ACTEW Corporation

Murrumbidgee Ecological Monitoring Program

Tantangara to Burrinjuck

Spring 2008

Brisbane - Canberra - Melbourne - Sydney - Regional offices

CERTIFICATE OF APPROVAL FOR ISSUE OF DOCUMENTS

Report Title: Tantangara to Burrinjuck spring 2008

Document No: CN211063/2008/001

Project Title: Murrumbidgee Ecological Monitoring Program

Document Status: Final

Date of Issue: 3/12/2009

Client: ACTEW CORPORATION

	Position	**Name**	**Signature**	**Date**
Prepared by:	Environmental Project Officer	Phil Taylor		2/12/2009
Internal Review by:	Manager Qld. consulting	Garry Bennison		30/11/2009
Peer Review by:	Aquatic Ecologist	Dr. Peter Hancock		30/11/2009
Approved by:	Manager ACT consulting	Norm Mueller		3/12/2009

For further information on this report, contact:

Name: Phil Taylor
Title: Environmental Project Officer
Address: 16a Lithgow Street, Fyshwick, ACT 2609

Phone: 02 6270 7926

Mobile: 040 6375 290

E-mail: p.taylor@ecowise.com.au

Document Revision Control

Version	**Description of Revision**	**Person Making Issue**	**Date**	**Approval**
1				

Ecowise Australia Pty Ltd ABN 94 105 060 320

Table of Contents

List of Figures

List of Tables

Appendices

List of abbreviations

ACT – Australian Capital Territory
ACTEW – ACTEW Corporation Limited
ANOSIM – Analysis of Similarities (statistics)
ANOVA – Analysis of Variance (statistics)
AUSRIVAS – Australian River Assessment System
CMA – Catchment Management Authority
CRCFE – Cooperative Research Centre for Freshwater Ecology
DNR – Department of Natural Resources (NSW)
DPI – Department of Primary Industries (NSW)
EIS – Environmental Impact Statement
EPA – Environmental Protection Authority
GL/a – Gigalitres per annum
GPS – Global Positioning System
LWD – Large Woody Debris
M2G – Murrumbidgee to Googong
ML/d – Megalitres per day
NATA – National Association of Testing Authorities
NMDS – Non-metric Multidimensional Scaling (statistics)
PCA – Principal Components Analysis
PC – Principal Component
QA – Quality Assurance
QC – Quality Control
SIMPER – Similarity Percentage (statistics)
SRA – Sustainable Rivers Audit
TN – Total Nitrogen
WAE – Water Allocation Entitlement

Executive summary

The major water security program introduced by ACTEW Corporation in 2007 is in the process of upgrading and installing infrastructure in order to secure water for the Australian Capital Territory in light of continuing drought in the region. Included in the new water security projects is the proposed "Tantangara transfer" which will involve transferring water from the Tantangara Reservoir in the upper Murrumbidgee catchment to the ACT via the Murrumbidgee River with aim of providing a source of water that is less dependent on rainfall within the ACT.

The Murrumbidgee (River) Ecological Monitoring Programme (MEMP) is designed to address ecological concerns brought up by both Government and non-Government stakeholders; and provides ACTEW with relevant information and data regarding beneficial and/or detrimental ecological effects of this project. The aims of this monitoring program have been established to monitor the condition of the Murrumbidgee River water quality and river health at key sites both upstream and downstream of the abstraction point, before and after the proposed abstractions are implemented.

The key aims of this sampling run were to:

1. Establish baseline macroinvertebrate data for key sites along the Murrumbidgee River and in doing so establishing a data base of the existing condition prior to any releases from Tantangara reservoir;

2. Commence in-situ water quality sampling – including nutrient analysis as a baseline for future condition assessment;

3. Provide ACTEW with AUSRIVAS assessments of riffle and edge habitats at sites within the ACT.

This report presents the results from the macroinvertebrate sampling run carried out in spring 2008. During spring 2008 Ecowise conducted biological sampling from downstream of Tantangara Dam to approximately 2km upstream of the Burrinjuck Dam delta. HESS sampling was conducted at each site in triplicate to collect quantitative biological "signatures" of each site. These data were complimented with AUSRIVAS assessments of riffle and edge habitats.

The key outcomes of the spring 2008 MEMP include:

1. Significant differences in macroinvertebrate communities among zones were evident, most notably the separation of sites upstream of Cooma – showing a decline of sensitive taxa. This is thought to be in response to changing landuse;

2. Strong gradients in water quality – particularly EC, alkalinity and nutrient levels;

3. Most sites within the ACT are close to reference condition; deviations from this condition are thought to be due mainly to habitat quality (and perhaps interactions with the current drought conditions) and landuse rather than water quality;

4. The level of replication appears to be adequate to describe communities at these sites. Some within-site variation suggests that a single replicate is not representative of a given site;

5. The inability to run the NSW AUSRIVAS model indicates that this model is not suitable for these sites. It is recommended that all sites be assessed in future runs with the ACT protocols and appropriate model.

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 is 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 4: Tantangara to Burrinjuck.

The major water security program introduced by ACTEW Corporation in 2007 is in the process of upgrading and installing infrastructure to secure water for the Australian Capital Territory (ACT). This is in light of current drought impact and possible long term water yield reduction in the region. Included in the new water security projects is the "Tantangara transfer" which will involve releasing water from the Tantangara Reservoir into the upper Murrumbidgee River which will then flow by run of river to the ACT.

To use water from the Tantangara Reservoir, ACTEW is committed to the proposed construction of a river offtake, from Angle Crossing (southern border of the ACT). The proposed system will pump water from Angle Crossing through an underground pipeline to discharge into Burra Creek, and then transfer the water by run of river flow into the Googong Reservoir. The system is being designed to enable pumping of up to 100 ML/d, and to be in operation around 2011. Abstraction will be dictated by demand for water, and the availability of water in the Murrumbidgee River. The proposal is referred to as the Murrumbidgee to Googong project (M2G). A schematic overview of the proposed operations is given in **Appendix A**.

Water abstractions will be regulated through the *ACT Environmental Flow Guidelines, 2006.* ACT and NSW Government agencies, and recreational and rural users in the regional Murrumbidgee River reach (both upstream and downstream of Angle Crossing), are key stakeholders in the M2G project.

The Murrumbidgee River Ecological Monitoring Programme (MEMP) is designed to address concerns raised by both Government and non-Government stakeholders; and provide ACTEW with relevant information and data regarding any beneficial and/or detrimental ecological effects of the project. The project is to be implemented prior to the commencement of the M2G project, allowing ACTEW to collect pre and post abstraction data.

1.1 Objectives

The overall objective of the MEMP is to monitor physical, biological and water quality indicators along the length of the upper Murrumbidgee River from Tantangara to Burrinjuck reservoirs (details are given in Ecowise, 2009). The intention of this first season of sampling is to establish baseline macroinvertebrate data for key sites along the Murrumbidgee River and in doing so establishing a data base of the existing condition prior to any releases from Tantangara Reservoir. This will also include the commencement of *in-situ* water quality sampling – including nutrient analysis as a baseline for future condition assessment and finally provide ACTEW with AUSRIVAS assessments of riffle and edge habitats at sites within the ACT.

With these procedures in place, Ecowise will be able to provide ACTEW and the Environmental Protection Authority (EPA) with appropriate information to further develop knowledge and understanding of environmental flows and ecosystem thresholds. The information derived from this program will also support ACTEW's and the ACT EPA adaptive management approach to water abstraction and environmental flow provision in the ACT. Frequent assessments of the program will ensure that the monitoring program put in place has the capacity to adapt to changing environmental, social and economic conditions, with regard to ACTEW's operations and requirements.

1.2 Scope of works

The scope of this report is to convey the results from the Spring 2008 Round 1 and Round 2 sampling events. Specifically, as outlined in the MEMP proposal to ACTEW Corporation (Ecowise, 2009) this work includes:

Round 1

- Sampling to commence in spring 2008
- Macroinvertebrate sampling in triplicate in both riffle and edge habitats;
- Riffle samples to be collected quantitatively using a HESS sampler;
- Edge samples to be collected as per the NSW AUSRIVAS protocols;
- Macroinvertebrates to be identified and counted to the taxonomic level of genus;
- Edge samples to be assessed through the appropriate AUSRIVAS model;
- In-situ water quality measurements to be collected and analysed;
- Nutrient samples to be analysed in Ecowise's NATA accredited laboratory.

Following further consultation with Ecowise, ACTEW requested a second round of sampling to include:

Round 2

- Re-sampling ALL ACT sites only;
- Samples to be collected in the riffle and edge habitats in strict accordance with the ACT AUSRIVAS protocols;
- ACT riffle and edge AUSRIVAS bands to be provided.

2 Materials and method

2.1 Study sites

As stated in the objectives of the program, macroinvertebrate community composition and water quality will be monitored from Tantangara Reservoir to upstream of Burrinjuck Reservoir along the Murrumbidgee River, with the aim of obtaining baseline ecological condition information following the ANZECC guidelines for ecological monitoring (ANZECC & ARMCANZ, 2000).

The upper Murrumbidgee River catchment includes various land-uses, so it was important to select a sufficient number of sites for the program to provide a reasonable snap-shot of macroinvertebrate community structure in both riffle and edge habitats. Sites were chosen based on several criteria which included:

1. Accessibility – based on available roads or tracks, safety, and approvals from land owners;

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

3. 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 reference condition and comparisons between sites and among sites that are monitored with similar characteristics in the ACT and surrounds can be used for comparison.

Potential sites were identified from topographic maps, then visited prior to sampling to assess suitability. In total, 21 sites suited the criteria mentioned above. These sites include ten sites upstream of Angle Crossing (in NSW) and eleven sites downstream (8 in the ACT + 3 NSW). The sites include locations upstream and downstream of the major abstraction site at Angle Crossing, locations upstream and downstream of the Lower Molonglo Water Quality Control Centre (LMWQCC), and several of the Murrumbidgee River's major tributaries. Site details are provided in Table 1.

The sites were divided into four macro-reaches (zones) which represent geographic or hydrological changes (Allan and Castillo, 2008) throughout the system; and obvious changes in landuse, erosional processes and/or other potential anthropogenic impacts. These classifications are to some extent subjective, but are based on previous frameworks which have suggested methods for such classifications (e.g. Allan and Castillo, 2008; Frissell *et al.*, 1986). The zones are listed in Table 2.

2.2 Sampling details

Sampling occurred in spring 2008. All sampling was carried out by ACT AUSRIVAS accredited staff. The conditions during the period were predominantly dry and overcast with occasional showers. The second round of sampling occurred following consultation with ACTEW after the completion of Round 1 at which point Ecowise was requested to provide ACTEW with ACT AUSRIVAS assessments for the riffle and edge habitats within the ACT only. Sampling for Round 2 began ten days after the first round. Small rainfall events in between sampling resulted in the river levels being slightly higher than they were for the first round of sampling. Despite this, conditions were generally similar for both events.

Table 1. Sampling site location and details.

Site Code	Location	Alt. (m)	Dominant Landuse	Habitat sampled
MUR 1	D/S Tantangara Reservoir	1150	Native	Edge
MUR 2	Yaouk Bridge	1070	Grazing	Riffle and Edge
MUR 3	Camp ground of Bobyon Road	968	Recreation/ Grazing	Riffle and Edge
MUR 4	Bobeyan Road Bridge	968	Grazing	Riffle and Edge
MUR 6	D/S STP Pilot Creek Road	743	Native Residential	Edge
MUR 9	Murrells Crossing	723	Grazing	Edge
MUR 12	Through Bredbo township	698	Grazing / Residential / Recreation	Riffle and Edge
MUR 15	Near Colinton - Bumbalong Road	658	Grazing / Recreation	Riffle and Edge
MUR 16	The Willows - Near Michelago	646	Grazing / Recreation	Not sampled
MUR 18	U/S Angle Crossing	608	Grazing	Riffle and Edge
MUR 19	D/S Angle Crossing	603	Grazing / Recreation	Riffle and Edge
MUR 22	Tharwa Bridge	572	Recreation Grazing Residential	Riffle and Edge
MUR 23	Point Hut Crossing	561	Recreation/ Residential	Riffle and Edge
MUR 27	Kambah Pool	519	Recreation/ Residential	Riffle and Edge
MUR 28	U/S Cotter River confluence	466	Grazing	Riffle and Edge
MUR 29	Uriarra Crossing	445	Grazing/ Ex-forestry	Riffle and Edge
MUR 30	U/S Molonglo Confluence	448	Grazing	Riffle and Edge
MUR 31	D/S Molonglo Confluence	443	Grazing	Riffle and Edge
MUR 34	Halls Crossing	393	Grazing	Riffle and Edge
MUR 35	~ 5km U/S Taemas Bridge	371	Grazing	Edge
MUR 36	Taemas Bridge	367	Grazing	Edge

Table 2. Zone structure of sites along the Murrumbidgee River

Macro-reach	Zone	Sites included	Land use
Tantangara - Cooma	1	MUR 1-4	Native. Reservoir within National Park. Recreation. Agricultural land downstream of Yaouk
Cooma – Angle Crossing	2	MUR 6- 18	Agriculture dominant. Some urbanization. Sewage Treatment Plant upstream of MUR 6.
Angle Crossing - LMWQCC	3	MUR 19- 30	Residential and residential / urban development increases. Less grazing.
LMWQCC – Taemas bridge	4	MUR 31-36	Intensive agricultural landuse. Downstream of LMWQCC. Previous work has shown a marked change in water quality downstream of the treatment plant

2.2.1 Hydrology and rainfall

River flows and rainfall for the sampling period were recorded at gauging stations at Lobb's Hole (410761: downstream of Angle Crossing) and Mt. MacDonald (410738: downstream of the Cotter River Confluence) that are maintained by Ecowise. Site locations and codes are given in Table 3.

Stations are visited monthly and data is downloaded, verified and quality coded before archiving into the database. Rain gauges are calibrated each visit and adjusted if required. Records are stored using the HYDSTRA© data management system.

Table 3. River flow monitoring locations and parameters

Site	Site Code	Location/Notes	Parameters*	Latitude	Longitude
1	410738	M'bidgee River @ Mt. MacDonald	WL, Q	S 35.2917	E 148.9565
2	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

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

2.2.2 Water quality

Baseline *in-situ* physico-chemical parameters including temperature, pH, electrical conductivity, turbidity and dissolved oxygen were obtained using a multiprobe YSI 556 Surveyor. The probe was calibrated in accordance with QA procedures and the manufactures requirements prior to sampling.

From each site, grab samples were taken in accordance with the AUSRIVAS protocols (Coysh *et al.*, 2000) for verification and nutrient analysis. All samples were returned, on ice, to the ECOWISE laboratory and analysed for nitrogen oxides (total NOx), total nitrogen (TN) and total phosphorus (TP) in accordance with the protocols outlined in A.P.H.A (2005). Collectively, these water quality parameters will assist in the interpretation of biological data and help gauge changes potentially resulting from flow reductions at these key sites following water abstractions.

2.2.3 Macroinvertebrate sampling

2.2.3.1 Round 1

Benthic macroinvertebrate communities were sampled in the riffle zone using a HESS sampler. The HESS sampler is a cylindrical device that is placed on the bottom of a river bed and used to sample an area of $0.9m^2$. At each site, triplicate samples were taken in the riffle zone. The substrate was agitated to a depth of approximately 10 cm using a trowel. Larger cobbles and pebbles were scrubbed with a nylon brush until all of the substrate within the sampler was covered. The samples were then preserved in 70% ethanol, clearly labelled with site codes, replicate numbers and date, then stored for eventual sorting in the laboratory..

The edge habitat was sampled in strict accordance with the NSW AUSRIVAS (Australian River Assessment System) protocols (Turak and Waddell, 2001). This semi-quantitative, rapid bioassessment (RBA) approach was used because quantitative methods such as HESS sampling is not suitable for pool / edge habitats. At each site, one sample was taken from the edge habitat using a framed net (350mm wide) with 250 µm mesh size. The nets and all other associated equipment were washed thoroughly between sampling events to remove any macroinvertebrates retained on them. Samples were collected by sweeping the collection net along the edge habitat at the sampling site; the operator worked systematically over a ten metre section covering overhanging vegetation, submerged snags, macrophyte beds, overhanging banks and areas with trailing vegetation.

Each RBA sample was placed into a sorting tray and the macroinvertebrates were picked for a minimum of 40 minutes. If new taxa were found between thirty and forty minutes, sorting was continued for a further 10 minutes. If no new taxa were found, after an additional 10 minute period, then this process ceased. If new taxa were found, this process continued up to a maximum of 1 hour.

2.2.3.2 Round 2

In Round 2, each habitat was sampled and analysed in strict accordance with the ACT spring riffle and edge AUSRIVAS (Australian River Assessment System) protocols (Coysh et al., 2000) during spring (November 24th – 26th) 2008. At each site, one sample was taken from the riffle habitat (flowing broken water over gravel, pebble, cobble or boulder, with a depth greater than 10cm, Coysh et al. 2000) 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 streambed upstream of the net was disturbed by vigorous kicking and agitating, allowing any dislodged material to be carried into the net. The process continued, working upstream for 10 metres. The samples were preserved in 70% ethanol, clearly labelled with site codes and date. Sampling protocols for edge habitat followed those described above, except that samples were preserved in the field as per the riffle samples, instead of being sorted live, and returned to the laboratory for analysis.

2.3 Sample processing

Analyses for rounds one and two differed because of the different methods used.

Edge and riffle samples collected in round 1 were identified to genus level with the exception of Acarina (class) and Turbellaria (family). For the AUSRIVAS model, family level identification was used for the edge samples. 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.

Round 2 samples were processed in accordance to the ACT processing protocols, which require sub-sampling to be conducted in the laboratory.

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 agitated to evenly distribute the sample and the contents of randomly selected cells removed. The macroinvertebrates in each cell were identified to family level except Chironomidae (identified to sub-family), Oligochaeta (class) and Acarina (order) until 200 animals were identified (identification followed taxonomic keys published by Hawking (2000)). If 200 were identified before a cell had been completely analysed, identification continued until the animals within the entire cell were identified. Data was entered directly into electronic spreadsheets to eliminate errors associated with manual data transfer.

Upon the completion of macroinvertebrate identification, the samples were transferred to a solution of 75% methanol and 5% glycerol for long-term storage. This process allows samples to be re-examined at a later date if required (e.g. if the taxonomy changes significantly during the course of a long term monitoring program).

2.4 Data analysis

Water quality data are presented in **Appendix B**. Taxonomic inventories from both rounds of sampling are provided in **Appendix D**.

2.4.1 Water quality

Principal Components Analysis (PCA) based on Euclidean distances was used to determine which physico –chemical variables were most associated with differences among sites. PCA is a multivariate analysis technique that is commonly used on environmental data as an exploratory technique. It compresses a set of variables, in this case water quality, into a smaller number of derived variables, called components. These components are linear combinations of the original variables that help explain as much of the variation in the data matrix as possible (Quinn and Keough, 2002). PCA summarises the data in a way which best explains the variance, so is similar to a multivariate extension of linear regression.

The output from the PCA includes a two- or three-dimensional plot, similar to those produced by non-metric multidimensional scaling (NMDS), and a list of eigenvalues and eigenvectors. The eigenvalues represent the amount of the original variance explained by each new component and the eigenvectors are coefficients or weights that show how much each original variable contributes to each new derived variable or component.

PCA was performed using PRIMER version 6 (Clarke and Gorley, 2006) using normalized and log-transformed (except pH) water quality variables collected in Round 1 only. The analysis began with 14 variables; following initial inspections of the data, dissolved oxygen in mg/L and dissolved organic

carbon were removed from the analysis because they highly correlated with dissolved oxygen as % saturation and total organic carbon respectively. Nitrate, nitrite, and ammonia records were removed from the analysis because most values were censored and could not be reliably analysed in PRIMER. Furthermore all three analytes were very highly correlated with Total Nitrogen, which was subsequently retained. Water quality parameters were examined for compliance with ANZECC water quality guidelines for healthy ecosystems in upland streams (ANZECC, 2000).

2.4.2 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 community expected (E) in the absence of environmental stressors. The expected fauna from sites with similar sets of predictor variables (physical and chemical characteristics not influenced by human activities, e.g. altitude) are then compared to the observed fauna (O) and the ratio derived (O/E) is used to indicate the extent of any impact. The ratio derived from this analysis is compiled into bandwidths (i.e. X, A-D; Table 4) 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 edge samples from Round 1 were assessed using the NSW AUSRIVAS spring edge model; while the riffle and edge samples for Round 2 were analysed using the ACT AUSRIVAS spring riffle model based on macroinvertebrate community data.

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 assessed as Band A in the edge and Band B in the riffle is given an overall site assessment of Band B (Coysh *et al.*, 2000).

The use of the O/E 50 scores is standard in AUSRIVAS, but it 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 limit the inclusion of rare and sensitive taxa, and might also reduce the ability of the model to detect changes in macroinvertebrate community composition over time (Cao *et. al.*, 2001). However, the presence or absence of rare taxa varies over time, and their inclusion in the model may suggest false changes in the site classification because presence or absence might be caused by insufficient sampling effort rather than ecological change.

2.4.3 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.

2.4.4 Macroinvertebrate communities

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 in addition to examining patterns among sites. All multivariate analyses were performed using PRIMER version 6 (Clarke and Gorley, 2006). Univariate statistics were performed using R version 2.8.1 (R Development Core Team, 2008).

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 facilitates its 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 and Warwick, 2001). The number of dimensions (axes) used in the NMDS procedure was based on the resultant stress levels. 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).

The similarity percentages (SIMPER) routine was carried out on the datasets following a significant ANOSIM test to examine which taxa were responsible for, and explained the most variation among statistically significant groupings (Clarke and Warwick, 2001), this was also used to describe groups (i.e. in terms of which taxa characterised each group of sites).

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

In the case of taxonomic richness, high taxa richness scores do not necessarily indicate better ecological condition at a given site. While in certain instances high scores can indicate favourable conditions, they can also indicate altered conditions, indicative of an ecologically impacted site. Where the disturbed conditions provide habitat that might not naturally occur; a new environment for previously absent taxa is provided. For the purposes of this program, taxa richness was quantified as baseline information from which further analyses, such as community stability, which assesses (as a percentage) temporal changes in community composition (turnover). Community turnover is a useful metric for assessing small scale changes in macroinvertebrate communities and can provide complimentary information to the AUSRIVAS output. For all analyses, alpha was set to 5%.

2.5 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 who had 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.
- Characteristics of geological and instream attributes were documented according to AUSRIVAS methods. These characteristics were cross-checked between sites with similar characteristics to ensure that habitat descriptions were consistent (some of the attributes involve percentage estimates, and are subjective by definition).

All procedures were performed by AUSRIVAS accredited staff.

2.6 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.

Table 4. AUSRIVAS band-widths and interpretations for the NSW spring edge model.

Band	O/E bandwidth	Explanation
X -	>1.12	*More diverse than expected. Potential enrichment or naturally high diversity.*
A -	0.88-1.12	*Similar to reference. Water quality and / or habitat in good condition.*
B -	0.64-0.87	*Significantly impaired. Water quality and/or habitat potentially impacted resulting in loss of taxa.*
C -	0.15-0.48	*Severely impaired. Water quality and/or habitat compromised significantly, resulting in a loss of biodiversity.*
D -	0-0.14	*Extremely impaired. Highly degraded. Water and /or habitat quality is very low and very few of the expected taxa remain.*

Table 5. AUSRIVAS band-widths and interpretations for the ACT spring edge and riffle models.

	Riffle	**Edge**	
Band	**O/E bandwidth**	**O/E bandwidth**	**Explanation**
X -	>1.14	>1.13	*More diverse than expected Potential enrichment or naturally high diversity.*
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	0.35-0.61	*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.*

3 Results

3.1 Hydrology and rainfall

Sampling was completed in November 2008.

Sample collection occurred at the peak of two minor events that occurred in the lower catchment. Cumulative rainfall from the beginning of sampling to the end of Round 1 totalled 15.2 mm and resulted in small peaks in the Murrumbidgee flow at Mt. MacDonald. On the 23rd of November, 13 mm was recorded at Lobb's Hole; this created another small spike in the hydrograph resulting in the Round 2 samples being collected on the rising limb. Despite these minor events, the total rainfall for Spring 2008 was only 114 mm (long term mean 187 mm). The highest daily rainfall for the season occurred on the 22nd of September (18.4 mm).

Monthly median flow recorded at Mt. MacDonald (410738) during spring were above the 2008 median flow of 176.1 ML/d in September and October but lower in November (see Table 5). At Lobb's Hole, the monthly median flow in September and October were above the 2008 Spring median of 103.1 ML/d but in November were 78 % lower than the spring median for 2008 (Table 5).

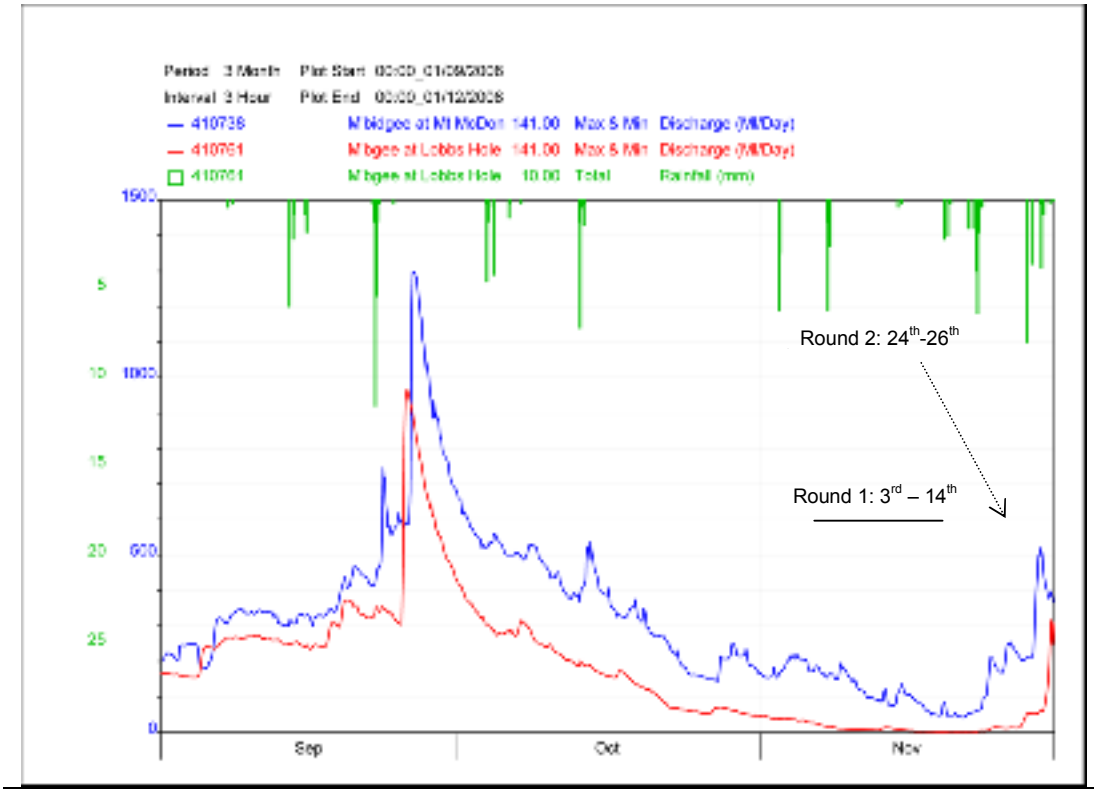


Figure 1. Spring hydrograph of the Murrumbidgee River at Lobb's Hole (red) and Mt. MacDonald (blue). Total rainfall (mm) is shown in green.

Table 5. Monthly flow and rainfall for spring 2008 at Lobb's Hole (410761) and Mt. MacDonald (410738). Flow values are medians (ML/d). Rainfall values are totals (mm).

SITE (CODE)	September	October	November	Annual	Rainfall (annual)	Rainfall (spring only)
Lobb's Hole (410761)	337	176	23.1	103	456	114
Mt. MacDonald (410738)	448	366	154	1761	NA	NA

3.2 Water quality

Water quality results are summarised in Appendix B.

The results from the grab samples show strong longitudinal gradients in electrical conductivity (EC) and alkalinity from the upper-most sites to the lower limit of Burrinjuck Reservoir. EC was lowest at MUR 1 (23 µs/cm), downstream of Tantangara and highest at Halls Crossing (310 µs/cm). There is a marked increases in EC and alkalinity downstream of the Lower Molonglo Water Quality Control Centre (LMWQCC) and maximum values for all nutrient analytes were recorded downstream of the LMWQCC, including: ammonia (6.4 mg/L) and total nitrogen (10 mg/L) at MUR 31. The results from the grab samples show that most of the analytes recorded values within the ANZECC (2000) water quality guidelines for ecosystem health, however there were some exceptions. All sites sampled from Tantangara reservoir to Cooma had EC levels below the recommended lower threshold of 30 µs/cm. All other analytes in this section of the Murrumbidgee River were within the guidelines, with the exception of MUR 4, which exceeded the recommended nutrient levels and from this point downstream, Nitrogen Oxides (NOx), Total Phosphorus (TP) and Total nitrogen (TN) exceeded the guideline at each site until site MUR 31, at which point there were up to ten-fold increases in the analytes downstream to Burrinjuck reservoir.

Turbidity was exceeded at 10 of the 21 sites sampled. These sites were mainly in the mid-sections, close to residential areas and recreational sites. The turbidity readings were not especially high; with the highest recorded value being 53 NTU(recorded at site MUR 36).

Dissolved Oxygen (% saturation) was high at MUR 36 (129.7%). The results from the Principal Components Analysis (PCA) show that ~79% of the variation in the data matrix is explained by two principal components. PC1 explained 67.5% of the variation and several parameters contributed approximately the same amount of variation which separated the sites along the first principal components (x) axis. The main physicochemical parameters separating sites along this axis were electrical conductivity, alkalinity, pH and TP. There appears to be a clear longitudinal pattern for zones along the river for this axis (Figure 2).

PC2 explained 11.3% of the variation and separated sites with increasing turbidity and total nitrogen. These relationships are visualized in Figure 2. A distinct gradient is evident from site 1 through to site 36 as EC, TP and alkalinity increase; while on PC2, increasing turbidity and TN explain the separation of sites. Correlations and contribution of each of the water quality parameters to each component are listed in **Appendix C**.

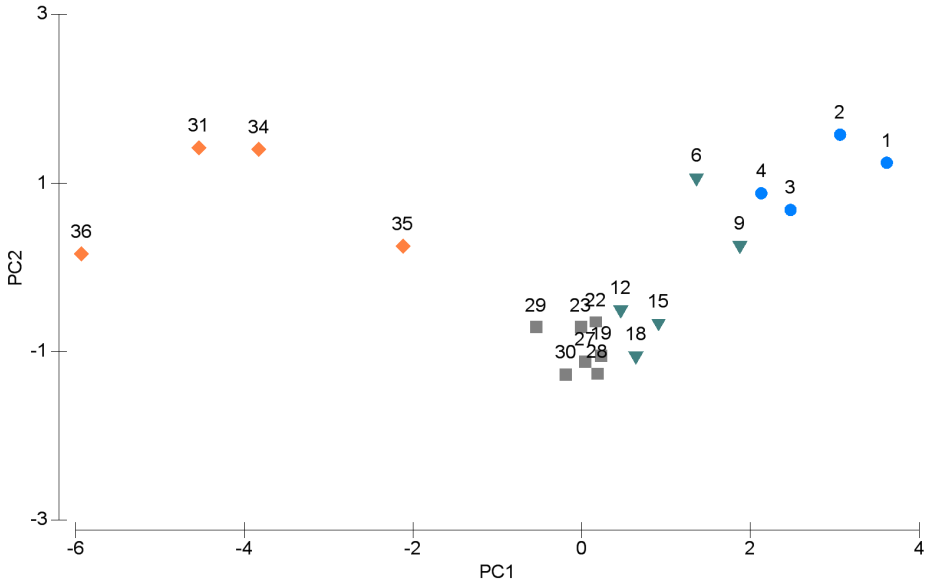


Figure 2. Correlation based Principal Components Analysis on water quality data collected in spring 2008.

The prefix "MUR" and been removed from the site labels for clarity but the numbers still refer to the site codes described in Tables 1 and 2. ● = Zone 1; ▼= Zone 2; ■ = Zone 3; ♦ = Zone 4.

3.3 Macroinvertebrates

The results from this round of sampling show a distinct separation of sites in the upland reaches in Zone 1 from Zones 2-4. ANOSIM results show significant differences in the macroinvertebrate communities between zones in both the riffle and edge habitats with Global R values (and p-values) of 0.35 ($p<0.001$) and 0.45 ($p<0.001$) respectively. Pair-wise comparisons between zones in the riffle habitat show there is significant separation between all zones except 2 and 3 (i.e. the sections downstream of Angle Crossing to Halls Crossing). All pair-wise combinations were significant in the edge habitat (Appendix E).

3.3.1 Spring riffle (round 1)

The relatively small R-value for the initial ANOSIM test suggest that while there appears to be distinct macroinvertebrate community structure within each zone, there is some overlap among sites, which is illustrated in the NMDS plot (Figure 4). However, the stress illustrated in the NMDS plots is relatively high, indicating that the depiction of the relationship between the sampling sites should be treated with some caution. This is particularly true for the positioning of site 34 (Halls Crossing) which are well separated from other sites in the cluster analysis (Figure 3) (Clarke and Warwick, 2001) and 3-Dimensional NMDS plot (not shown), suggesting some distortion of the multivariate structure represented in Figure 4.

Sites 2 and 4 within Zone 1 were distinct from all other sites sampled in spring 2008. The similarity percentages (SIMPER) analysis showed that within all zones, there were no specific taxa contributing to average group similarities, but were characterized the cumulative contributions of several taxa. Sites 2 and 4 in Zone 1 in the upper reaches of the Murrumbidgee River were characterized by high abundances of mayflies represented by the genera *Austrophlebioides sp*. (Leptophlebiidae), *Cheumatopsyche sp.* (Hydropsychidae) and *Tasmanocoenis sp.* (Caenidae) and a combination of Oligochaeta (worms); Chironomids (midges) and one genus in the family, Simuliidae (black flies). These sites had approximately equal relative abundances of generally sensitive taxa (i.e. EPT taxa [Ephemeroptera, Plecoptera and Trichoptera]) and tolerant taxa (i.e. OCD [Oligochaeta; Chironomids and other Dipterans]) (Figure 7).

Sites downstream of Cooma to ~ 1km upstream of Angle Crossing (sites: Mur 12, 15 and 18) were dominated by *Simulium sp*. and *Austrosimulium sp*. - both in the black fly family (Simuliidae). These two taxa, combined with Oligochaeta had a cumulative contribution of 70% of the average similarity with Zone 2. EPT taxa were markedly lower at these sites, contributing to an average of 10% of the total macroinvertebrate community assemblage (Figure 7), compared to 35% in Zone 1.

Between Angle Crossing and the upstream side of the Lower Molonglo Water Quality Control Centre (LMWQCC) (Zone 3), sites Mur 19, 22, 23, and 27-30 were characterized by a similar composition of taxa to those sampled in Zone 2. Four taxa, Oligochaeta, *Cricoptus sp.* (Chironomidae: *sf.* Orthocladiinae), *Austrosimulium sp*. and *Cheumatopsyche sp*. & *Asmicridea sp*. (Hydropsychidae) contributed >80% of the within-zone similarity (amongst sites).

The group of taxa characterizing the sites downstream of the LMWQCC is almost identical to Zone 3, which is consistent with the non-significant R-values generated from the ANOSIM analysis and the position of these sites in the cluster and NMDS analyses (Figures 3 and 4 respectively). The main difference appears to be an increase in the abundance of black fly larvae (Simuliidae) and midges *Polypedilum sp.* (Chironomidae: *sf*. Chironominae) and a decline in the number of *Cheumatopsyche sp.* downstream of the treatment plant.

Taxonomic richness was highest at the genus level at site Mur 4 (Yaouk), with 55 genera collected from 28 families. The lowest was recorded at site Mur 28 (upstream of the Cotter River confluence) with 18 genera recorded representing 8 families. Zone 1 tended to contain the most families (21 and 28), Zone 2 ranged from 11 – 18 families, Zones 3 ranged from 8-20 families, and Zone 4 from 12-16 families. Genus richness in Zone 2 ranged from 21-34, Zone 3:18-32 and Zone 4: 29-31 (Figure 8).

3.3.2 Spring edge (round 1)

The sampling protocols for the edge habitat differed to the riffle samples because rapid bioassessment methods were used. This is because the HESS sampler adopted for the riffle sampling, is not designed for deeper, low velocity water. To overcome this, samples were collected using a sweep net. The adoption of this form of rapid bioassessment allows AUSRIVAS modelling of the macroinvertebrate community structure to estimate the ecological condition of each site.

The NSW edge model in the AUSRIVAS modelling platform did not recognize any of the sites sampled in this program; indicating in the output window that each site was outside the experience of the model (OEM). Therefore, no assessment is available at this stage for the edge samples collected in spring.

Significant R-values from the ANOSIM analysis, shown in Appendix F, indicate that the macroinvertebrate community structure is significantly different between all Zones (1-4). Replicates taken within sites generally clustered together, although some clustering of individual replicates from differing sites (and zones) was recognized - noticeably sites Mur 6, Mur 15 and Mur 31, but also from site Mur 18. The position and clustering together of two replicates from sites Mur 15 and 22 are a result of no *Micronecta sp.* (Corixidae: the water boatman family) or *Triplectides sp*. (Leptoceridae: mayfly), which were otherwise two of the numerically dominant taxa in the remaining samples at these two sites.

In Zone 1, 11 taxa contributed to 70% of Zone 1 average similarity (Appendix E).The five taxa best characterizing sites in this zone were (in order of numerical dominance): *Dinotoperla sp*. (Plecoptera: stoneflies); *Micronecta sp*., *Cricoptus sp*., *Atalophlebia sp*. (Leptophlebiidae) and *Ablabesmyia sp*. (Chironomidae: sf. Tanypodinae). The communities sampled at sites within Zones 2 and 3 were very similar structurally, but were separated by the numerical dominance of key taxa (listed above). These similarities are reflected in the low R-value and the apparent overlap of sites in ordination space depicted in Figure 6. Three taxa in Zone 4 contributed to 70% of the within group similarity; with over half (36%) determined by Micronecta sp.. *Polypedilum sp*. (Chironomidae: sf. Orthocladiinae) and the introduced freshwater snail: *Physa acuta* contributed 29% and 12% respectively, to the overall within group similarity measure.

Edge taxonomic richness was less variable than the riffle zone. Genus richness was highest at Mur 2 (Yaouk) with 35 genera collected in 21 families. The lowest number of taxa collected was at Mur 36 (upstream Taemas Bridge) with 15 genera representing 13 families collected.

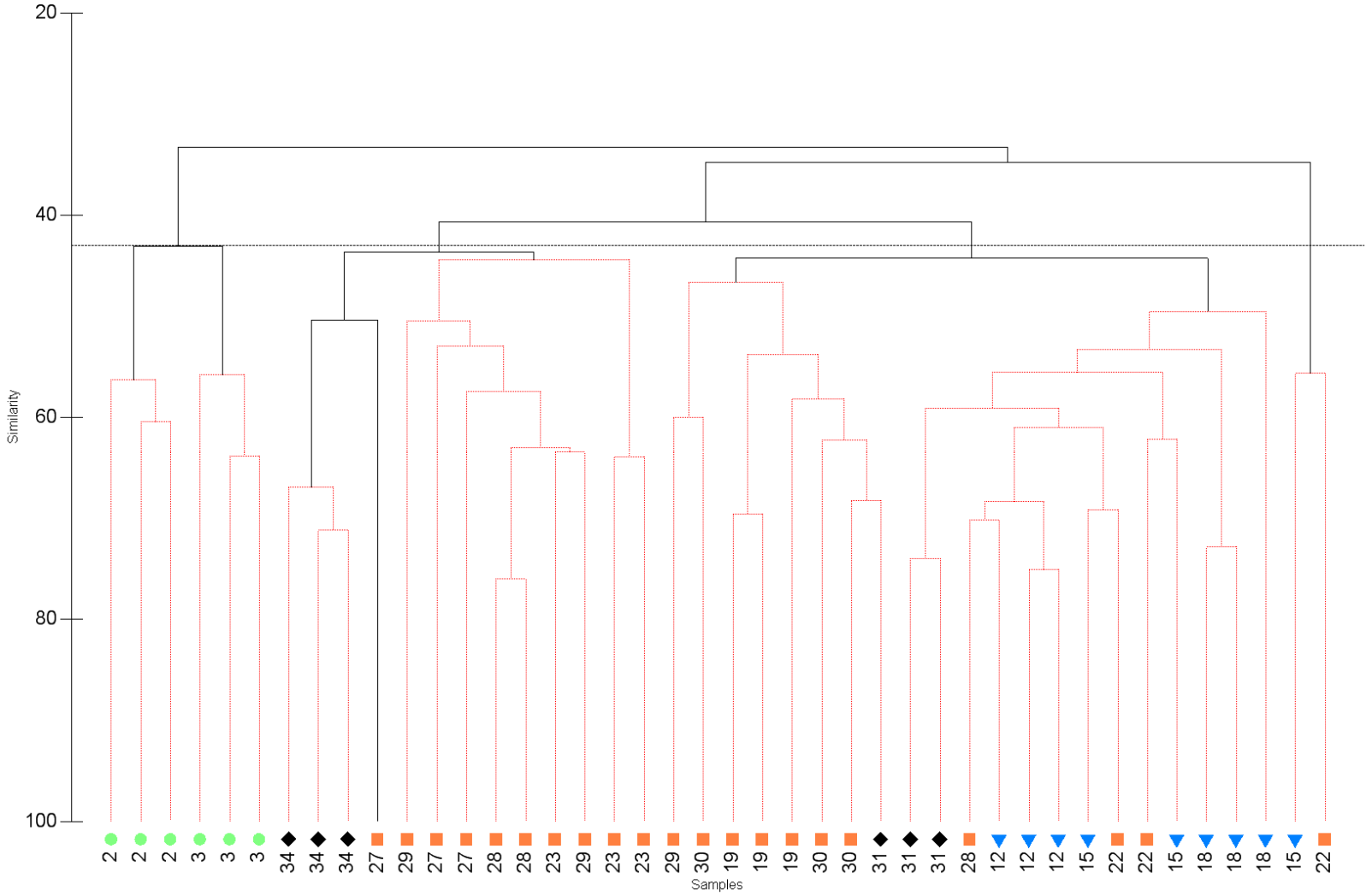


Figure 3. Cluster analyis based on genus level data for spring riffle samples. The horizontal line represents the 43% cut point of the two major groups. Red lines indicate significant structuring as determined through the SIMPROF analysis.

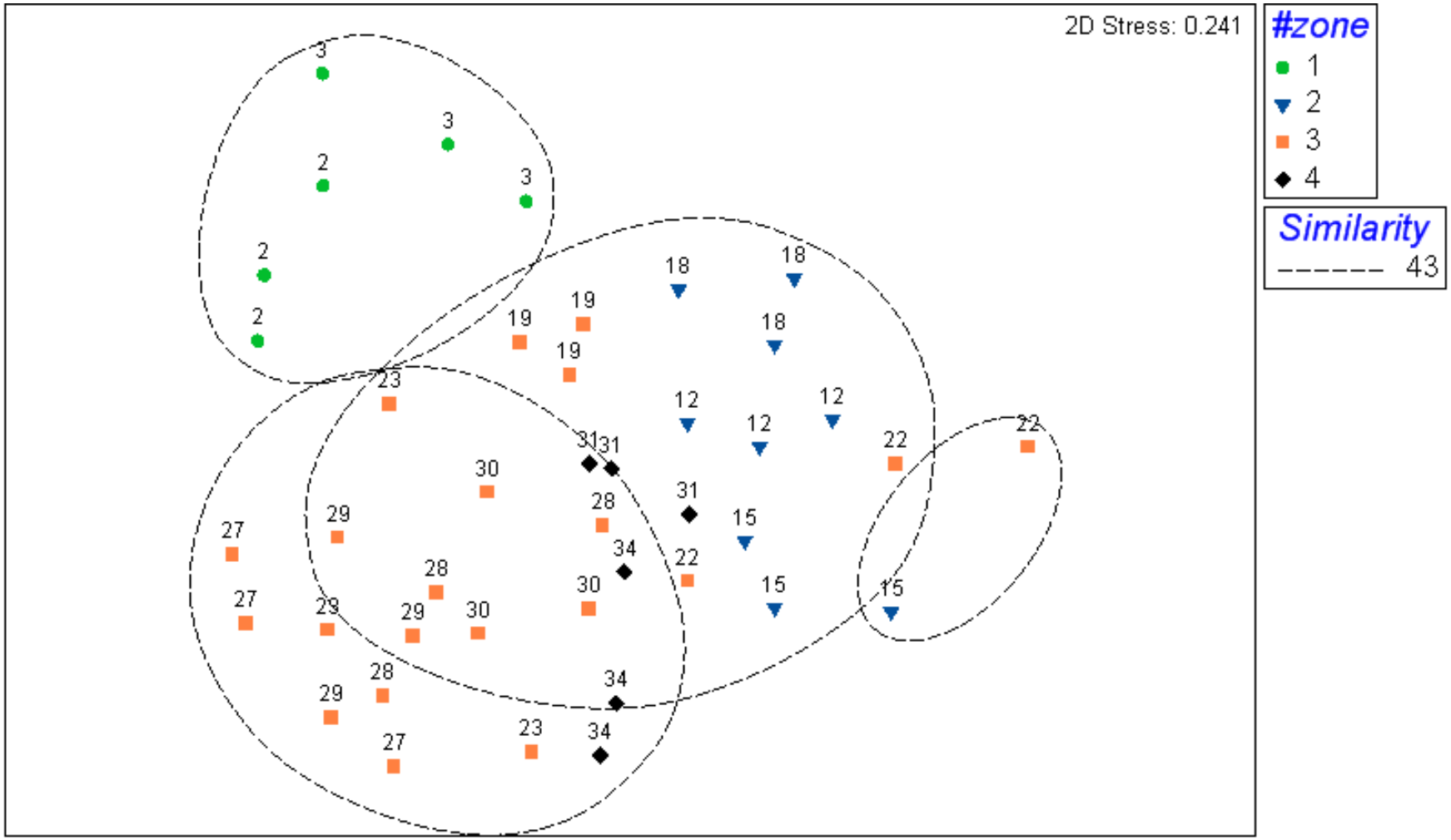


Figure 4. Non-metric multidimensional scaling of genus level data for the spring riffle samples**.** Ellipses represent the 43% similarity groupings superimposed from the cluster analysis.

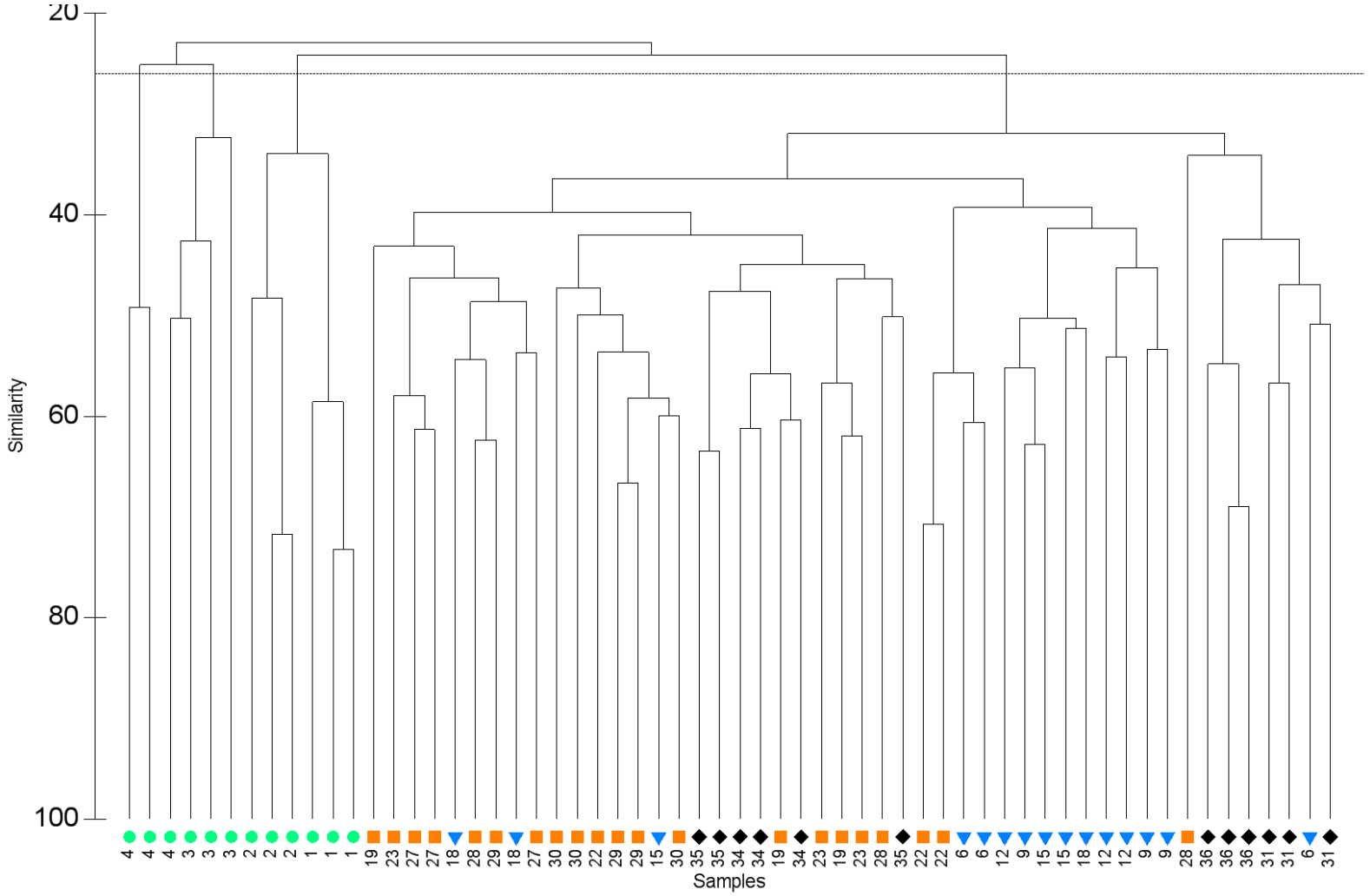


Figure 5. Cluster analysis based on genus level data for spring edge samples. The horizontal line represents the 26% cut point of the two major groups.

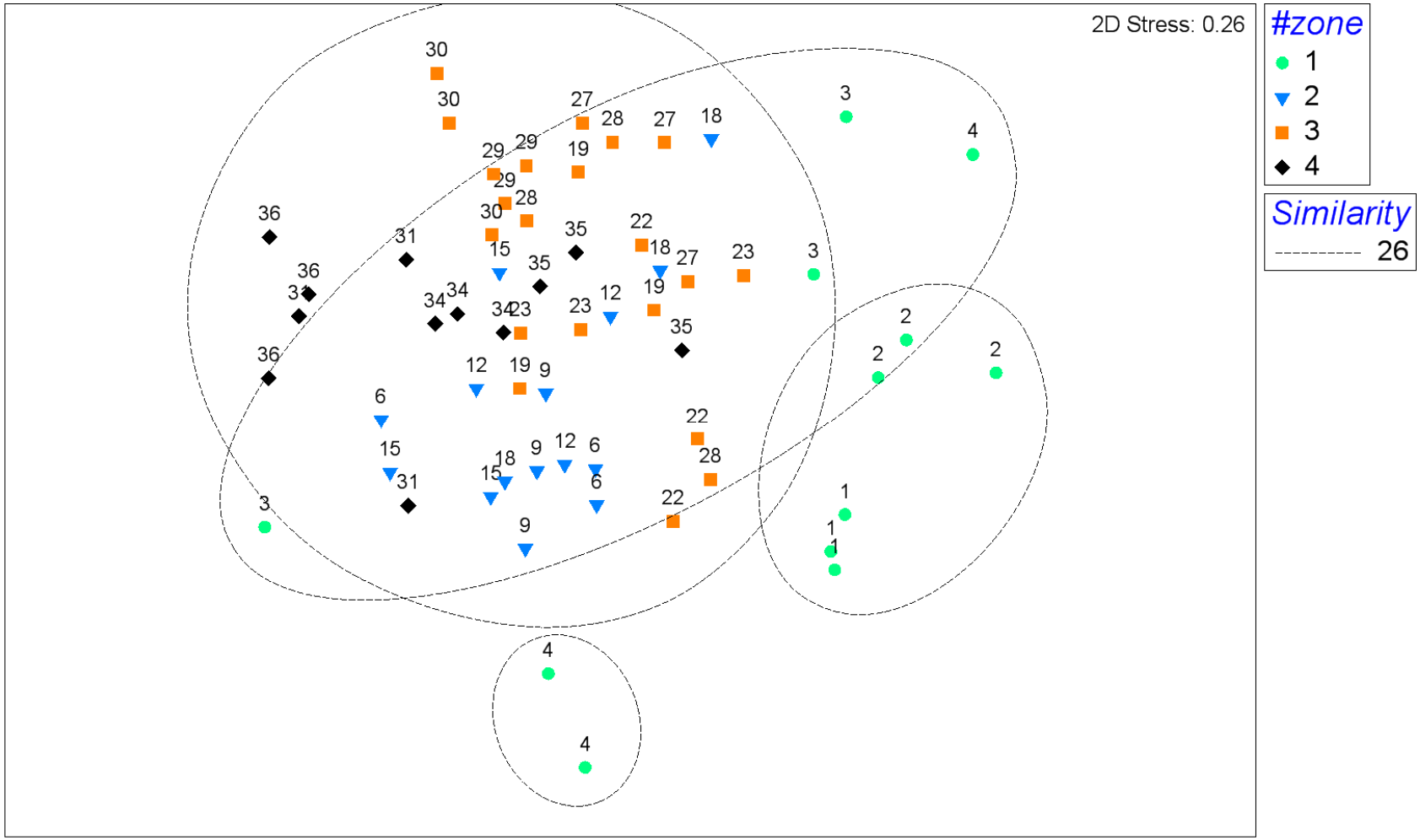


Figure 6. Non-metric multidimensional scaling of genus level data for the spring edge samples. Ellipses represent the 26% similarity groupings superimposed from the cluster analysis.

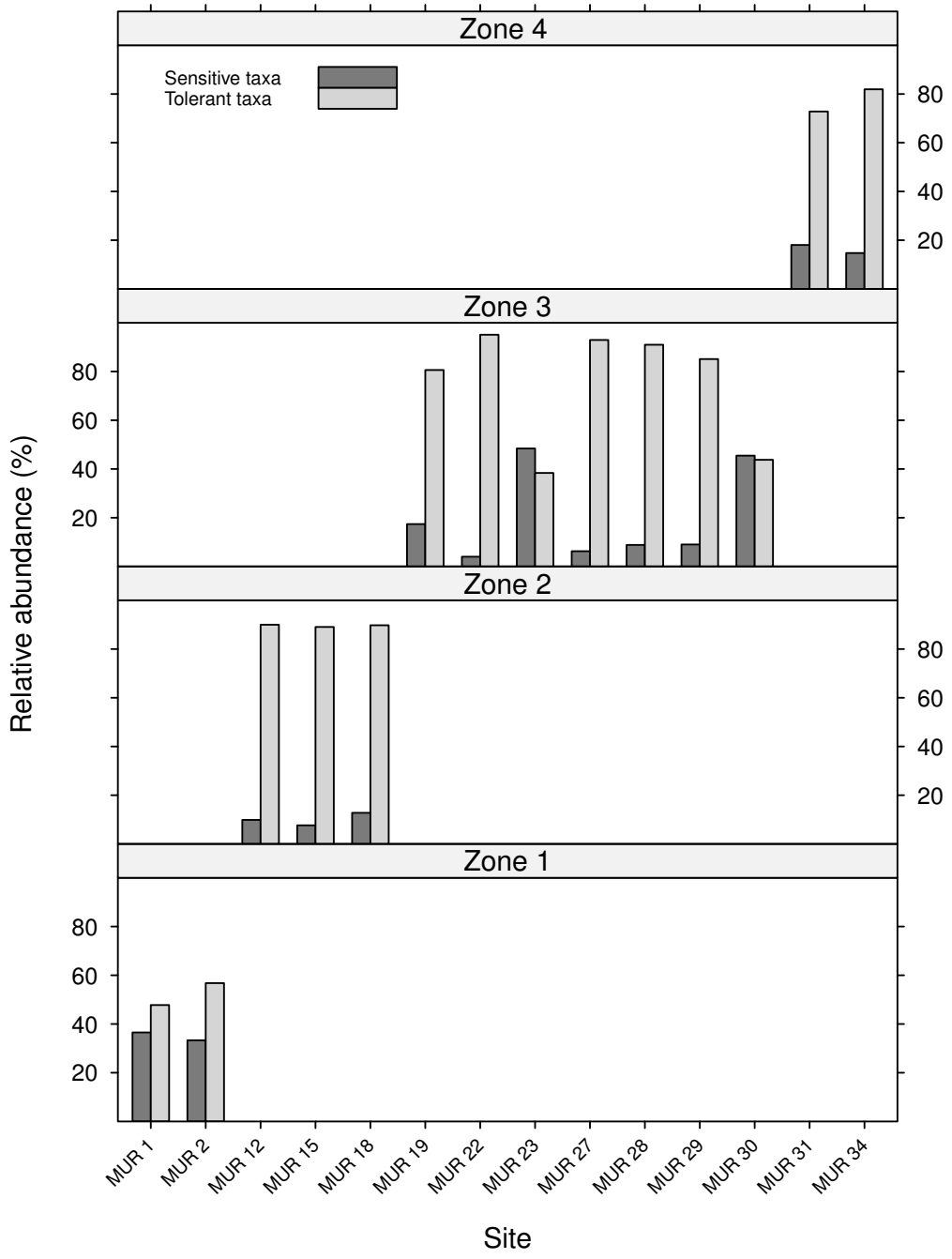


Figure 7. Relative abundances of sensitive* and tolerant* taxa at each riffle site.

The sensitive taxa group represents the commonly used “EPT” metric which is made up of: Ephemeroptera, Plecoptera and Trichoptera. The tolerant group comprises Oligochaeta, Chironomids and other Dipterans. Note: sites are grouped by zone (refer to Table 2).

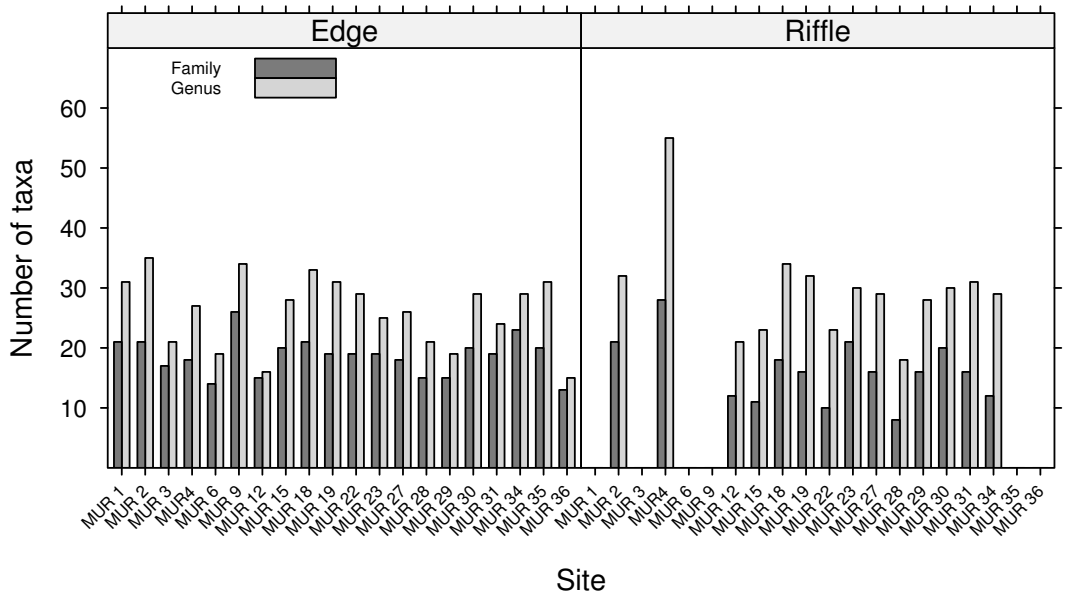


Figure 8. Taxonomic richness at riffle and edge sites at family and genus level

Round 2: AUSRIVAS assessment (ACT)

The results from the second round of sampling, assessed using the ACT AUSRIVAS protocols for river health assessment, indicate that three of the sites sampled are close to reference condition in both the riffle and edge habitats, and half of the sites were significantly impaired. At sites Mur 28 and 29, only two replicates were taken due to a lack of appropriate habitat.

3.3.3 Spring riffle (round 2)

Riffle zones in the ACT were close to reference (Band A) in 50% of the sites sampled. The remaining 50% were significantly impaired (Band B). In each case the sites final assessment was based on the lowest band width of the three replicates (Table 7). The condition of the four sites assessed as significantly impaired (Band B), including: Kambah Pool; Uriarra Crossing and Mur 30, upstream of the LMWQCC, all had one Band A replicate. Only site Mur 31, ~km downstream of the LMWQCC had consistent B-bands across all replicates.

Taxa expected with >50% probability, but absent from the samples (with their associated SIGNAL score) are listed in Appendix F. Mur 28 had the least missing taxa from the three replicates (2 unique taxa), while the most taxa were missing from Mur 30 and 31, upstream and downstream of the LMWQCC respectively.

Glossosomatidae (SIGNAL = 9), a caddis fly (Trichoptera), was predicted only at Mur 28, but was absent. This family was only recovered at two sites in this program: Boboyan Road Bridge (Mur 2) and Yaouk Bridge (Mur 4) during the first round of sampling. Gripopterygidae, a sensitive stonefly family (SIGNAL = 8) (Plecoptera) was missing from all sites except Mur 19 (downstream of Angle Crossing), where it was present in relatively low numbers (17). Elmidae (SIGNAL-7), the riffle beetle family (Coleoptera), was absent from Mur 31 and from replicates 1 and 2 at Mur 19. Sphaeriidae (SIGNAL -5) freshwater clams, were absent from Mur 31 and missing from 2 of three replicates from Mur 29.

3.3.4 Spring edge (round 2)

AUSRIVAS assessments of edge habitats agreed with the health rating given to the riffle zones at five out of the eight sites. The exceptions were Mur 28, 29 & 30 (u/s Cotter River confluence, Uriarra Crossing and upstream of the LMQWQCC respectively). Replicate 2 from Mur 29 (Uriarra Crossing) had the lowest banding of all sites, resulting a severely impaired assessment from the AUSRIVAS output. The results from this site varied significantly as replicates 1 and 3 were rated as an A and a C respectively. All other sites had low within-site replicate variation, differing by the absence of only one or two taxa (Table 7; Appendix F). Site Mur 31, downstream of the LMWQCC had the most taxa missing that were expected to occur (6).

Gripopterygidae (SIGNAL = 8) was missing from all sites in the second round of sampling, but was collected at sites 19,22,23 & 27 in the first round, 10 days earlier.

Other high SIGNAL scoring taxa (≥7) missing from the edge samples included members of the Leptophlebiidae (mayfly) family at sites 30 and 31 and partial absence (i.e. missing in 1 or two replicates) at all other sites except Mur 19 (downstream of Angle Crossing).

Table 7. AUSRIVAS observed to expected ratios and overall AUSRIVAS assessment for round 2 (ACT sites only).

Site	Location	Rep.	AUSRIVAS O/E score		AUSRIVAS BAND		Overall assessment	
			Riffle	Edge	Riffle	Edge	Riffle	Edge
Mur 19	d/s Angle Crossing	1	*0.95*	*1.11*	A	A	**A**	**A**
Mur 19		2	*1.05*	*1.00*	A	A		
Mur 19		3	*1.14*	*1.00*	X	A		
Mur 22	Tharwa Bridge	1	*1.05*	*1.00*	A	A	**A**	**A**
Mur 22		2	*1.05*	*0.89*	A	A		
Mur 22		3	*0.95*	*0.89*	A	A		
Mur 23	Point Hut Crossing	1	*1.14*	*0.89*	X	A	**A**	**A**
Mur 23		2	*1.05*	*1.11*	A	A		
Mur 23		3	*0.86*	*1.00*	A	A		
Mur 27	Kambah Pool	1	*0.76*	*0.78*	B	B	**B**	**B**
Mur 27		2	*0.67*	*0.78*	B	B		
Mur 27		3	*0.95*	*0.89*	A	A		
Mur 28	u/s Cotter River Confluence	1	*1.06*	*0.89*	A	A	**A**	**B**
Mur 28		2	*1.06*	*0.78*	A	B		
Mur 28		3	*na*	*1.00*	*na*	A		
Mur 29	Uriarra Crossing	1	*0.87*	*0.66*	A	B	**B**	**C**
Mur 29		2	*0.58*	*0.55*	B	C		
Mur 29		3	*na*	*0.89*	*na*	A		
Mur 30	u/s LMWQCC	1	*0.61*	*1.00*	B	A	**B**	**A**
Mur 30		2	*0.91*	*0.89*	A	A		
Mur 30		3	*0.71*	*0.89*	B	A		
Mur 31	d/s LMWQCC	1	*0.83*	*0.66*	B	B	**B**	**B**
Mur 31		2	*0.83*	*0.66*	B	B		
Mur 31		3	*0.83*	*0.66*	B	B		

4 Discussion and conclusion

4.1 Macroinvertebrate communities

The upper Murrumbidgee riffle sites between Tantangara Dam and Cooma were characterized by approximately equal proportions of tolerant and sensitive taxa. A sharp 3-fold decline in sensitive taxa occurred downstream of Cooma, corresponding with an increase in tolerant taxa at these sites. The remaining sites, with the exception of Point Hut Crossing and Upstream of the LMWQCC (Mur 23 and 30 respectively) all had EPT proportions lower than 20% - the lowest (<4%) was recorded at Tharwa Bridge (Figure 7).

These changes in relative abundance of EPT taxa are likely to be, at least in part, due to changes in landuse, water quality, and available habitat within the catchment. There was a steady increase in the amount of sand, silts and clays moving downstream of the Tantangara Dam. This stretch of river is is known to favour burrowing taxa such as Chironomids and Oligochaetes, and has a low relative abundance of many EPT taxa (Zweig and Rabeni, 2001), as these generally require a heterogeneous substrate and cool, fast flowing water for survival.

Although hydrological changes are also likely to affect the distribution and abundance of many sensitive taxa, as might have been expected considering the ongoing drought and considerable deviation from median flows (Figure 1), the presence of very high abundances (n>500) of Simuliidae in Zones 2 and 3, suggest that flow alone is not the main contributing factor for these differences between Zones because Simuliidae, being filtering collectors, are sensitive to low flows (Harrod, 1964). However, simulids do need a relatively clean substrate for survival, which would suggest that the "in-filling" of interstitial spaces rather than complete smothering of the substrate is a probable cause for the patterns observed in these ratios (Figure 7). For example, substrate diversity was highest (i.e. percentages of cobbles, pebbles, sand etc…) at Mur 2, 4, 19 and 23 – all of which recorded the highest ratios of EPT and high taxonomic richness (conversely, low richness has been linked to a loss of habitat (Allan and Castillo, 2008)).

Water quality samples indicate some separation of sites (Figure 2), with the most influential parameters determined from PCA being electrical conductivity, TN, pH and turbidity (Appendix C). The clustering of sites in Zones 2 and 3 suggest that the observed differences in the community structure are not related to water quality, but rather to habitat and/or landuse. Communities in these zones were generally rapid colonizers following disturbance, and tolerant to changes in water quality (Gooderham and Tsyrlin, 2005).

Although there is a strong downstream gradient of electrical conductivity, it is unclear at this stage what the influence is on macroinvertebrate communities. Landuse practices and geology influence electrical conductivity for the length of the Murrumbidgee River, with the most noticeable change occurring downstream of the LMWQCC (**Appendix B**).

Previous work by Ecowise (Ecowise, 2007) has shown that sites upstream and downstream of the Molonglo River confluence showed similar patterns of temporal variation, suggesting that effluent in itself is not the only factor affecting community structure at the downstream sites. Other influences, such as landuse (i.e. urbanization and agriculture), also appear to be affecting the macroinvertebrate assemblages at these sites. This is supported in this study where, despite strong separation of sites based on water quality parameters (chiefly driven by EC), there was considerable overlap in ordination space of macroinvertebrate communities (Figure 4) resulting in non-significant R-values between

Zones 3 and 4.Sites downstream of the LMWQCC show distinct similarities to those in urbanized and agricultural areas. Salinity is known to affect distributions of macroinvertebrates (e.g. Metzeling *et al.*, 2006), although a review of tolerance levels (Hart *et al.*, 1991) shows that even sensitive taxa are tolerant to electrical conductivity levels much higher than those recorded in this sampling period.

The edge habitat showed significant separation between all zones despite some overlap between sites in Zones 2 and 3. Site 36 was distinct from all other sites, except a single replicate from Site 31. The community was characterized by *Physa acuta* (introduced snail); *Micronecta sp*. and *Necterosoma sp*. (diving beetles: Coleoptera), taxa that have very low SIGNAL-2 scores, the ability to tolerate low oxygen levels (*Physa acuta*) and have affinities to fine sediments (*Necterosoma sp*.), and are generally ubiquitous in edge habitats (*Micronecta sp.)*. The characteristics at Site 36 (upstream of Taemas Bridge) are the best explanation for its apparent lack of sensitive taxa and diversity (Figure 8). The substrate was 100% sand, there were no emergent or submerged macrophytes, woody debris or trailing bank vegetation; thus the site was unable to support the diversity recorded at other sites.

Within all Zones, *Micronecta sp*. dominated the communities. This is consistent with the NMDS and cluster analysis (Figures 5 and 6), which shows weak separation of Zones (i.e. there is considerable overlap amongst these groups of sites). The main differences appear to be a loss of *Dinotoperla sp*. (Plecoptera: Stoneflies) and sensitive mayflies in the family Leptophlebiidae progressively downstream in Zones 2, 3 and 4. Stoneflies are highly sensitive to water quality and their absence from Zones 2-4 are indicative of the PCA analysis which shows clear separation of sites in Zone 1 from the others. Identifying the parameter most influencing this shift requires further investigation. The main change in each other zone was a replacement of sensitive taxa (i.e. *Dinotoperla sp.* and *Atalophlebia sp*.) with more tolerant, opportunistic colonizers such as *Cricoptus sp*., Oligochaetes and *Polypedilum sp*..

4.2 AUSRIVAS river health assessment

River health, as assessed using the AUSRIVAS standards for the ACT, was a combination of sites considered close to reference (Band A) and those considered significantly impaired (Band B) (Table 7). Impaired sites (Band B), i.e. Kambah Pool (Mur 27), Uriarra Crossing (Mur 29) u/s LMWQCC (Mur 30) all had at least one replicate indicating reference condition. Uriarra Crossing was particularly variable with observed to expected scores ranging from 0.55-0.89 (C-A) in the edge habitat and 0.58-0.87 in the riffle zone (B-A), so the assignment of a C rating might be misleading considering the wide range of results from all the replicates.

The riffle and edge habitats at this site (Mur 29) were predominantly bedrock with sand deposition evident in both habitats. Trailing vegetation and macrophytes were minimal at this site. Water odour and large quantities of fine organic matter in the edge at this site suggest organic pollution and anaerobic conditions.

Downstream of the LMWQCC (Mur 31), all replicates from riffle and edge habitats resulted in a significantly impaired (Band B) health assessment. All other sites contained replicates in reference condition but this site did not. This may be due to effluent from the treatment plant. However, effluent may not be the case since Mur30, upstream of the treatment plant, was also significantly impaired.

Ecowise's historical assessment of these sites consistently shows signs of environmental stress (Ecowise, 2007). Ecological differences between sites has resulted in changes in taxa abundances rather than the loss of taxa, suggesting signs of flow related impacts (Jowett, 2003). This is consistent with this sampling run, where similar taxa were collected at each site upstream and downstream of the LMWQCC. The NMDS plot shows no clear separation of the sites in either habitat. Furthermore, the similar taxonomic richness results (Figure 8) from Mur 30 and 31 and the similar suite of taxa missing

but expected to occur (**Appendix F**) at both these sites does suggest similar stressors at both sites. However the absence of Baetids (Baetidae: Mayflies) from the upstream site but not downstream might indicate that flow is affecting the riffle communities upstream since the inflow from the Molonglo River might compensate sites downstream in periods of reduced flow in the Murrumbidgee.

The influence of the ongoing drought and reduced flows in November are unclear at this point, but the habitat likely to be impacted the most is the riffle zone. Apart from siltation at certain sites (which could be linked to low flows), there is no conclusive evidence to link the observed communities with drought-related affects. However, the influence of recent drought conditions on Australian rivers cannot be dismissed and should at least be considered as a factor in shaping ecological communities. Other likely causes for site-specific differences are the changes in habitat structure, such as increases in sediment load, due to land use and river regulation.

5 Recommendations

5.1 The current design: sites and sampling protocols

It was not possible to run data using the NSW AUSRIVAS model because: *"all sites were recorded as being outside the experience of the model"* (OEM). Considerable effort has been given to resolve this problem. For example, all of the required habitat variables were thoroughly scrutinised by examining the format of the required variable units. Particular attention was paid to the geographic coordinates because the AUSRIVAS model relies on these data to find comparable reference sites. At this point no solution has been found, and recent discussions with staff from e-water CRC have confirmed that these are recognised issues in the model (Harrison *pers comm*., 2009). Therefore, it is recommended that the NSW model and protocols be replaced with the ACT protocol at all sampling locations.

Most of the sites sampled in this initial run had adequate riffle and edge habitat and access in most cases was safe and deemed acceptable by landowners. However, access to Mur 16 was not possible because the owners have since locked the gate and contact has not been possible. It is recommended to move the site downstream where access can be obtained.

It is also recommended that MUR 29 be re-located downstream of the bridge, where more representative habitat is available, thus enabling reliable assessments between sites.

The level of replication is considered appropriate. The examination of the multivariate community structure through cluster analysis and NMDS plotting suggest that within-site variation is resulting in some replicates showing higher similarity percentages to other sites than to replicates within the same site, suggesting that a single sample is not an adequate representation of that particular site. This was true also for at least some of the sites analysed by the AUSRIVAS model, where there was considerable variation in the resulting health ratings at these sites (Table 7.)

5.2 Taxonomic resolution

An ongoing, and well debated issue (e.g. Chessman *et al.*, 2007, Lenat and Resh, 2001, Warwick, 1993) for environmental impact studies and monitoring programs is the level of taxonomic resolution required to a) meet the requirements of a given program and b) balance the costs associated with lower level resolution (e.g. genus or species level) with the information gained or lost from omitting or including a particular level (Downes *et al.* 2002). In this program, genus level has been used as a starting point to assess structure and relationships within and between sites.

The level of resolution will be re-examined following further discussions with the key stakeholders, Ecowise, and the client to determine the best, most cost-efficient strategy for the project. For the time being we recommend continuing with genus level identification. This will benefit the program by allowing the detection of potentially subtle, genus-specific changes within a given family (Growns and Growns, 2001), while concurrently allowing for the more broad-scale river health monitoring to be implemented through the AUSRIVAS protocols at family level.

6 Literature Cited

A.P.H.A. (2005). Standard methods for the examination of water and waste water.21st Edition. American Public Health Association. Washington.

Allan, J.D. & Castillo, M.M. (2008). Stream Ecology: *Structure and Function of Running Waters. Springer*. The Netherlands.

ANZECC & ARMCANZ (2000). Australian Guidelines for Monitoring and Reporting, National Water Quality Management Strategy Paper no. 7. Australia and New Zealand Environment and Conservation Council / Agriculture and Resource Management Council of Australia and New Zealand.

Chessman, B.C., Williams, S. & Besley, C. (2007). Bioassessment of streams with macroinvertebrates: effect of sampled habitat and taxonomic resolution. *Journal of the North American Benthological Society*, 26, 546-565.

Clarke, K.R. & Gorley, R.N. (2006) PRIMER v6: User Manual/Tutorial. PRIMER-E: Plymouth.

Clarke, K.R. & Warwick, R.M. (2001) Change in marine communities: an approach to statistical analysis and interpretation, 2nd edition. PRIMER-E: Plymouth.

Coysh, J.L., Nichols, S.J., Simpson, J.C., Norris, R.H., Barmuta, L.A., Chessman, B.C. & Blackman, P. (2000) Australian River Assessment System (AUSRIVAS) National River Health Program Predictive Model Manual. Co-operative Research Centre for Freshwater Ecology, Canberra.

Ecowise, 2007. Biological Monitoring for the Operation of the LMWQCC - 2006. Final Report. Internal Report (2007/030).

Ecowise. 2009. Murrumbidgee Ecological Monitoring Program. Part 1: Angle Crossing. Proposal to ACTEW Corporation.

Frissell, C.A., Liss, W.J., Warren, C.E. & Hurley, M.D. (1986). A hierarchical framework for stream habitat classification: viewing streams in a watershed context. *Environmental Management*, **10**, 199-214.

Gooderham, J. & Tsyrlin, E. (2005). The Waterbug Book: *A guide to the freshwater macroinvertebrates in temperate Australia*, CSIRO Publishing, Victoria.

Growns, I.O. & Growns, J.E. (2001) Ecological effects of flow regulation on macroinvertebrate and periphytic diatom assemblages in the Hawkesbury-Nepean River, Australia. *Regulated Rivers: Research and Management*, 17, 275-293.

Harrod, J.J. (1964). Effect of Current Speed on the Cephalic Fans of the Larva of *Simulium ornatum var. nitidifrons* Edwards (Diptera: Simuliidae) *Hydrobiologia*, **26**, 8-12.

Hart, B.T., Bailey, P., Edwards, R., Hortle, K., James, K., Mcmahon, A., Meredith, C. & Swadling, K. (1991). A review of the salt sensitivity of the Australian freshwater biota. Hydrobiologia, 210, 105-144. Jowett, I.G. (2003) Hydraulic constraints on habitat suitability for benthic invertebrates in gravel-bed rivers. *River Research and Applications*, **19**, 495-507.

Keen, G. (2001). Australia - Wide Assessment of River Health: Australian Capital Territory Bioassessment Report (ACT Interim Final Report), Monitoring River Health Initiative Technical Report no 3, Commonwealth of Australia and Environment ACT.

Kruskal, J.B. (1964). Multidimensional scaling by optimizing goodness of fit to a non-parametric hypothesis. *Psychometrika*, **20**, 1-27.

Lenat, D. & Resh, V.H. (2001) Taxonomy and stream ecology - The benefits of genus- and species-level identification. *Journal of the North American Benthological Society*, **20**, 287-298.

Marchant, R. (1989). A subsampler for samples of benthic invertebrates. *Bulletin of the Australian Society of Limnology*, **12**, 49-52.

Metzeling, L., Perriss, S. & Robinson, D. (2006). Can the detection of salinity and habitat simplification gradients using rapid bioassessment of benthic invertebrates be improved through finer taxonomic resolution or alternative indices? *Hydrobiologia*, **572**, 235-252.

Quinn, G.P. & Keough, M.J. (2002) Experimental Design and Data Analysis for Biologists. Cambridge University Press.

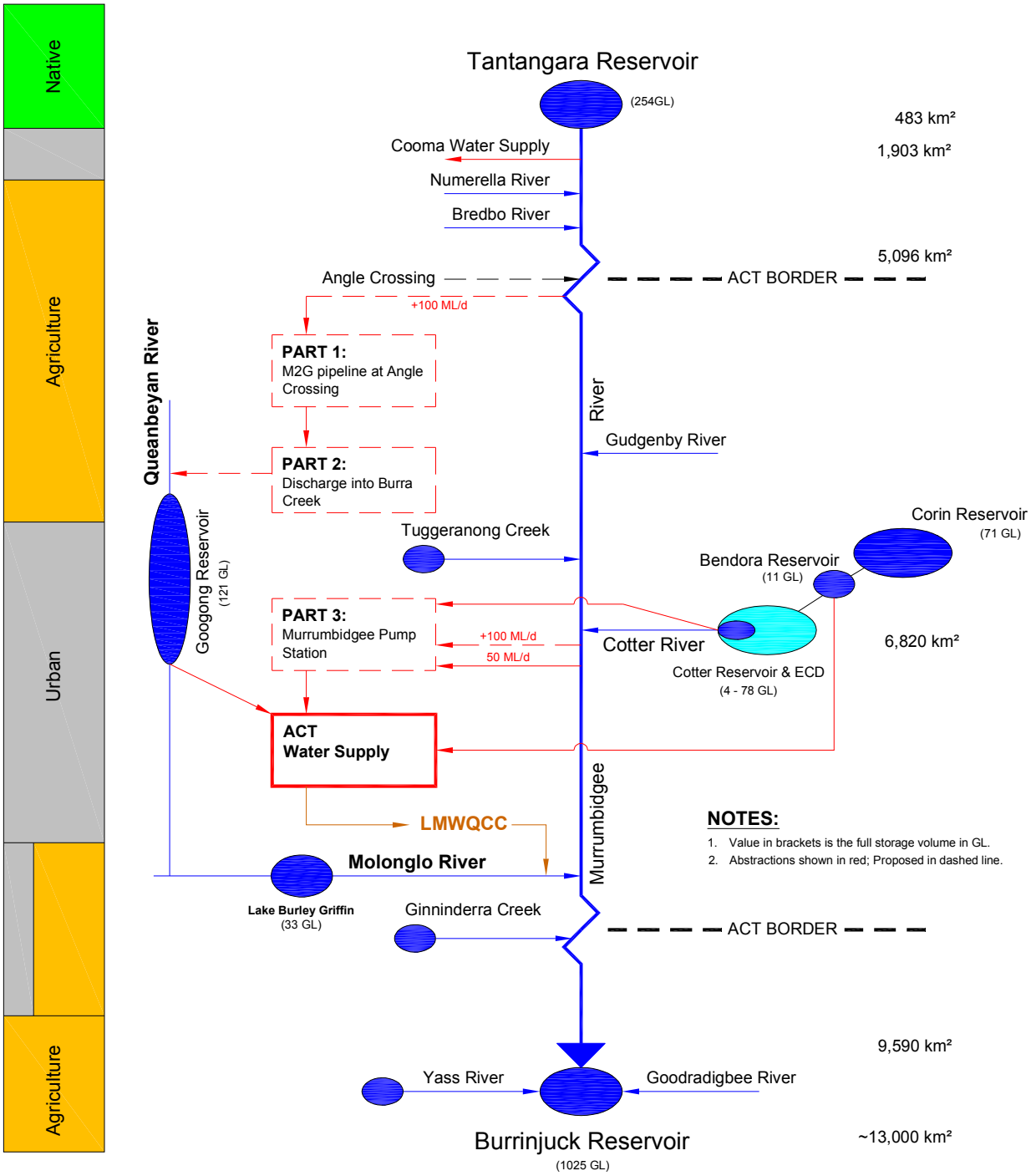
R Development Core Team (2008). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org.

Turak, E. & Waddell, N. (2001). New South Wales (NSW) Australian River Assessment System (AUSRIVAS) Sampling and Processing Manual. http://AUSRIVAS.canberra.edu.au.

Warwick, R.M. (1993). Environmental impact studies on marine communities: Pragmatical considerations. *Australian Journal of Ecology*, **18**, 63-80.

Zweig, L.D. & Rabeni, C.F. (2001). Biomonitoring for deposited sediment using invertebrates: a test on 4 Missouri streams. *Journal of the North American Benthological Society*, **20**, 643-657.

Appendix A –
Schematic representation of the Murrumbidgee Catchment and ACTEW's major water projects


Native
Agriculture
Urban
Agriculture
Tantangara Reservoir
(254GL)
483 km²
Cooma Water Supply
1,903 km²
Numerella River
Bredbo River
5,096 km²
Angle Crossing
ACT BORDER
+100 ML/d
PART 1:
M2G pipeline at Angle Crossing
PART 2:
Discharge into Burra Creek
Queanbeyan River
Googong Reservoir
(121 GL)
River
Gudgenby River
Tuggeranong Creek
Corin Reservoir
(71 GL)
Bendora Reservoir
(11 GL)
PART 3:
Murrumbidgee Pump Station
+100 ML/d
50 ML/d
Cotter River
6,820 km²
Cotter Reservoir & ECD
(4 - 78 GL)
ACT
Water Supply
LMWQCC
Murrumbidgee
NOTES:
1. Value in brackets is the full storage volume in GL.
2. Abstractions shown in red; Proposed in dashed line.
Molonglo River
Lake Burley Griffin
(33 GL)
Ginninderra Creek
ACT BORDER
9,590 km²
Yass River
Goodradigbee River
Burrinjuck Reservoir
(1025 GL)
~13,000 km²

Appendix B –
In-situ water quality results: spring

APPENDIX B: In-situ water quality results for spring 2008. ANZECC guidelines are in bold parentheses. Breaches of guidelines are highlighted yellow.

ZONE	Site	Time	Temp.	EC (µs/cm) **(30-350)**	Turbidity (NTU) **(2-25)**	pH **(6.5-8)**	D.O. (% Sat.) **(90-110)**	D.O. (mg/L)	Alkalinity	NOX (mg/L) **(0.015)**	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	Total Phosphorus (mg/L) **(0.02)**	Total Nitrogen (mg/L) **(0.25)**
Tantangara - Cooma	**MUR 1**	10:15	15	23	2.4	7.3	94.5	9.53	14	<0.01	<0.01	<0.01	<0.01	0.01	0.18
	MUR 2	14:30	15.9	25	2	7.4	102.5	10.15	15	<0.01	<0.01	<0.01	<0.01	<0.01	0.13
	MUR 3	16:45	15.7	30	3.4	7.5	93.2	9.21	17	<0.01	<0.01	<0.01	<0.01	0.02	0.2
	MUR 4	13:45	15.7	28	3.1	7.4	9.31	9.24	16	<0.01	<0.01	<0.01	<0.01	0.1	0.9
Cooma – Angle Crossing	**MUR 6**	16:00	20	38	4.4	7.2	102.4	9.33	19	<0.01	<0.01	<0.01	0.01	0.03	0.5
	MUR 9	10:00	16.7	35	10	7.3	97.4	9.5	19	<0.01	<0.01	<0.01	0.01	0.05	0.28
	MUR 12	09:45	19.9	48	18	7.7	96.4	8.04	24	<0.01	<0.01	<0.01	<0.01	0.05	0.35
	MUR 15	10:50	16.3	49	27	7.7	95.3	9.37	25	<0.01	<0.01	<0.01	<0.01	0.04	0.39
	MUR 18	09:30	16.4	57	27	7.7	95.2	8.66	28	<0.01	<0.01	<0.01	<0.01	0.37	0.34
Angle Crossing – LMWQCC	**MUR 19**	0:800	19	45	29	7.6	94.2	8.71	30	0.01	0.01	0.01	0.01	0.04	0.63
	MUR 22	11:00	18	59	26	7.9	100	9.44	29	<0.01	<0.01	<0.01	0.02	0.04	0.36
	MUR23	12:35	19.8	61	26	7.8	99.1	9.04	30	<0.01	<0.01	<0.01	<0.01	0.05	0.36
	MUR 27	15:00	18	65	32	7.7	92.2	8.7	31	<0.02	<0.01	<0.01	0.04	0.06	0.44
	MUR 28	09:00	18.8	62	47	7.7	92.9	8.7	28	<0.01	<0.01	<0.01	0.01	0.06	0.46
	MUR 29	12:00	20	62	31	7.7	102.9	9.37	30	<0.01	<0.01	<0.01	<0.01	0.05	0.45
	MUR 30	09:15	20.5	64	23	7.7	103.1	9.35	30	<0.01	<0.01	<0.01	<0.01	0.06	0.47
LMWQCC – Taemas Bridge	**MUR 31**	15:30	19.2	300	38	7.7	92.1	8.52	94	1.3	0.6	0.6	6.4	0.29	10
	MUR 34	17:00	21.3	310	11	8	107.5	9.54	90	2.8	2.4	0.44	4.2	0.06	9
	MUR 35	13:30	20	280	13	8	95.6	8.6	73	2.3	2.3	0.03	0.04	0.04	3.1
	MUR 36	12:45	25	260	52	9	129.7	14.19	51	2	2.1	0.15	1.7	0.15	6

Appendix C –

Principal Components Analysis of water quality variables

Appendix C. Principal Components Analysis detailing the eigenvectors and values for the analysis of water quality spot samples: spring 2008.

Principal Component Analysis

Eigenvalues

PC	Eigenvalues	%Variation	Cumulative .%Variation
1	6.08	67.5	67.5
2	1.02	11.3	78.8
3	0.853	9.5	88.3
4	0.4	4.4	92.8
5	0.298	3.3	96.1

Eigenvectors

(Coefficients in the linear combinations of variables making up PC's)

Variable	PC1	PC2	PC3	PC4	PC5
Water temp.	-0.349	-0.117	0.258	0.073	-0.523
EC	-0.386	0.082	-0.178	-0.230	-0.267
pH	-0.332	-0.206	0.418	-0.296	0.210
D.O (% Sat.)	-0.269	0.349	0.686	0.207	0.107
Turbidity	-0.240	-0.769	-0.006	0.292	-0.007
Alkalinity	-0.372	0.033	-0.331	-0.186	-0.348
TP	-0.326	0.168	-0.279	0.764	0.213
TN	-0.356	0.418	-0.191	-0.110	0.068
TOC	-0.342	-0.139	-0.177	-0.307	0.655

Appendix D –

Taxonomic inventory from round one (edge and riffle): spring 2008

Appendix D. Taxonomic inventory of the macroinvertebrate taxa collected in spring round 1 (edge and riffle).

rder	Family	Genus	MUR1	MUR2	MUR3	MUR4	MUR6	MUR9	MUR12	MUR15	MUR18	MUR19	MUR22	MUR23	MUR27	MUR28	MUR29	MUR30	MUR31	MUR34	MUR35	MUR36
			Edge	Edge	Edge	Edge	Edge	Edge	Edge	Edge	Edge	Edge	Edge	Edge	Edge	Edge	Edge	Edge	Edge	Edge	Edge	Edge
Acarina			●			●																
Amphipoda	Ceinidae	Ceinidae				●																
Amphipoda	Talitridae	Talitridae				●																
Bivalvia	Corbiculidae	Corbiculina												●						●		
Bivalvia	Sphaeriidae	Sphaeriidae	●	●										●								
Coleoptera	Curculionidae	Curculionidae																		●		
Coleoptera	Dytiscidae	Platynectes		●	●																	
Coleoptera	Dytiscidae	Rhantus			●															●		
Coleoptera	Dytiscidae	Sternoriscus	●	●																		
Coleoptera	Dytiscidae		●	●			●	●			●	●		●								
Coleoptera	Dytiscidae	Necterosoma					●		●													●
Coleoptera	Dytiscidae	Antiporus	●	●			●	●	●	●	●	●	●	●								
Coleoptera	Gyrinidae														●	●						
Coleoptera	Gyrinidae	Macrogyrus									●			●	●	●	●			●	●	
Coleoptera	Hydraenidae	Hydraena						●		●							●			●	●	
Coleoptera	Hydrochidae	Hydrochus						●														●
Coleoptera	Hydrophilidae	Paranacaena																				
Coleoptera	Hydrophilidae											●							●			●
Coleoptera	Scirtidae		●	●	●			●	●													
Collembola	Collembola																		●	●		●
Cladocera			●				●	●	●	●		●		●			●	●			●	●
Copepoda				●	●		●											●				●
Ostracoda			●		●	●	●	●						●				●				
Decapoda	Atyidae	Paratya	●					●	●	●	●	●			●	●	●		●	●		●
Decapoda	Palaemonidae	Macrobrachium						●			●				●	●	●		●	●		
Decapoda	Parastacidae											●				●	●	●				
Diptera	Ceratopogonidae							●														
Diptera	Ceratopogonidae	Ceratopogoninae	●	●	●		●			●	●		●				●	●	●			
Diptera	Chironomidae									●		●										
Diptera	Chironominae	Dicrotendipes											●		●							
Diptera	Chironominae	Riethia						●						●		●						
Diptera	Chironominae	Tanytarsini															●					
Diptera	Chironominae	Stempellina	●							●	●	●		●	●	●				●	●	
Diptera	Chironominae			●	●			●		●	●	●	●	●	●	●	●	●		●	●	●
Diptera	Chironominae	Polypedilum	●	●	●	●	●	●	●	●	●	●						●		●	●	●
Diptera	Chironominae	Tanytarsus	●		●		●			●	●	●	●	●	●	●	●	●	●		●	
Diptera	Orthocladiinae	Cardiocladius									●	●	●									
Diptera	Orthocladiinae				●	●	●						●	●	●			●		●	●	
Diptera	Orthocladiinae	Cricotopus			●	●	●	●	●		●	●	●	●	●			●		●	●	
Diptera	Simuliidae	Austrosimulium		●	●				●				●	●	●						●	
Diptera	Tanypodi	Pentaneurin	●	●								●	●				●		●			

	nae	i																			
Diptera	Tanypodinae	Ablabesmyia	●	●		●				●			●								
Diptera	Tanypodinae	Procladius	●	●		●		●		●	●					●	●		●		●	
Diptera	Tanypodinae		●	●	●	●				●	●		●			●			●			
Ephemeroptera	Baetidae	Cloeon	●											●								
Ephemeroptera	Baetidae	Centroptilum	●	●		●		●											●	●	●	
Ephemeroptera	Baetidae			●																		
Ephemeroptera	Baetidae		●	●					●			●			●	●						
Ephemeroptera	Caenidae	Wundacaenis																●		●		
Ephemeroptera	Caenidae															●						
Ephemeroptera	Caenidae					●																
Ephemeroptera	Caenidae	Tasmanocoenis	●	●		●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	
Ephemeroptera	Leptophlebiidae	Koorrnonga				●																
Ephemeroptera	Leptophlebiidae			●																	●	
Ephemeroptera	Leptophlebiidae	Austrophlebioides																				
Ephemeroptera	Leptophlebiidae	Ulmerophlebia		●		●																
Ephemeroptera	Leptophlebiidae					●																
Ephemeroptera	Leptophlebiidae	Jappa									●	●			●		●		●			
Ephemeroptera	Leptophlebiidae	Atalophlebia	●	●	●	●	●	●		●	●	●	●	●	●	●	●	●	●	●	●	
Ephemeroptera	Oniscigastridae	Tasmanophlebia				●																
Gastropoda	Ancylidae	Ferrissia								●										●	●	
Gastropoda	Lymnaeidae						●						●			●						
Gastropoda	Lymnaeidae	Pseudosuccinea			●	●																
Gastropoda	Physidae	Physa		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Hemiptera	Corixidae	Micronecta	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Hemiptera	Gerridae	Rheumatometra																	●			
Hemiptera	Mesoveliidae												●								●	
Hemiptera	Notonectidae	Paranisops					●			●												
Hemiptera	Notonectidae	Notonecta								●	●		●						●			
Hemiptera	Notonectidae							●		●	●	●	●					●		●		●
Hemiptera	Veliidae	Drepanovelia	●													●						
Hydracarina	Trombidioidea							●														
Hydracarina	Unionicolidae																		●			
Hydracarina	Unionicolidae		●																			
Hydracarina	Unionicolidae	Unionicola																	●			
Hydracarina	Unionicolidae	Recifella								●								●	●	●		
Lepidoptera	Pyralidae																	●				
Odonata	Aeschnidae	Aeshna		●														●				
Odonata	Aeschnidae																				●	●
Odonata	Coenagrionidae	Pseudagrion																●				
Odonata	Coenagrionidae			●			●	●			●							●		●	●	
Odonata	Coenagrionidae	Ischnura	●	●			●	●	●	●			●					●		●		
Odonata	Epiproctophora		●	●																		
Odonata	Gomphidae	Austrogomphus		●									●				●				●	
Odonata	Lestidae	Austrolestes		●																		
Odonata	Libellulidae	Orthetrum														●						
Odonata	Libellulidae	Nannophlebia			●			●														
Odonata	Protoneuridae	Nososticta																			●	

Odonata	Telephlebiidae	Spinaeschna						●															
Odonata	Telephlebiidae	Austrophlebia				●				●													
Odonata	Zygoptera	Zygoptera																●		●	●	●	
Oligochaeta	Earthworm	Earthworm		●					●														
Oligochaeta	Enchytraeidae	Enchytraeidae																					
Oligochaeta	Lumbriculidae	Lumbriculidae	●		●			●			●	●						●					
Oligochaeta	Naididae	Nais									●												
Oligochaeta	Naididae	Branchiura						●															
Oligochaeta	Naididae	Naidinae		●									●	●									
Oligochaeta	Naididae	Tubificinae									●	●		●	●			●			●		
Oligochaeta	Naididae																	●	●				
Oligochaeta	Oligochaeta	Oligochaeta									●										●		
Oligochaeta	Tubificidae	Branchiura																●					
Plecoptera	Gripopterygidae	Dinotoperla		●	●	●		●		●	●	●	●	●	●								
Trichoptera	Atriplectidae	Atriplectides						●															
Trichoptera	Calamatoceridae	Anisocentropus	●							●													
Trichoptera	Ecnomidae	Ecnomus					●	●	●		●	●	●		●			●	●		●	●	
Trichoptera	Hydrobiosidae	Hydrobiosidae													●								
Trichoptera	Hydrobiosidae	Taschorema				●									●								
Trichoptera	Hydropsychidae	Asmicridea												●	●								
Trichoptera	Hydropsychidae	Cheumatopsyche													●						●		
Trichoptera	Hydroptilidae	Oxyethira												●									
Trichoptera	Hydroptilidae	Hellyethira						●	●	●	●	●						●	●	●	●		
Trichoptera	Leptoceridae	Oecetis										●			●								
Trichoptera	Leptoceridae	Notalina	●	●		●		●				●	●										
Trichoptera	Leptoceridae	Triaenodes		●		●				●	●	●	●							●	●		
Trichoptera	Leptoceridae	Triplectides	●		●	●	●	●	●	●	●	●	●	●	●	●	●		●	●	●		
Turbellaria	Dugesiidae	Dugesiidae									●									●			
		Total number of genera	**31**	**35**	**21**	**27**	**19**	**34**	**16**	**28**	**33**	**31**	**29**	**25**	**26**	**21**	**19**	**29**	**24**	**29**	**31**	**15**	
		Total number of families	**21**	**21**	**17**	**18**	**14**	**26**	**15**	**20**	**21**	**19**	**19**	**19**	**18**	**15**	**15**	**20**	**19**	**23**	**20**	**13**	

Appendix D. Taxonomic inventory of the macroinvertebrate taxa collected in spring round 1 (edge and riffle).

Order	Family	Genus	MUR2	MUR4	MUR12	MUR15	MUR18	MUR19	MUR22	MUR23	MUR27	MUR28	MUR29	MUR30	MUR31	MUR34
			Riffle	Riffle	Riffle	Riffle	Riffle	Riffle	Riffle	Riffle	Riffle	Riffle	Riffle	Riffle	Riffle	Riffle
Acarina				●			●				●			●		
Bivalvia	Corbiculidae	Corbiculina				●	●	●	●	●				●	●	●
Bivalvia	Sphaeriidae	Musculium	●													
Coleoptera	Elmidae	Kingolus		●												
Coleoptera	Elmidae	Stetholus								●						
Coleoptera	Elmidae	Coxelmis												●		●
Coleoptera	Elmidae	Simsonia								●	●					
Coleoptera	Elmidae	Austrolimnius		●					●							
Coleoptera	Elmidae	Elmidae		●					●	●						
Coleoptera	Gyrinidae	Macrogyrus			●	●			●					●		
Coleoptera	Psephenidae	Sclerocyphon	●													
Coleoptera	Scirtidae			●												
Cladocera				●									●	●		●
Copepoda				●	●						●	●	●			●
Ostracoda				●			●	●		●	●	●	●	●	●	●
Diptera	Aphroteniinae	Aphroteniella		●												
Diptera	Ceratopogonidae	Ceratopoginae								●				●		●
Diptera	Chironominae	Cladotanytarsus					●									
Diptera	Chironominae	Microtendipes		●												
Diptera	Chironominae										●					
Diptera	Chironominae	Dicrotendipes		●												
Diptera	Chironominae	Riethia		●							●		●			
Diptera	Chironominae	Tanytarsini complex				●				●					●	
Diptera	Chironominae	Stempellina		●						●	●	●	●	●	●	
Diptera	Chironominae		●	●	●	●		●	●	●	●		●	●	●	●
Diptera	Chironominae	Polypedilum		●		●		●	●		●	●	●	●	●	●
Diptera	Chironominae	Tanytarsus	●	●		●	●			●	●	●	●	●	●	●
Diptera	Dolichopodidae								●							
Diptera	Empididae		●													
Diptera	Orthocladiinae	Parakiefferiella		●		●										
Diptera	Orthocladiinae	Stictocladius		●			●									
Diptera	Orthocladiinae	Botryocladius		●		●	●									
Diptera	Orthocladiinae	Corynoneura		●									●			
Diptera	Orthocladiinae	Cardiocladius		●	●		●	●	●			●	●	●	●	
Diptera	Orthocladiinae			●	●	●		●	●	●	●	●	●	●	●	●
Diptera	Orthocladiinae	Cricotopus	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Diptera	Simuliidae			●	●	●	●	●	●			●	●		●	●
Diptera	Simuliidae	Simulium			●	●	●		●			●			●	●
Diptera	Simuliidae	Austrosimulium	●	●	●	●	●	●	●	●		●	●	●	●	●
Diptera	Tanypodinae	Coelopynia	●													
Diptera	Tanypodinae							●								
Diptera	Tanypodinae	Pentaneurini	●													
Diptera	Tanypodinae	Ablabesmyia	●													
Diptera	Tanypodinae		●	●											●	

Diptera	Tipulidae		●				●	●		●	●	●	●		●	
Ephemeroptera	Baetidae			●	●	●	●	●	●	●						
Ephemeroptera	Baetidae		●	●			●	●	●	●			●	●	●	●
Ephemeroptera	Caenidae						●	●							●	●
Ephemeroptera	Caenidae			●			●		●	●	●		●	●	●	
Ephemeroptera	Caenidae	Tasmanocoenis	●	●	●	●	●	●	●	●	●	●	●		●	●
Ephemeroptera	Coloburiscidae	Coloburiscoides	●	●												
Ephemeroptera	Leptophlebiidae	Austrophlebioides	●	●												
Ephemeroptera	Leptophlebiidae	Ulmerophlebia	●		●	●	●	●							●	
Ephemeroptera	Leptophlebiidae		●	●	●	●	●	●	●	●	●			●	●	●
Ephemeroptera	Leptophlebiidae	Jappa	●		●	●	●		●				●		●	
Ephemeroptera	Leptophlebiidae	Atalophlebia						●			●			●	●	
Gastroopoda	Ancylidae						●									
Gastropoda	Ancylidae	Ferrissia		●			●			●	●					
Gastropoda	Planorbidae															●
Gastropoda										●			●			
Hemiptera	Corixidae	Micronecta						●			●		●			
Hirudinea	Erpobdellidae															●
Hirudinea	Erpobdellidae	Vivabdella												●	●	●
Megaloptera	Corydalidae		●	●												
Megaloptera	Corydalidae	Archichauliodes	●	●												
Odonata	Epiproctophora			●												
Odonata	Gomphidae		●	●												
Odonata	Gomphidae	Hemigomphus	●	●												
Oligochaeta	Earthworm	Earthworm		●	●	●	●	●	●					●		●
Oligochaeta	Enchytraeidae	Enchytraeidae			●										●	
Oligochaeta	Lumbriculidae	Lumbriculidae	●	●			●	●			●		●	●		●
Oligochaeta	Naididae	Branchiura						●							●	
Oligochaeta	Naididae		●	●	●	●	●	●	●	●	●	●	●	●	●	●
Oligochaeta	Oligochaeta	Oligochaeta	●	●	●	●	●	●		●	●	●	●	●		●
Plecoptera	Gripopterygidae	Leptoperla						●								
Plecoptera	Gripopterygidae	Illiesoperla		●			●									
Plecoptera	Gripopterygidae	Eunotoperla	●	●			●			●						
Plecoptera	Gripopterygidae	Dinotoperla		●				●								
Trichoptera	Conoesucidae		●	●												
Trichoptera	Ecnomidae	Daternomina		●												
Trichoptera	Ecnomidae		●	●			●			●	●	●	●			
Trichoptera	Ecnomidae	Ecnomus			●	●			●	●	●	●		●	●	●
Trichoptera	Glossosomatidae	Agapetus	●	●												
Trichoptera	Hydrobiosidae	Hydrobiosidae		●			●	●								
Trichoptera	Hydrobiosidae	Taschorema					●	●			●			●		
Trichoptera	Hydropsychidae	Hydropsychidae														
Trichoptera	Hydropsychidae	Asmicridea		●				●		●	●			●	●	
Trichoptera	Hydropsychidae	Cheumatopsyche	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Trichoptera	Hydroptilidae	Hydroptila											●	●		
Trichoptera	Hydroptilidae	Oxyethira					●	●		●	●		●			●
Trichoptera	Hydroptilidae	Hellyethira														●
Trichoptera	Polycentropodidae	Paranyctiophylax	●													
Trichoptera	Polycentropodidae	Neureclipsis		●	●											

Turbellaria	Dugesiidae	Dugesiidae		●				●		●	●			●	●	
		Total number of genera	**32**	**55**	**21**	**23**	**34**	**32**	**23**	**30**	**29**	**18**	**28**	**30**	**31**	**29**
		Total number of families	**21**	**28**	**12**	**11**	**18**	**16**	**10**	**21**	**16**	**8**	**16**	**20**	**16**	**12**

Appendix E –

Anosim results for riffle and edge Habitats

Appendix F. Analysis of Similarity results for both riffle and edge habitats.

RIFFLE

ANOSIM
Analysis of Similarities

Global Test
Sample statistic (Global R): 0.347
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

Pairwise Tests

Groups	R Statistic	Significance Level %	Possible Permutations	Actual Permutations	Number >= Observed
1, 2	0.865	0.1	5005	999	0
1, 3	0.598	0.1	296010	999	0
1, 4	0.88	0.2	462	462	1
2, 3	0.312	0.1	14307150	999	0
2, 4	0.365	0.3	5005	999	2
3, 4	-0.045	65.7	296010	999	656

EDGE

ANOSIM
Analysis of Similarities

Global Test
Sample statistic (Global R): 0.458
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

Pairwise Tests

Groups	R Statistic	Significance Level %	Possible Permutations	Actual Permutations	Number >= Observed
1, 2	0.595	0.1	17383860	999	0
1, 3	0.637	0.1	354817320	999	0
1, 4	0.583	0.1	1352078	999	0
2, 3	0.27	0.1	Very large	999	0
2, 4	0.408	0.1	17383860	999	0
3, 4	0.366	0.1	354817320	999	0

Appendix F–

Macroinvertebrate taxa expected to occur but missing from riffle and edge habitats (round 2)

Site	Taxa	Sphaeriidae	Oligochaeta	Acarina	Elmidae	Ceratopogonidae	Simuliidae	Tanypodinae	Baetidae	Caenidae	Leptophlebiidae	Glossosomatidae	Gripopterygidae	Leptoceridae	Orthocladiinae	Total number of missing taxa
	Signal score	5	2	6	7	4	5	4	5	4	8	9	8	6	4	
Mur 19	Edge												●			1
Mur 19						●							●			2
Mur 19						●							●			2
Mur 22	Edge					●							●			2
Mur 22									●		●		●			3
Mur 22									●		●		●			3
Mur 23	Edge							●			●		●			3
Mur 23													●			1
Mur 23								●					●			2
Mur 27	Edge								●		●		●			3
Mur 27						●		●	●				●			4
Mur 27						●					●		●			3
Mur 28	Edge								●		●		●			3
Mur 28									●		●		●	●		4
Mur 28									●				●			2
Mur 29	Edge							●			●		●		●	4
Mur 29								●	●		●		●		●	5
Mur 29								●					●		●	3
Mur 30	Edge										●		●			2
Mur 30									●		●		●			3
Mur 30								●			●		●			3
Mur 31	Edge							●	●		●		●		●	5
Mur 31						●		●	●		●		●			5
Mur 31								●	●		●		●			4
Mur 19	Riffle				●	●										2
Mur 19					●								●			2
Mur 19													●			1
Mur 22	Riffle	●											●			2
Mur 22				●									●			2
Mur 22		●		●									●			3
Mur 23	Riffle												●			1
Mur 23				●									●			2
Mur 23		●		●		●	●						●			4
Mur 27	Riffle					●	●	●	●				●			5
Mur 27					●		●	●	●		●		●			6
Mur 27						●			●				●			3
Mur 28	Riffle											●	●			2
Mur 28												●	●			2
Mur 28													●			1
Mur 29	Riffle	●		●			●		●				●			5
Mur 29		●		●	●			●	●				●			6
Mur 29								●	●				●			3
Mur 30	Riffle		●					●	●	●	●		●			6
Mur 30								●	●				●			3
Mur 30				●					●		●		●			4
Mur 31	Riffle	●		●	●	●							●			5
Mur 31		●			●	●		●					●			5
Mur 31		●		●	●	●							●			5