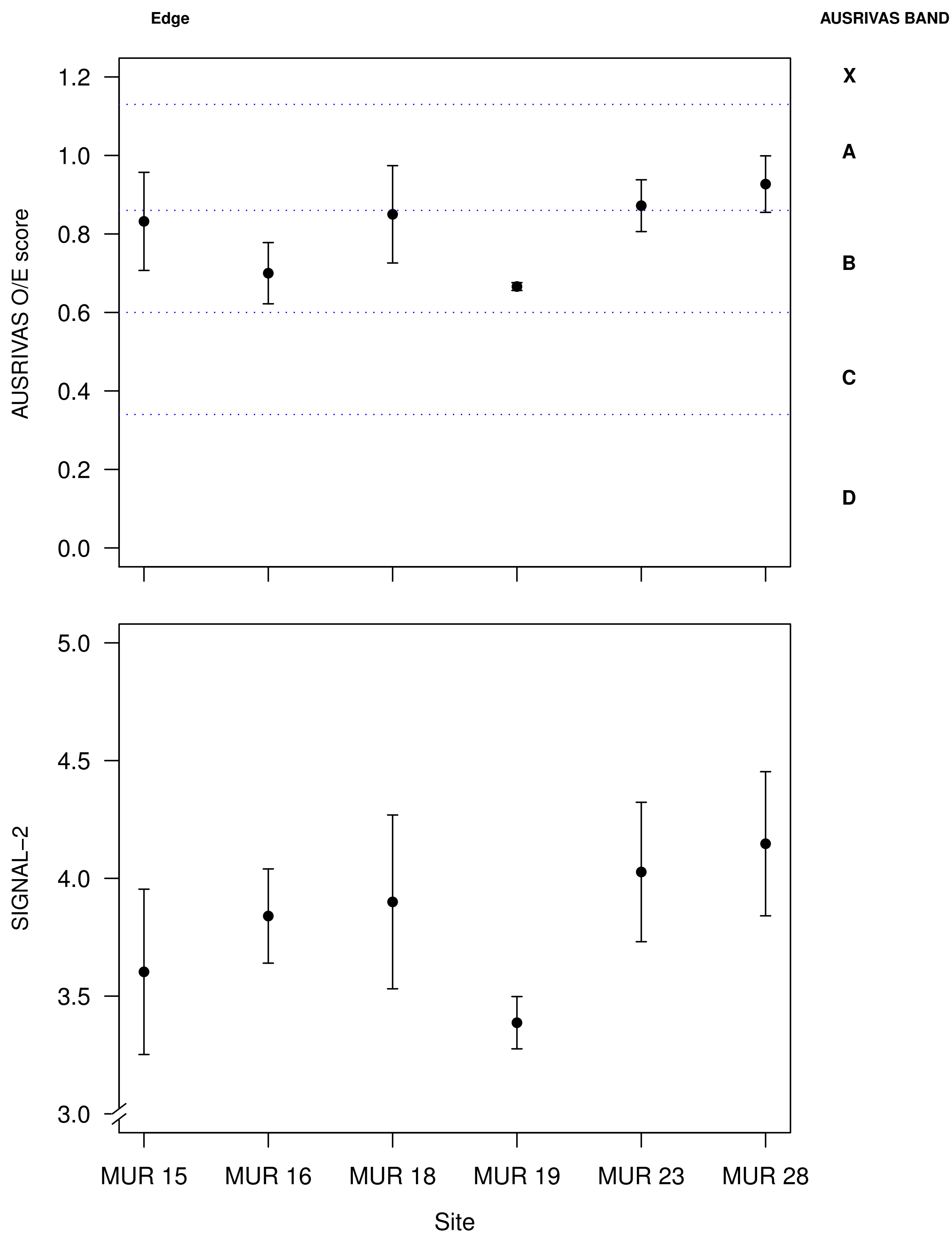

Figure 12. Average AUSRIVAS OE50scores (top) and SIGNAL-2 scores for EDGE samples upstream and downstream of Angle Crossing. Error bars are 95% confidence intervals.

4 Discussion

4.1 Water quality and periphyton

Steady rainfall in the catchment throughout spring is likely to have caused nutrient levels to inflate since autumn via surface runoff from the surrounding landscape. Increased nutrients (specifically nitrogen and phosphorus) can create problems to the health of river systems by increasing periphyton biomass (where nutrients are limiting) and cause proliferations of filamentous algae growth. This in turn can result in alterations in water quality (specifically declines in pH and can alter the diurnal patterns in dissolved oxygen), degrade the aesthetics of rivers and streams, cause operational difficulties (e.g. clogging intake valves) and can reduce the number of sensitive taxa in the macroinvertebrate communities (Suren *et al.*, 2003). However, as noted by Biggs and Close (1989) periphyton biomass can only respond to increased nutrient availability during periods of stable low flows.

During spring, flows fluctuated extensively (Figure 2) so despite the higher nutrient loads during this period in early November, it is unlikely that the AFDM and Chlorophyll-*a* data presented in this report (Figure 4 a & b) represent responses to nutrient levels, but instead are an indication of natural responses to these high flows. As previous mentioned, there was a lack of correlation between any of the water quality parameters and the AFDM and Chlorophyll-*a* data, which we believe to be due to a potential lag-effect owing to periphyton being a cumulative response to antecedent WQ conditions. In this study the instantaneous water samples were collected at the time periphyton biomass samples were collected, therefore, there might be more evidence of such correlations by comparing data against mean nutrient levels for the three months prior to periphyton sample collection.

Chlorophyll-*a* levels were elevated at MUR 23 which could have been because, prior to the high flows, the standing stock was very high such that chlorophyll-a concentrations remained relatively high despite some scour removal of periphyton.. Biggs and Close (1989), for example, found pre-flood levels of Chlorophyll-*a* to be more important than the event itself in determining post flood levels. The other explanation is that post flood recruitment was particularly rapid at this site. Diatoms for example have been shown to recover within 2 days of high flow disturbances Include in reference section (Grimm & Fisher, 1989). Rapid recovery may also have been stimulated by high nutrient levels associated with flows from Point Hut Pond tributary, which, due to the urban construction works in its surrounding catchment area are likely to contain a rich source of nutrients. Over topping from Point Hut Pond was common during spring (APPENDIX E).

The remaining water quality parameters represented responses to flow. Electrical conductivity for example decreased through much of September and October as a result of dilution associated with high flow conditions. The EC spike in early November reflected a higher input of solutes from surface run off, which declined as flows receded. Gradual increases in EC again at the onset of summer are most likely due to the reduced flow conditions, which in turn, concentrated existing salts in the system.

4.2 River health and patterns in macroinvertebrate communities

There was no statistical difference found between upstream and downstream locations in either habitat based on the ANOVA results for AUSRIVAS OE50, or SIGNAL -2 scores (Figure 11 and 12). The results from this sampling period also indicate that all sites upstream and downstream of Angle Crossing are in moderate ecological condition, with all sites being assessed as "*significantly impaired*" (AUSRIVAS - BAND B). These results are equivalent to the health rating for the same sites in autumn 2009. The riffle samples from all of the sites in this program were dominated by black fly larvae – Simuliidae (SIGNAL =5), non-biting midges –Chironomidae (SIGNAL =3) and segmented worms – Oligochaeta (SIGNAL =2) and lacked many of the more sensitive taxa predicted to be presented by the AUSRIVAS model. The edge samples were also dominated by these taxa with the addition of Corixidae (except MUR 16 where they were absent) and *Physa acuta* an introduced snail (SIGNAL=2).

Compared to autumn, these samples showed a sharp decline in the number of EPT taxa especially in the order Ephemeroptera (mayflies) which are usually abundant and diverse (Figure 9). For example, Leptophlebiidae and Baetidae were present at most of the sites sampled, but in much reduced numbers but there were also marked declines in the Trichopteran faunal richness (declines of 40-50%) and abundances (e.g. 100 fold decreases in Hydrobiosidae).

The decline in EPT taxa resulted in AUSRIVAS assessments of "*significantly impaired*" for each site, where up to 60% of all of the taxa missing but predicted by the AUSRIVAS model (APPENDIX D) came from the EPT suite of taxa.

Declines in EPT taxa have been attributed to pollution, poor water quality and degraded habitat conditions, include sedimentation (Griffith *et al.*, 2005). Reductions in EPT taxa have also been correlated to periphyton biomass. For example, Biggs (2000) found >50% reductions in EPT relative abundances where periphyton biomass exceeded 5 g AFDM or Chlorophyll-a was above 13mg/m^{-2}. The results from this study do support these findings to a degree, with sharp declines in EPT taxa correlating with increased algal biomass since autumn. However, this is largely circumstantial evidence and the cause/effect relationship cannot be established through bi-annual monitoring.

In this study, pollution does not appear to account for the sharp decline in EPT taxa given that there is no evidence in the key parameters from the water quality records to indicate this. The monitoring to date has indicated some potential enrichment downstream of Point Hut crossing in response to Point Hut Pond spills, which is supported by higher Chlorophyll-a and periphyton biomass as AFDM at this site (Figure 4a) and slighter elevated richness values (Figure 9), but the changes in water quality to date have reflected seasonal fluctuations punctuated by responses to drought and high flows rather than point source or non-point source pollution effects. Furthermore, the presence - albeit in low numbers - of some highly sensitive taxa (e.g. Glossosomatidae: SIGNAL =9; Gripopterygidae: SIGNAL =8 and Leptophlebiidae (SIGNAL = 8)) further points towards other factors influencing this seasons results.

The results of this study are consistent with the community structure observed elsewhere following high flow events (Molles JR., 1985; Wallace, 1990; Lake, 2000) such as the one which preceded spring sampling (Figure 2). Hydrological disturbances affect macroinvertebrates directly through dislodgment and indirectly through the habitat smothering and gill-clogging effects of increased sediment mobilisation (Resh *et al.*, 1988; Collier & Quinn, 2003). Such effects can result in lower diversity and reductions in relative abundances by as much as 99% compared to pre-event conditions (Fritz & Dodds, 2004).

Data from this study supports the hypothesis that the high flow event was the major contributor to the status of the macroinvertebrate community in spring. Oligochaetes, which are sediment dwellers, and are therefore less likely to be affected by high flows, were found in high number at all sites in Spring. On the other hand, free- living taxa such as mayflies, which are more prone to dislodgement, were poorly represented in the samples collected. These results are consistent with Molles Jr. (1985) who found very similar assemblage patterns following a flash flood. Black fly larvae (Simulids) and Chironomids are opportunistic colonists following disturbances and the very high numbers of these taxa collected in these samples indicate early stages of recolonisation. Being filter feeders, Simulids require clean substrata (Harrod, 1964). Hence their relatively high abundance in Spring 2009 might indicate that the high flow event flushed some of the fine sediments that built up during periods of low flow at some of the sites (namely MUR 15, 16, 23 and 28; Phil Taylor, Ecowise Environmental, *pers. obs.*). Notably, pollution-tolerant taxa: Dytiscidae (diving beetles: SIGNAL =2) and Decapoda (shrimps: SIGNAL =4) were absent from MUR 19. Both taxa have preferences for slow flowing water.

Downstream of Angle Crossing at MUR 19, there was a noticeable decline in the number of taxa in both habitats (Figure 9). There was some evidence of lower AUSRIVAS O/E 50 and SIGNAL -2 scores downstream of Angle Crossing, but this was most pronounced for edge habitat (Figure 12). MUR 19 was particularly poorly represented by mayflies: the only members of which that were collected belong to *Baetis spp.* (Baetidae: SIGNAL=5) and *Tasmanocoenis spp.* (Caenidae: SIGNAL=4). Both genera are relatively tolerant to pollution and *Tasmanocoenis spp.* is one of the more tolerant mayflies to silt (Gooderham & Tsyrlin, 2005).

The lack of both sensitive taxa and the pollution tolerant taxa in the pool/edge at MUR 19 indicates that the combination of high flows, increased suspended sediments (inferred from the turbidity records) and runoff from the unsealed roads flanking the low level crossing at Angle Crossing (see cover photograph and Figure 2) have probably caused the shift in community structure at these sites, with the water shear stress removing taxa typically found in slow water taxa and sensitive taxa being removed or relocating themselves via drift in response to increased sediments both through re-suspension and from overland runoff from the adjacent unsealed roads. This is consistent with Hogg and Norris (1991) who found storm runoff significantly decreased invertebrate diversity and abundance downstream of Tuggeranong Creek following a storm event. Moreover, the absence of usually common taxa, sensitive taxa and taxa with preferences for slow moving water, while most pronounced at MUR 19, applied to some extent at all of the sites under investigation. Corixidae and Dytiscidae were poorly represented at all of the sites, the latter was commonly absent from samples, while Corixidae (Water boatmen: SIGNAL =2) were absent from many of the samples and completely absent from site 16.

Following high flow disturbances, recovery to pre-event conditions is usually rapid (Niemi *et al.*, 1990; Wallace, 1990; Hogg & Norris, 1991; Radar *et al.*, 2008); and considering that the spring 2008 samples suggested that many of these sites were close to reference condition, it is likely that there will be similar patterns of recovery, notwithstanding other hydrological disturbances occurring.

5 Conclusions

There was no change in the river health assessment at any of the sites since autumn. All sites were determined to be "*significantly impaired"* – BAND-B by the AUSRIVAS model. These results reflect the fact that all sites were dominated by Oligochaetes (worms), Simuliidae (blackfly larvae) and Chironomids (non-biting midges). The make up of these community assemblages are consistent with communities that have recently been impacted by a high flow event, as is the case in this study.

Nutrient levels exceeded ANZECC & ARMCANZ (2000) water quality guidelines at all sites, and were up to 6 times the levels recorded in autumn. This is due to increasing surface runoff from regular rainfall throughout the season. The water quality trends for spring are consistent with temporal changes induced by changes in ambient temperatures and high flows for the sampling period. Electrical conductivity for example was below the recommended minimum values at 5 of the 6 sites, which is likely to be a dilution effect associated with increased surface flows and a lower groundwater contribution.

In this monitoring program to date, the effects of drought (autumn) and high flows (spring) have probably masked any site-specific impacts because of their widespread impacts on the ecosystem. The impaired health rating given to all sites in this study resulted from a combination of the loss of many of the sensitive EPT taxa being missing from most, if not all of the samples at a given site and an increase in the abundance of pollution and high-flow tolerant taxa such as Oligochaetes and Chironomidae. Despite the important influence of the high flow event on the current site assessments, there are indications that outside of this natural impact, the sites under assessment are in relatively good condition given that each site contained some very sensitive Mayflies and Caddisflies. Furthermore, the second round of sampling in spring 2008 was restricted to sites only in the ACT. Of those sites, MUR 19, 23 and 28 were all given BAND-A, "*close to reference assessments*". Assuming drought effects do not take hold over the summer period, recovery at many of these sites should occur rapidly in the absence of further hydrological disturbance events occurring.

6 Recommendations

A condition stated in the Angle Crossing monitoring proposal (section 5.1.5) is that the program is to be adaptive and that the methods, sites, and analysis in previous runs be reviewed so the objectives of ACTEW are being met satisfactorily.

This is the second round of sampling where the impacts of naturally occurring disturbances (i.e. autumn: drought; this report: seasonal high flow event) have probably masked any site specific anthropological impacts. In light of this, the recommendations from the autumn report (which follow) stand.

1. The high within-site variation found in this round of sampling suggests that a single replicate might not be adequate to describe the sites in this assessment. This is consistent with the findings of (Nichols et al., 2006) who recommended taking replicate samples at impaired sites for biological assessments. Taxonomic diversity and abundances differed considerably between replicates and subsamples, which resulted in considerable variability in the AUSRIVAS bioassessment of a given site. It is recommended that this level of replication be maintained.
2. Continuous water quality monitoring is restricted to Lobb's Hole (410761) which misses the potential impacts of water entering the Murrumbidgee River at Point Hut Crossing from Point Hut Pond and potential impacts upstream during storm events. Grab samples taken during storm events should help explain the distinctly different composition of macroinvertebrates at this site. Additional nutrient sampling in the lead up to the next round of sampling is also recommenced, this would enable the assessment of any nutrient-biota interactions in a way that captures any lag effect as mentioned in Sections 3.3 and 4.1.

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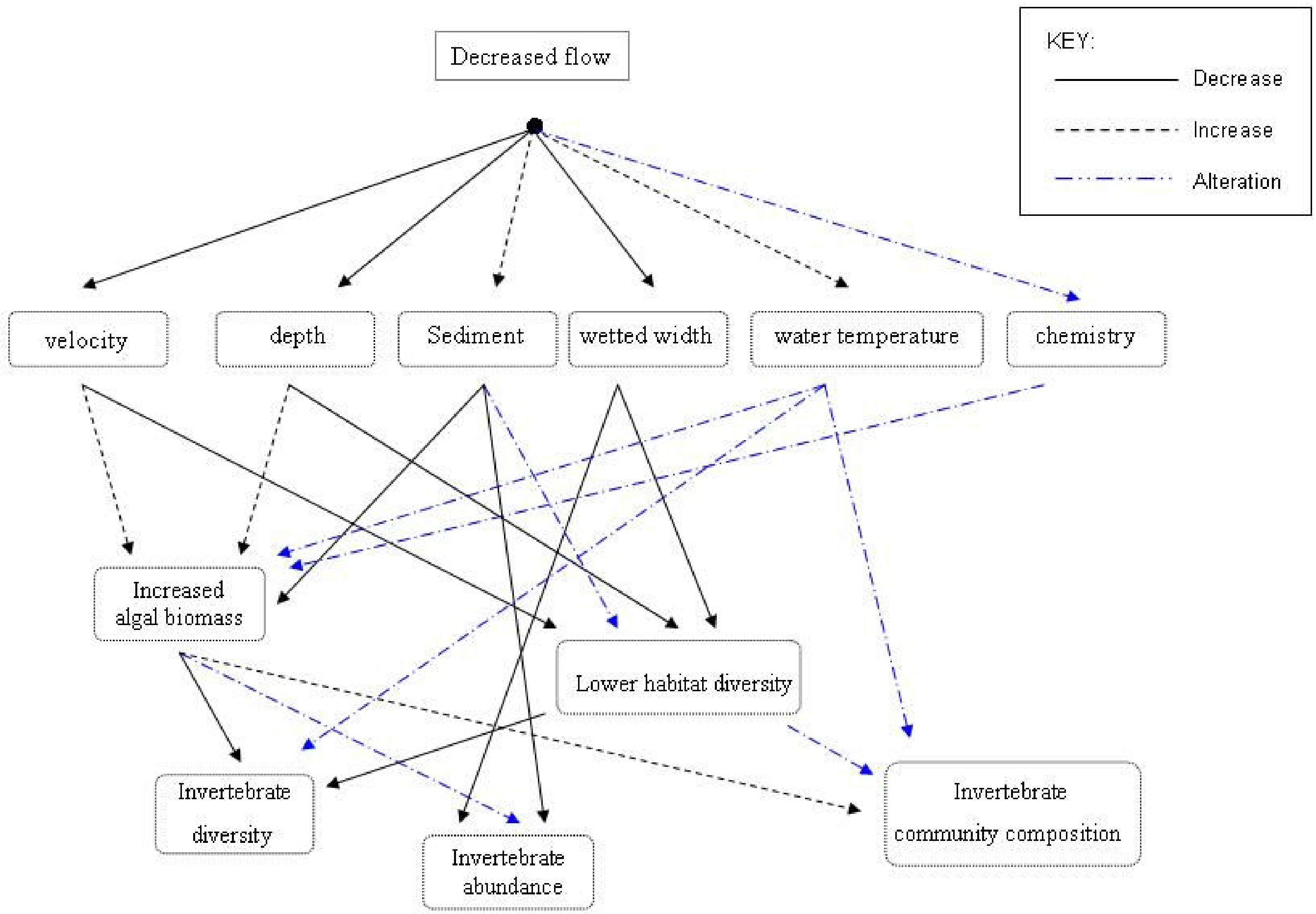
Appendix A –

Potential effects of reduced flow and their knock-on effects on habitat conditions and macroinvertebrate communities



Summary of the effects of reduced flows on various habitat conditions and macroinvertebrate communities from recent literature (Dewson et al. 2007)*.

*Reproduced with permission from the authors.

Appendix B –

MUR WQ 09 (Upstream Angle Crossing) gauging station installation

APPENDIX B. MUR WQ 09 (Upstream Angle Crossing) gauging station installation and location

a) Inspection pit and galvanised pipe housing at MURWQ09

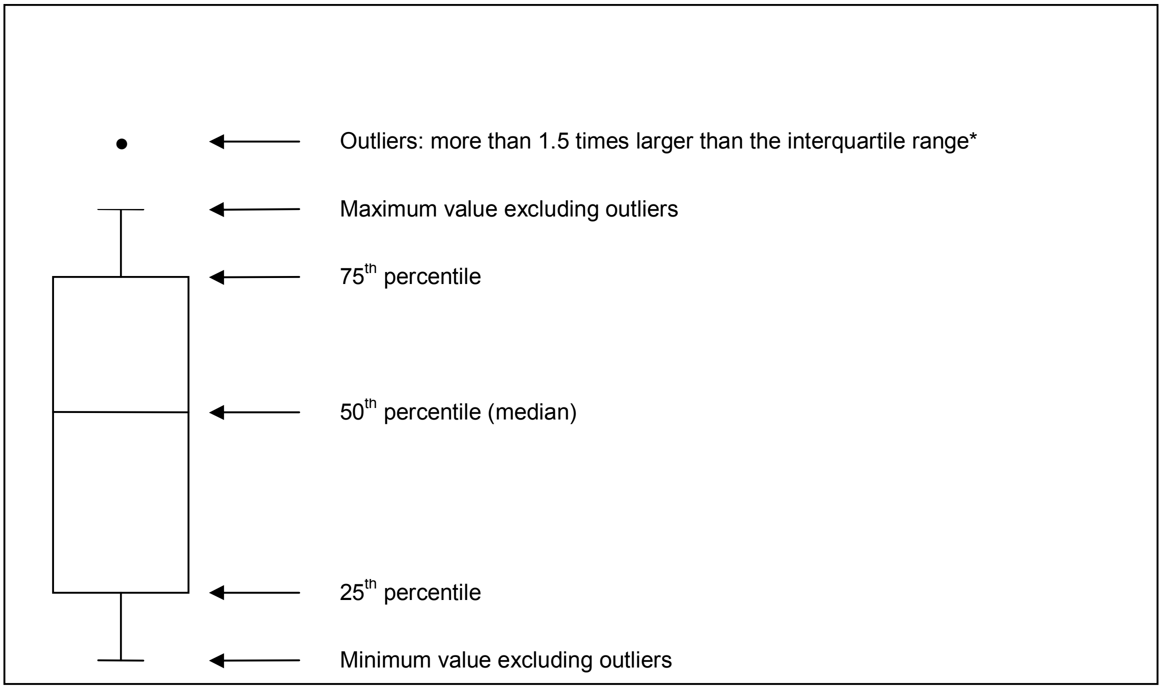
b) Complete station

c) Gauging station MURWQ09 upstream of Angle Crossing

Appendix C –
Interpreting box and whisker plots

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 red 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 – ANOSIM output for riffle and edge samples

ANOSIM

Analysis of Similarities

Two-Way Nested Analysis

RIFFLE

TESTS FOR DIFFERENCES BETWEEN # ***site*** *GROUPS*
(across all # location groups)
Global Test
Sample statistic (Global R): 0.737
Significance level of sample statistic: 0.1%
Number of permutations: 999 (Random sample from a large number)
Number of permuted statistics greater than or equal to Global R: 0

TESTS FOR DIFFERENCES BETWEEN # ***location*** *GROUPS*
(using # site groups as samples)
Global Test
Sample statistic (Global R): 0.37
Significance level of sample statistic: 10%
Number of permutations: 10 (All possible permutations)
Number of permuted statistics greater than or equal to Global R: 1

EDGE

TESTS FOR DIFFERENCES BETWEEN # site GROUPS
(across all # location groups)
Global Test
Sample statistic (Global R): 0.86
Significance level of sample statistic: 0.1%
Number of permutations: 999 (Random sample from a large number)
Number of permuted statistics greater than or equal to Global R: 0

TESTS FOR DIFFERENCES BETWEEN # location GROUPS
(using # site groups as samples)
Global Test
Sample statistic (Global R): -0.296
Significance level of sample statistic: 90%
Number of permutations: 10 (All possible permutations)
Number of permuted statistics greater than or equal to Global R: 9

Appendix E –

Taxa predicted to occur with >50% probability but were not collected in the spring samples

APPENDIX D. Taxa expected, but not collected in the riffle habitat.

Site	Taxa	Acarina	Elmidae	Psephenidae	Tipulidae	Ceratopogonidae	Tanypodinae	Chironominae	Baetidae	Leptophlebiidae	Gripopterygidae	Hydrobiosidae	Glossosomatidae	Hydropsychidae	Conoesucidae	Total number of missing taxa
	SIGNAL	6	7	6	5	4	4	3	5	8	8	8	9	6	7	
Mur 15	Riffle		×	×	×		×		×			×	×	×	×	9
Mur 15			×	×			×		×			×			×	6
Mur 15				×	×		×		×			×	×	×	×	8
Mur 15	Riffle		×	×	×		×		×	×		×	×	×	×	10
Mur 15			×	×	×		×		×	×		×	×	×	×	10
Mur 15				×	×		×		×	×		×	×	×	×	9
Mur 16	Riffle		×	×	×		×				×	×	×		×	8
Mur 16			×	×	×	×	×		×		×	×		×	×	10
Mur 16			×	×		×						×	×	×	×	7
Mur 16	Riffle		×	×	×		×					×	×		×	7
Mur 16			×	×			×				×	×		×	×	7
Mur 16			×	×			×					×			×	6
Mur 18	Riffle		×	×	×		×								×	5
Mur 18			×	×	×		×		×				×		×	7
Mur 18			×	×	×										×	4
Mur 18	Riffle			×	×		×		×				×		×	6
Mur 18				×	×		×					×	×		×	6
Mur 18				×			×					×	×		×	5
Mur 19	Riffle	×		×	×		×		×			×	×		×	8
Mur 19			×	×	×		×				×	×	×		×	8
Mur 19				×	×		×	×	×			×	×		×	8
Mur 19	Riffle			×	×		×		×			×	×		×	7
Mur 19		×	×	×	×		×			×	×		×		×	9
Mur 19				×	×		×		×	×		×	×		×	8
Mur 23	Riffle	×				×	×		×				×			5
Mur 23					×		×				×		×			4
Mur 23			×		×		×		×		×		×			6
Mur 23	Riffle				×		×				×		×			4
Mur 23					×		×				×		×			4
Mur 23			×		×		×		×		×		×			6
Mur 28	Riffle			×			×			×	×	×	×		×	7
Mur 28			×	×						×	×	×	×		×	7
Mur 28		×	×	×			×				×	×	×		×	8
Mur 28	Riffle		×	×	×		×		×		×	×	×		×	9
Mur 28			×	×	×		×			×	×	×	×		×	9
Mur 28			×	×	×		×					×	×		×	7

APPENDIX D (cntd.). Taxa expected, but not collected in the edge habitat spring 2009.

Site	Taxa	Ceratopogonidae	Tanypodinae	Baetidae	Leptophlebiidae	Caenidae	Corixidae	Gripopterygidae	Leptoceridae	Total number of missing taxa
	SIGNAL	4	4	5	8	4	2	8	6	
MUR 15	Edge			×	×	×		×	×	5
MUR 15	Edge	×		×	×			×	×	5
MUR 15	Edge			×	×			×	×	4
MUR 15	Edge			×	×				×	2
MUR 15	Edge			×	×				×	3
MUR 15	Edge			×	×					2
MUR 16	Edge		×	×		×	×		×	5
MUR 16	Edge	×	×				×		×	4
MUR 16	Edge	×	×	×			×		×	5
MUR 18	Edge	×	×	×				×		4
MUR 18	Edge		×	×				×		3
MUR 18	Edge			×				×		2
MUR 18	Edge			×		×		×	×	4
MUR 18	Edge			×				×		2
MUR 18	Edge		×	×					×	3
MUR 19	Edge	×	×					×	×	4
MUR 19	Edge	×	×					×	×	4
MUR 19	Edge	×	×					×	×	4
MUR 19	Edge	×	×					×	×	4
MUR 19	Edge	×	×					×	×	4
MUR 19	Edge	×	×			×		×		4
MUR 23	Edge	×		×						2
MUR 23	Edge		×	×				×		3
MUR 23	Edge		×	×						2
MUR 23	Edge			×				×		2
MUR 23	Edge	×		×						2
MUR 23	Edge	×	×	×						3
MUR 28	Edge							×		1
MUR 28	Edge	×	×							2
MUR 28	Edge		×	×						2
MUR 28	Edge			×				×	×	3
MUR 28	Edge		×	×				×		3
MUR 28	Edge	×		×					×	3

Appendix F–

Point Hut Pond Hydrograph: spring 2009

Appendix E. Hydrograph of point hut pond and Lobb's Hole for spring 2009. Arrows indicate spill events.