ACTEW Water

Murrumbidgee Ecological Monitoring Programme
Spring 2012

May 2013

Executive summary

The Murrumbidgee Ecological Monitoring Programme (MEMP) commenced in 2008. The project is being undertaken by the GHD Water Sciences Group for ACTEW Water to establish baseline river data prior to the commissioning of, and during initial operation of, the Murrumbidgee to Googong (M2G) transfer project and the Murrumbidgee Pump Station. Collectively, there are four component areas being considered under the MEMP:

Part 1 - Angle Crossing

ACTEW Water has constructed an additional pumping intake structure and pipeline to abstract water from the Murrumbidgee River near Angle Crossing (southern border of the ACT). The system is designed to pump up to 100 ML/d, and was completed in August 2012;

Part 2 - Burra Creek

This component of the ecological monitoring programme aims to establish the baseline river condition prior to water discharges into Burra Creek over a three year period and then to continue monitoring after the commencement of the operation phase of the M2G project to determine what changes, if any, are attributable to water discharges from the Murrumbidgee River into Burra Creek;

Part 3 - Murrumbidgee Pump Station

The Murrumbidgee Pump Station (MPS) is located just downstream of the Cotter River confluence with the Murrumbidgee River. The Murrumbidgee Pump Station has undergone a significant upgrade which increased its pumping capacity to Stromlo Water Treatment plant from 50ML/d to approximately 150ML/d. The framework for this programme responds primarily to the ACTEW water abstraction licence reporting requirements. Water abstraction at the MPS, requires an assessment of the response of the river through monitoring methods that can quantify subtle impacts;

Part 4 - Tantangara to Burrinjuck

One of the project options put forward was the "Tantangara transfer" which involves transferring water from the Tantangara Reservoir on the upper Murrumbidgee River to the ACT via run of river flow, and then abstracting the water and transferring it to the Googong Reservoir via M2G. This provides a source of water that is less dependent on rainfall within the ACT.

The key results from the spring 2012 sampling run are summarised below:

Part 1 - Angle Crossing

Prior to the spring sampling run, a high flow event peaking at 9,100 ML/d scoured much of the macrophyte growth that had previously been noted and there was some evidence of fresh sand deposits in the edge habitat and silt removal in the riffle habitat. pH and nutrient values exceeded the ANZECC guidelines at the majority of sites and although this can be attributed to preceding high flow event, these values are within the range of values that are regularly recorded in this part of the catchment.

There was no evidence from the periphyton data of a location effect, suggesting that local environmental or geomorphological conditions, as opposed to factors relating to the M2G are driving these patterns. The AUSRIVAS model showed mixed results across the Angle Crossing sites. There were incidences of increases and decreases in the overall health assessments; however these were not specific to either the upstream or downstream locations suggesting site specific processes at work rather than being specifically driven by the abstractions at Angle Crossing. The majority of high flow events occur over the winter and spring months in the upper Murrumbidgee Catchments, although large events have occurred in summer in recent times. Based on data collected in 2009 during a particularly dry period, it is expected that changes in water quality may occur when flows are < 80 ML/d for prolonged periods. Under current conditions, it is expected that low flows such as these are likely to occur in autumn and summer, which is when local water demands are highest. Furthermore, we predict that abstractions occurring in winter and spring would be unlikely to have any long term effects on water quality, periphyton communities or macroinvertebrate populations because during these months water abstractions are likely to be low proportional to base flows.

It is recommended that autumn sampling be undertaken to target flows following the next operational period of M2G. In this way, the influence of naturally occurring hydrological disturbances may be minimised resulting in more robust estimates of water quality and biological responses to the water abstractions. The recommended approach would be to collect autumn data once, prior to scheduled releases and then again after the release(s). Comparisons post release to previous autumn sampling periods would be one option; however this approach we believe would not provide the same degree of rigour as the full approach involving the before and after method.

Part 2 - Burra Creek

Commissioning of M2G began in late August and a full test of the ramp up / ramp down pumping regime occurred in September. The water quality and biological results from this round of sampling were collected approximately 6 weeks after the final release in September and approximately 3 weeks after a natural high flow event in October. The result show that continuous water quality parameters responded in similar ways to natural high flow events of similar magnitudes. In the case of EC and pH this led to values within the guidelines and higher compliance during the release periods compared to periods of normal base flow.

Periphyton results showed elevated chlorophyll-a concentrations directly downstream of Williamsdale Bridge. This elevation in chlorophyll-a has been linked to nutrient in-flow from Holden Creek in autumn 2102 and therefore is not likely to be related to the M2G discharge. The AUSRIVAS and macroinvertebrate community analysis results from the spring 2012 sampling run show some evidence of ecological health improvements at two of the sites downstream of the discharge point, however these improvements were not unique to sites downstream of the discharge point as there were similar patterns was seen at the Queanbeyan control site and upstream of the discharge point in Burra Creek. This suggests that the main driver was the high flow event in mid-October, which is likely to have improved habitat conditions and resulted in improved AUSRIVAS bands.

This sampling run was the first to have occurred following a full test of the M2G infrastructure, these initial results suggest that changes to water quality are short lived, and resemble natural high flow events. However, Burra Creek is subject to high spatial and temporal discontinuities in flow, resulting in highly variable and patchy macroinvertebrate assemblage, highly seasonal fluctuations in water characteristics; and although there is a high degree of resilience of the macroinvertebrate fauna in Burra Creek the ability to recover will depend on the duration and frequency of these releases and these will in turn vary from season to season. It is therefore recommended that autumn sampling should occur as soon as possible following any scheduled releases. Ideally this would occur three to four weeks after the next full ramp up/ramp down schedule and will avoid natural high flow events. While this is out of our control, additional sampling events within a given season would provide a better understanding of short term responses while sampling at longer intervals would provide information on the longer term responses in Burra Creek.

Part 3 - Murrumbidgee Pump Station

Water quality was generally within the guidelines during spring 2012, with the exceptions being pH and nutrient concentrations. Elevated pH was recorded at all MPS sites and is the highest recorded at these locations since the inception of the MEMP. While elevated nutrients levels are a result of inputs located upstream of the study area. Periphyton varied considerably amongst sites and there was no evidence of location differences in these data. The AUSRIVAS model determined al sites as Band-B, "significantly impaired," which is consistent with all previous sampling events. There was some evidence of different macroinvertebrate community structures between upstream and downstream locations. These differences are largely due to increased abundances of black fly larvae downstream of the MPS, although it should be noted that this taxa was present at both locations. The increased abundance is probably related to increased flows from the Cotter River (i.e. the ECD) and Bendora Scour Valve being released from prior to sample collection rather than the operation of the MPS.

It is recommended that the pumping schedule and Cotter Dam release schedule are made available to GHD to allow field schedules to be planned outside of the Scour Value operation and releases from the Cotter Dam. This will allow more accurate assessments of the MPS operation outside of these additional factors.

Part 4 - Tantangara to Burrinjuck

As reported for the other components of the MEMP, pH and nutrient data were frequently outside of the guideline values for ecological health. Zone 1 sites exhibited the best water quality overall, however the water quality recorded in Zone 2 and 3 was degraded compared to previous sampling runs. Differences were detected in the macroinvertebrate community between sites but trends across the Zones were less obvious and difficult to interpret. However, there were some familiar patterns in the taxa between zones. As was observed in previous sampling events, larger numbers of Hydropsychidae and Simuliidae were observed at Zone 3 and Zone 4 sites because of their preference for faster flows and their tolerance to slight nutrient enrichment. Similarly, sensitive taxa such as Gripopterygidae were observed at Zone 1 sites presumably due to the improved water quality within this region.

AUSRIVAS bands were generally comparable or higher to those found in previous sampling runs and although richness is only moderate, the proportion of EPT (sensitive) taxa was generally fairly high. There is no evidence to indicate that the water abstraction has had a negative impact on the macroinvertebrate community of the Murrumbidgee River. However, the recent high flow event in the catchment may have concealed any impacts (positive or negative) that may have eventuated from the abstractions at Angle Crossing. The same set of recommendations that were made for the Angle Crossing study applies to this component of the MEMP.

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Table of contents

Table Index

Figure Index

Appendices

List of abbreviations

ACT	Australian Capital Territory
ACTEW	ACTEW Corporation Limited
AFDM	Ash Free Dry Mass (periphyton)
ALS	Australian Laboratory Services
ANOSIM	Analysis of similarities (statistics)
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
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
M2G	Murrumbidgee to Googong
MEMP	Murrumbidgee Ecological Monitoring Programme
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
PERMANOVA	PERMutational Multiple Analysis Of Variance
QA	Quality Assurance
QC	Quality Control
OCD	Oligochaeta, Chironomidae and other Diptera
SIMPER	Similarity Percentages
TN	Total Nitrogen
TP	Total Phosphorus

1. Introduction

During the recent drought period in the Australian Capital Territory (ACT) and surrounding regions of New South Wales (NSW), the ACT's dam storage volumes declined to unprecedented levels. ACTEW Corporation, the major water utility company in the ACT, developed a water security programme that involved building additional; and upgrading existing infrastructure to improve the future water supply security for the residents of Canberra and Queanbeyan (see APPENDIX A for a schematic representation of these projects).

The water security projects include:

1. Murrumbidgee to Googong transfer pipeline (M2G): from Angle Crossing just within the ACT's southern border to Burra Creek in the Googong Dam catchment, at up to 100ML/d;
2. Murrumbidgee Pump Station (MPS): adjacent to the existing Cotter Pump station to increase pump capacity from ~50ML/d to 150ML/d (nominally 100ML/d);
3. Tantangara Reservoir release for run of river flow to the M2G abstraction point at Angle Crossing, and;
4. A new 78GL Cotter Dam called the Enlarged Cotter Dam (ECD) just downstream of the existing 4 GL Cotter Dam.

The Murrumbidgee Ecological Monitoring Programme (MEMP) was set up by ACTEW Water to evaluate the potential impacts of water abstraction from the Murrumbidgee River. It was designed to address concerns raised by both Government and non-Government stakeholders; and to provide ACTEW Water with relevant information regarding any beneficial and/or detrimental ecological effects of the project. The MEMP was implemented prior to the commencement of the M2G project, allowing ACTEW Water to collect pre-abstraction baseline data to compare against the post-abstraction data once the M2G project is in operation. Pre-operational sampling has been conducted in spring and autumn each year since 2008.

There are four component areas being considered as part of the MEMP[1]:

- Part 1: Angle Crossing (M2G);
- Part 2: Burra Creek (M2G);
- Part 3: Murrumbidgee Pump Station (MPS) and;
- Part 4: Tantangara to Burrinjuck (Tantangara Transfer).

[1] Note that the MEMP does not include monitoring related to the Enlarged Cotter Dam (point 4 in section 1).

1.1 Background of major projects

1.1.1 Parts 1 and 2 - Murrumbidgee to Googong transfer pipeline (M2G)

The Murrumbidgee to Googong transfer incorporates **Part 1** (Angle Crossing) and **Part 2** (Burra Creek).

The pumping system at Angle Crossing will transfer water from the Murrumbidgee River through a 12km underground pipeline into Burra Creek. The water will then be transported a further 13km by run of river flows into the Googong Reservoir. Water abstraction from the Angle Crossing pump station will be dictated by the Googong Reservoir's capacity and by the availability of water in the Murrumbidgee River. The system is designed to enable pumping of up to 100 ML/d, and construction was completed in August 2012. Abstraction from the Murrumbidgee River and the subsequent discharges to Burra Creek will be dictated by the Operational Environment Management Plan - (OEMP).

During periods of low flow (whether climate related or artificially induced), impacts upon aquatic environments can be measured using surrogate indices based on changes to macroinvertebrate communities, such as changes in species richness, abundances and community structure. Such changes can result either directly through invertebrate drift, or indirectly through reductions in habitat diversity or flow conditions which do not suit certain taxa. Dewson, *et al.* (2007) reported that certain macroinvertebrate taxa are especially sensitive to reductions in flow and can be useful indicators in flow restoration assessments and can assist in longer term management of flows in regulated river systems. It is possible that there will be changes to the aquatic ecosystem within the Murrumbidgee River as a result of M2G, specifically the water abstractions downstream of Angle Crossing. 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 (see APPENDIX B for examples). This current monitoring program will form the basis of an Ecological Monitoring Program to satisfy EIS requirements for the M2G Project.

In light of the natural low flow conditions in Burra Creek compared to the maximum pumping rate of 100 ML/d, it is expected that the increased flow due to the discharge from the Murrumbidgee River may have several impacts on water quality, channel and bank geomorphology and the ecology of the system. Some beneficial ecological effects might occur in the reaches of Burra Creek between the discharge point (just upstream of Williamsdale Road) to downstream of the confluence of the Queanbeyan River.

These may include, but are not limited to:

- The main channel being more frequently used by fish species due to increased flow permanence and longitudinal connectivity between pools;
- Increased biodiversity in macroinvertebrate communities; and
- A reduction in the extent of macrophyte encroachment in the Burra Creek main channel.

On the other hand, there is potential for the transfer of Murrumbidgee River water into Burra Creek to adversely affect the natural biodiversity within Burra Creek due to the different physico-chemical characteristics of water in each system (particularly with regards to EC). Furthermore, the inter-basin water transfer also poses a risk of spreading exotic plant and fish species which could displace native biota directly through competition or indirectly through the spread of disease. Other potential impacts are highlighted in Table 1-1.

1.1.2 Part 3 - Murrumbidgee Pump Station (MPS)

The Murrumbidgee Pump Station (MPS) is located just downstream of the Cotter River confluence with the Murrumbidgee River. It is adjacent to the Cotter Pump Station which can abstract up to 100 ML/d, contributing to the water supply for the ACT. New infrastructure has increased the abstraction amount from the Murrumbidgee River to approximately 150 ML/d via the MPS. The upgraded infrastructure also provides a recirculating flow from the Murrumbidgee to the base of the Enlarged Cotter Dam (ECD), providing environmental flows to the lower Cotter Reach below the dam especially during the construction of the ECD. This project is referred to as Murrumbidgee to Cotter (M2C) transfer. The MEMP project does not aim to monitor the effects of the M2C transfer, but rather provides a characterisation of the Murrumbidgee River condition upstream and downstream of the MPS.

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

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

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

1.1.3 Part 4 -Tantangara Reservoir release for run of river flow to the M2G abstraction point at Angle Crossing

One of the new water security projects put forward was the "Tantangara transfer" which will involve transferring water from the Tantangara Reservoir in the upper Murrumbidgee River to the ACT via run of river flow, with the aim of providing a source of water that is less dependent on rainfall within the ACT. As previously mentioned, abstraction will be dictated by the storage level in Googong reservoir, the level of demand for the water, the availability of water in the Murrumbidgee River allowing for environmental flow requirements, and by the water quality trigger values.

Table 1-1 Potential impacts to Burra Creek following Murrumbidgee River discharges

Property	Possible impact	Source
Water Quality	Increased turbidity from Murrumbidgee water which could decrease light penetration, resulting in lower macrophyte and algal growth.	Martin and Rutlidge (2009)
	The inter-basin transfers (IBT) of soft Murrumbidgee water into the harder water of Burra Creek may change the natural biodiversity within Burra Creek.	Fraser (2009)
	Changes in water temperature could be expected from the IBT and increased turbidity. This may affect plant growth, nutrient uptake and dissolved oxygen levels and ultimately compromise the quality of fish habitat.	Martin and Rutlidge (2009)
Ecology	Changes in macroinvertebrate communities and diversity through habitat loss from sedimentation, riparian vegetation and scouring of macrophytes. Changes in macroinvertebrates are also expected with an increase of flow (e.g. increased abundances of flow dependant taxa).	Bunn and Arthington (2002)
	Potential risk of exotic species recruitment from IBT, this could displace native species in the catchment and pose a risk of the spread of disease.	Martin and Rutlidge (2009); Davies *et al.* (1992)
	Infilling from fine sediment transport could threaten the quality of the hyporheic zone, which provides important habitat for macroinvertebrates in temporary streams.	Brunke and Gonser (1997)
	Increased flow with improved longitudinal connectivity which will potentially provide fish with more breeding opportunities and range expansion, although this will be dependent on the flow regime.	Martin and Rutlidge (2009)
Bank Geomorphology	Bank failure from the initial construction phase and first releases. This could result in increased sedimentation, loss of riparian vegetation and increased erosion rates from bank instability.	Skinner (2009)
Channel Geomorphology	Scouring of the river bed may result in a loss of emergent and submerged macrophyte species. This would result in a reduction of river bed stability and a change in macroinvertebrate diversity and dynamics.	Harrod (1964)

1.2 Environmental flows and the 80:90 percentile rule

The environmental flow rules for the Murrumbidgee to Googong project (M2G) have been adopted from the framework outlined in the Environmental Flow Guidelines (ACT Government, 2006).

Under the current licence agreement (ACTEW's Licence to take water, 2012), flows in the Murrumbidgee River at the Cotter Pump Station must be maintained at 20ML/d during any stage of water restrictions (www.actew.com.au). When these restrictions do not apply, flows must be maintained at the 80th or 90th percentile flow, depending on the time of year. The 80:90 rule has been applied to hydrological modelling of the Murrumbidgee River at Angle Crossing for the M2G operational plan; and was based on data collected from the Lobb's Hole gauging station. Specifically the 80th percentile flow applies from November to May and the 90th percentile from June through to October (Figure 1-1).

As can be seen from the figure above, the lowest flows in the Murrumbidgee River occur in summer and autumn. The 80th percentile flows from November to May are less than the 90th percentile flows except for November. It is during these low flow months that abstraction from the Murrumbidgee River is likely to have the most significant impact, as the proportion of the abstraction rate to the base flow is the greatest.

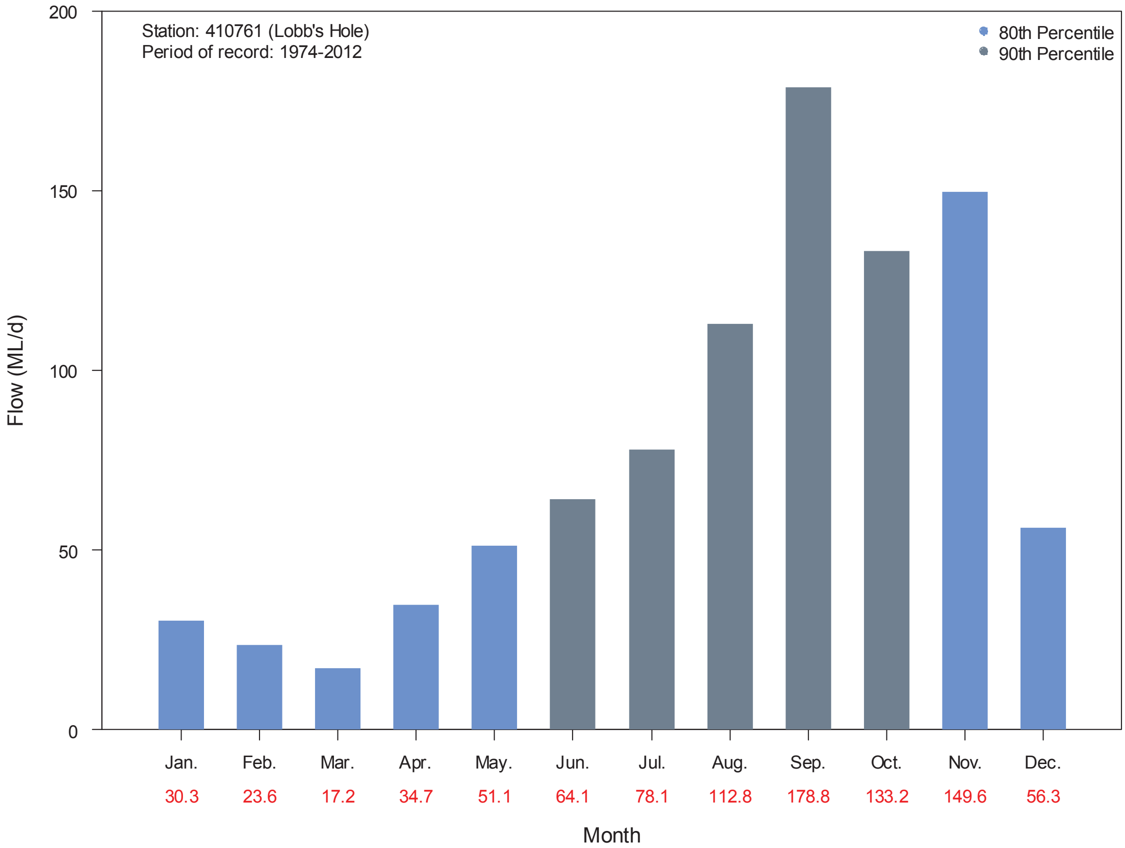

Figure 1-1 Environmental flow values for the operation of the M2G project

Note: Flow data are current to 31/12/2012. Monthly values in red are megalitres per day (ML/d) and are based on continuous daily flow data from the Lobb's Hole gauging station (410761) since its commencement of operation in 1974.

1.3 The Upper Murrumbidgee River

The Murrumbidgee River flows for 1600 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. Land use is dominated by urbanisation between Point Hut Crossing and the North Western suburbs of Canberra near the confluence with the Molonglo River. The major contributing urbanised tributary flowing into the Murrumbidgee River is Tuggeranong Creek which enters the Murrumbidgee River downstream of Point Hut crossing.

Annual rainfall in the Upper Murrumbidgee River catchment ranges from greater than 1400 mm in the mountains, to 620 mm at Canberra airport (B.O.M, 2012).

Prior to spring 2010, drought was the most significant impact on catchment quality within the upper Murrumbidgee catchments in recent times. During this period, more than 80% of catchments had been drought-affected since late 2002. Some of the effects of this were drought-induced land degradation increased stress on surface and groundwater resources, increased soil erosion and a shift from mixed farming and cropping, to grazing and reduced stock numbers. Since the spring of 2010, the drought broke in the ACT and surrounding NSW regions, with more frequent high flow events occurring throughout that year and an upward trend in the monthly average base flows (Figure 1-2).

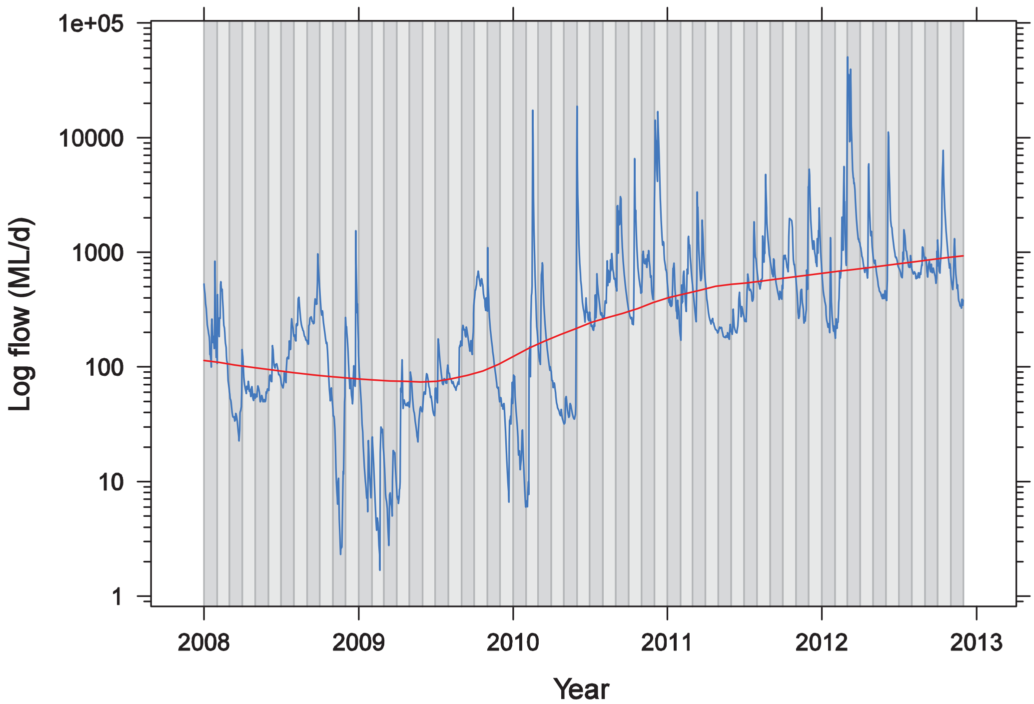

Figure 1-2 Hydrograph of the Murrumbidgee River at Lobb's Hole (410761) from 2008 to 30th November 2012*

**The red line is locally weighted smoother (LOWESS) trend line with a smoothing function coefficient of 0.5.*

1.4 Burra Creek

Burra Creek is a small intermittent stream which flows north to north-east along the western edge of the Tinderry Range into Googong Reservoir. The majority of its catchment is pastoral and small rural holdings with the Tinderry Range being natural dry sclerophyll forest. Burra Creek is characterised by emergent and submergent macrophyte beds with limestone bedrock and frequent pool-riffle sequences throughout its length. During low periods the main channel is commonly choked with *Typha sp.* The creek is within a wider eroded channel in the lower section upstream and downstream of the London Bridge (natural limestone arch). When Googong Reservoir is >80% the lower sections of Burra Creek become inundated by the reservoir.

The mean daily flow in Burra Creek (from January 1st 2008 to the 31st December 2012) was 10.3 ML/d - slightly higher from the previous sampling period due to the operation of the M2G pipeline in August and September.

Since flow records began in 1985 a mean monthly flow of 100 ML/d has been exceeded 8 times, while flows in excess of 100 ML/d have occurred less than 2 % (1.68%) of the time on a daily basis.

Flow conditions have varied considerably since the inception of the MEMP in late 2008 (Figure 1-3). In 2008 mean daily flow was 0.15ML/d and this was followed by an equally dry year in 2009 when the mean daily flow was 0.18 ML/d. In early 2010 there were a few rainfall events and this pattern continued throughout most of the year resulting in an upward trend of daily mean flows, which reached 23.4 ML/d. 2011 was a moderately dry year and mean flows fell back to less than 5 ML/d until March 2012 which saw another period of large rainfall events. These resulted in another upward trend in average flows until early spring (Figure 1-3).

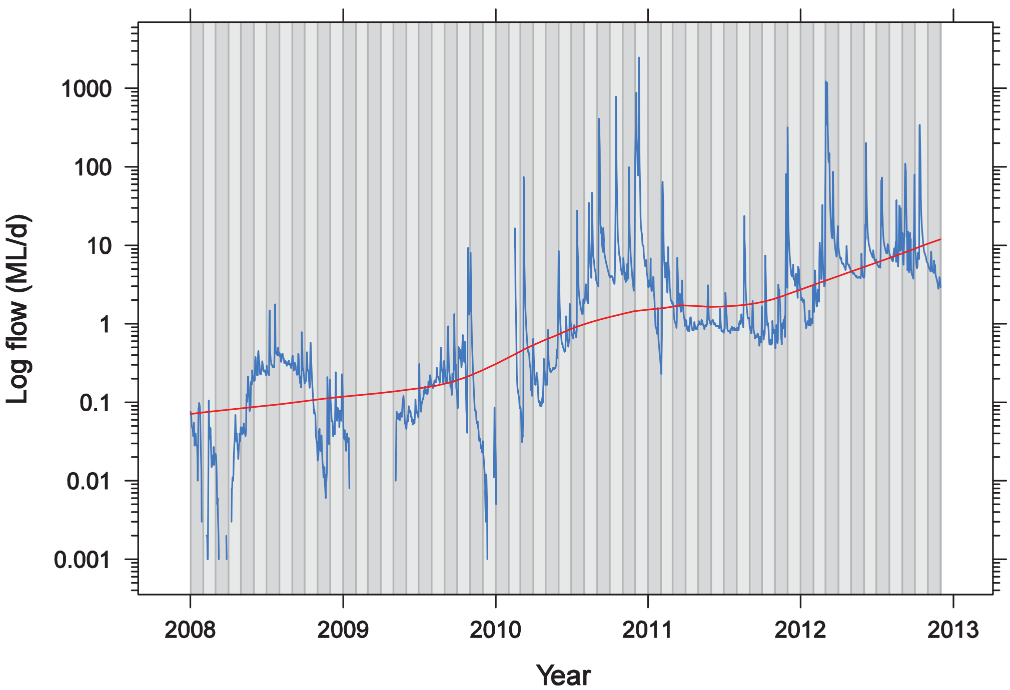

Figure 1-3 Hydrograph of Burra Creek (410774) from 2008 to 30th November 2012*

**The red line is locally weighted smoother (LOWESS) trend line with a smoothing function coefficient of 0.5.*

1.5 Project objectives

The Murrumbidgee Ecological Monitoring Programme (MEMP) was set up by ACTEW Water to evaluate the potential impacts of water abstraction from the Murrumbidgee River and the subsequent changes that might occur in Burra Creek as a result of the M2G project (Parts 1 and 2). Part 3 of the project assesses the condition of the Murrumbidgee River in terms of water quality and ecological condition at key sites both upstream and downstream of Murrumbidgee Pump Station (MPS) to assess potential impacts related to the increase in abstraction from the upgraded infrastructure; and Part 4 of the MEMP (Tantangara to Burrinjuck) assesses the physical, biological and water quality indicators along the length of the upper Murrumbidgee River from Tantangara to Burrinjuck reservoirs.

Increasing water abstractions from the Murrumbidgee River could have several impacts on water quality, riparian vegetation, riverine geomorphology and the aquatic ecology of the system. Some beneficial ecological effects could be expected in the reaches downstream of Tantangara Reservoir and in Burra Creek (downstream of the discharge point) under the proposed flow release regime, including increased habitat availability for native fish species. The increased flow in those locations is also likely to favour flow dependent macroinvertebrates and improve surface water quality.

The key aims of the MEMP are:

- to determine whether or not, and to what extent, abstraction from Murrumbidgee River is affecting the maintenance of healthy aquatic ecosystems within the river or impacting Burra Creek, in terms of biological communities;
- to determine whether or not, and to what extent, abstraction of water at Angle Crossing is impacting riverine habitat through changes in sediment movement;
- to determine whether or not, and to what extent, abstraction of water at Angle Crossing is impacting riverine habitat through changes in flow;
- to establish baseline information regarding water quality, the structure of macroinvertebrate communities, and ecosystem health throughout the upper Murrumbidgee catchment;
- to establish baseline and operational information on water quality and stream flow, macroinvertebrate communities, fish, riverine vegetation and geomorphology, relating to aquatic systems impacted by the water abstraction and discharge (M2G);
- to monitor water quality between Tantangara and Burrinjuck Reservoirs, and also within Burra Creek, to establish normal annual and seasonal variation so that any changes resulting from the operations of abstraction and release are identified.

These potential impacts have been assessed by the relevant Government authorities through submission of Environmental Impact Statements (EIS) or similar assessments. One of the components of the EIS is to undertake an ecological monitoring programme, on which this programme is based.

The frequency, monitoring locations and resolution of the monitoring on the Murrumbidgee River and Burra Creek will differ between the components as changes occur at different spatial and temporal scales. This monitoring programme is designed to be adaptive. Through the reporting of data and results, liaison with the client and technical advisory groups, it may be decided that certain monitoring methodologies need to be changed or adapted to enhance the outcomes of the program. However, with these procedures in place, GHD will be able to provide ACTEW Water with appropriate information to further develop knowledge and understanding of environmental flows and ecosystem thresholds. The information derived from this programme will also support ACTEW Waters' adaptive management approach to water abstraction and environmental flow provision in the ACT. Frequent review of the MEMP will ensure that the monitoring has the capacity to adapt to changing environmental, social and economic conditions with regard to ACTEW Water's operational requirements.

1.6 Scope of work

1.6.1 Parts 1-3: Angle Crossing; Burra Creek and MPS

The current ecological health of the sites monitored as part of the MEMP 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 2012 sampling. Specifically, as outlined in the MEMP proposal to ACTEW Corporation (GHD, 2012) this work includes:

- Sampling conducted in spring 2012;
- 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 the Australian Laboratory Services (ALS) Canberra NATA accredited laboratory.

1.6.2 Part 4: Tantangara to Burrinjuck

Several sites within this component of the MEMP are also key components of Parts 1-3 of this monitoring programme. The sampling regime for this component of the MEMP differs slightly to those reported in section 1.6.1. These differences are:

- Macroinvertebrate samples were not collected with replication (i.e. 1 per site and per habitat);
- Macroinvertebrate samples are counted and identified to the taxonomic level of family;
- Periphyton samples are not collected as part of this component of the project.

In order to compare data from the Tantangara to Burrinjuck study to those collected as part of other study components, the first sub-sample from the first replicate macroinvertebrate sample taken at each site from those other studies was selected for inclusion in the data analysis. As a result of this process, it should be recognised that there are small discrepancies between the taxonomic inventories, taxonomic richness measurements and presence / absence of taxa reported here and those reported in relation to other sub-sections of the MEMP.

1.7 Rationale for using biological indicators

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

Periphyton is the matted floral and microbial community that resides on the river bed. The composition of these communities is dominated by algae but the term periphyton also includes fungal and bacterial matter (Biggs and Kilroy, 2000). Periphyton is important to maintaining healthy freshwater ecosystems as it absorbs nutrients from the water, adds oxygen to the ecosystem via photosynthesis, and provides a food for higher order animals. Periphyton communities respond rapidly to changes in water quality, light penetration of the water column and other disturbances, such as floods or low flow, and this makes them valuable indicators 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 (Whitton and Kelly, 1995).

Water abstractions from Angle Crossing will not affect the timing or magnitude of higher flows, but could affect conditions during the seasonal low flow period, such as increasing the nutrient availability through increased residence time, reducing scouring impacts on benthic organisms 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

Prior to the sampling, comprehensive site assessments were carried out, including assessments of safety, suitability and access permission from landowners. There are no suitable reference sites in the proximity for the MEMP, so a Before – After / Control – Impact (BACI) design (Downes *et al.*, 2002) was adopted based on sites upstream of the abstraction point serving as 'Control' sites and sites downstream of the abstraction / construction point serving as 'Impacted' sites.

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 they are the most likely to be affected by abstractions;
- Sites which have historical ecological data sets (eg. 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 programme 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. The MEMP consists of 29 sites which meet these criteria. Details of these sites are given in Table 2-1 and are shown in Figure 2-1.

As the MEMP is separated by various components due to the large geographic and ecological scale of the project, some of the sites used in one component do overlap with sites used in a different component. Sampling sites were divided into four zones for Part 4 (Tantangara to Burrinjuck), which represent geographic or hydrological changes throughout the system (Allan and Castillo, 2008); and obvious changes in land use, 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. Frissell *et al*., 1986; Hynes, 1970; Allan and Castillo, 2008). Details of the four zones are provided in Table 2-2.

Macroinvertebrate community composition, periphyton assemblages and water quality were monitored from sites on the Murrumbidgee River, Burra Creek and the Queanbeyan River with the aim of obtaining baseline ecological condition information following the ANZECC guidelines for ecological monitoring (ANZECC & ARMCANZ, 2000).

Aquatic macroinvertebrates were sampled from two habitats (riffle and pool edges) and organisms identified to genus level (where practical) for Parts 1-3, and family level for part 4, to characterise each site. Periphyton was sampled in the riffle habitat at each site (Part 4 excluded) and analysed for chlorophyll-a and Ash Free Dry Mass (AFDM) to provide estimates of the algal (autotrophic) biomass and total organic mass respectively based on the methods of Biggs and Kilroy (2000).

Table 2-1 Sampling site locations and details

Site Code	Location	Alt. (m)	Landuse	Component of the MEMP	Latitude	Longitude
MUR 1	D/S Tantangara Reservoir	1200	Native	TB	**-35.799448**	**148.676497**
MUR 2	Yaouk Bridge	1070	Grazing	TB	**-35.826235**	**148.803273**
MUR 3	Bobeyan Road Bridge	968	Grazing	TB	**-35.980250**	**148.840200**
MUR 4	Camp ground off Bobyon Road	968	Recreation / Grazing	TB	**-35.980217**	**148.892800**
MUR 6	D/S STP Pilot Creek Road	743	Native / Residential	TB	**-36.163200**	**149.095317**
MUR 9	Murrells Crossing	723	Grazing	TB	**-36.109433**	**149.124983**
MUR 12	Through Bredbo township	698	Grazing / Residential / Recreation /Sand mining	TB	**-35.956233**	**149.129217**
MUR 15	Near Colinton - Bumbalong Road	658	Grazing / Recreation	AC / TB	**-35.866300**	**149.135017**
MUR 16	The Willows - Near Michelago	646	Grazing / Recreation	AC / TB	**-35.688033**	**149.136867**
MUR 18	U/S Angle Crossing	608	Grazing	AC / TB	**-35.587542**	**149.109902**
MUR 19	D/S Angle Crossing	608	Grazing / Recreation	AC / TB	**-35.583027**	**149.109486**
MUR 22	Tharwa Bridge	572	Recreation / Grazing / Residential	TB	**-35.508217**	**149.070700**
MUR 23	Point Hut Crossing	561	Recreation / Residential	AC /TB	**-35.451317**	**149.074400**
MUR 27	Kambah Pool	519	Recreation / Residential	TB	**-35.393317**	**149.009767**
MUR 931	"Fairvale" ~4km U/S of the Cotter Confluence	480	Grazing	MPS / TB	**-35.372883**	**148.991050**
MUR 28	U/S Cotter River confluence	468	Grazing	AC / MPS / TB	**-35.324382**	**148.950381**
MUR 935	Casuarina sands	471	Grazing	MPS / TB	**-35.319483**	**148.951667**
MUR 937	Mt. MacDonald ~5km D/S of the Cotter Confluence	460	Grazing / ex-forestry/ Recreation	MPS / TB	**-35.291817**	**148.9569**
MUR 29	Uriarra Crossing	445	Grazing	MPS / TB	**-35.242983**	**148.952133**
MUR 30	U/S Molonglo Confluence	445	Grazing	TB	**-35.239784**	**148.962613**
MUR 31	D/S Molonglo Confluence	443	Grazing	TB	**-35.237050**	**148.974792**
MUR 34	Halls Crossing	393	Grazing	TB	**-35.131550**	**148.944083**
MUR 37	Boambolo	372	Grazing / Sand mining	TB	**-35.034217**	**148.896317**
BUR 1a	Upper Burra Creek	815	Native	Burra Creek	**-35.598461**	**149.228868**
BUR 1c	Upstream Williamsdale Road	762	Grazing / residential	Burra Creek	**-35.556511**	**149.221238**
BUR 2a	Downstream Williamsdale Road	760	Grazing	Burra Creek	**-35.554345**	**149.224477**
BUR 2b	Downstream Burra Road Bridge	751	Woodland / Grazing	Burra Creek	**-35.541985**	**149.230407**
BUR 2c	Approximately 1km u/s London Bridge	730	Recreational / Grazing	Burra Creek	**-35.517894**	**149.261452**
QBYN 1	Flynn's Crossing	685	Recreational / Native	Burra Creek	**-35.524317**	**149.303300**

Notes: AC = Angle Crossing; BC = Burra Creek; MPS = Murrumbidgee Pump Station; TB = Tantangara to Burrinjuck

Table 2-2 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. Agricultural land downstream of Yaouk.
Cooma – Angle Crossing	2	MUR 6-18	Land use is mainly for agriculture. Some urbanisation. STP upstream of MUR 6.
Angle Crossing – LMWQCC	3	MUR 19 - 30	Residential and urban development increases.
LMWQCC – Taemas Bridge	4	MUR 31 - 37	Intensive agricultural land use downstream of the LMWQCC. Distinct changes in water quality profile downstream of the Molonglo River confluence.

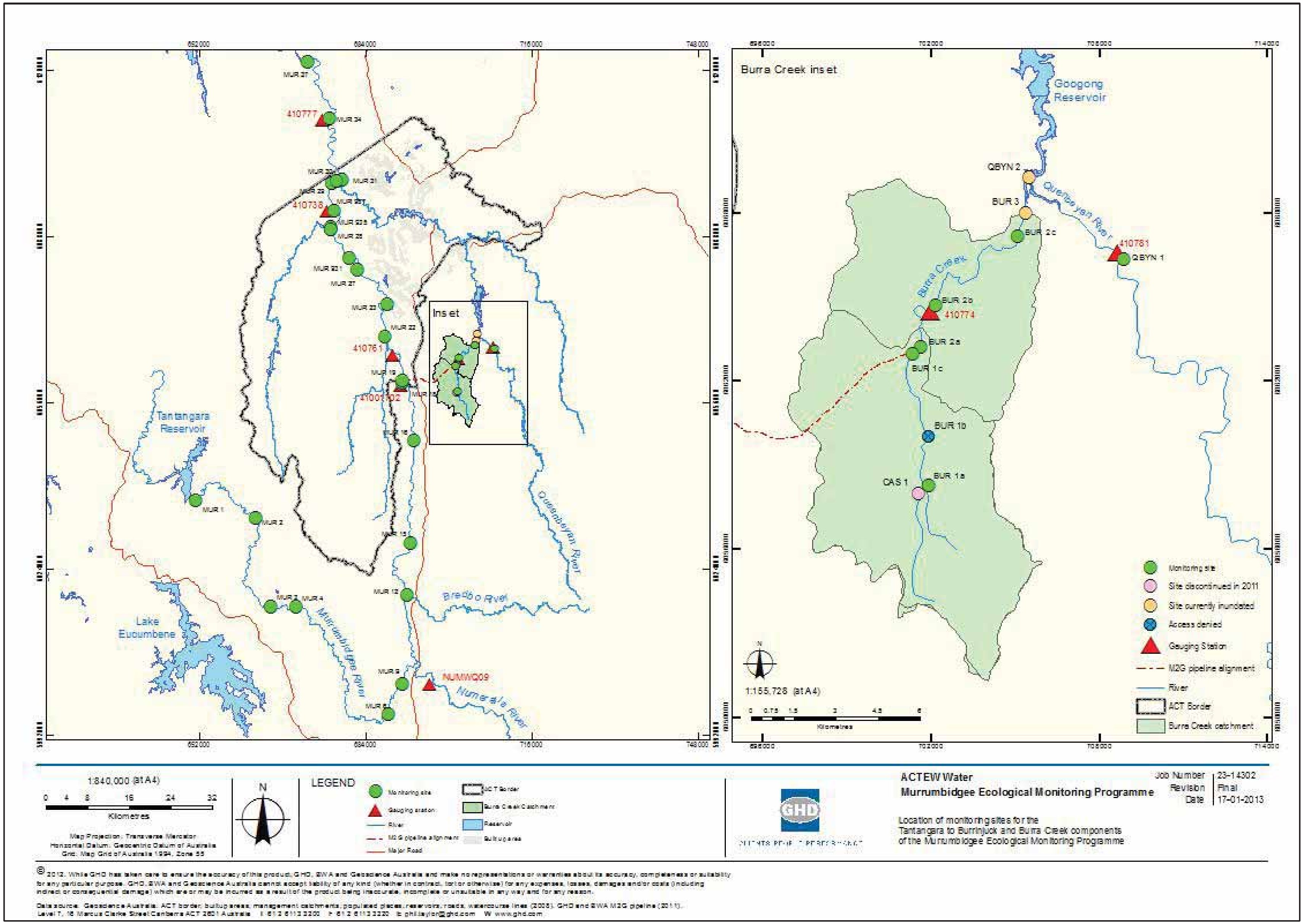

Figure 2-1 Map of site locations on the Murrumbidgee River, Burra Creek and the Queanbeyan River for the MEMP

2.2 Hydrology and rainfall

River flows and rainfall for the sampling period were recorded at ALS operated gauging stations located: upstream of Angle Crossing (41000270); at Lobb's Hole (downstream of Angle Crossing: 410761); at Mount MacDonald (downstream of the Cotter River confluence: 410738), Halls Crossing (at MUR 34: 410777), Burra Creek (upstream of BUR 2b: 410774) and the Queanbeyan River (upstream of Googong Reservoir: 410781). A list of parameters measured at each station is given in Table 2-3. Stations were calibrated according to ALS protocols and data were downloaded and verified before quality coding and storage in the ALS database. Water level data was manually verified by comparing the logger value to the physical staff gauge value and adjusted if required. Rain gauges were also calibrated and adjusted as required. Records were stored using the HYDSTRA© database management system.

Table 2-3 River flow monitoring locations and parameters

Site Code	Location/Notes	Parameters*	Latitude∞	Longitude	Component of the MEMP
41001720	M'bidgee River, upstream of Angle Crossing	WL, Q, pH, EC, DO, Temp, Turb, Rainfall	-35.5914	149.1204	AC, TB
410761	M'bidgee River @ Lobb's Hole (D/S of Angle Crossing)	WL, Q, pH, EC, DO, Temp, Turb, Rainfall	-35.5398	149.1001	AC, MPS, TB
410738	M'bidgee River @ Mt. MacDonald	WL, Q	-35.2916	148.9552	MPS, TB
410777	M'bidgee River @ Hall's Crossing	WL, Q, pH, EC, DO, Temp, Turb, Rainfall	-35.1327	148.9425	TB
410774	Burra Creek road bridge	WL, Q, pH, EC, DO, Temp, Turb, Rainfall	-35.5425	149.2279	BC
410781	Queanbeyan River US of Googong Reservoir	WL, Q, pH, EC, DO, Temp, Turb, Rainfall	-35.5222	149.3005	BC

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

∞ WSG 84

2.3 Water quality

Baseline 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 2-1. 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.*, 2000) for Hydrolab verification and nutrient analysis. All samples were placed on ice, returned to the ALS Canberra 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 was used to 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.

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.*, 2000) and potentially allow the programme to isolate flow-related impacts from other disturbances. The reasoning behind this is that each habitat is likely to be affected 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 using the ACT AUSRIVAS (Australian River Assessment System) protocols outlined in Coysh, *et al*. (2000). The sampling nets and all other associated equipment were washed thoroughly between habitats, sites and sampling events to remove any macroinvertebrates retained on them.

Two replicate samples[2] were collected from each of the two habitats (edge and riffle - where available) at most sites in autumn. Sampling of the riffle habitat involved using a framed net with 250 µm mesh size. Sampling began at the downstream end of each riffle, with the net held perpendicular to the substrate and the opening facing upstream. The stream bed directly upstream of the net opening was agitated by vigorous kicking, allowing dislodged invertebrates to be carried into the net by the current. The process continued, working upstream over ten metres of riffle habitat.

The edge habitat sample was collected by sweeping the collection n*et al*ong the edge of the creek line at the sampling site, with the operator working systematically over a ten metre section covering all microhabitats such as overhanging vegetation, submerged snags, macrophyte beds, overhanging banks and areas with trailing vegetation.

The bulk samples were placed in separate containers, preserved with 70% ethanol, and clearly labelled inside and out with project information, site code, date, habitat, and sampler details.

Processing of the aquatic macroinvertebrate bulk samples followed the ACT AUSRIVAS protocols. In the laboratory, each preserved macroinvertebrate sample was placed in a sub-sampler, comprising of 100 (10 X 10) cells (Marchant, 1989). The sub-sampler was then agitated to evenly distribute the sample, and the contents of randomly selected cells were removed and examined under a dissecting microscope until a minimum of 200 animals were counted. All animals within the selected cells were identified.

In order to provide additional replication within the experimental design, laboratory processing of each sample was repeated 3 times[3] to total up to 6 samples per habitat per site (2 field replicates x 3 laboratory processed replicates). Macroinvertebrates were identified to genus level (where possible) using taxonomic keys outlined in Hawking (2000) and later publications. 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.

[2] Note that only one sample per habitat type was collected for Part 4 of the MEMP
[3] No replication of sub samples was carried out for Part 4 of the MEMP

2.5 Periphyton

Estimates of algal biomass were made using complementary data from both chlorophyll-a (which measures autotrophic biomass) and ash free dry mass (AFDM, which estimates the total organic matter in periphyton samples and includes the biomass of bacteria, fungi, small fauna and detritus in samples) measurements. All periphyton (i.e. adnate and loose forms of periphyton, as well as organic/inorganic detritus in the periphyton matrix) samples were collected using the in situ syringe method similar to Loeb (1981), and as described in Biggs and Kilroy (2000)[4]. A one metre wide transect was established across riffles at each site. Along each transect, twelve samples were collected at regular intervals, using a sampling device consisting of two 60 ml syringes and a scrubbing surface of stiff nylon bristles, covering an area of ~637 mm^2.

The samples were divided randomly into two groups of six samples to be analysed for Ash Free Dry Mass (AFDM) and chlorophyll-a. Samples for Ash Free Dry Mass and chlorophyll-a analysis were filtered onto glass filters and frozen. Sample processing followed the methods outlined in APHA (2005). Qualitative assessments of the estimated substrate coverage by periphyton and filamentous green algae were also conducted at each site in accordance with the AUSRIVAS habitat assessment protocols (Nichols *et al.*, 2000)(Nichols *et al.*, 2000) to compliment the quantitative samples.

2.6 Macroinvertebrate quality control

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

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

All procedures were performed by AUSRIVAS accredited staff.

2.7 Licences and permits

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

All GHD field staff holds current AUSRIVAS accreditation.

[4] Periphyton is not collected for Part 4 of the MEMP

3. Data analysis

Data were analysed using both univariate and multivariate techniques. Analyses were performed in PRIMER v6 (Clarke and Gorley, 2006) and R version 2.15.2 (R Development Core Team, 2011). Descriptive statistics performed on rainfall, hydrology and continuous water quality parameters were organised in the time series data management software - HYDSTRA©.

3.1 Water quality

Water quality parameters were examined for compliance with ANZECC water guidelines for healthy ecosystems in upland streams (ANZECC and ARMCANZ, 2000). This report presents results based on spring 2012 sampling.

A Principal Components Analysis (PCA) was conducted to determine the combination of physical/chemical variables that most strongly contributes to differences between Zones. From the available environmental variables, DO (mg/L) and TSS were omitted as these variables were strongly correlated with DO (% saturation) and turbidity, respectively. The variables TKN and Nitrite were also omitted as Nitrogen levels were better represented by Total Nitrogen. Draftsman plots were used in PRIMER to determine which data transformation, if any, should be applied to the environmental variables. Draftsman plots were examined for raw data (i.e. no transformation) and data which had square root, fourth root and log (x+1) transformations applied. Based on these plots, all data were left in their raw form except for Ammonia, Total Nitrogen and NOx which were subjected to fourth root transformation. Measurements of Ammonia that were at the limits of reporting (LOR) were divided by two (2) before inclusion in the PCA. However, interpretation of the PCA in relation to ammonia must be made with caution since there is no differentiation between the LOR values which falsely indicates a similarity between these sites.

3.2 Macroinvertebrate communities

3.2.1 Univariate analysis

The univariate techniques performed on the macroinvertebrate data include:

- Taxa Richness and EPT taxa index (richness and relative abundance)
- SIGNAL-2 Biotic Index , and:
- ACT AUSRIVAS O/E scores and bandings.

3.2.1.1 Taxa richness

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, Chironomids and other Diptera) 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 may, though 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.

3.2.1.2 SIGNAL-2

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).to these assigned bandwidths to aid the interpretation of each site assessment. The SIGNAL index is then calculated as the average grade number for all families present in the sample. The resulting index score can then be interpreted by comparison with reference and/or control sites. These grades have been improved and standard errors applied under the SIGNAL-2 model approach developed by Chessman (2003). These changes were introduced to improve the reliability of the SIGNAL index. The variation in the above univariate indices between location ('upstream' versus 'downstream' site groups) and also individual sites was assessed using analysis of variance (ANOVA) methods.

3.2.1.3 AUSRIVAS

In addition to assessing the composition and calculating biometrics from the macroinvertebrate data, riffle and edge samples, river health assessments based on the ACT AUSRIVAS Autumn 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 cannot 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 3-1) which are used to gauge the overall health of particular site (Coysh *et al*. 2000). Data are 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 (Table 3-1).

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*., 2000). 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.

3.2.1.4 Univariate analysis techniques

We conducted linear mixed effects ANOVA models separately for the riffle and edge samples to test for location differences in the univariate metrics: SIGNAL-2 scores and AUSRIVAS O/E 50 ratios. The factor, “site” (nested within location) was considered a random effect 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. Models were constructed using lme4 (Bates *et al*., 2011) a statistical package applied in the R environment (R Development Core Team, 2011). For all analyses, the level of significance (alpha) was set to 5%.

3.2.2 Multivariate analysis

The initial step in this process was to calculate a similarity matrix for all pairs of samples based on the Bray-Curtis similarity coefficient (Clarke and Warwick, 2001). For the macroinvertebrate data collected during this survey, the final number of dimensions was reduced to two.

Non-metric multidimensional scaling (NMDS) ordination was performed to reduce dimensionality of the macroinvertebrate data in order to provide a visual representation of the macroinvertebrate relationships between sites and locations. Within the NMDS plot, sites closer together indicate that the macroinvertebrate communities are more similar to one another than sites further apart in the ordination space. In other words, NMDS reduces the dimensionality of the data by describing trends in the joint occurrence of taxa. This procedure was performed on the macroinvertebrate community data following the initial cluster-analysis.

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 values near zero suggest that NMDS patterns are very representative of the multidimensional data, while stress values greater than 0.2 indicate a poor representation and, therefore, the need to interpret NMDS plots with these sorts of stress values with caution (Clarke and Warwick, 2001).

An Analysis Of Similarities test (ANOSIM) was performed on the macroinvertebrate similarity matrix to test whether macroinvertebrate communities were statistically different between upstream and downstream locations. Sites were nested within location for the analysis (Parts 1-3 only). 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 and Warwick, 2001). This process was also used to determine which taxa characterised particular groups of sites.

All multivariate analyses were performed using PRIMER version 6 (Clarke and Gorley, 2006) Univariate statistics were performed using R version 2.15.2 (R Development Core Team, 2012).

Table 3-1 AUSRIVAS band-widths and interpretations for the ACT spring edge and riffle models

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

3.3 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, analysis of variance was fitted to the Log-transformed data for AFDM and Chlorophyll-a. The factor “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 model. Log-transformation was necessary to meet the assumptions of normality. For the purposes of graphical visualisation; however, raw data are presented.

Part 1 - Angle Crossing

4. Angle Crossing

4.1 Summary of sampling and river condition

The monitoring sites were sampled on the 7th, 12th and 14th of November. Heavy rainfall on the 7th of November meant that a delay was unavoidable due to rising river levels.

Conditions were variable, with fine spells turning to persistent rain at times. Temperature ranged from 13°C to 21°C during this period. Murrumbidgee River flow was consistently dropping for the sampling period, with a small increase resulting from the rainfall event that occurred on the 7th of November while we were sampling MUR 19.

Photos of the sampling sites are shown in Plate 4-1, and full site summaries are shown in APPENDIX D.

One edge sample was missed at MUR 28 because access to the edge slightly upstream of the riffle zone was made difficult under the flow conditions. Sampling of MUR 15 was conducted at the specified location as opposed to the contingency site used in autumn 2012 due to high flows during that period.

MUR 15. Looking upstream from the riffle towards the edge habitat

MUR 16. Looking upstream

MUR 18. Looking upstream

MUR 19. Looking across the riffle habitat towards the M2G intake structure

MUR 23. Riffle habitat looking upstream

MUR 28. Looking downstream towards the MPS

Plate 4-1 Photographs of the sampling sites for the Angle Crossing component of the MEMP

4.2 Hydrology and rainfall

Total rainfall in spring 2012 was 165 mm, which was the lowest recorded spring total since 2009 (Figure 4-1; Table 4-1). September rainfall was slightly above the historical average of 56.6 mm, while both October and November were below the historical average of 65.4 mm and 74.9 mm respectively. The flow and rainfall summaries for the upstream Angle Crossing and Lobb's Hole gauging stations are located in Table 4-1

Base flows of 600-800 ML/d characterised surface flow conditions in early spring 2012. In the second week of October, a high flow event peaking at approximately 9,000 ML/d occurred; and because of the long recession time of this event, sampling was delayed by a week. A second event, occurring at the beginning of the second week of November prevented sampling from resuming at the Angle Crossing sites until the 14th of November.

Commissioning of M2G began in late August 2012 and continued throughout September, and the final spring releases occurred in the last week of September. The hydrograph in Figure 4-2 also identifies reductions in flow during August and September when commissioning of M2G was taking place. These abstractions are identifiable by small sharp decreases in flow at Lobb's Hole, relative to the upstream Angle Crossing station (41001702). Full capacity pumping of the M2G on the 10^{th} of September reduced flows in the Murrumbidgee River by approximately 12%. The hydrograph includes August to show the period when M2G commissioning begun.

Archived data is currently not available for analyses from the gauging station at upstream Angle Crossing due to the ongoing access issues to the site which prevents monthly calibrations.

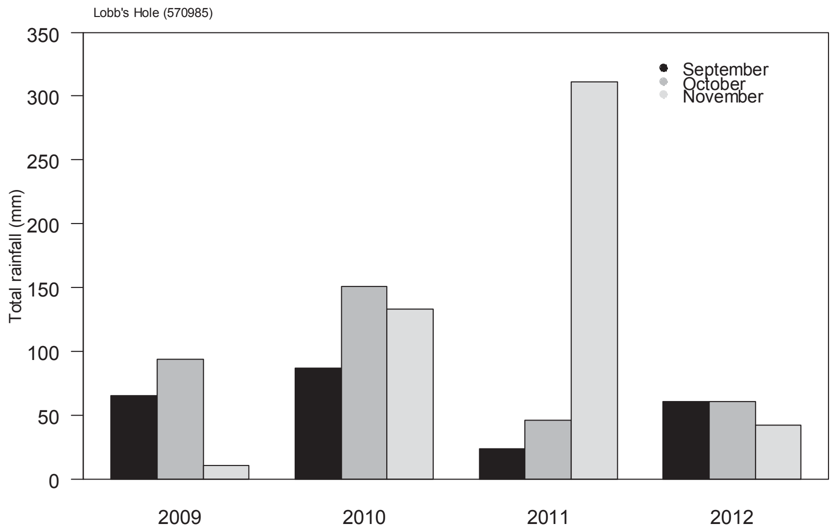

Figure 4-1 Annual comparisons of spring rainfall (mm) recorded at Lobb's Hole (570985)

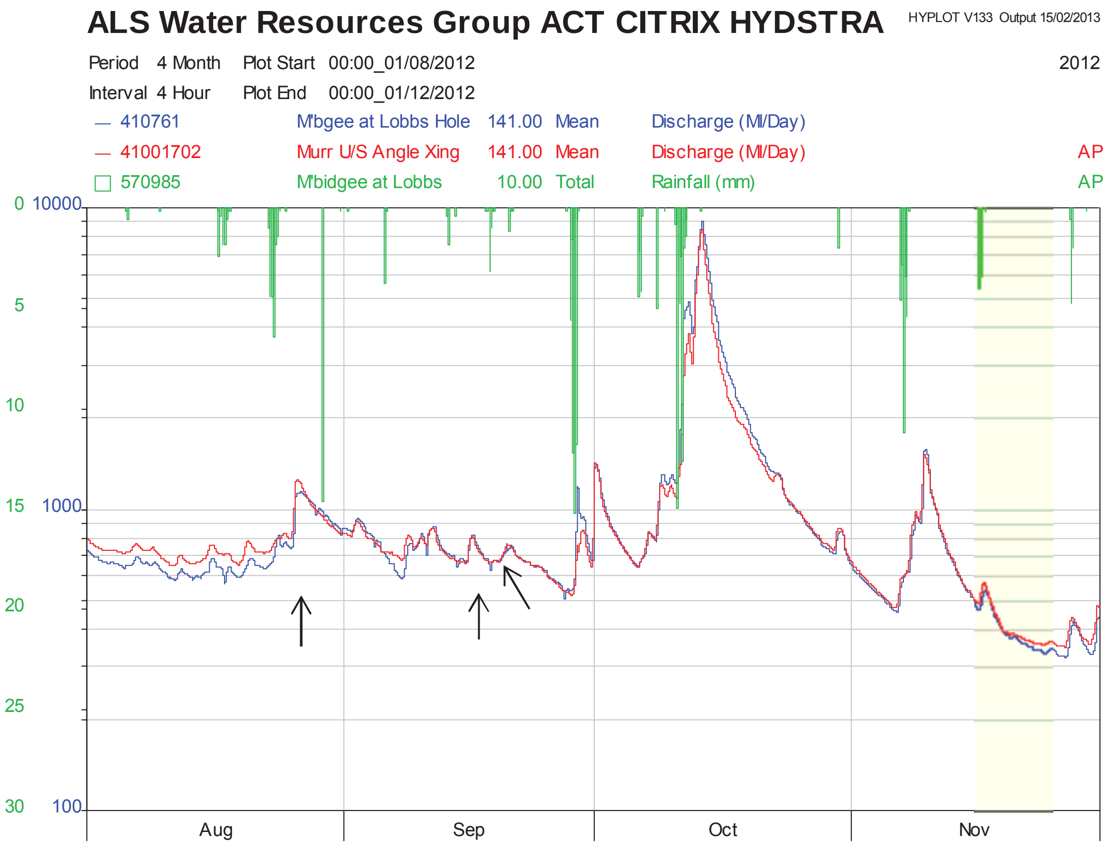

Figure 4-2 Spring hydrograph of the Murrumbidgee River upstream of Angle Crossing (41001702) and downstream of Angle Crossing at Lobb's Hole (410761)*

Notes: 1) Green shading indicates sampling period

* Arrows indicate Murrumbidgee River water extractions

Table 4-1 Spring rainfall and flow summaries upstream and downstream of Angle Crossing

	Upstream Angle Crossing (41000270)		Lobb's Hole (410761)	
	Rainfall Total (mm)	Mean Flow (ML/d)	Rainfall Total (mm)	Mean Flow (ML/d)
September	48.8	716	60.8	724
October	69.8	1,690	61.4	1,870
November	44.6	559	42.8	541
Spring (mean)	**163.2 (54.40)**	**988**	**165.0 (55.0)**	**1045**

4.3 Water quality

4.3.1 Grab samples and *in-situ* parameters

The results from the lab analysed grab samples and the *in-situ* measured parameters are presented in Table 4-2. Water temperature ranged from 18.6°C at MUR 16 to 20.5°C at MUR 19. Electrical conductivity (EC) and turbidity were within the ANZECC & ARMCANZ (2000) guidelines at all sites. The pH values showed no longitudinal pattern with MUR 16, 18, 19 & 28 exceeding the ANZECC & ARMCANZ (2000) guidelines.

Dissolved oxygen (DO) was also below the recommended lower limit at MUR 15, 16, 18 & 23 with a range of 84.1% saturation (at MUR 23) to 101.5% sat. at MUR 28.

Nutrient concentrations exceeded the guideline trigger values at all sampling sites in spring 2012 (Table 4-2). NO_X values were below the ANZECC & ARMCANZ (2000) guideline levels at all sites, while total phosphorus (TP) levels exceeded the guidelines trigger levels at all sites. Total nitrogen (TN) levels also exceeded the guidelines at all sites with the exception of MUR 23. These nutrient levels are comparable with those from the spring 2011 results where all sites exceeded both the TP and TN guidelines.

4.3.2 Continuous water quality monitoring

Water quality parameters from the gauging stations at upstream Angle Crossing (41001702) and Lobb's Hole (410761) are presented in Figures 4.3 & 4.4 and Table 4-3.

The comparison of the gauging station parameters between gauging stations upstream and downstream of Angle Crossing does not indicate any location differences driven by M2G operations.

Table 4-4 shows that daily means were within the ANZECC and ARMCANZ (2000) guidelines a larger percentage of the time at the downstream gauging station (Lobb's Hole) when compared to the upstream gauging station.

Table 4-3 shows the monthly water quality summaries for both upstream Angle Crossing and Lobb's Hole monitoring stations. Electrical conductivity and dissolved oxygen were within ANZECC & ARMCANZ (2000) guidelines 100% of the spring period (based on daily means) (Table 4-4). pH was outside the upper limit of the guidelines for extended periods in November. Turbidity values were mostly within guideline boundaries at Lobb's Hole during spring, with values at upstream Angle Crossing outside the guidelines for the whole period.

Table 4-2 In-situ water quality results from Angle Crossing during spring 2012

ANZECC guidelines are in red bold parentheses, yellow cells indicate values outside of ANZECC and ARMCANZ (2000) guidelines

	Site	Date	Time	Temp. (°C)	EC (µs/cm) (30-350)	Turbidity (NTU) (2-25)	TSS mg/L	pH (6.5-8)	D.O.(% Sat.) (90-110)	D.O. (mg/L)	Alkalinity (mg/L)	NO_x (mg/L) (0.015)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L) (0.02)	TN (mg/L) (0.25)
Upstream	MUR 15	7/11/2012	10:30	19.7	113.3	12.7	18	7.81	84.9	7.74	47	0.002	< 0.001	< 0.002	< 0.002	0.040	0.28
	MUR 16	12/11/2012	10:15	18.6	117.8	10.8	11	8.15	88.2	8.25	46	0.003	0.001	< 0.002	0.003	0.031	0.31
	MUR 18	12/11/2012	12:45	19.9	112.9	12.7	13	8.05	87.2	7.94	45	0.003	0.001	< 0.002	0.004	0.034	0.30
Downstream	MUR 19	12/11/2012	14:20	20.5	114.0	12.7	11	8.07	91.0	8.17	45	0.003	0.001	< 0.002	0.005	0.032	0.30
	MUR 23	7/11/2012	15:10	19.9	125.7	8.6	11	7.82	84.1	7.66	52	0.002	< 0.001	< 0.002	< 0.002	0.022	0.23
	MUR 28	14/11/2012	09:35	19.9	130.8	13.0	10	8.16	101.5	9.26	51	0.003	0.001	< 0.002	< 0.002	0.026	0.33

Table 4-3 Monthly water quality statistics from upstream (41001702) and downstream (410761) of Angle Crossing

Analyte	Temp. °C		EC (uS/cm) (30-350)		pH (6.5-8.0)		Turbidity (NTU) (2-25)		D.O. (% sat.) (90-110)	
Location	U/S[1]	D/S	U/S	D/S	U/S	D/S	U/S[2]	D/S	U/S[3]	D/S
September	12.0	12.1	81.5	128	7.98	7.78	90.7 (163)	6.06 (23.7)	96.3-101.5	93.1-96.2
October	15.3	15.5	80.0	124	7.92	7.88	253 (443)	16.5 (66.1)	95.2-101.8	93.5-96.5
November	20.3	20.5	90.2	133	7.96	8.19	124 (375)	10.4 (44.0)	94.2-103.0	91.8-95.3
Spring	**15.9**	**16.0**	**83.9**	**128**	**7.95**	**7.95**	**156**	**11.0**	**95.2-102.1**	**92.8-96.0**

NOTES:

1) All values are means, except dissolved oxygen (% saturation) which is expressed as mean monthly minimums and maximums. Maximum values for turbidity are in parentheses. ANZECC & ARMCANZ (2000) guidelines are in red parentheses**.**

2) U/S – upstream; D/S – downstream; [1] does not include 1 day in October; [2] does not include 1 day in September; [3] does not include 1 day in October

Table 4-4 Compliance (%) to ANZECC & ARMCANZ (2000) guideline values from the continuous gauging stations upstream (41001702) and downstream (410761) of Angle Crossing

Analyte	EC (us/cm)		pH		Turbidity (NTU)		D.O. (% sat.)	
Location	U/S*	D/S	U/S*	D/S	U/S*	D/S	U/S*	D/S
September	100	100	60	93.5	0	100	100	100
October	100	100	67.7	100	0	80.6	100	100
November	100	100	60	0	0	86.7	100	100
Spring	**100**	**100**	**62.6**	**64.5**	**0**	**89.1**	**100**	**100**

NOTES:

1) There are currently no guidelines for water temperature.

2) Compliance values are expressed as the percentage of days throughout the autumn period (based on daily means) that values met the guidelines.

* Data are not validated upstream of Angle Crossing due to ongoing issues with site access.

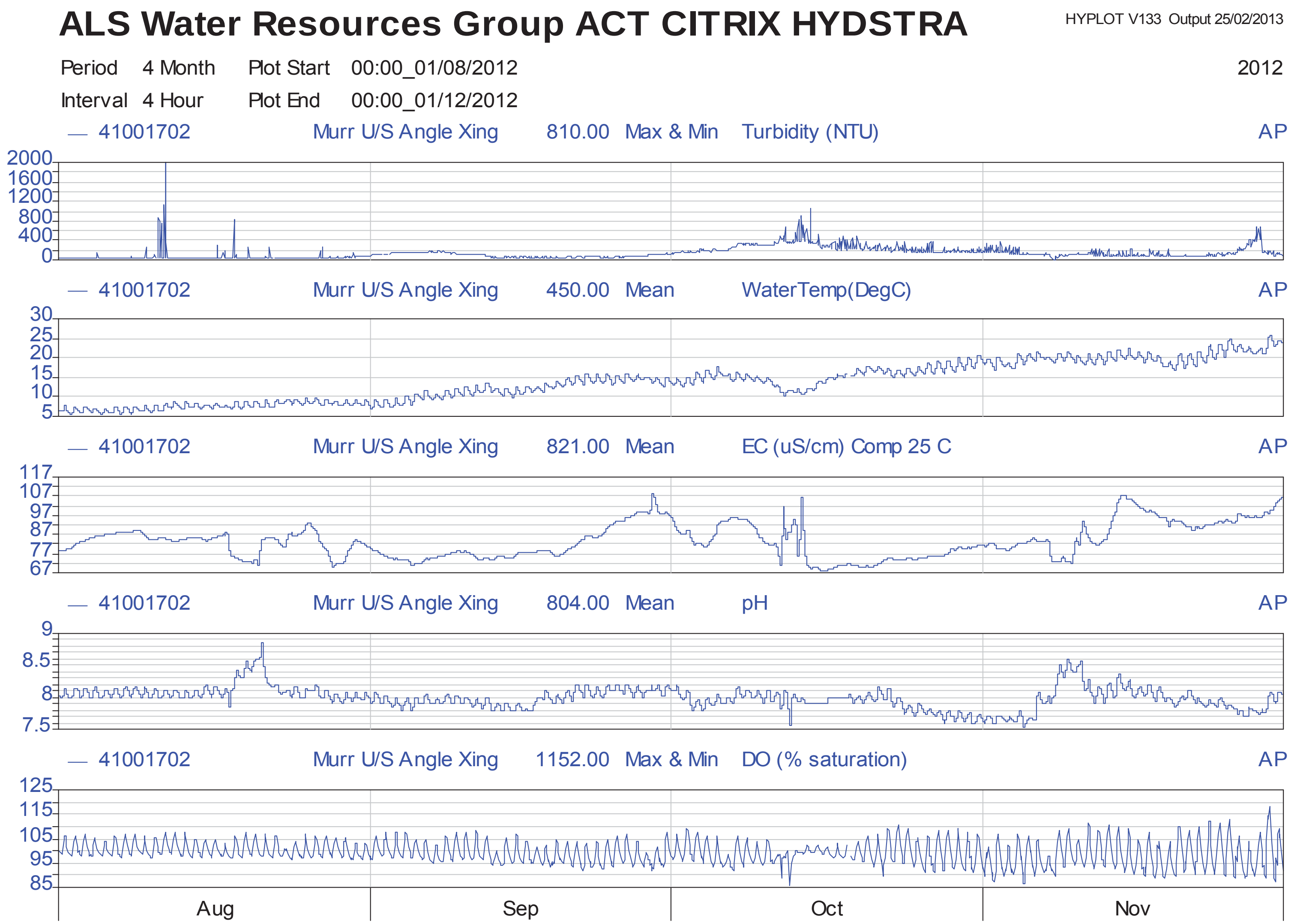

Figure 4-3 Continuous water quality records from upstream of Angle Crossing (41001702) for spring 2012

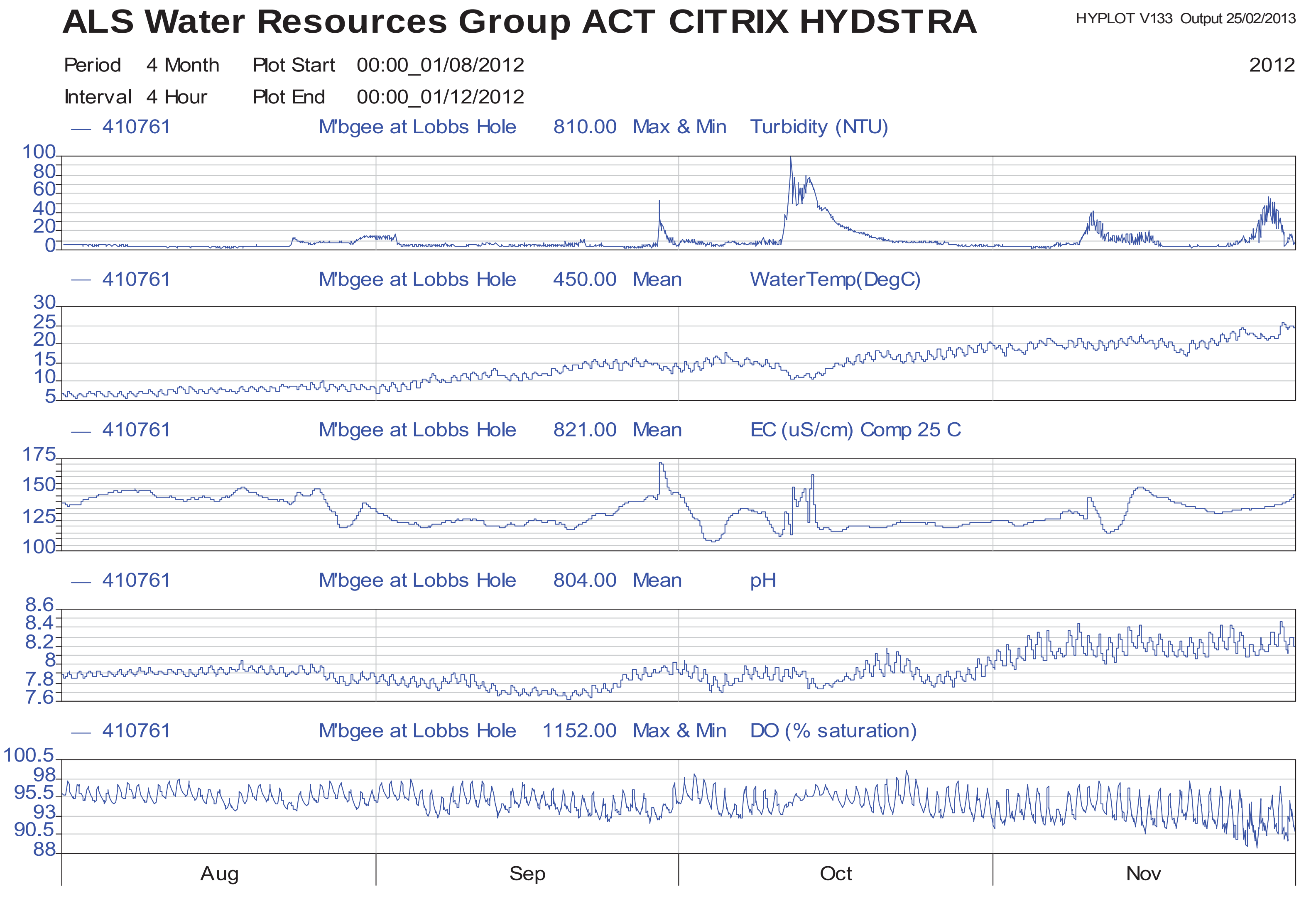

Figure 4-4 Continuous water quality records from Lobb's Hole (410761) for spring 2012

4.4 Periphyton

The distribution of chlorophyll-a and ash free dry mass (AFDM) show similar patterns in their spatial distribution, in that site MUR 18 and MUR 19 (immediately upstream and downstream of Angle Crossing respectively) have the lowest mean values and variance compared to all other sites (Figure 4-5 and Figure 4-6). By location, chlorophyll-a tended to be higher on average downstream of Angle Crossing (20,606 µg/m^2) compared to upstream (14,526 µg/m^2) although in line with previous reports, this is largely driven by higher values at MUR 23 and mean chlorophyll-a concentration was not statistically different between locations ($F_{1,35}$ = 0.26; *P*=0.64; Table 4-5). Similarly, AFDM was highest at MUR 23, but similar concentrations at MUR 16 and equally low values seen at MUR 18 and 19 resulted in a non-significant location effect for AFDM ($F_{1,35}$ = 0.01; *P*=0.94; Table 4-5).

MUR 23 remains consistently high relative to the other sampling sites for both parameters, which agrees which our field observations and qualitative field assessments. This site had a high degree of periphyton cover relative to the other sampling sites and also a higher percentage of substrate cover by *Myriophyllum spp.* indicating that conditions at this site were conducive for aquatic plant growth. Interestingly, this site had the lowest TN and TP concentrations of all the study sites (Table 4.2); but turbidity at this site was also lowest indicating that there could potentially be greater light penetration allowing faster growth rates, which may have resulted in higher nutrient uptake.

Table 4-5 Nested analysis of variance results for chlorophyll-a and AFDM concentrations Angle Crossing

Response	Source	DF	F	P-value
Chlorophyll-*a*	Location	1	0.26	0.64
	Site [Location]	4	5.85	<0.001
	Residual	35		
AFDM	Location	1	0.01	0.94
	Site [Location]	4	6.86	<0.001
	Residual	35		

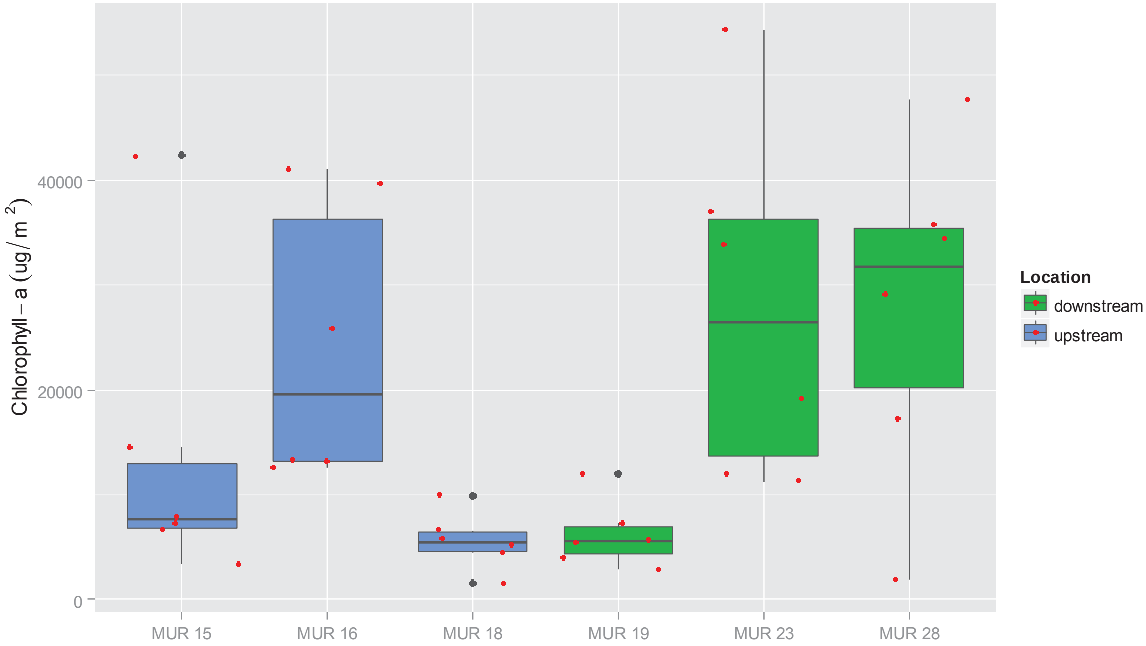

Figure 4-5 Chlorophyll-a concentrations up and downstream of Angle Crossing

Red points represent the raw values for each site

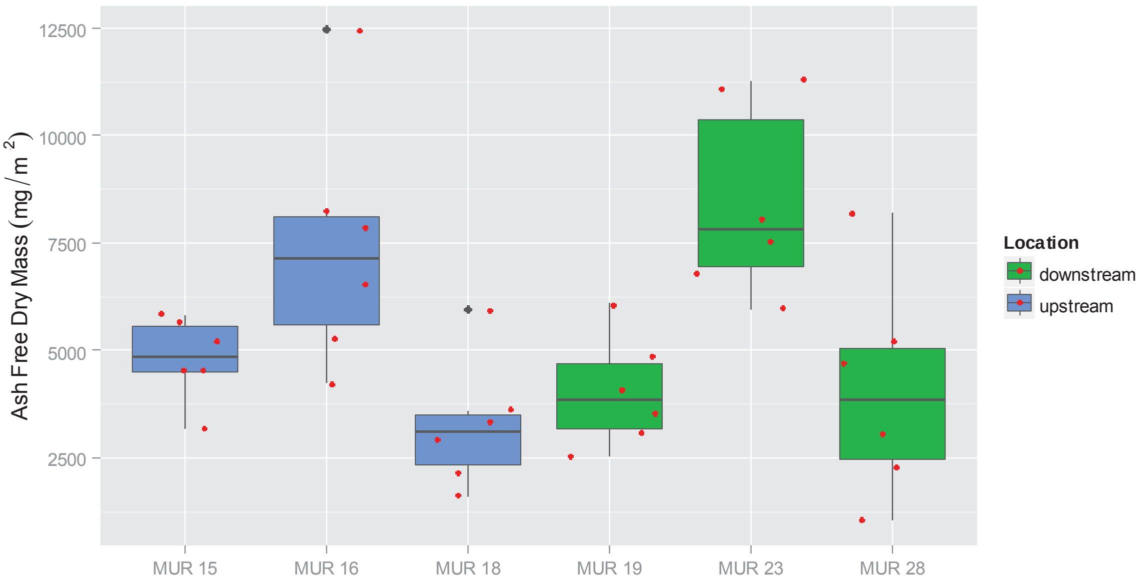

Figure 4-6 Ash free dry mass at Angle Crossing sites

Red points represent the raw values for each site

4.5 Macroinvertebrates

4.5.1 Community assemblages

4.5.1.1. Riffle habitat

The grouping structure of the macroinvertebrate riffle community assemblages in two dimensional ordination space were similar to that seen in spring 2011; where samples scores for MUR 28 and MUR 23 formed individual groups; while samples scores for the remaining sites formed a larger group (Figure 4-7). The analysis of similarity (ANOSIM) results showed that there was no statistical significant differences between upstream and downstream locations ($R=0.14$; $P=0.4$) and this is essentially because MUR 19 is grouped with the upstream sites (MUR 15-18).

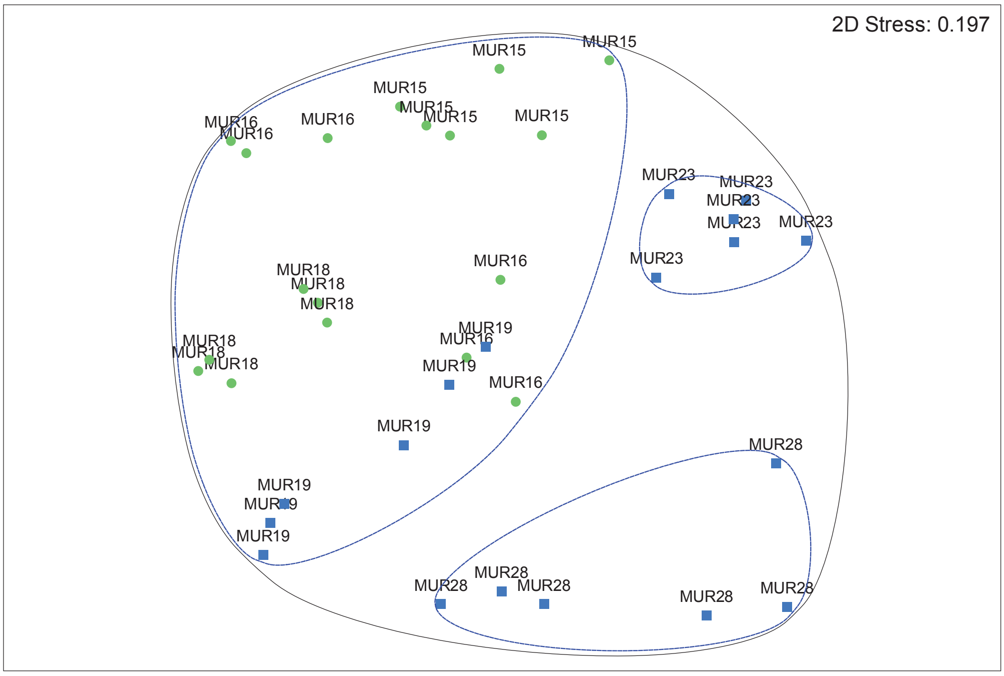

Figure 4-7 Non metric multidimensional scaling of macroinvertebrate (genus level) data collected from the riffle habitat

Note: black ellipse = 50% similarity; blue ellipse = 60% similarity ; green circles represent sites upstream of Angle Crossing and blue squares represent sites downstream of Angle Crossing

Family richness ranged from 16 to 21 which is the same range reported for spring 2011. The highest number of families was collected at MUR 23 and the lowest at MUR 18 (Figure 4-8). The highest number of genera (28) was collected at MUR 23 and MUR 10, while MUR 15 recorded the lowest number of genera (21). The number of taxa collected from the EPT group ranged from 7 at MUR 28 to 9 (at all of the remaining sites). EPT diversity at the genus level was highest at MUR 16 and lowest at MUR 15 with 17 and 11 taxa recorded at each site respectively (Figure 4-9).

Macroinvertebrate communities from the riffle habitat were numerically dominated by moderately tolerant taxa across several taxonomic orders including Simuliids (SIGNAL =5; Diptera); Chironomids (SIGNAL =3; Diptera); Caenids (SIGNAL = 4; Ephemeroptera). However there were several highly sensitive groups represented in these samples, albeit represented by much fewer individuals. These included the flow and water quality sensitive Elmidae (SIGNAL=7), which was only present at MUR 15 and MUR 23 and Gripopterygidae (SIGNAL =8) and Leptophlebiidae (SIGNAL=8) which were present at most sites.

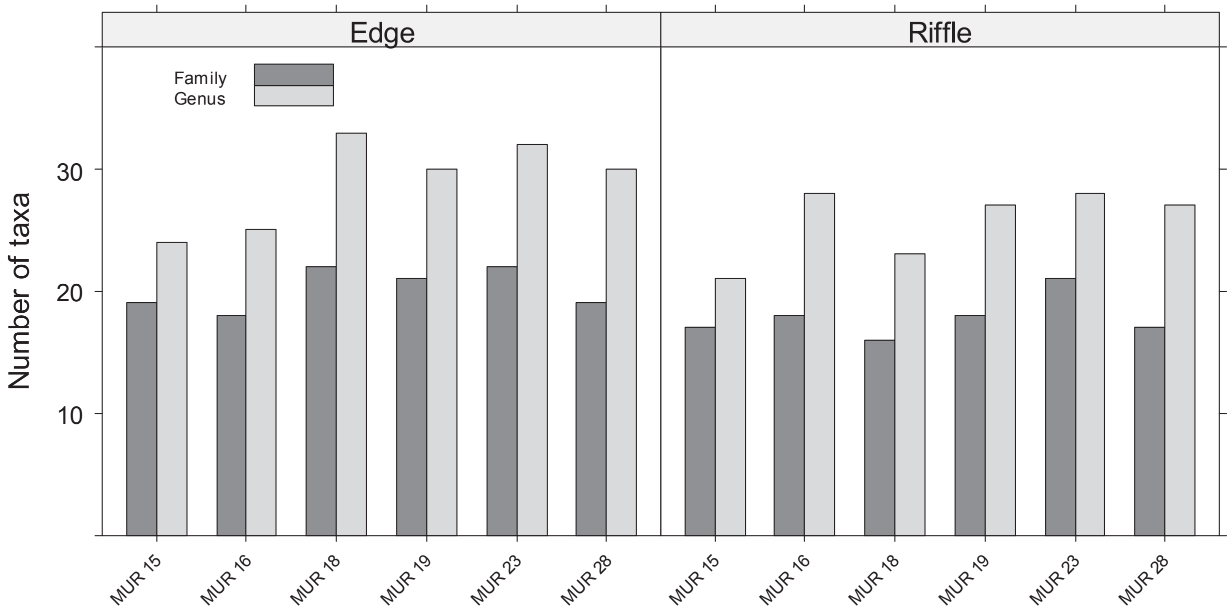

Figure 4-8 Total number of taxa at genus and family level from riffle and edge habitats

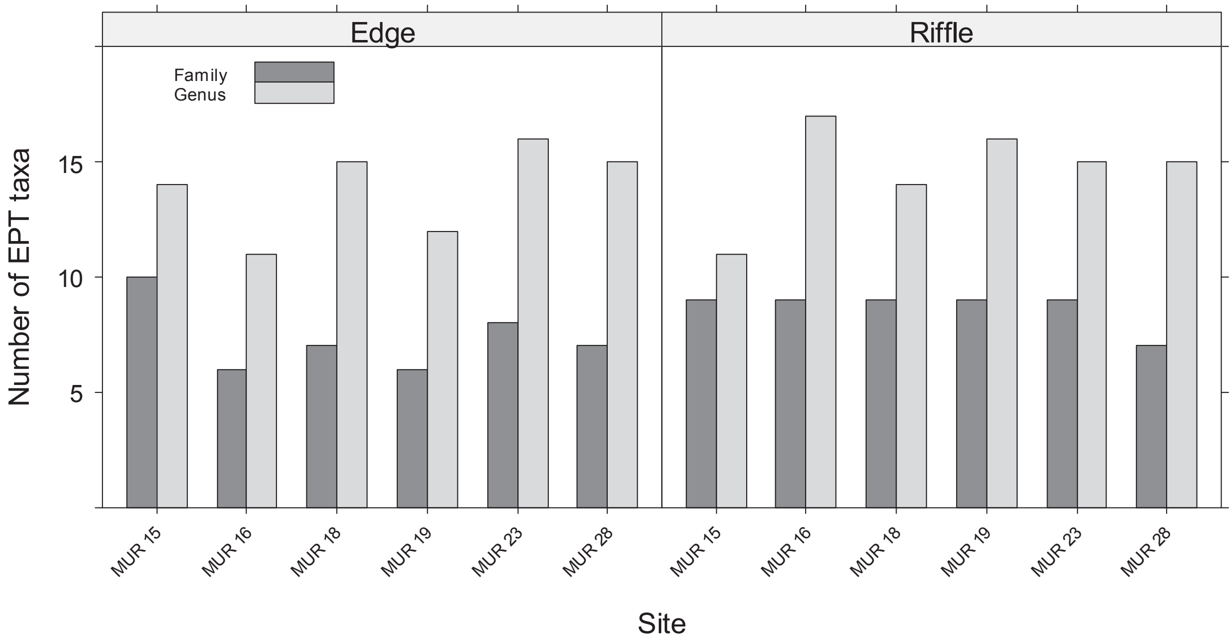

Figure 4-9 Total number of EPT taxa at genus and family level from riffle and edge habitats

4.5.1.2 Edge habitat

There were no upstream versus downstream patterns evident in terms of taxa richness at the family level based on the edge habitat sample data for spring 2012 (Figure 4-8). The number of families ranged from 18 at MUR 16 to 22 families collected at MUR 18 and MUR 23. The number of genera collected was lowest at MUR 15 and MUR 16 with 24 and 25 genera collected respectively. MUR 18 was the richest site with 33 taxa collected on this sampling occasion. MUR 15 recorded the highest number of EPT families (10) (Figure 4-9) and which, proportionally accounted for 52% of the total family richness at that site. MUR 16 and MUR 18 had 6 EPT families which represented 32 % and 33% of the total number of families respectively.

As with the riffle macroinvertebrate assemblages, the grouping structure in the ordination plot shows no evidence of a location effect upon the communities (Figure 4-10). All of the sampling sites were grouped together with approximately 50% (Figure 4-10) and the analysis of similarity results (ANOSIM) (R=-0.11; *P*=0.7) strongly indicate there is no location effect in the structure of the communities, and in effect some sites upstream of Angle Crossing (i.e. MUR 16 and MUR 18) are more similar to sites downstream (i.e. MUR 19 and MUR 23) than they are to sites within the upstream location treatment group.

The position of MUR 15 is consistent with the previous two sampling runs in that there is a distinct separation from the main sub group, MUR 28 is also separated from the main group, which represents a 5-8% decrease in the similarity coefficient since the previous two sampling runs. There were no Gripopterygidae collected at MUR 28, and there were fewer Leptophlebiidae, Hydroptilidae and Simuliids compared to the main group. At MUR 15, there were no Dytiscidae (diving beetles) (SIGNAL = 2) collected and there were for the most part, fewer individuals in the Baetidae and Gripopterygidae families compared to the main group.

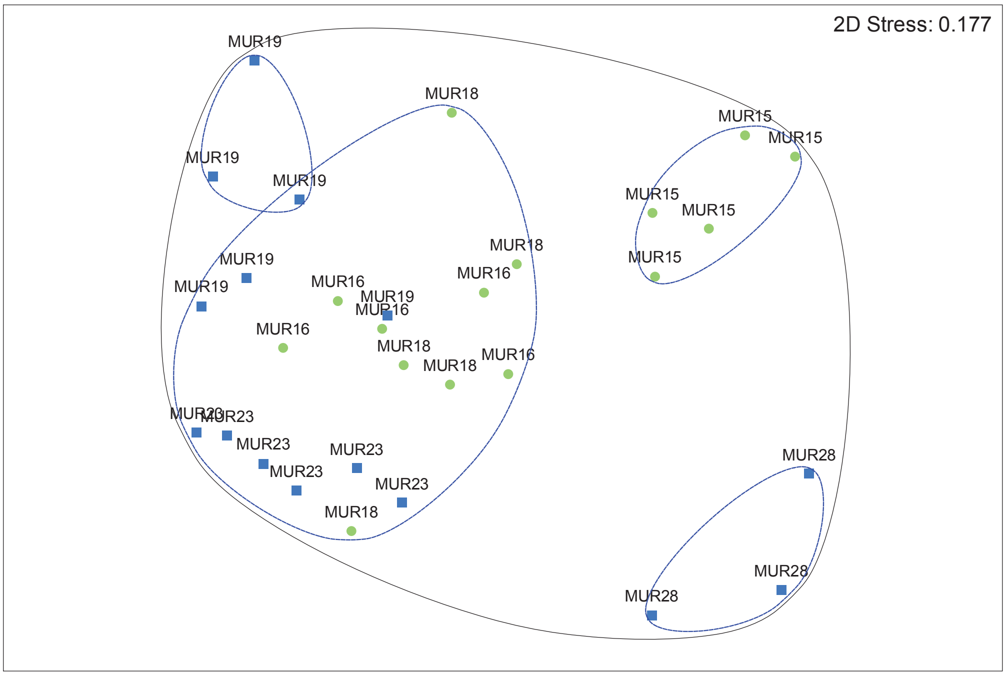

Figure 4-10 Non metric multidimensional scaling of macroinvertebrate (genus level) data collected from the edge habitat

Note: black ellipse = 50% similarity; blue ellipse = 65% similarity; green circles represent sites upstream of Angle Crossing and blue squares represent sites downstream of Angle Crossing

4.5.2 AUSRIVAS

There was improvement of the overall river health assessment at MUR 15 and MUR 23 moving from BAND B to BAND A (Table 4-6). MUR 28 remained at BAND B and had the lowest overall OE/50 ratios (on the lower end of the BAND width) compared to the other sites, despite obtaining similar site assessment. It should also be pointed out that although MUR 16, MUR 18 and MUR 19 had overall site assessments in the BAND B category, the edge habitats at each of these sites were assessed as BAND A and had a maximum of three missing taxa from a given site.

The distribution of missing taxa shows some consistency across sites. From the riffle samples for example, Psphenidae (SIGNAL =6); Conoesucidae (SIGNAL = 7) and Glossosomatidae (SIGNAL =9) were absent at all sites where they were predicted. In contrast, several of the more tolerant taxa such as Tanypodinae (SIGNAL=4) Ceratopogonidae (SIGNAL =4) were present at the majority of sites at which they were predicted. However, their distribution was patchy and they were not collected in each replicate. The stonefly, Gripopterygidae (SIGNAL=8) was the most common of the sensitive taxa, while the flow sensitive Elmidae (SIGNAL=7) was rather rare given its high probability of occurrence (0.92-0.96). Elmid beetles were not collected at all upstream of Angle Crossing in spring 2011, while they were common downstream of the Angle Crossing except at MUR 28, where only a few individuals were found.

There were no statistical differences found in the AUSRIVAS O/E50 ratio between upstream and downstream locations from the riffle ($F_{1,35}$=0.33; P=0.59; Table 4.7) or edge samples ($F_{1,35}$=0.37; P=0.63; Table 4-7). In both habitats, the effect of location accounted for less than 2% of the total variation from the fitted linear model. Most of the variation in the riffle samples was accounted for site to site differences (~70%); whereas in the edge samples, the majority of the total variation occurred within each site (Table 4-8).

SIGNAL-2 scores derived from the riffle samples were higher downstream (mean= 5.21) compared to upstream (5.06) although this difference was not statistically significant (Table 4-7). SIGNAL-2 scores from the edge habitat were almost identical between upstream (mean=4.18) and downstream (mean =4.17) locations and the location effect was therefore strongly non-significant (Table 4-8). These results do show that the weighted SIGNAL-2 scores tended to be higher in the riffle habitat compared to the edge and this is due to the more common (and expected) occurrence of pollution-sensitive taxa such as Leptophlebiidae, and Gripopterygidae in the riffle habitat compared to the edge.

Table 4-6 Overall site assessments for the current and previous three sampling runs for Burra Creek

	Autumn 2011	Spring 2011	Autumn 2012	Spring 2012	Change since previous sampling run
MUR 15	B	B	B	A	↑
MUR 16	B	A	B	B	–
MUR 18	A	B	B	B	–
MUR 19	A	A	B	B	–
MUR 23	B	B	B	A	↑
MUR 28	B	B	B	B	–

Table 4-7 Nested analysis of variance results for riffle samples

Response	Source	DF	F	P-value
OE 50	Location	1	0.33	0.59
	Site [Location]	4	14.42	<0.001
	Residual	35		
SIGNAL-2	Location	1	3.01	0.15
	Site [Location]	4	3.37	0.02
	Residual	35		

Table 4-8 Nested analysis of variance results for edge samples

Response	Source	DF	F	P-value
OE 50	Location	1	0.37	0.60
	Site [Location]	3	4.04	0.02
	Residual	24		
SIGNAL-2	Location	1	0.001	0.99
	Site [Location]	3	4.04	0.02
	Residual	24		

Table 4-9 AUSRIVAS and SIGNAL-2 scores for spring 2012

= nearly outside the experience of the model; NS =no sample

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	4.92	4.40	1.16	1.11	X	A	A	A	A
MUR 15	2	5.17	4.40	1.16	1.11	X	A			
MUR 15	3	5.17	4.40	1.16	1.11	X	A			
MUR 15	4	5.10	4.40	0.97	1.11	A	A			
MUR 15	5	4.92	4.50	1.16	1.22	X	X			
MUR 15	6	5.10	NS	0.97	NS	A	NS			
MUR 16	1	5.27	4.40	1.01	1.11	A	A	B	A	B
MUR 16	2	5.10	4.40	0.92	1.11	A	A			
MUR 16	3	4.78	NS	0.83	NS	B	NS			
MUR 16	4	4.70	4.40	0.92	1.00	A	A			
MUR 16	5	4.70	4.40	0.92	1.11	A	A			
MUR 16	6	4.70	4.40	0.92	1.00	A	A			
MUR 18	1	4.90	4.60	0.78	1.11	B	A	B	A	B
MUR 18	2	5.00	4.67	0.86	1.00	A	A			
MUR 18	3	5.25	4.50	0.93	0.89	A	A			
MUR 18	4	5.00	4.67	0.70	1.00	B	A			
MUR 18	5	5.00	4.44	0.70	1.00	B	A			
MUR 18	6	4.78	NS	0.70	NS	B	NS			
MUR 19	1	5.25	4.67	0.94	1.00	A	A	B	A	B
MUR 19	2	5.36	4.25	0.86	0.89	A	A			
MUR 19	3	4.90	4.00	0.78	0.89	B	A			
MUR 19	4	5.44	4.55	0.71	1.22	B	X			
MUR 19	5	5.00	4.60	0.71	1.11	B	A			
MUR 19	6	5.30	4.00	0.78	1.00	B	A			
MUR 23	1	5.08	4.00	1.14	0.89	X	A	A	A	A
MUR 23	2	5.36	4.25	0.88	0.89	A	A			
MUR 23	3	5.25	4.22	0.96	1.00	A	A			
MUR 23	4	5.42	4.40	0.96	1.11	A	A			
MUR 23	5	5.50	4.44	0.96	1.00	A	A			
MUR 23	6	5.31	4.44	1.04	1.00	A	A			
MUR 28	1	4.67	4.22	0.68	1.00	B	A	B	B	B
MUR 28	2	5.25	4.00	0.90	0.89	A	A			
MUR 28	3	5.00	3.33	0.90	0.66	A	B			
MUR 28	4	4.90	NS	0.75	NS	B	NS			
MUR 28	5	5.00	NS	0.83	NS	B	NS			
MUR 28	6	5.09	NS	0.83	NS	B	NS			

4.6 Discussion

4.6.1 Water quality and periphyton

The water quality results show there was a high level of compliance to the ANZECC & ARMCANZ (2000) guidelines for both the grab samples and the continuous gauging stations (Table 4-4). From these data, there is no firm evidence to indicate that there was an impact of the initial abstractions from the M2G commissioning period during this sampling season on the water quality downstream of Angle Crossing.

Although pH data exceeded the upper limit of the ANZECC guideline values levels, these values are regularly recorded in these reaches of the Murrumbidgee River following high flow events or rainfall. Turbidity showed a high degree of compliance at Lobb's Hole (89%) given the high flow events throughout the spring period. Upstream of Angle Crossing the gauging station data indicated zero compliance for the spring period. However, at the time of writing, these values have not been verified and are therefore considered to be unreliable. This parameter has been problematic at this site in the past due to the position of the hydrolab and there is a tendency for silt to build up if not fully maintained. Currently there are access issues with the upstream Angle Crossing site; these issues are currently being resolved, however in the meantime the field hydrology team are unable to maintain the site which is likely contributing to these turbidity readings.

Nutrient levels commonly exceeded the ANZECC & ARMCANZ (2000) guidelines with respect to total phosphorus and total nitrogen. These elevated nutrient concentrations are not unexpected as they have been at these levels regularly within this section of the Murrumbidgee River since the inception of the MEMP. Further, the exceedances in all cases were mild and showed no pattern with respect to position in relation to Angle Crossing.

Point Hut Crossing (MUR 23) was the only site that recorded total nitrogen concentrations within the guideline range. This may have been due to factors such as increased uptake by aquatic plants (based on the high chlorophyll-a and AFDM concentrations recorded at this site and the abundance of *Myriophyllum* spp. observed at this site) or assimilation of nitrogen into the sediments of the pool directly upstream of the causeway during periods of low flow.

The results from the AFDM and chlorophyll-a data were consistent with the historical data collected from these sites. The majority of the variation in the ANOVA models for AFDM and chlorophyll-a was accounted for by within site and site-to-site variation as opposed to location differences (<5%). This suggests that local environmental or geomorphological conditions, as opposed to factors relating to M2G were the main factors driving spatial variability in chlorophyll-a and AFDM concentrations.

Sites MUR 18 and 19 tended to have lower concentrations of AFDM and chlorophyll-a and this is likely to be because of the steeper gradient through the riffle habitat and therefore, higher flow velocities (Biggs and Stokseth, 1996) compared to the other sites. The higher concentrations recorded at MUR 23, MUR 28 and, in this sampling run, MUR 16, correspond with field observations which showed higher coverage of macrophytes and filamentous algae at those sites compared to the other sites. This may reflect greater resistance and resilience to the effects of the high flow event that occurred in mid-October at these sites.

4.6.2 AUSRIVAS and macroinvertebrate assemblages

Prior to sampling in spring 2012, there was a 1:1 yr ARI event that peaked at 9,100 ML/d. Leading up to the sampling period in 2011, there was an environmental flow release at approximately the same time, which was held at approximately 2,000 ML/d for ten days. In both cases, macroinvertebrate sampling was undertaken three weeks after each event. However, base flows during the current sampling run were approximately double those during spring 2011. As with the spring 2011 sampling run, the observations during the sampling period revealed sites of the Murrumbidgee River void of macrophyte cover in the riffle habitat and along the margins, and there were signs of sand deposition in the edge habitat and silt removal from the riffle habitat resulting from the preceding high flow events.

The multivariate analysis of the macroinvertebrate community data showed that for both the riffle and edge habitats all sampling sites were approximately 50% similar (Figure 5-9; Figure 5-13) and that there was not a significant difference between sites upstream of Angle Crossing and sites downstream – for either the riffle or edge habitat data.

The small differences that did exist were mainly driven by variation in estimated abundances between sampling sites rather than compositional differences (Figure 5-10; Figure 5-11). For example, the macroinvertebrates communities characterising each of the sampling are dominated by Simuliidae, Orthocladiinae and Chironominae, which have been described in the literature as early colonisers following disturbance (Niemi *et al.*, 1990; Reice *et al.*, 1990). These taxa often thrive after high flow events and can reach very high densities until other taxa begin the colonisation processes and intra-species interactions (e.g. predation and resource competition) take hold. These colonisation paths have been described in this component of the MEMP on several previous occasions following high flow events including the 2011 environmental flow release from Tantangara Reservoir (ALS, 2011).

At MUR 15, however, there were fewer taxa (overall) at the genus level (Figure 5-10) and fewer genera from the EPT group (Figure 5-11) compared to the other sites. One explanation for this is that MUR 15 was sampled 5 days earlier than the remaining sites (see section 4.1) meaning that the extra time between the high flow event and sampling at the other sites could have resulted in high taxonomic radiation at the genus level. An alternative explanation is that the higher richness (generally at the genus level) downstream of MUR 15 was due to displaced macroinvertebrates via downstream drift following the high flow events in mid-October and early November (Brittain and Eikeland, 1988).

The AUSRIVAS results show improved site assessments at MUR 15 and MUR 23 and declines at MUR 16 and MUR 19. The BAND B assigned to MUR 19 was a result of both, Caenidae and Elmidae missing from the samples compared to spring 2011. Elmidae were missing from all the samples at MUR 19 but the absence of these taxa was not unique to this site (APPENDIX E) suggesting that their absence was probably caused by dislodgement after the high flow events. Similar patterns at MUR 16 accounted for the drop from BAND A to BAND B in this sampling round. At both sites, it was the riffle habitat that declined in its health rating whereas the edge remained at BAND A.

At MUR 15 and MUR 23, the improved site assessments occurred because of improved edge habitat assessments. At MUR 15, only one taxa (Leptoceridae) was missing from the AUSRIVAS predictions compared to spring 2011, where up to five taxa were missing from the edge samples. One explanation for this is that although both sampling periods were subject to high flow events prior to sampling, the differences in duration and magnitude were quite different. In spring 2011, flows were maintained over a ten day period at 2,000 ML/d, while in this sampling event peak flows reached approximately 9,000 ML/d and began recession almost immediately, which may have allowed re-colonisation to occur quicker than it was possible during the ten day environmental flow release. There were several BAND X's recorded at MUR 15 and although assessed as BAND A, this majority of samples were assessed as BAND X; with only one missing taxon from 4 of the 6 samples.

We found no evidence from the OE/50 or SIGNAL-2 scores of an impact related to M2G (i.e. there were no differences found between locations for either index) (Table 4-7; Table 4-8). As in previous sampling runs, the distribution of missing taxa shows consistency across sites supporting the non-significant results found in this study. From the riffle samples for example, Psphenidae (SIGNAL =6); Conoesucidae (SIGNAL = 7) and Glossosomatidae (SIGNAL =9) were absent at all sites where they were predicted. In contrast, several of the more tolerant taxa were present, but in patchy distributions suggesting that either they have recolonised in a non-uniform way following the disturbance; or as in the case of some of the Chironomid taxa, there burrowing ability may have allowed a certain degree of resistance (ability to withstand dislodgement) during the high flow disturbance.

Despite several of the sites being assessed as BAND B, it is important to keep in mind that the condition of the Murrumbidgee River is an artefact of background conditions (i.e. land use, water quality and sediment quality). As such, it should be noted that Psphenidae, Conoesucidae and Glossosomatidae, although predicted by the AUSRIVAS model are rarely collected in this component of the MEMP which is probably a result of these antecedent conditions. Indeed, Conoesucidae have not been collected at any of the Angle Crossing sites since the project began and Glossosomatidae have only been collected at a few sites on three occasions. Psphenidae are noted as being rarely collected in silty, sandy or loose substratum and this would help explain their absence from many of the sites under assessment in the Angle Crossing component of MEMP.

4.7 Conclusion and recommendations

The overall community assemblages seen here are indicative of those seen in previous sampling events and further highlight high resistance and/or resilience of these communities in the Murrumbidgee River. The consistent nature of these community responses to high flow events have meant that over the period the MEMP, site assessments and macroinvertebrate community structures have been highly comparable despite being subject to various flow magnitudes and durations.

The key issue for the MEMP, however, is water abstractions and how the operation of M2G will influence the river ecology downstream of the abstraction point at Angle Crossing. This is the first sampling run since the trial abstractions from the Murrumbidgee River and based on the current results, it appears that these trial releases have not impacted any of the indicators considered in this project. This is because the main overriding influence on the periphyton, macroinvertebrates and water quality indicators was the high flow event that occurred prior to sampling.

The other consideration is that the proportion of water pumped out of the Murrumbidgee River during this trial period (i.e. 12%) was low relative to base flow. Walters and Post (2011), diverted up to 80% of summer flows and found that although there were changes in biomass and abundances with the water abstractions, taxa richness did not change. We found similar results in the early phases of this project (i.e. autumn 2009 and autumn 2010) when flows were as low as 35 ML/d (~90% lower than the most recent autumn flows). During these very low flow periods, health assessments were BAND B amongst all sampling sites, although taxonomic richness was approximately the same as current values; however there were signs of deteriorating water quality under these conditions and dissolved oxygen began increasing (presumably due to increasing photosynthesis) and elevated water temperatures began to feature as flows fell below 90 ML/d.

Based on these results we suggested that during summer and autumn, it is expected that changes in water quality may occur when flows are < 80 ML/d for prolonged periods. Furthermore, we had predicted (ALS, 2011) that abstractions occurring in winter and spring would be unlikely to have any long term effects on water quality, periphyton communities or macroinvertebrate populations because during these months water abstractions are likely to be low proportional to base flows.

The M2G pipeline will be used to supplement the raw water supply when the Googong reservoir volume falls below a set trigger level. The pipeline might be operated during the summer months and this will result in potentially larger proportions of the Murrumbidgee River's flow being extracted than there were during the initial commissioning of M2G (August and September 2012). If flows during these vulnerable periods are artificially maintained through ongoing water abstractions, we could expect to see deterioration in water quality that would then begin to influence the more sensitive macroinvertebrate taxa, which may eventually be eliminated. Recovery will likely occur in the following season, but as Marsh *et al.* (2012) point out, community composition may diminish if this pattern is repeated over subsequent years (i.e. due to the cumulative effects of water abstraction). This will have repercussions to fish populations also which relay on healthy macroinvertebrate populations as a food resource, but are also sensitive to changes in water quality outside their natural thresholds (Ingram and De Silva, 2007; King, 2005; Tonkin *et al.*, 2006).

It is recommended that autumn sampling be undertaken to target flows following the next operational period of M2G. In this way, the influence of naturally occurring hydrological disturbances may be minimised resulting in more robust estimates of water quality and biological responses to the water abstractions. The recommended approach would be to collect autumn data once, prior to scheduled releases and then again after the release(s). Comparisons post release to previous autumn sampling periods would be one option; however this approach we believe would not provide the same degree of rigour as the full approach involving the before and after method.

PART 2 – Burra Creek

5. Burra Creek

5.1 Summary of sampling and river condition

Burra Creek and Queanbeyan River sampling was conducted on the 29th and 30th of October 2012. Over the two day period, the weather varied between fine periods, thunderstorms and heavy showers. Ambient temperatures remained fairly constant despite the changing conditions. One sample was missed from the sample schedule at BUR 1a as there was a lack of suitable edge habitat due to low flows in the upper section of Burra Creek. BUR 3 was inundated by water from the Googong Reservoir (Plate 5-1) as was the QBYN 2 site.

Site photographs are shown in Plate 5-3, and full site summaries are shown in APPENDIX D.

Plate 5-1 Burra Creek (BUR 3) looking downstream towards drawdown crossing

There was a notable reduction of silt and organic material from the riffle habitats across all sites. This was particularly evident at BUR 1c (Plate 5-2), which because of its situation upstream of the M2G outlet, suggests that the high flow events in early and mid-October (Figure 5-1) were the likely cause of the reduced silt and organic matter found in the riffle habitats. However, there was further evidence of this downstream of the discharge point, but the differences were not as clear as they were at BUR 1c.

Plate 5-2 Substrate at BUR 1c in autumn 2012 (left) and spring 2012

QBYN 1. Riffle habitat looking upstream. Flow at the time was 95 ML/d

BUR 1a. Looking upstream. Note the declining wetted width in the foreground

BUR 1c. Looking upstream

BUR 2a. Looking downstream

BUR 2b. Note the *Typha spp.* growth on the left bank

BUR 2c. Looking downstream

Plate 5-3 Photographs of sampling sites for the Burra Creek component of the MEMP

5.2 Hydrology and rainfall

Commissioning of M2G began in late August 2012 and continued throughout September, with the last spring releases occurring in the final week of September Figure 5-1. During this period there were several trial releases of between 20 -50 ML/d before the first of the “step up / step down” releases which occurred in early September. Details of the releases in early September are shown in Table 5-1.

Outside of the commissioning releases, there were very few natural events in spring; the most notable being the event in mid-October which peaked at 1,460 ML/d in Burra Creek (Figure 5-1) and 4,450 ML/d in the Queanbeyan River (Figure 5-2), both corresponding to nearly 100 mm of rain (96.6 mm) over a four day period. Compared to previous sampling runs, the average spring rainfall was the lowest since the Burra Creek component of the MEMP began, with 63.1 mm falling on average over the three month period (Table 5-2) compared to 86.4mm in 2011 (Figure 5-3). Average flow in Burra Creek was 19.8 ML/d (averaged over the three month period), which was approximately 3.5 times the average volume recorded in spring 2011 (5.6 ML/d) and 60 % of the average in 2010 when the average spring flow was 32.1 ML/d (Figure 5-4).

Table 5-1 High Level Pump Station transfer details for the ramp up and ramp down release in early September

Date	Time	Details	Volume transferred per day during performance trial
05/09/2012	09.00	Transfer System start initiated, system transferring at 21.5 ML/day	15.9 ML
05/09/2012	21.40	System step up (20 to 40ML/day), system transferring at 50.3 ML/day	
06/09/2012	10.04	System step up (40 to 60ML/day), system transferring at 68.8 ML/day	61.9 ML
06/09/2012	22.30	System step up (60 to 80ML/day), system transferring at 93.0 ML/day	
07/09/2012	10.50	System step up (80 to 100ML/day), system transferring at 110.0 ML/day	101.5 ML
07/09/2012	23.08	System step down (100 to 80ML/day), system transferring at 93.0 ML/day	
08/09/2012	11.15	System step down (80 to 60ML/day), system transferring at 68.8 ML/day	79.5 ML
08/09/2012	23.20	System step down (60 to 40ML/day), system transferring at 50.3 ML/day	
09/09/2012	11.27	System step down (40 to 20ML/day)	23.8 ML

Table 5-2 Spring rainfall and flow summaries for Burra Creek and the Queanbeyan River

	Burra Creek (410774)		Queanbeyan River (410781)	
	Total Rainfall (mm)	Mean Flow (ML/d)	Total Rainfall (mm)	Mean Flow (ML/d)
September	57.0	19.3	43.4	94.6
October	83.8	35.5	90.4	335.9
November	48.4	4.6	43.4	73.0
Spring (mean)	189.2 (63.1)	19.8	177.2 (59.1)	167.8

Note: Flow values are monthly means; rainfall is monthly total (mm)

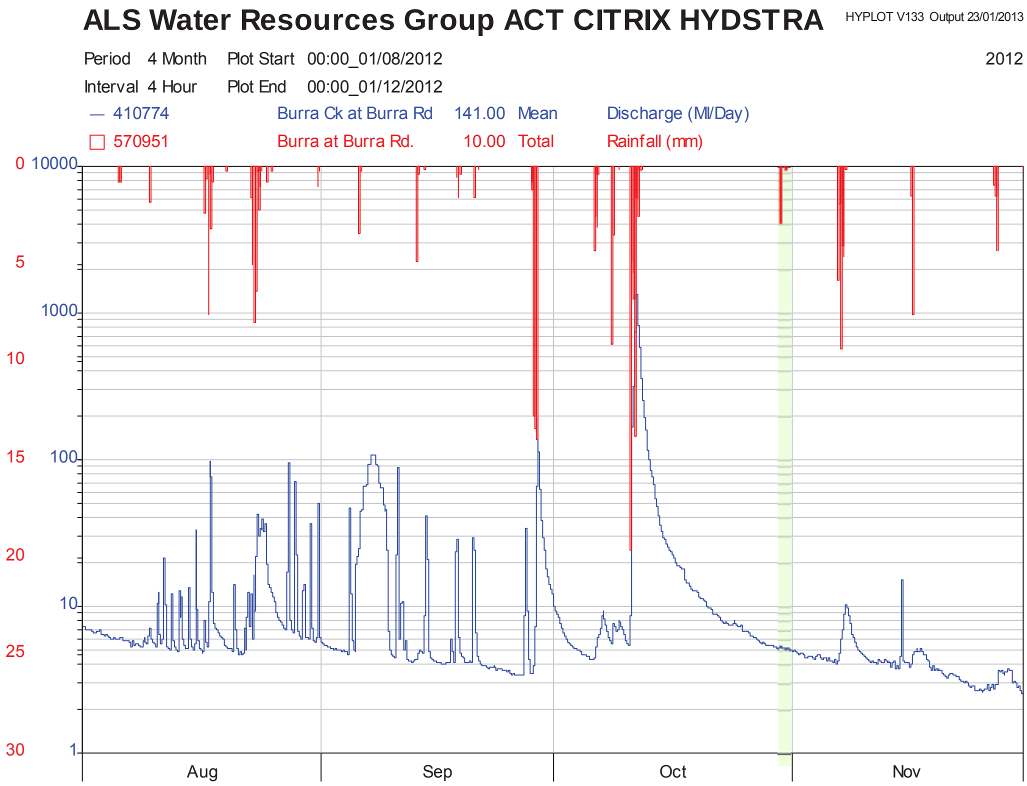

Figure 5-1 Hydrograph and rainfall from Burra Creek over the spring period, 2012

Note: Green shading indicates sampling period

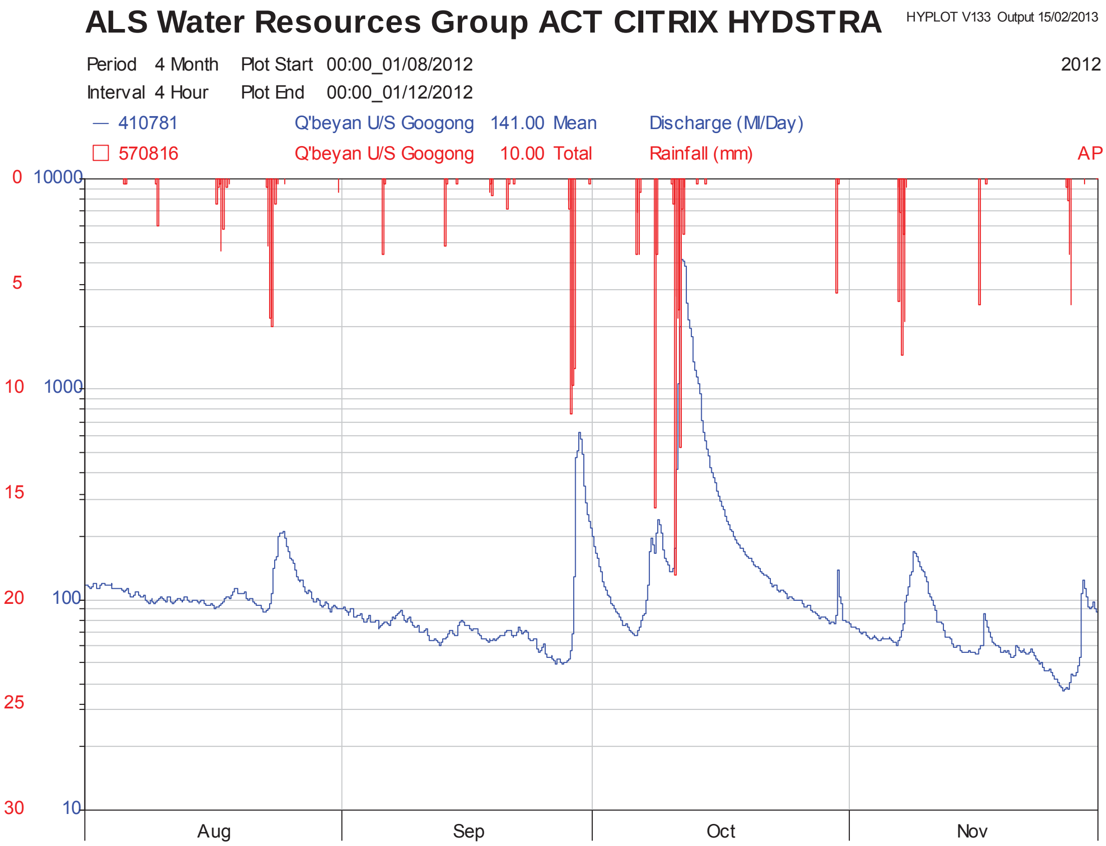

Figure 5-2 Hydrograph and rainfall from the Queanbeyan River (410781) during the spring 2012 period

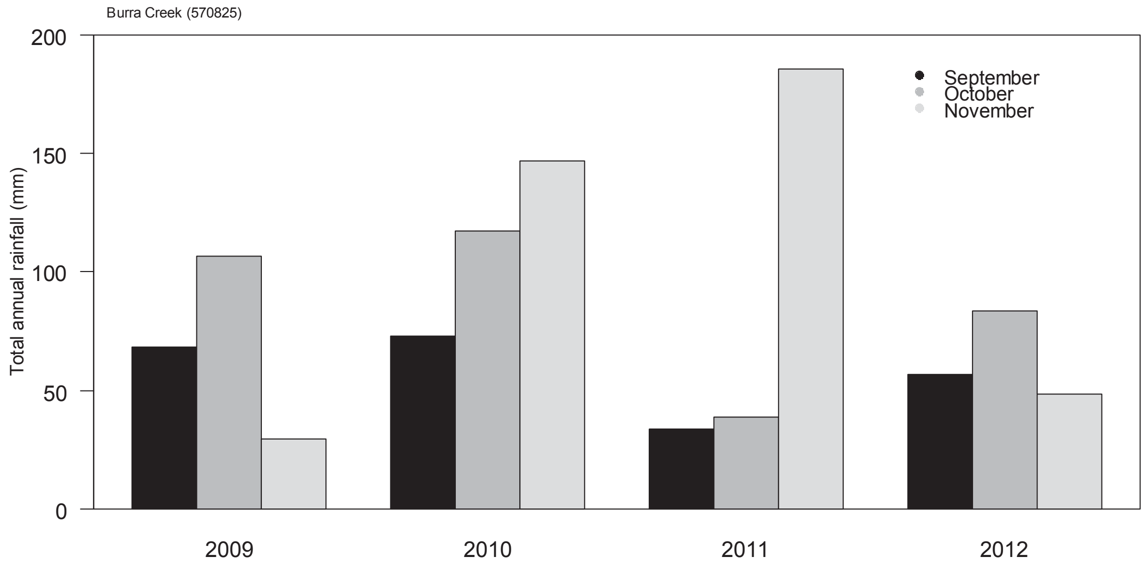

Figure 5-3 Annual comparisons of spring rainfall (mm) recorded at Burra Creek (570951)

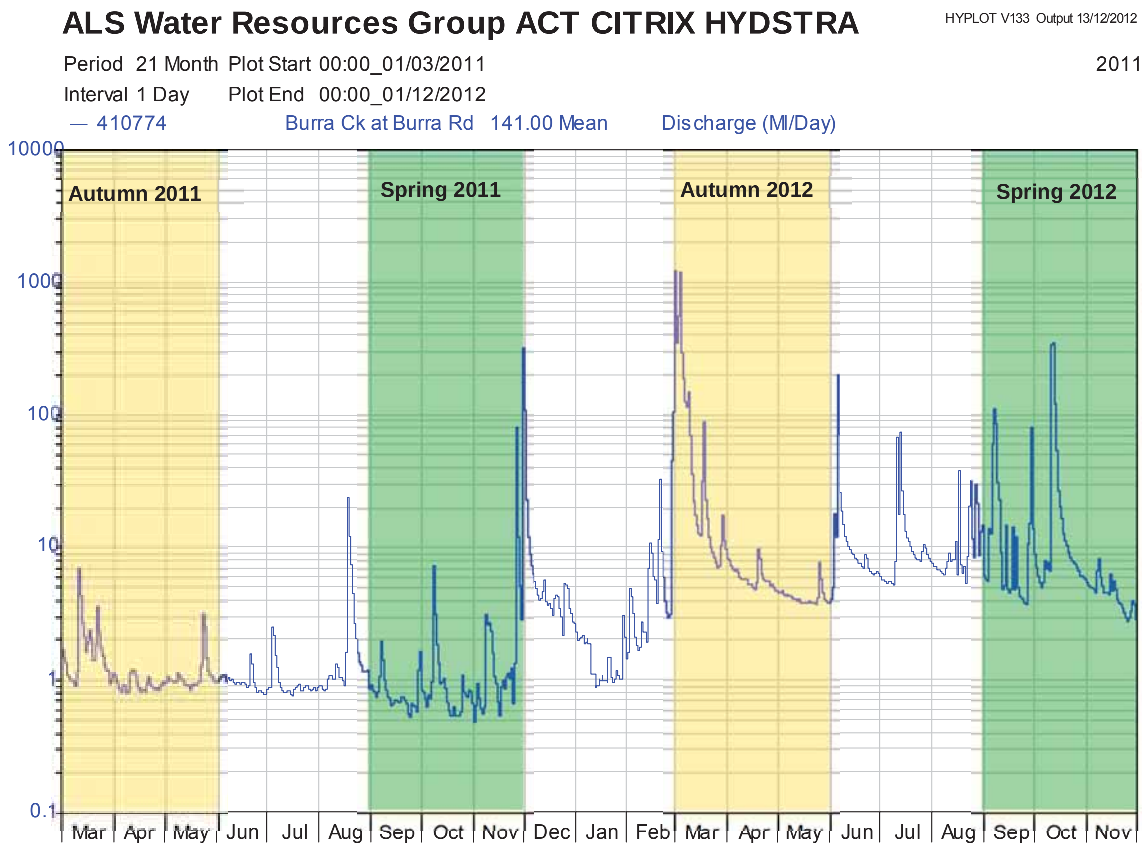

Figure 5-4 Burra Creek hydrograph highlighting the past four sampling periods between March 2011 and November 2012

5.3 Water quality

5.3.1 Grab samples and *in-situ* parameters

The results from the lab analysed grab samples and the *in-situ* measured parameters are presented in Table 5-4. Temperatures ranged from 14.7°C at BUR 2a to 22.2°C at BUR 1a. Turbidity values at all sites were found to be within the ANZECC & ARMCANZ (2000) guidelines, while electrical conductivity (EC) values were within the guidelines at QBYN 1 and BUR 1a but exceeded the guidelines at all sites downstream of this point.

Electrical conductivity readings are consistently higher than the recommended guidelines in Burra Creek and have been discussed in previous reports (GHD, 2012). The pH levels exceeded the guidelines at BUR 2b & 2c and were on the cusp of the guidelines at BUR 1c, while dissolved oxygen was below the guideline levels at BUR 1a and BUR 2a.

Total nitrogen concentrations exceeded the guidelines at all sites for spring 2012 (Table 5-4), but the total phosphors concentrations were within the guidelines at all sites sampled. There was no difference in TP concentrations between spring 2011 and spring 2012 (t=0.19, d.f.=5, P=0.85); however, TN concentrations were significantly higher (t=5.81, d.f.=5, P=0.002) compared to spring 2011 by up to 65% in this round of sampling.

QBYN 1 and BUR 1a were the only sites that did not exceed the ANZECC & ARMCANZ (2000) guidelines trigger values for NO_X (Table 5.4).

5.3.2 Continuous water quality monitoring

Time series data for the Burra Creek gauging station (410774) are shown in Figure 5-5. The highest amount of variability occurred during the trial release period in September. Following this period, most water quality parameters stabilised, but changed following the three rainfall events which occurred after the trail releases finished on the 27th of September and in mid-October and mid-November.

During the trial release period, there was high compliance of the water quality parameters relative to the remainder of spring (Table 5-3). Despite the increased flows during the release period, turbidity remained within the ANZECC guideline for that entire period. Turbidity spikes only occurred during rainfall events suggesting that the finer sediments were not entrained during this period and that the main influence is from surface runoff following rainfall events. pH and EC increased in their compliance during the trial releases demonstrating the dilution influence of additional surface flow into Burra Creek. Outside of the trial releases and rainfall events, pH and EC were both above the recommended guideline limits, but were still within the long term 80th percentile values from the period of record.

Diurnal variation of dissolved oxygen decreased as flows increased. Daily averages were usually 1-2 % below the lower guideline limit of 90% and this mainly occurred during September when surface water temperatures were on average 2-3 °C cooler. This seasonal influence may confound the effects of the M2G releases; however these temperature differences are normal for this time of year.

Table 5-3 Compliance statement for Burra Creek water quality parameters during trial releases and throughout spring

Period	Turbidity	pH	EC	D.O.%
During trial releases (28/08/12-27/09/12)	100%	70%	89%	50%
Spring (inclusive of trial releases)	85%	32%	39%	59%

Note: Values are expressed as percentage of days throughout each period that values (daily means) are within the ANZECC and ARMCANZ water quality guidelines.

Table 5-4. In-situ water quality results from Burra Creek during spring 2012

ANZECC guidelines are in red bold parentheses, yellow cells indicate values outside of ANZECC and ARMCANZ (2000) guidelines, orange cells indicate value is on the cusp of the guideline

	Site	Date	Time	Temp. (°C)	EC (µs/cm) **(30-350)**	Turbidity (NTU) **(2-25)**	TSS mg/L	pH **(6.5-8)**	D.O.(% Sat.) **(90-110)**	D.O. (mg/L)	Alkalinity (mg/L)	NOx (mg/L) **(0.015)**	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L) **(0.02)**	TN (mg/L) **(0.25)**
Upstream	BUR 1a	29/10/2012	14.25	22.2	118	14.6	3	7.3	88.7	7.73	27	0.005	0.002	0.003	0.006	0.02	0.44
Upstream	BUR 1c	29/10/2012	12.10	18.8	365	9.3	11	8.0	93.6	8.73	144	0.056	0.054	0.002	0.006	0.01	0.39
Downstream	BUR 2a	29/10/2012	10.15	14.7	435	5.8	5	7.9	87.6	8.85	179	0.2	0.198	0.002	0.005	0.01	0.49
Downstream	BUR 2b	30/10/2012	15.00	21.7	448	5.6	5	8.1	101.7	8.96	182	0.060	0.058	0.002	0.006	0.014	0.38
Downstream	BUR 2c	30/10/2012	13.40	20.5	440	3.4	<2	8.2	102.6	9.16	184	0.051	0.049	<0.002	0.002	0.009	0.32
Control	QBYN 1	30/10/2012	10.50	19.7	108	6.7	4	7.9	102.0	9.31	47	0.003	0.001	<0.002	0.004	0.02	0.32

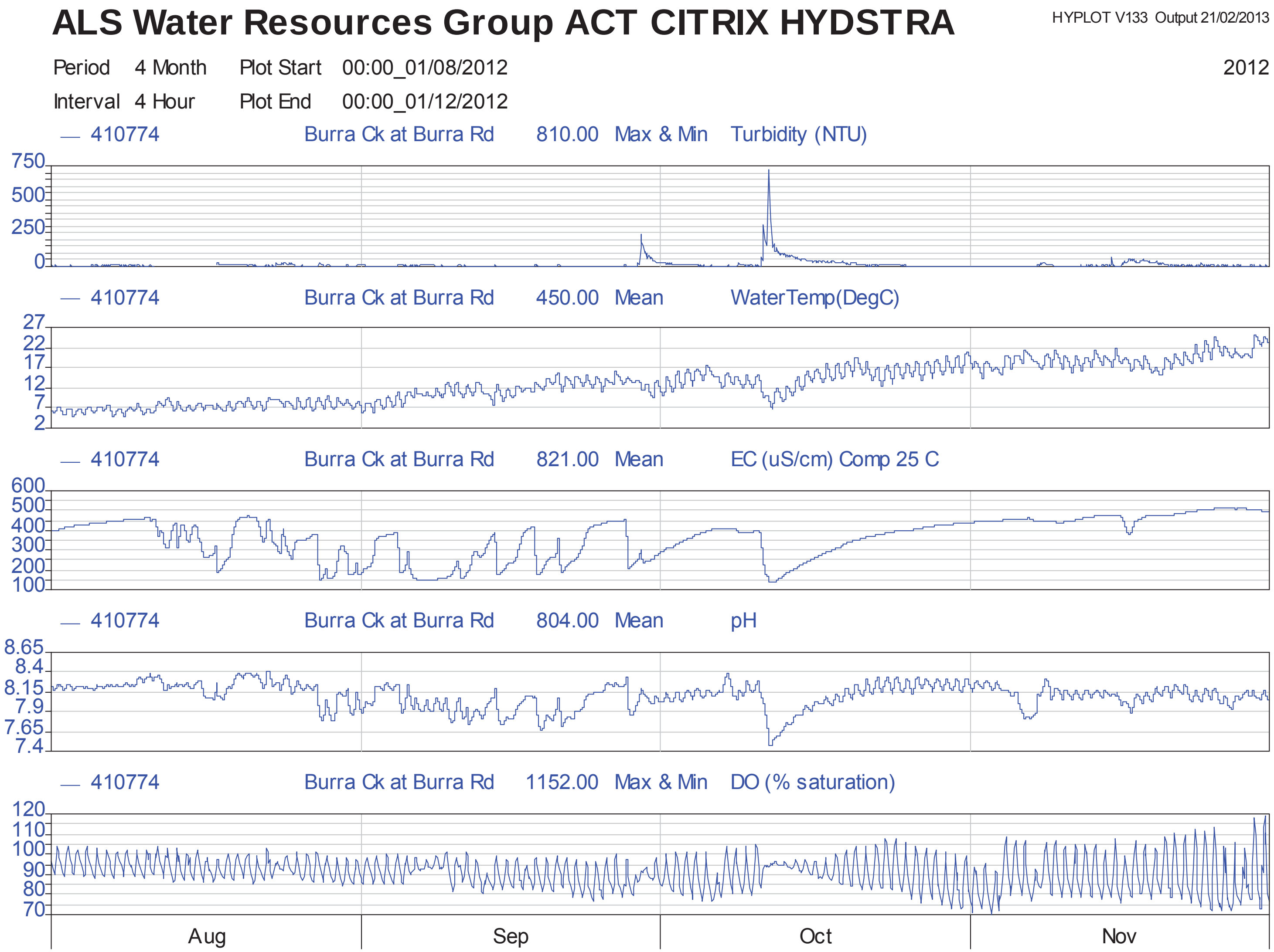

Figure 5-5 Continuous water quality records from Burra Creek (410774) for spring 2012

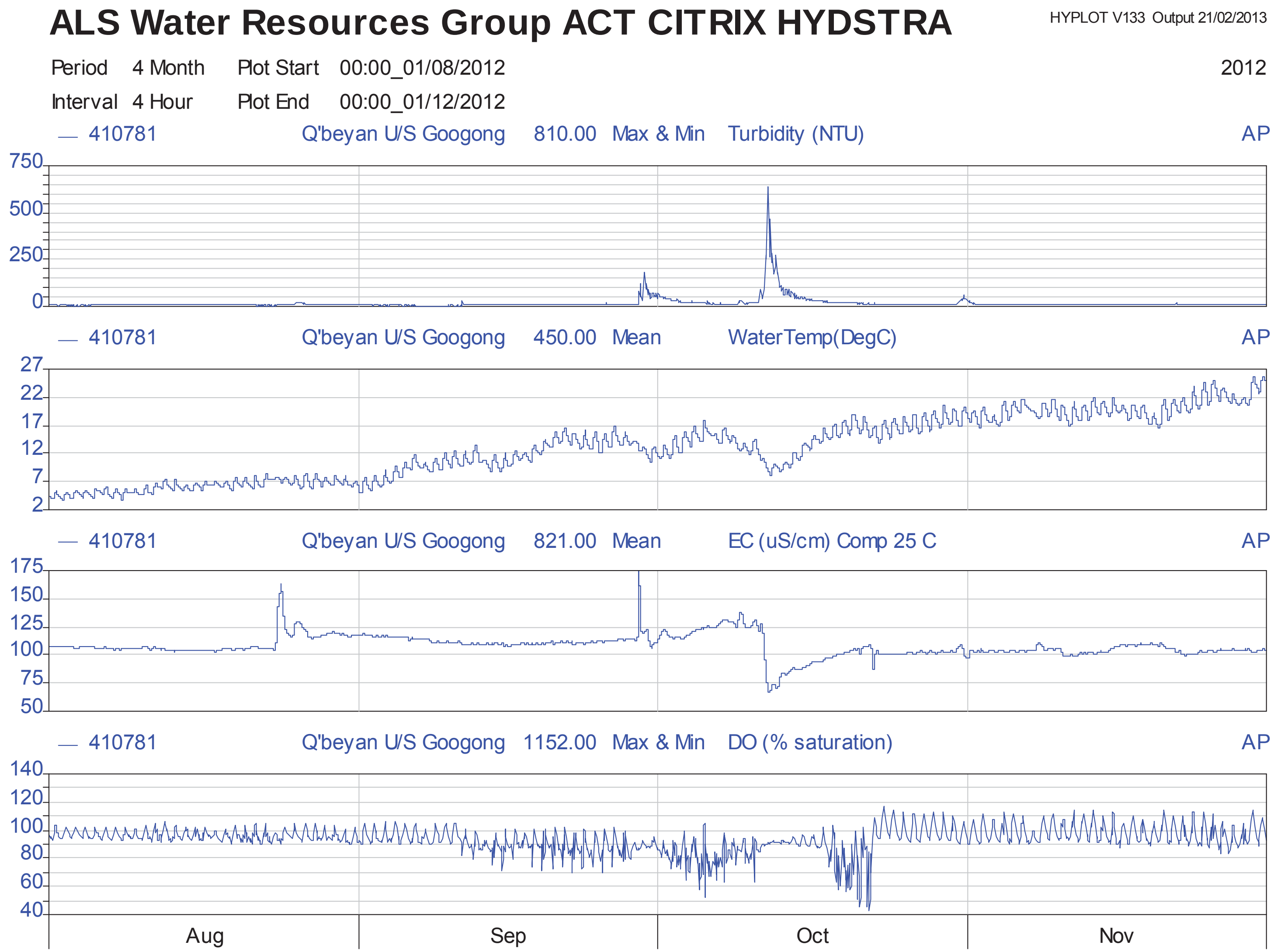

Figure 5-6 Continuous water quality records from the Queanbeyan River (410781) for spring 2012

5.4 Periphyton

The live component of the periphyton samples, which was estimated from the chlorophyll-a concentrations, shows a weakly significant difference downstream of the discharge point in Burra Creek compared to upstream and control sites ($F_{2,35}$ = 13.97; *P*=0.05; Table 5-5; Figure 5-7). The average chlorophyll-a concentration downstream of the discharge point was 22,339 µg/m^2 compared to 7,927 µg/m^2 and 7,010 µg/m^2 upstream of the discharge point and the Queanbeyan River control site respectively. The majority of the variation in the model was explained by the differences between sampling locations (56.9%) which is considerably higher than the previous sampling run, when it explained only 28% of the variation. Site to site differences accounted for 42 % of the variation of the model.

The mean values biomass (estimated by AFDM) of for each location did not differ between sampling locations ($F_{2,35}$ = 0.52; *P*=0.64; Table 5-5; Figure 5-8). Compared to spring 2011, the average AFDM values for each sampling location were considerable lower. In spring 2011 for example, AFDM ranged from 3,047-72,000 mg/m^2 compared to 1,987 mg/m^2 – 5,034 mg/m^2 in this sampling run. Highest biomass estimates were found at BUR 2b and BUR 2c (Figure 5-8); although mean values at BUR 1c (upstream of the discharge point) were relatively high. Model variation was explained largely by within site variation (66 %) with variation between sites explaining the remainder (34%).

Table 5-5 Nested analysis of variance results for chlorophyll-a and AFDM concentrations for Burra Creek

Response	Source	DF	F	P-value
Chlorophyll-*a*	Location	2	9.69	0.05
	Site [Location]	3	2.21	0.11
	Residual	35		
AFDM	Location	2	0.52	0.64
	Site [Location]	3	3.72	0.02
	Residual	35		

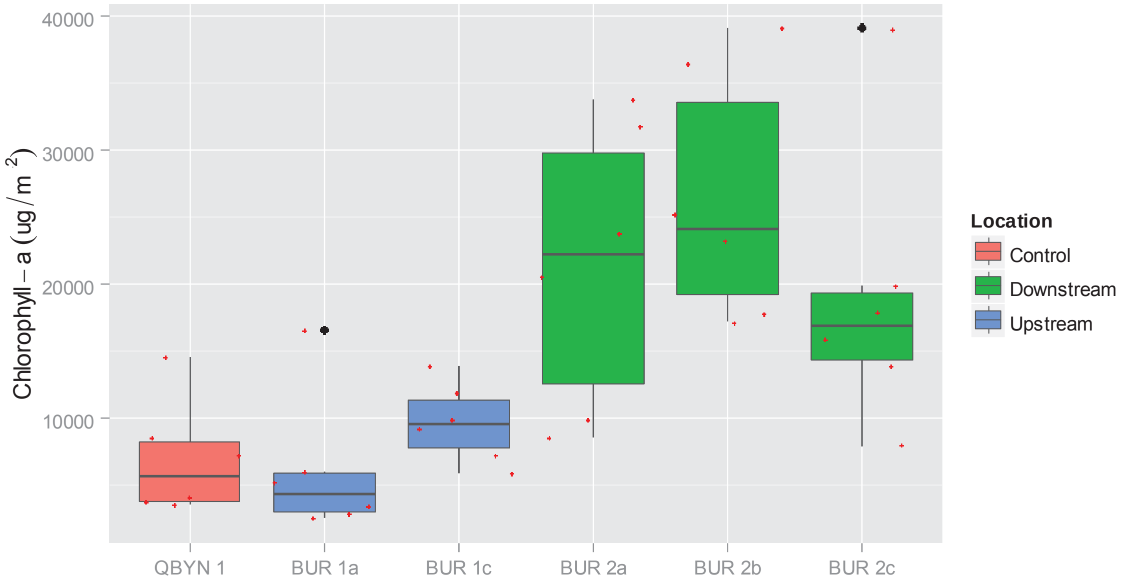

Figure 5-7 Chlorophyll-a concentrations in Burra Creek and the Queanbeyan River

Red points represent the raw values for each site

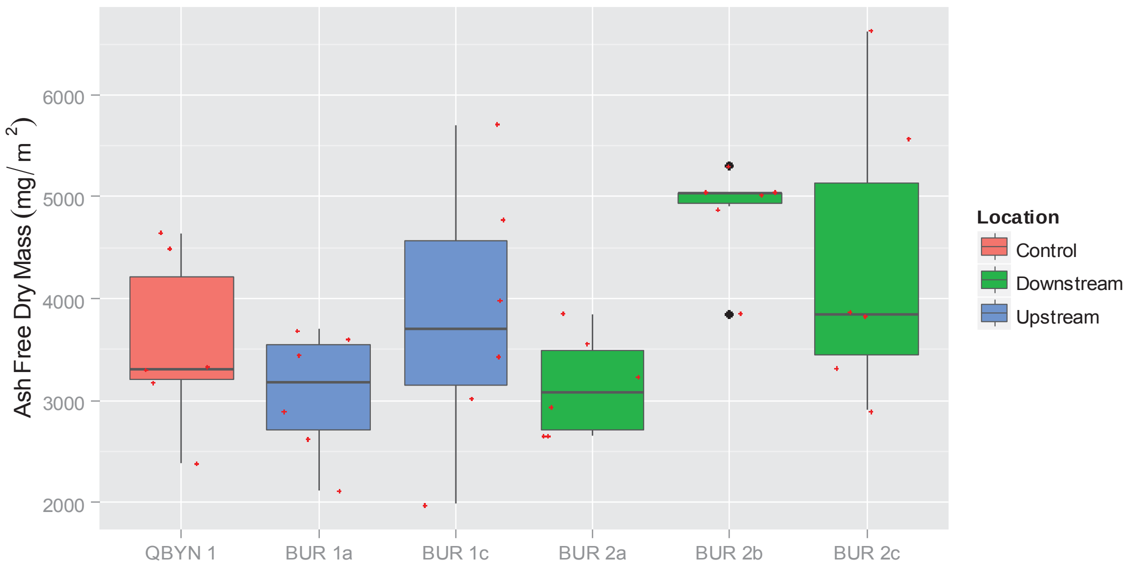

Figure 5-8 Ash free dry mass in Burra Creek and the Queanbeyan River

Red points represent the raw values for each site

5.5 Macroinvertebrates

5.5.1 Community assemblages

5.5.1.1 Riffle habitat

The structure of the macroinvertebrate communities is highly comparable (72% Bray-Curtis similarity) to the previous two sampling runs, in that there is a clear separation of the Queanbeyan Control site and the remaining sites (Figure 5-9). ANOSIM results indicate a moderate degree of separation between groups although these differences are not statistically significant (R=0.54; *P*=0.06). As explained in the autumn 2012 report (GHD, 2012), the non-significant ANOSIM test is likely to have been a function of the position of BUR 1c compared to BUR1a, which indicate a high level of similarity to sites downstream of the discharge structure at Williamsdale Road bridge compared to BUR1a.

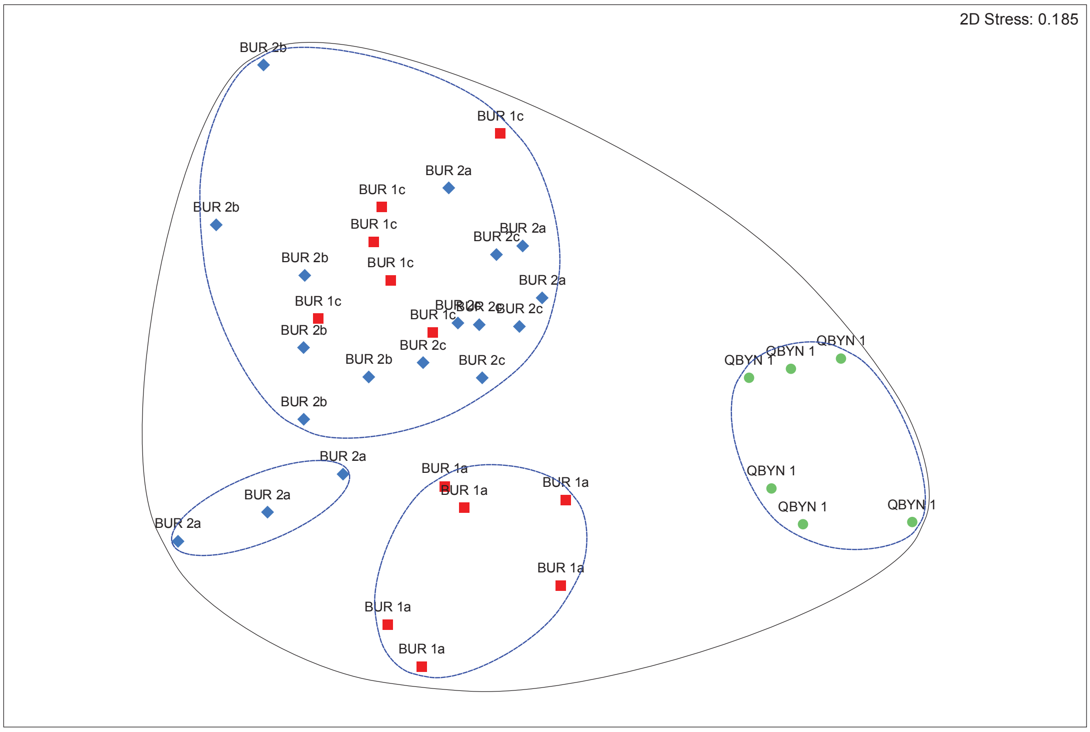

Figure 5-9 Non-metric multidimensional scaling ordination plot of genus level macroinvertebrate data from the spring riffle samples

Note: Ellipses represent 53% (Black) and 65% (Blue) similarity groupings derived from cluster analysis. Red squares represent sites upstream of the discharge point; blue diamonds are sites downstream of the discharge point

The total number of taxa collected in this spring sampling run for riffle habitats declined at the Queanbeyan control site and at BUR 1a compared to spring 2011. At BUR 1c, however there was an increase in the number of families (2) and the number of genera (8) collected compared to spring 2011. Immediately downstream of the discharge point (BUR 2a) and at BUR 2c there was no net gain or loss of the total number of families, but a small increase in the number of genera. Overall taxa richness at the family level for the spring riffle samples ranged between 17-22 taxa (Figure 19).

There was a decline in the number of sensitive (EPT) taxa at QBYN 1 and BUR 1a compared to spring 2011 (Figure 5-12), while at BUR 1c there was an increase in the number of families (2) and a sharp increase in the number of EPT genera (from 5 to 13) compared to spring 2011, the same increase (8) was seen at BUR 2a. BUR 2b and 2c also saw small increases of 1 and 3 EPT genera respectively (Figure 5-12).

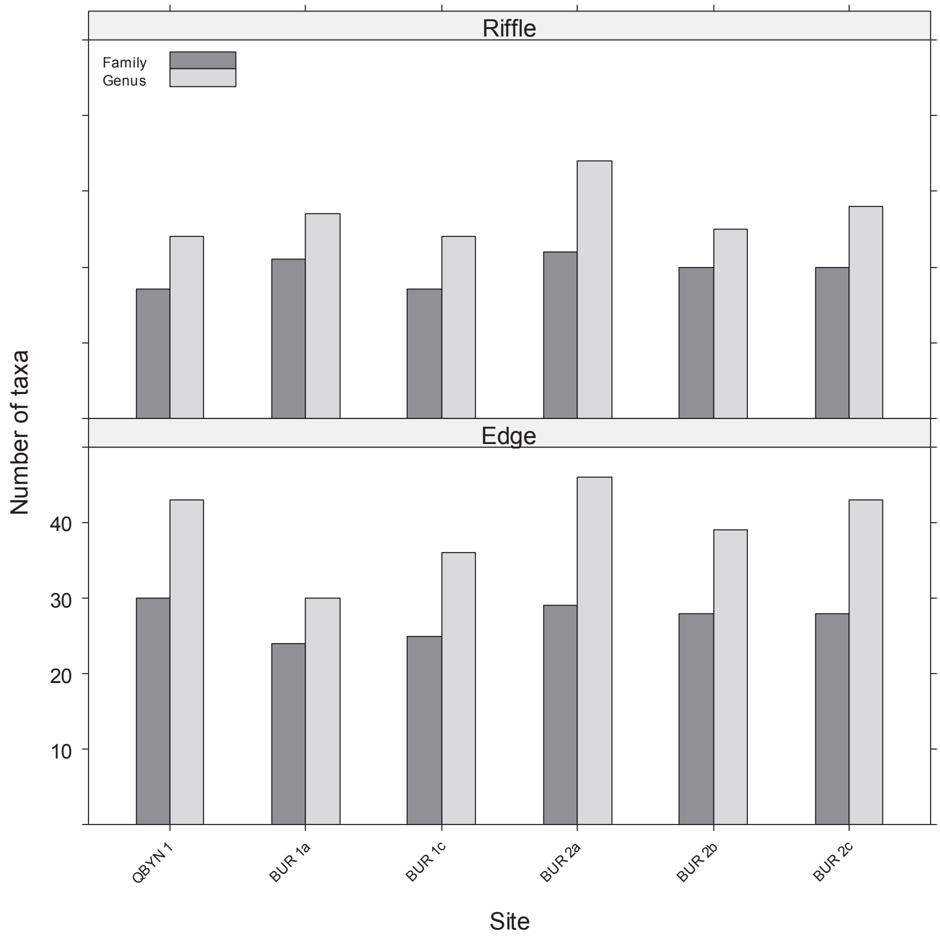

Figure 5-10 Number of taxa collected from the riffle and edge habitats

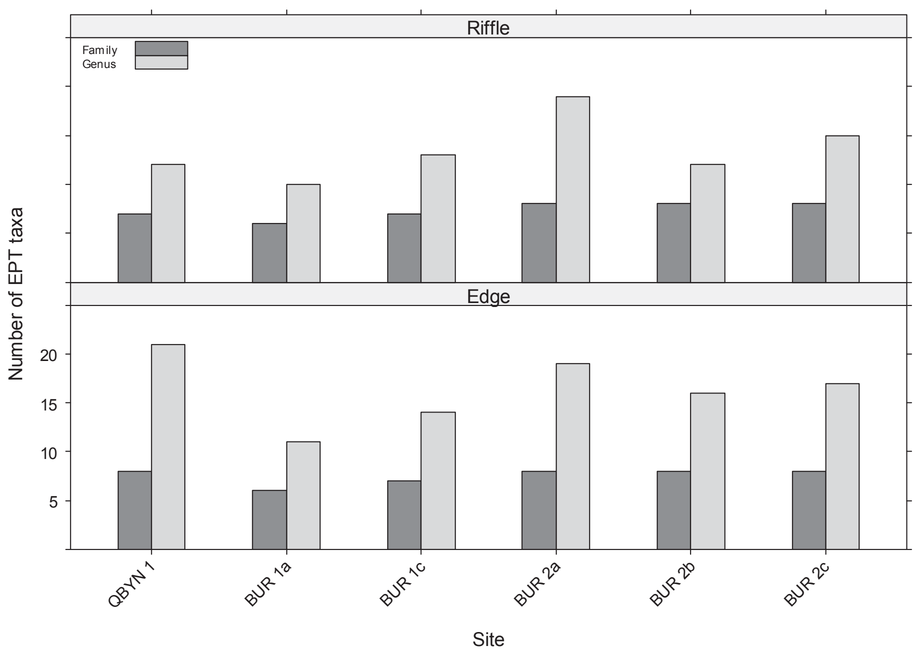

Figure 5-11 Number of EPT taxa collected from the riffle and edge habitats

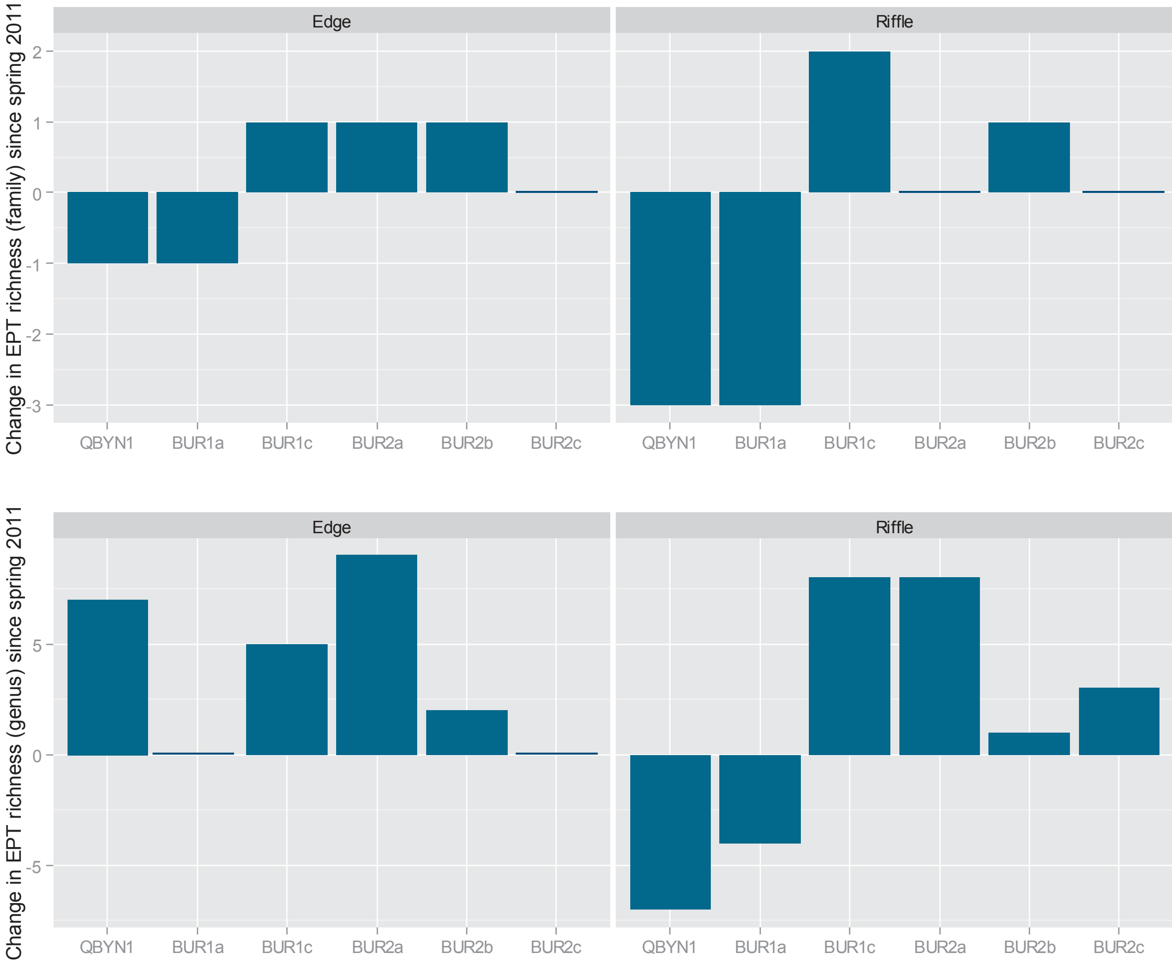

Figure 5-12 Change in the number of EPT taxa at the family level (top) and genus level (bottom) compared to spring 2011

5.5.1.2 Edge habitat

The edge community grouping structure is very similar to the pattern shown in the riffle community data and is also comparable to the edge spring 2011 ordination plot, except that rather than the Queanbeyan control site being grouped with BUR 1a, it is now a sub group with the majority of the downstream Burra sites including BUR 1c. Analysis of similarity (ANOSIM) results indicate a low degree of separation which are not statistically significant (R=0.22; *P*=0.31).

The key difference between the main group and BUR 1a is that Baetidae (SIGNAL=5) are absent from the edge samples at BUR 1a. BUR1a also has larger counts of the highly sensitive Mayfly – Leptophlebiidae (SIGNAL =8), the dragonfly, Gomphidae (SIGNAL=5) and a ten fold increase in the number of Leptoceridae (SIGNAL =4) comapred to the other sites.

The univariate data indicates higher taxa richness at sites downstream of the discharge point compared to sites upstream (Figure 5-10) there is also higher EPT richness at both the genus and family levels downstream of the discharge point (Figure 5-11). Since spring 2011, the number of EPT families has increased by 1 at BUR 1c, BUR 2a and BUR 2b (Figure 5-12) while there was a loss of 1 at BUR 1a and QBYN 1; there was no change recorded at BUR 2c. At the genus level, there was an increase at BUR 2a of 8 genera compared the spring 2011 sampling period; BUR 1c also saw an increase as did BUR 2b (Figure 5-12). The Queanbeyan control site saw an increase of 6 genera and there was no change at BUR 1a or BUR 2c.

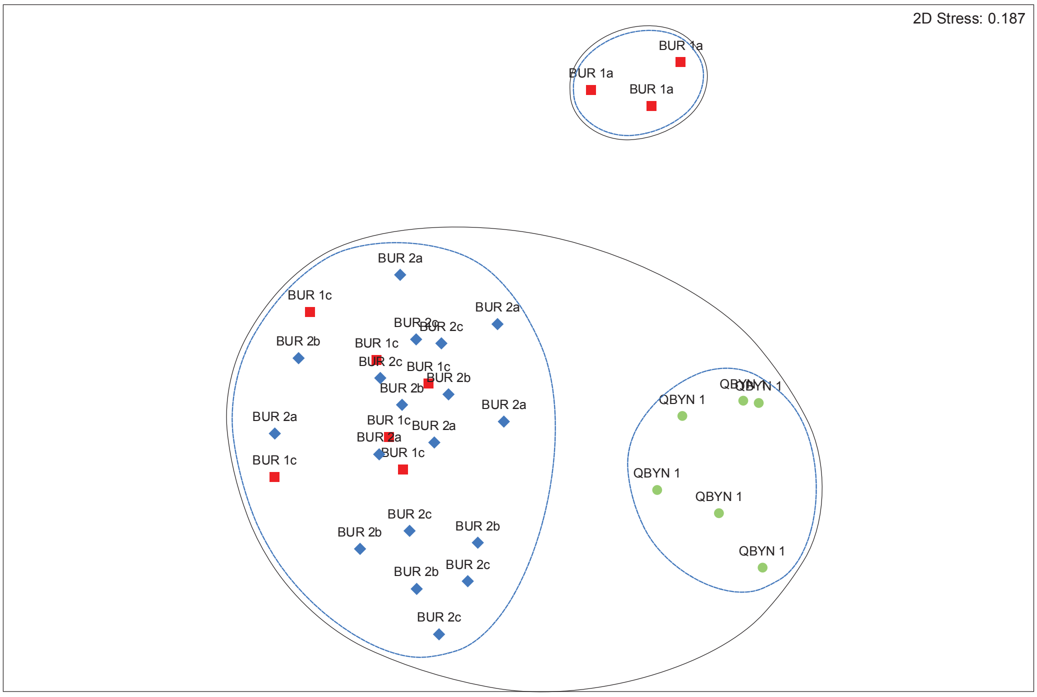

Figure 5-13 Non-metric multidimensional scaling ordination plot of genus level macroinvertebrate data from the spring edge samples

Note: Ellipses represent 52% (Black) and 60% (Blue) similarity groupings derived from cluster analysis. Red squares represent sites upstream of the discharge point; blue diamonds are sites downstream of the discharge point

5.5.2 AUSRIVAS

River health assessments based on the AUSRIVAS protocols show signs of improvement in Burra Creek compared to all previous sampling runs (Table 5-6). The Queanbeyan control site showed an improvement since autumn 2012, however based on the previous sampling runs, this site tends to fluctuate between Band A in spring and Band B in autumn.

The average OE/50 scores were highest in the downstream riffle zones (0.95) compared to upstream sites (0.85) and the Queanbeyan control site (0.92); however these differences were not statistically significant ($F_{2,35}$ = 0.68; *P*=0.57: Table 5-7). The average Signal-2 scores were highest at the Queanbeyan control site (4.96) compared to sites downstream (4.78) and upstream (4.58) of the discharge point, although again these differences were not statistically significant ($F_{2,35}$ = 5.61; *P*=0.09: Table 5-7). Signal 2 and OE/50 scores for the edge habitat were both higher at the Queanbeyan control site (OE/50=1.17; SIGNAL-2 =4.8) compared to Burra upstream sites (OE/50=1.01; SIGNAL-2 =4.54) and Burra downstream sites (OE/50=1.05; SIGNAL-2=4.62); however these, as with the riffle habitat data, did not show any statistical differences amongst locations (Table 5-8).

Individual habitat assessments from this sampling period indicate ecological health close to the expected reference condition at most sampling sites (Table 5-9). In the edge habitat 58% of samples were considered BAND A and 42% were BAND X, indicating a very high occurrence of expected families (Barmuta *et al.*, 2003). Despite the riffle samples at BUR1a and 2b having overall sites assessments of BAND B, there were several BAND A's returned for each site among some of the replicates. Taxa missing from these sites included Baetidae (SIGNAL=5), Gripopterygidae (SIGNAL=8), Oligochaeta (SIGNAL=2) and Caenidae (SIGNAL=4), all of which were recorded in at least one replicate (APPENDIX F).

Missing taxa from the edge samples ranged from 0 – 4 (APPENDIX F). BUR 2b had the most missing taxa (4) which included Elmidae (SIGNAL=7), Acarina (SIGNAL=6) and Gripopterygidae (SIGNAL=8).

Table 5-6. Overall site assessments for the current and previous three sampling runs for Burra Creek

	Autumn 2011	Spring 2011	Autumn 2012	Spring 2012	Change since previous sampling run
QBYN1	B	A	B	A	↑
BUR1a	B	B	B	B	-
BUR1c	NS	NRA	B	B	-
BUR 2a	NRA	NRA	B	A	↑
BUR 2b	B	B	B	B	-
BUR 2c	B	B	B	A	↑

Note: NS = not sampled; NRA = No Reliable Assessment

Table 5-7 Nested analysis of variance results from the riffle samples based on OE/50 and Signal-2 scores

Response	Source	DF	F	P-value
OE 50	Location	2	0.68	0.57
	Site [Location]	3	4.62	0.008
	Residual	35		
SIGNAL-2	Location	2	5.61	0.09
	Site [Location]	3	1.27	0.30
	Residual	35		

Table 5-8 Nested analysis of variance results from the edge samples based on OE/50 and Signal-2 scores

Response	Source	DF	F	P-value
OE 50	Location	2	0.70	0.56
	Site [Location]	3	12.44	<0.001
	Residual	32		
SIGNAL-2	Location	2	1.26	0.40
	Site [Location]	3	3.83	0.02
	Residual	32		

Table 5-9 AUSRIVAS and Signal -2 scores for spring 2012

Site	Rep.	SIGNAL-2		AUSRIVAS O/E score		AUSRIVAS band		Overall habitat assessment		Overall site assessment
		Riffle	Edge	Riffle	Edge	Riffle	Edge	Riffle	Edge	
QBYN 1	1	5.10	4.80	0.92	1.17	A	X	A	X	A
QBYN 1	2	4.80	4.80	0.92	1.17	A	X			
QBYN 1	3	5.10	4.80	0.92	1.17	A	X			
QBYN 1	4	4.90	4.80	0.92	1.17	A	X			
QBYN 1	5	4.80	4.80	0.92	1.17	A	X			
QBYN 1	6	5.10	4.80	0.92	1.17	A	X			
BUR 1a	1	4.82	4.56	1.01	0.91	A	A	B	A	B
BUR 1a	2	4.33	4.89	0.83	0.91	B	A			
BUR 1a	3	4.50	4.56	0.92	0.91	A	A			
BUR 1a	4	4.38	NS	0.73	NS	B	NS			
BUR 1a	5	4.29	NS	0.64	NS	B	NS			
BUR 1a	6	4.90	NS	0.92	NS	A	NS			
BUR 1c	1	4.82	4.67	1.01	1.00	A	A	B	A	B
BUR 1c	2	4.80	4.60	0.92	1.11	A	A			
BUR 1c	3	4.70	4.55	0.92	1.22	A	X			
BUR 1c	4	4.70	4.20	0.92	1.11	A	A			
BUR 1c	5	4.33	4.44	0.83	1.00	B	A			
BUR 1c	6	4.43	4.44	0.64	1.00	B	A			
BUR 2a	1	4.82	4.80	1.01	1.16	A	X	A	A	A
BUR 2a	2	4.82	4.80	1.01	1.16	A	X			
BUR 2a	3	4.82	4.80	1.01	1.16	A	X			
BUR 2a	4	4.50	4.67	0.92	1.04	A	A			
BUR 2a	5	4.64	4.80	1.01	1.16	A	X			
BUR 2a	6	4.92	4.67	1.10	1.04	A	A			
BUR 2b	1	4.33	4.60	0.83	1.02	B	A	B	B	B
BUR 2b	2	4.91	4.60	1.01	1.02	A	A			
BUR 2b	3	4.50	4.80	0.92	1.02	A	A			
BUR 2b	4	4.43	4.25	0.64	0.81	B	B			
BUR 2b	5	5.13	4.44	0.74	0.92	B	A			
BUR 2b	6	4.89	4.25	0.83	0.81	B	B			
BUR 2c	1	4.82	4.80	1.01	1.17	A	X	A	A	A
BUR 2c	2	4.90	4.80	0.92	1.17	A	X			
BUR 2c	3	5.09	4.80	1.01	1.17	A	X			
BUR 2c	4	4.92	4.44	1.11	1.05	A	A			
BUR 2c	5	4.91	4.44	1.01	1.05	A	A			
BUR 2c	6	4.82	4.44	1.01	1.05	A	A			

5.6 Discussion

5.6.1 Water quality

During the trial releases into Burra Creek, water quality parameters responded in a similar way to natural high flow events; although the return to conditions prior to the release happened at a quicker rate compared to the natural event in mid-October. During the releases EC and pH responded to the extra volumes so that both parameters were within the ANZECC and ARMCANZ (2000) water quality guidelines for those periods; resulting in higher compliance to the guidelines during the release periods compared to natural base flows. Turbidity was unaffected by the M2G releases and remained within the guideline values for 100% of the discharge period (Table 5-3). In comparison, during the high flow event in mid-October turbidity peaked at over 750 NTU suggesting runoff to be the major contributor to increased turbidity as opposed to remobilisation within the channel, as would have been the case if turbidity spikes had resulted from the M2G releases.

Water quality parameters returned to pre-release levels usually within 24 hours of the trial releases (Table 5-5) which would suggest that risk to the flora and fauna would have been minor during this period; because this pulse disturbance was indicative of changes seen during natural events and the results from this project to date show that following these natural flow events, macroinvertebrate communities are either not impacted or in the few cases when they have been impacted, return to pre-disturbance condition within three or four weeks. The grab sample results do not indicate any lasting effects from the M2G releases as all parameters are within the same range as the results from all pre-release sampling runs (e.g. ALS, 2011).

Total nitrogen exceeded guideline values at all sites (Table 5-4) although this is a common pattern for the sampling sites in this project. However, the concentrations recorded in this sampling run were significantly higher than in spring 2011 (when the majority of sites were below the recommended nitrogen concentrations) by up to 65%. There are two key lines of evidence to suggest that these elevated concentrations are not related to the M2G releases. The first is that the elevated concentrations are seen across all sampling sites (i.e. upstream of the discharge structure and at the Queanbeyan River control site (Table 5-4) and based on this, the most likely cause in this increase is from rainfall runoff just prior to sampling. The second point is that nitrogen concentrations, higher still than the current were recorded in spring 2010 and maximum concentrations (0.63 mg/L were recorded at the Native Burra site (BUR 1a). In contrast phosphorus concentrations were within guideline values at all Burra Creeks sites (the exceptions were QBYN 1 and BUR 1a which were both on the upper limit of the guideline). These concentrations are highly consistent with previous sampling runs, further indicating no apparent or lasting effects from the trial releases.

The highest concentrations of nitrogen were recorded at BUR 2a downstream of the discharge structure. This was also seen in autumn 2012 and a follow up investigation found that the source of these elevated concentrations was Holdens Creek which flows into Burra Creek downstream of BUR 1c and runs parallel to the M2G alignment near the mini hydro. Based on the baseline data from the MEMP, it appears likely that the source is related to land use practices unrelated to M2G since the elevated TN concentrations at this site date back to 2009, which was prior to the construction of the M2G infrastructure.

There was some indication of a longitudinal increase in the live component (as chlorophyll-a) from the periphyton samples downstream of the discharge point compared to the control sites (Table 5-5; Figure 5-7), which could be related to the increased nitrogen concentrations entering upstream. Another possibility is that with the increased flows over the riffle zones, there has been greater absorption of nutrients and high growth rates downstream of the discharge point. Previous assessments have shown similar patterns although on these occasion maximum Chlorophyll-a concentrations have occurred farther downstream at BUR 2b (i.e. GHD, 2012_b).

Owing to differences in the bio-physical nature of these sites (e.g. channel and bank features, macrophyte stands) there has likely been different degrees of scouring and new growth amongst sites. For example, because BUR 1c is located within a straight channel with little in stream vegetation or bends to buffer the impacts of high flows, it is likely that the lower standing crops are a result of the mid-October high flow event. Similarly, the less embedded and therefore looser substrate at BUR 1a would have been subject to more bed movement and higher rates of scouring than sites farther downstream. However, it is equally feasible that the addition nutrient input from Holders Creek is facilitating algal and macrophyte growth downstream of Williamsdale Road.

5.6.2 AUSRIVAS and macroinvertebrate assemblages

River health assessments based on the AUSRIVAS protocols show signs of improvement in Burra Creek compared to recent sampling runs (Table 5-6). The Queanbeyan control site showed an improvement since autumn 2012, however based on the previous sampling runs, this site tends to fluctuate between BAND A and BAND B depending on the season. The edge habitat at QBYN 1 was assessed as BAND X – indicating that this habitat is richer than reference condition. The interpretation of this band assignment is either to regard the site / habitat as a biodiversity hotspot or slight nutrient enrichment (Barmuta *et al.*, 2003). The most feasible interpretation for this particular site is slight nutrient enrichment given that farther upstream there are some moderate to high areas of bank and gully erosion and the difference between the given BAND X and BAND A for this site is the presence one taxonomic family.

There was no change in AUSRIVAS banding at the native site on Burra Creek (BUR 1a) compared to the past three previous sampling runs. This is due to the intermittent nature of the flow regime of the upper sections of Burra Creek. In this section of Burra Creek, flows are highly dependent upon rainfall and in between rainfall events, the wetted width, depth, riffle and edge habitat availability is diminished since it is highly dependent on groundwater. Another consequence of the intermittent nature of this section of Burra Creek is a loss, or reduction of connectivity between upstream and downstream sections of the Creek, resulting in macroinvertebrate communities with high beta diversity (Bond and Cottingham, 2008), which would explain the position of BUR 1a relative to the other sites in the ordination plots for the riffle (Figure 5-9) and edge (Figure 5-13) habitats.

The other sites showing no change were BUR 1c and BUR 2b which remain as BAND B (Table 5-9) as they have done for the majority of the time during this programme. However at BUR 1c, there was an improvement in the riffle habitat, which was BAND C in spring 2011, compared to the current assessment of BAND B. The riffle and edge at BUR 2b (Plate 5-3), are highly silted and the riffle, especially, contains large amounts of organic matter which is rarely removed after high flow events. The main reason for this is likely because the riffle is situated immediately downstream of a large pool, which may buffer the effects of increasing flow volumes, which in turn lessons the scouring capacity of the flow during high flow events.

At BUR 1c there was evidence of the scouring effects of the October high flow event in that the substrate at this site had visibly less silt and periphyton cover on the upper surfaces compared to autumn (Plate 5-2) and the previous spring. Despite this scouring, site BUR 1c remains BAND B which may reflect other aspects of the habitat (i.e. velocity) and overall site condition which remain sub-optimal for recruitment or establishment of the full suite of predicted taxa by the AUSRIVAS model.

However, there is some evidence of improved habitat conditions at BUR 1c from the biological data. Compared to spring 2011, there are eight more genera at this site and many of these could be considered sensitive to silt deposition, such as genera in the Simuliidae, Leptophlebiidae and Gripopterygidae families. One other consideration of this result is that in spring 2011, only one replicate was collected compared to two in this sampling run and given that taxonomic richness tends to increase with sampling effort (Vinson and Hawkins, 1996), it is possible that this increase is also related to the additional replicated samples collected in spring 2012.

Improved overall AUSRIVAS bands were recorded at BUR 2a and BUR 2c. In spring 2011, BUR 2a had no reliable assessment for the edge habitat, despite the riffle being assessed as BAND A. The riffle at BUR 2a in this sampling run was also assessed as BAND A, although the average OE/50 score did show a marginal increase since spring 2011 as did the average Signal -2 score, which in both cases reflects the higher occurrence of Leptophlebiidae (SIGNAL =8), Baetidae (SIGNAL =5) and Acarina (SIGNAL=6).

A similar pattern was seen at BUR 2c where Leptophlebiidae (SIGNAL =8) and Gripopterygidae (SIGNAL=8) were collected in this run but were not recorded in spring 2011. The re-occurrence of these taxa is likely to a function of the effects of the most recent high flow event, which removed much of the surface silt and detritus in the same manner as BUR 1c; but also the higher base flows occurring during this spring sampling season (mean =19.8 ML/d) compared to spring 2011 (mean = 5.60 ML/d) (Figure 5-4). Walters *et al.* (2011) found a linear relationship between the severity of altered base flow (depletion and inflation) and EPT richness, taxa richness and community composition. The results of that study were not consistent amongst seasons suggesting the existence of complex relationships between macroinvertebrate communities, the flow regime (magnitude, timing and frequency) and seasonal influences. Flushing flows from the October high flow event would have provided a mechanism for the transport and deposition of organic material which provides food and habitat for many macroinvertebrate taxa (Hynes, 1970). This may account for the increase in the overall number of genera and EPT taxa recorded in this sampling run compared to spring 2011 (Figure 5-12).

There was no statistical difference between sampling locations in terms of macroinvertebrate assemblages. Both the NMDS ordination plots show similar patterns and grouping structures compared to spring 2011 and autumn 2012. Although there is evidence for increased richness (total and EPT) at a select few of these sites this does not appear to have affected the overall structure of the macroinvertebrate communities. One likely explanation of this is that the relative abundances of the additional taxonomic groups was low compared to the more abundant groups (i.e. Chironominae, Orthocladiinae and Caenidae); the additional taxa therefore, had little influence on the amongst group distance measures resulting in similar ordination plots as previous report.

The results from the macroinvertebrate community data suggest that the changes seen in the Burra Creek system compared to spring 2011 are related to the high flow event in mid-October and the increase in the seasonal average flow over the spring period. However, there may have also been benefits from the M2G release, which were undetected because of the high magnitude flow which occurred prior to the sampling run. This ultimately may have masked any of these potential benefits from the M2G trial releases in August and September.

5.7 Conclusions and recommendations

Commissioning of M2G began in late August and a full test of the ramp up / ramp down pumping regime occurred in September. The water quality and biological results from this round of sampling were collected approximately 6 weeks after the final release in September and approximately 3 weeks after a natural high flow event in October. Water quality parameters responded to the increased flow from the M2G release in a similar way to historical natural flows of approximately the same magnitude; and were back to pre-release values within 24 hours of the pumps being shut off, indicating that there were no lasting effects from theses releases. The biological indicators showed mixed responses. There was some evidence of ecological health improvements at two of the sites downstream of the discharge point, however these improvements were not unique to these sites as a similar pattern was seen at the Queanbeyan control site. This suggests that the main driver was the high flow event in mid-October, which is likely to have improved habitat conditions which resulted in the improved AUSRIVAS bands.

One of the key threatening processes identified under the M2G project was the potential risk to surface water quality from the inter-basin transfers which will occur once the operational phase of the project is reached. At this stage, these risks should be considered low, given the non-continuous pumping regime occurring at this time. Although this sampling run is the first to have occurred following a full test of the M2G infrastructure (and subsequent maintenance runs have occurred since), these initial results suggest that changes to water quality are short lived, and resemble natural high flow events. However, Burra Creek is subject to high spatial and temporal discontinuities in flow, resulting in highly variable and patchy macroinvertebrate assemblages, highly seasonal fluctuations in water characteristics; and although there is a high degree of resilience within the macroinvertebrate fauna in Burra Creek the ability to recover will depend on the duration and frequency of these releases and these effects will in turn vary from season to season.

It is therefore recommended that autumn sampling should occur as soon as possible following any scheduled releases. Ideally this would occur three to four weeks after the next full ramp up/ramp down schedule and will avoid natural high flow events. While this is out of our control, additional sampling events within a given season would provide a better understanding of the short term responses while sampling at longer intervals would provide information on the longer term responses in Burra Creek. Additional recommendations are documented in (ALS, 2012).

Part 3-Murrumbidgee Pump Station

6. Murrumbidgee Pump Station

6.1 Summary of sampling and river condition

The Murrumbidgee Pump Station sites were sampled on the 14th and 15th of November with maximum temperatures of 22 and 25°C respectively. Both days were fine with some clouds in patches. Flows in the Murrumbidgee River were receding during the period of sampling, following a rainfall event on the 7th of November.

Site photos are found in Plate 6-1, and full site summaries are shown in APPENDIX D.

The Bendora scour valve was in operation at MUR 28 prior to sampling, which was turned off for the 14th of November for sampling to be conducted. The sampling program for this MEMP study component generally met its objectives, apart from the fact that one of the edge habitat macroinvertebrate samples could not be collected because the edge habitat slightly upstream of the riffle habitat was inaccessible due to the persisting high volume flows.

MUR 931. Looking across the riffle habitat

MUR 28. Looking downstream towards the MPS

MUR 935. Looking across the riffle habitat

MUR 937. Riffle habitat looking upstream

MUR 29. Looking upstream towards the crossing

Plate 6-1 Photographs of sampling sites for the MPS component of the MEMP

6.2 Hydrology and rainfall

The flow conditions during spring 2012 were variable with multiple rainfall events producing periods of higher flows during all three months (Figure 6-1). The main feature of the spring 2012 hydrograph is the high flow event in mid-October which peaked at over 10,000 ML/d at the Mt. McDonald gauging station (410738) (Figure 6-1). This high flow event was caused by intense rainfall on the 11th of October producing 40.0 mm. A smaller event in September peaked at over 5,000 ML/d at the Mt. MacDonald gauging station, caused by intense rainfall on the 28th of September totalling 46.4 mm.

Figure 6-2 show the flows in the Cotter River downstream of the Enlarged Cotter Dam (ECD) for the spring period. With the exception of the two spikes during mid-October from the high flow events, were normal fluctuating between 50 and 500 ML/d across the period. Monthly flow and rainfall statistics for spring from both Lobb's Hole (410761) and Mt. McDonald (410738) are located in Table 6-1.

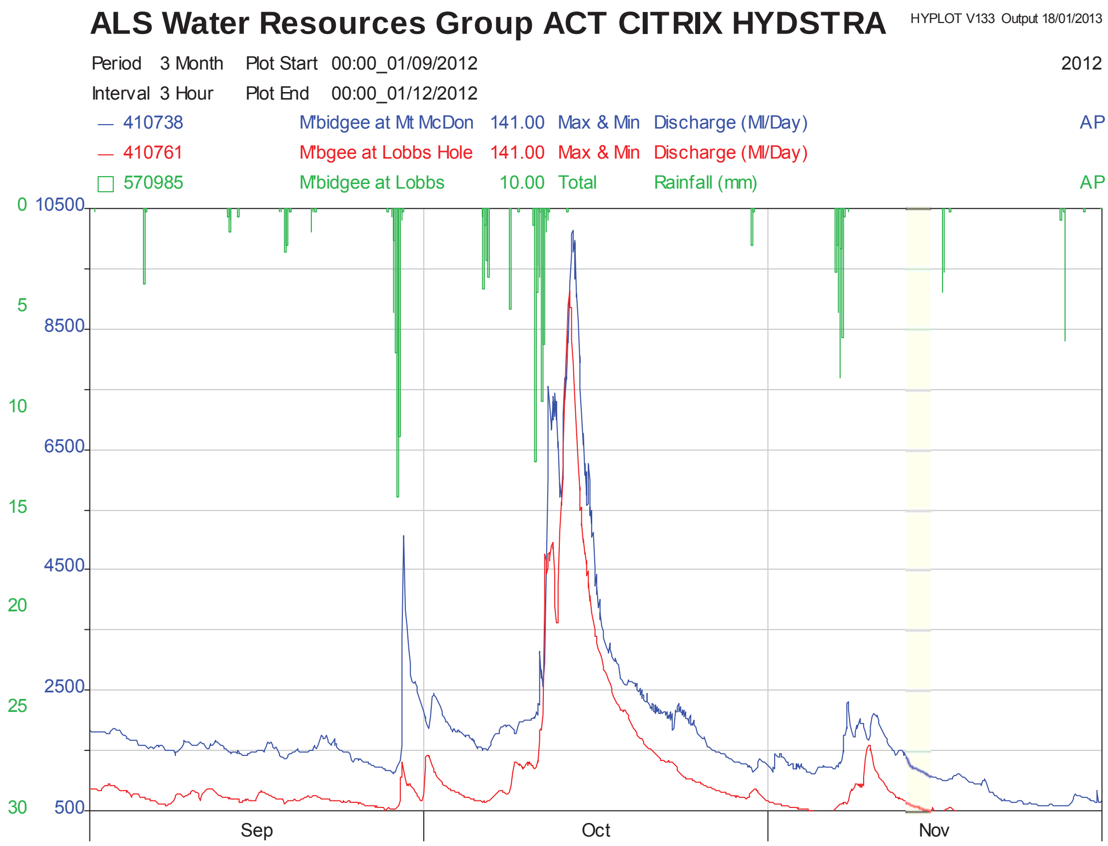

Figure 6-1 Spring hydrograph of the Murrumbidgee River at Lobb's Hole (410761) and Mt. MacDonald (410738), including total rainfall for the Lobb's Hole gauge (570985)

Note: Green shading indicates sampling period

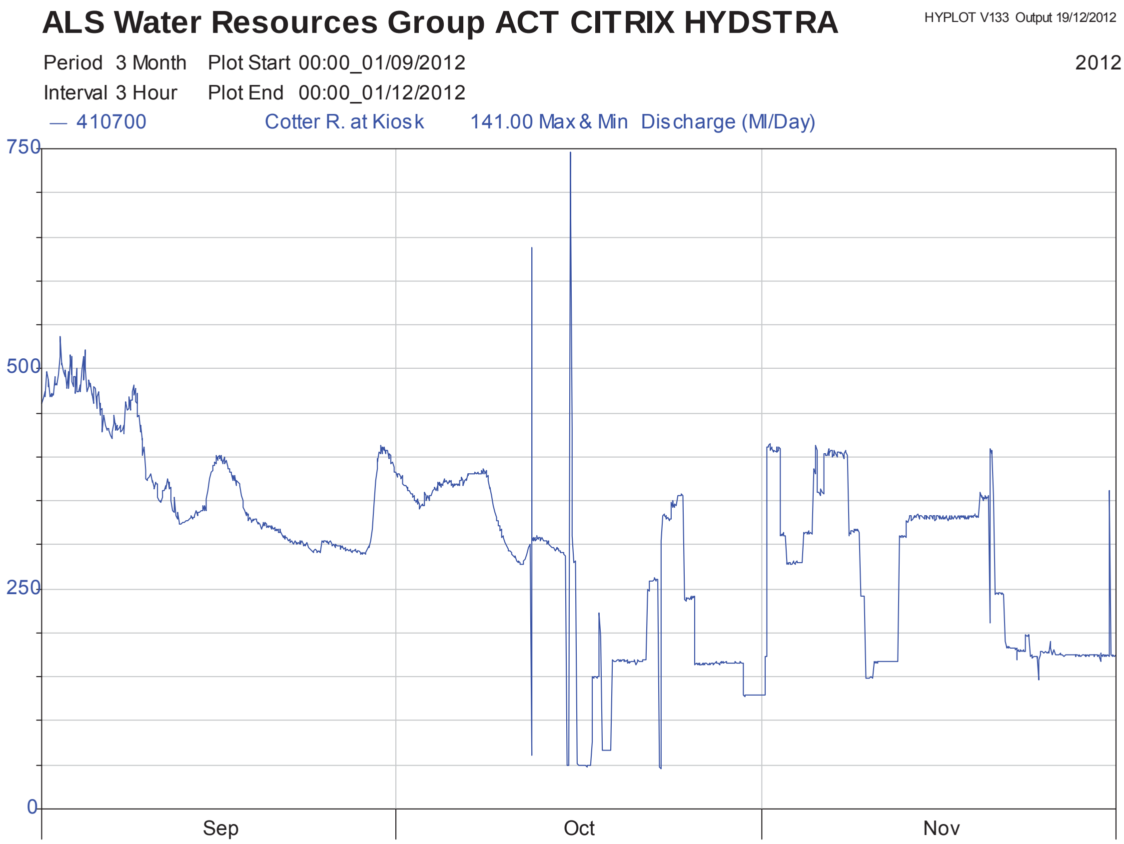

Figure 6-2 Hydrograph for the Cotter River downstream of the Cotter Dam (410700) for spring 2012

Table 6-1. Monthly flow and rainfall statistics for sprig 2012 at Lobb's Hole (410761) and Mt. MacDonald (410738)

	Lobb's Hole (410761)		Mt. MacDonald (410738)
	Total Rainfall (mm)	Mean Flow (ML/d)	Mean Flow (ML/d)
September	60.8	615	1,620
October	61.4	1,670	2,740
November	42.8	504	1,100
Spring (mean)	165.0 (55.0)	930	1,820

6.3 Water quality

6.3.1 Grab samples and *in-situ* parameters

The results from the lab analysed grab samples and the *in-situ* measured parameters are located in Table 6-2. Temperatures ranged from 19.9°C at MUR 28 to 22.3°C at MUR 937. All values for electrical conductivity (EC) and turbidity were within the ANZECC & ARMCANZ (2000) guidelines. The pH readings were slightly above the guideline range upper limit at all sites. Dissolved Oxygen concentrations were slightly below the lower guideline range at MUR 935 and at the lower range guideline limit at site MUR 931. Total nitrogen concentrations exceeded the ANZECC and ARMCANZ (2000) guideline trigger levels at all sites in spring 2012, while total phosphorus concentrations were above the guideline trigger level at the majority (5 of the 6) sites (Table 6-2). All sites were within the guidelines for NOx, while concentrations of nitrate, nitrite and ammonia were all low and comparable across the sites monitored.

6.3.2 Continuous water quality monitoring

Water quality parameters were monitored continuously during spring 2012 at Lobb's Hole (410761) (Figure 6-3). The only ANZECC & ARMCANZ (2000) guideline exceedances that were recorded during this period related to turbidity and pH readings. The turbidity exceedances were restricted to the periods of elevated flow. The pH guideline exceedances were restricted to November but occurred consistently throughout that month.

Figure 6-3 shows that all parameters which are monitored at Lobb's Hole tracked well for the period, reacting normally to both higher flows and periods of lower flows. The diurnal trends from the dissolved oxygen and the temperature are present, showing slight variations during periods of higher flow, while the temperature shows an increasing trend towards summer. The electrical conductivity was recorded well within the guidelines throughout spring, with variations present relating to the fluctuating flow levels.

Table 6-2 In-situ water quality results from Murrumbidgee Pump Station during spring 2012

ANZECC guidelines are in red bold parentheses, yellow cells indicate values outside of ANZECC and ARMCANZ (2000) guidelines, orange cells indicate value is on the cusp of the guideline

	Site	Date	Time	Temp. (°C)	EC (µs/cm) (30-350)	Turbidity (NTU) (2-25)	TSS mg/L	pH (6.5-8)	D.O.(% Sat.) (90-110)	D.O. (mg/L)	Alkalinity (mg/L)	NOx (mg/L) (0.015)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L) (0.02)	TN (mg/L) (0.25)
Upstream	MUR 931	15/11/2012	10:05	20.9	122.7	8.6	11	8.06	90.0	8.04	49	0.003	0.001	< 0.002	< 0.002	0.026	0.30
	MUR 28	14/11/2012	9:35	19.9	130.8	13.0	10	8.16	101.5	9.26	51	0.003	0.001	< 0.002	< 0.002	0.026	0.33
Downstream	MUR 935	14/11/2012	11:20	20.1	126.1	11.7	11	8.17	89.1	8.08	49	0.003	0.001	< 0.002	< 0.002	0.026	0.32
	MUR 937	15/11/2012	13:00	22.3	96.6	8.3	9	8.25	97.1	8.44	39	0.004	0.002	< 0.002	< 0.002	0.021	0.26
	MUR 29	14/11/2012	13:50	21.8	110.1	10.2	8	8.28	96.0	8.42	43	0.004	0.002	< 0.002	0.002	0.019	0.28

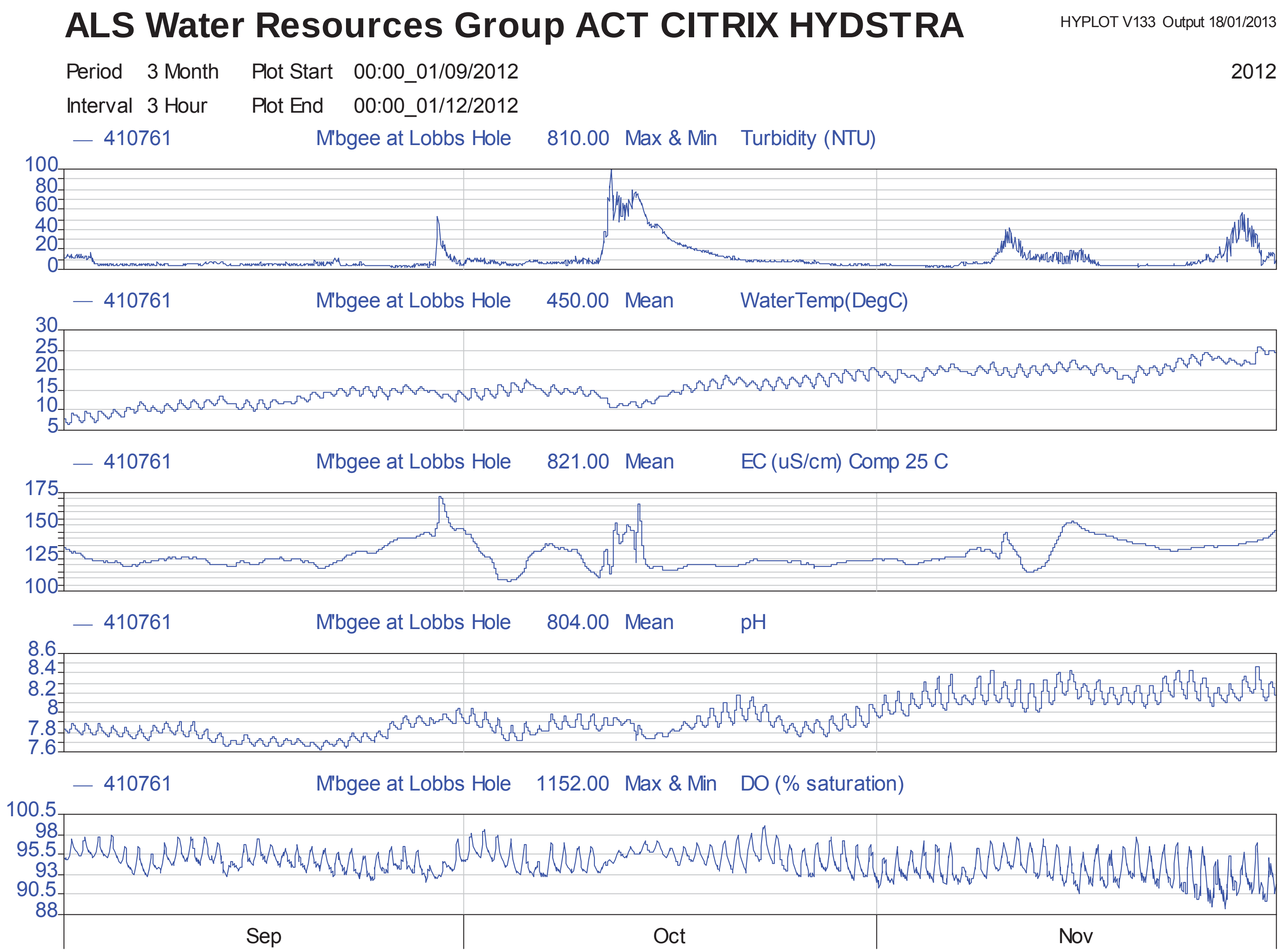

Figure 6-3 Continuous water quality records from Lobb's Hole (410761) for spring 2012

6.4 Periphyton

Chlorophyll-a concentrations were highest at MUR 29 and MUR 28 (Figure 6-4) and the lowest median values were recorded at MUR 935 and MUR 937. The mean values were slightly higher upstream of the Murrumbidgee Pump Station (21,055 µg/m^2) compared to downstream however this difference is not statistically significant ($F_{1,29}$ = 0.35; P=0.60; Table 6-3). Similarly, there was no location effect detected for the Ash Free Dry Mass concentrations in this sampling run ($F_{1,29}$ = 0.09; P=0.78; Table 6-3). Mean AFDM concentrations upstream of the MPS was 4,758 mg/m^2 compared to downstream (4,085 mg/m^2).

Table 6-3 Nested analysis of variance results for chlorophyll-a and AFDM concentrations for MPS

Response	Source	DF	F	P-value
Chlorophyll-*a*	Location	1	0.35	0.60
	Site [Location]	3	3.54	0.03
	Residual	29		
AFDM	Location	1	0.09	0.78
	Site [Location]	3	2.95	0.05
	Residual	29		

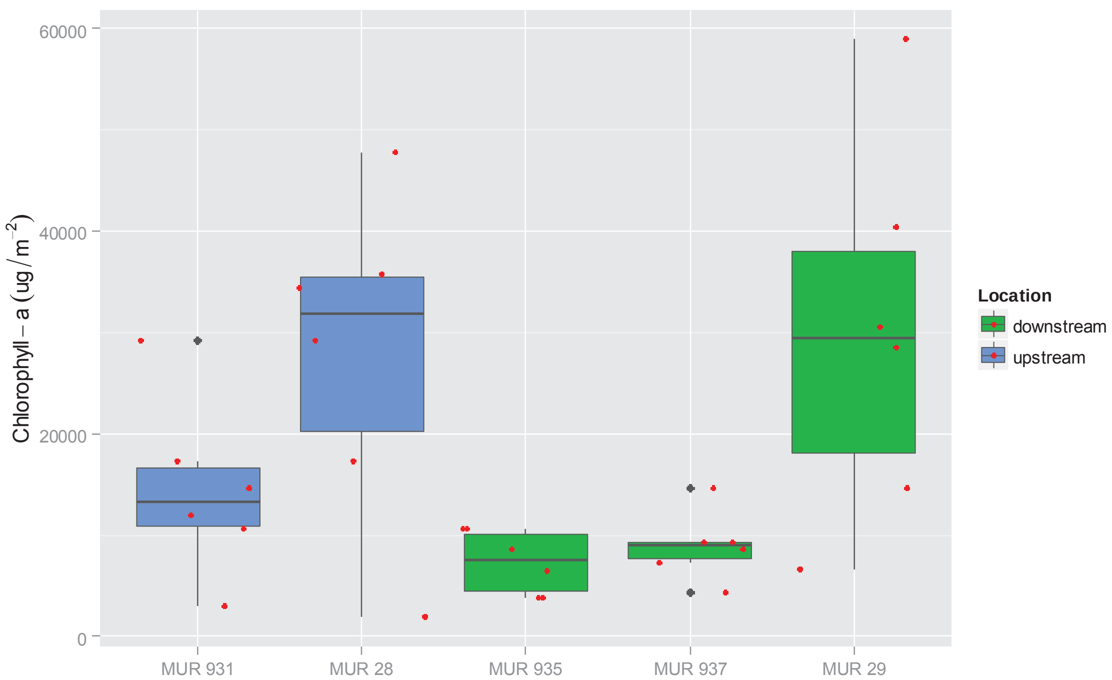

Figure 6-4 Chlorophyll-a concentrations upstream and downstream of the Murrumbidgee Pump Station

Red points represent the raw values for each site

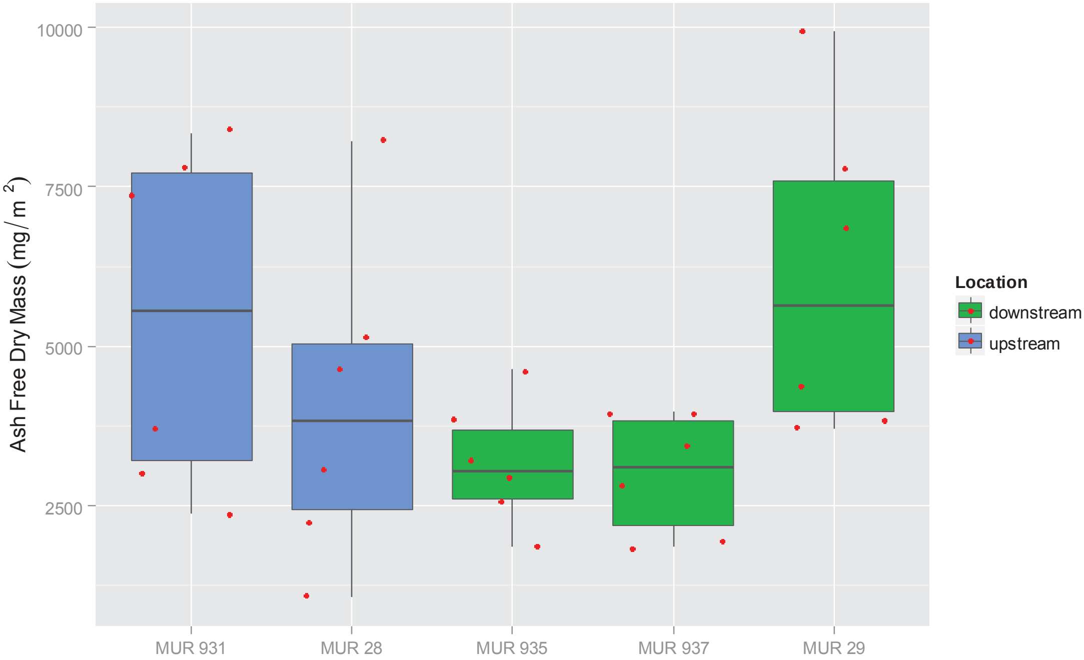

Figure 6-5 Ash free dry mass (AFDM) collected upstream and downstream of the Murrumbidgee Pump Station

Red points represent the raw values for each site

6.5 Macroinvertebrates

6.5.1 AUSRIVAS and SIGNAL-2

The analysis of variance (ANOVA) performed on the O/E 50 scores from the riffle habitat showed there was no significant difference between the upstream and downstream locations ($F_{1,29}$ =0.35; *P*=0.23) (Table 6-5). Overall, all riffle habitats were assessed as “significantly impaired,” or Band-B (Table 6-4). The model identified that Glossosomatidae (SIGNAL=9), Conoesucidae (SIGNAL=7) and Psphenidae (SIGNAL=6) were expected to occur in all replicates, however were not collected in any. These taxa were also predicted to occur in all replicates in spring 2009 & 2011 (no spring 2010 data available) but Glossosomatidae and Conoesucidae have only been recorded in a single replicate in spring 2009, so have not been common to the study area over the past few years. Macroinvertebrates which were predicted to occur by the AUSRIVAS model, but not collected in spring 2012 are presented in Appendix E.

The ANOVA performed on the O/E 50 scores from the edge habitat also showed no significance between upstream and downstream locations ($F_{1,29}$ = 2.18; *P*=0.52) (Table 6-6). The overall edge habitat assessments determined that all sites were “significantly impaired” or Band-B, with the exception of MUR 935 which was assessed as being “similar to reference” or Band-A (Table 6-4). Three of the replicates from the edge habitat which were categorised as Band-B were missing only 2 taxa in comparison to those replicates assessed as Band-A, while the other two replicates scoring Band-B were only missing a single taxa. The missing taxa are Gripopterygidae (SIGNAL=8), Leptophlebiidae (SIGNAL=8), Leptoceridae (SIGNAL=6), Baetidae (SIGNAL=5), Ceratopogonidae (SIGNAL=4) and Tanypodinae (SIGNAL=4). All of these taxa were recorded in replicates which were taken from the same sample. For the complete taxa list, refer to Appendix F.

Table 6-4 AUSRIVAS and SIGNAL-2 scores for spring 2012

= nearly outside the experience of the model

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 931	1	5.09	4.13	0.81	0.89	B	A	B	B	B
MUR 931	2	4.67	4.63	0.66	0.89	B	A			
MUR 931	3	4.78	4.25	0.66	0.89	B	A			
MUR 931	4	5.33	4.60	0.89	1.11	A	A			
MUR 931	5	5.20	4.33	0.74	1.00	B	A			
MUR 931	6	4.78	4.14	0.66	0.78	B	B			
MUR 28	1	4.67	4.22	0.68	1.00	B	A	B	B	B
MUR 28	2	5.25	4.00	0.90	0.89	A	A			
MUR 28	3	5.00	3.33	0.90	0.66	A	B			
MUR 28	4	4.90	NS	0.75	NS	B	NS			
MUR 28	5	5.00	NS	0.83	NS	B	NS			
MUR 28	6	5.09	NS	0.83	NS	B	NS			
MUR 935	1	5.25	4.20	0.90	1.11	A	A	B	A	B
MUR 935	2	5.00	4.22	0.82	1.00	B	A			
MUR 935	3	4.89	4.25	0.67	0.89	B	A			
MUR 935	4	5.00	4.22	0.67	1.00	B	A			
MUR 935	5	4.80	4.22	0.75	1.00	B	A			
MUR 935	6	4.75	4.22	0.60	1.00	B	A			
MUR 937	1	5.18	4.22	0.83	1.00	B	A	B	B	B
MUR 937	2	5.11	4.67	0.68	1.00	B	A			
MUR 937	3	5.00	NS	0.68	NS	B	NS			
MUR 937	4	5.00	4.00	0.75	0.78	B	B			
MUR 937	5	4.89	4.44	0.68	1.00	B	A			
MUR 937	6	5.36	4.25	0.83	0.89	B	A			
MUR 29	1	4.60	4.00	0.75	0.89	B	A	B	B	B
MUR 29	2	4.80	4.00	0.75	0.78	B	B			
MUR 29	3	4.63	4.25	0.60	0.89	B	A			
MUR 29	4	5.22	4.20	0.68	1.11	B	A			
MUR 29	5	4.89	3.50	0.68	0.66	B	B			
MUR 29	6	4.78	NS	0.68	NS	B	NS			

NS - No sample

Table 6-5 One-way analysis of variance results for O/E 50 and SIGNAL-2 scores from the riffle habitat

Response	Source	DF	F	P-value
OE 50	Location	1	2.18	0.23
	Site [Location]	3	4.82	0.008
	Residual	29		
SIGNAL-2	Location	1	0.02	0.89
	Site [Location]	3	1.69	0.19
	Residual	29		

Table 6-6 One-way analysis of variance results for O/E 50 and SIGNAL-2 scores from the edge habitat

Response	Source	DF	F	P-value
OE 50	Location	1	0.51	0.52
	Site [Location]	3	1.30	0.29
	Residual	24		
SIGNAL-2	Location	1	0.04	0.84
	Site [Location]	3	3.98	0.02
	Residual	24		

The historical results for the AUSRIVAS component of the MPS have been consistent with most sites being assessed as Band-B overall, with a few exceptions. This trend has continued in spring 2012 with all overall site assessments scoring Band-B (Table 6-4). However, Table 6-7 does identify some subtle changes which indicate some improvement in condition. The overall site assessment for MUR 931 has improved from ‘C’ to ‘B’ since spring 2011, while MUR 935 has been scored in Band-B instead of showing no reliable assessment in autumn 2012. The overall habitat assessment at MUR 935 has also increased to Band-A in the edge habitat since spring 2011 where it was assessed as Band-B.

The mean SIGNAL-2 scores from the riffle habitat were 4.89 upstream and 4.95 downstream. The downstream mean is similar to that from spring 2011 of 4.90, while the upstream SIGNAL-2 has improved from 4.55. In comparison the mean SIGNAL-2 scores from the edge habitat were 4.18 for both the upstream and downstream locations. This shows very little change from the mean SIGNAL-2 scores from spring 2011 which were 4.22 upstream and 4.10 downstream. Due to the similarity between the mean SIGNAL-2 scores for upstream and downstream in both habitats it is unsurprising to note that there was no significant difference detected (Table 6-5; Table 6-6).

Table 6-7 Overall site assessments for the current and previous three sampling runs for MPS

	Autumn 2011	Spring 2011	Autumn 2012	Spring 2012	Change since previous sampling run
MUR 931	B	C	B	B	–
MUR 28	B	B	B	B	–
MUR 935	B	B	NRA	B	–
MUR 937	B	B	B	B	–
MUR 29	B	B	B	B	–

6.5.2 Community assemblages

The MDS ordination plot of the riffle habitat shows some separation of the upstream sites from the downstream sites. However, based on the ANOSIM results this difference was not statistically significant (R=0.83; *P*=0.1; Figure 6-6). The dominant taxa in the riffle habitat were Orthocladiinae (SIGNAL=4), Simuliidae (SIGNAL=5), Baetidae (SIGNAL=5), Oligochaeta (SIGNAL=2) and Hydropsychidae (SIGNAL=6). Differences in the abundances of these taxa between upstream and downstream location could be contributing to the slight separation of locations. The most abundant taxa, Simuliidae, were far more abundant at the downstream sites with almost four times as many individuals recorded at those sites compared to the upstream sites. The further separation of MUR 931 could be due to the abundances of Hydropsychidae at the site. Hydropsychidae was collected in abundances of more than three times that of the next closest site.

The MDS ordination plot for the edge habitat shows separation of replicates into four individual groups (Figure 6-7). However, the ellipses shown in this NMDS plot highlight the fact that all samples were approximately 50% similar in terms of community composition and abundance; and the differences in taxonomic composition between the samples within the four clusters was only 10%. This indicates that there was little variation in the macroinvertebrate taxonomic composition upstream and downstream of the MPS.

Similar to the riffle zone there is a large increase in the total abundance of macroinvertebrates collected downstream in comparison to upstream. The dominant taxonomic groups which were collected from the edge habitat were Chironominae (SIGNAL=3), Orthocladiinae (SIGNAL=4), Corixidae (SIGNAL=2) and Oligochaeta (SIGNAL=2). The highest abundances of Corixidae were collected from sites: MUR 931 and MUR 29, which are the furthest upstream and furthest downstream sites respectively. By comparison, the upstream site MUR 28 had the lowest abundances of these dominant taxa of all the MPS sites. These factors likely explain some of the separation between groups in Figure 6-7.

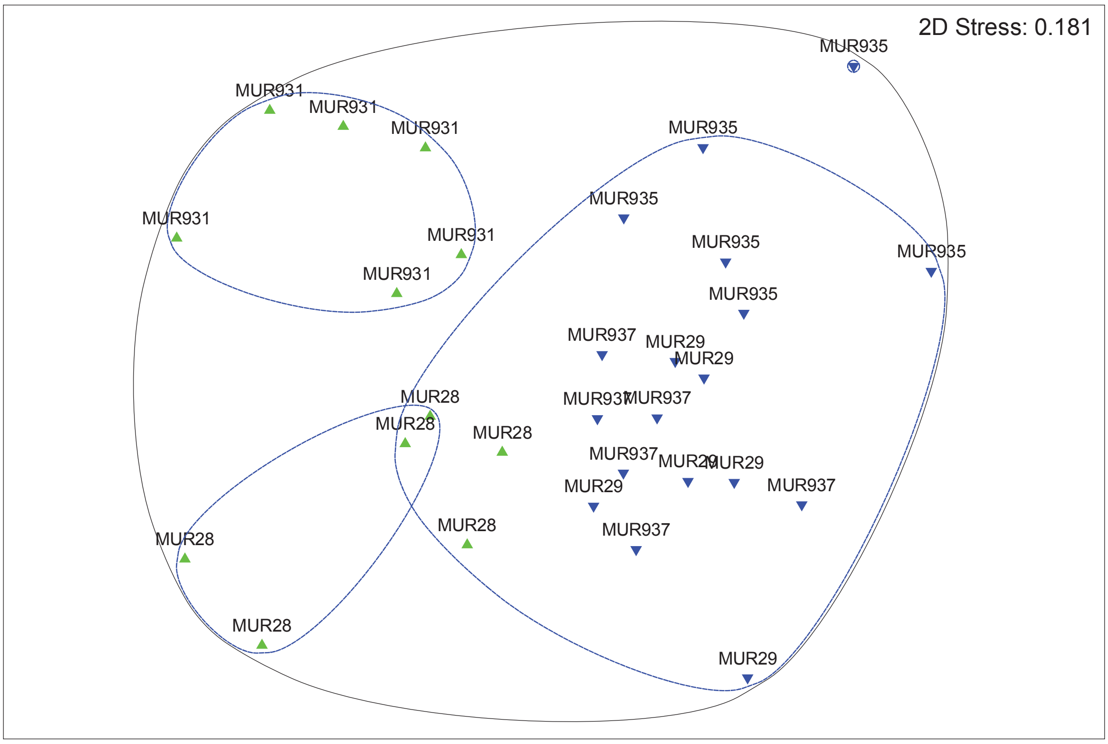

Figure 6-6 MDS ordination plot displaying spring 2012 riffle macroinvertebrate data

Note: Black ellipse represents 60% similarity grouping and blue ellipses represent 65% similarity groups based on cluster analysis output; green triangles represent sites upstream blue triangles represents sites downstream of the MPS.

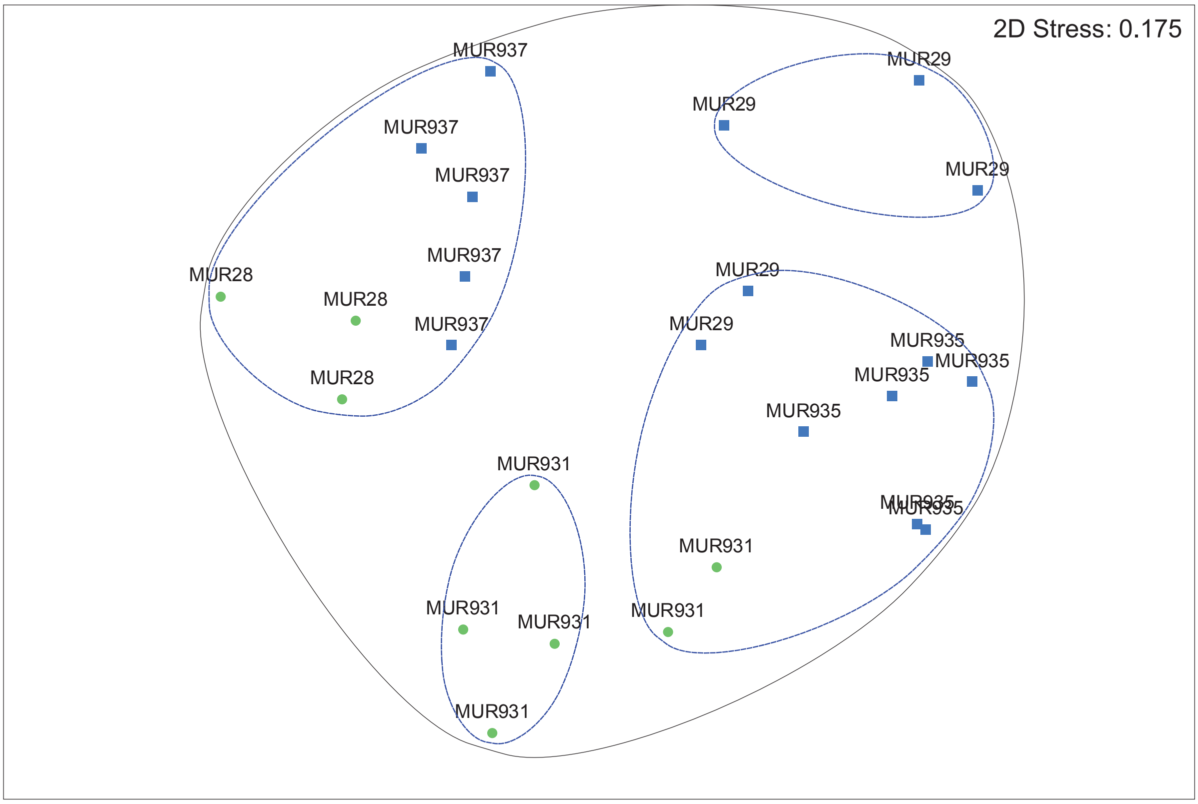

Figure 6-7 MDS ordination plot displaying spring 2012 edge macroinvertebrate data

Note: Black ellipse represents 50% similarity grouping and blue ellipses represent 60% similarity groups based on cluster analysis output; green triangles represent sites upstream blue triangles represents sites downstream of the MPS.

The number of Ephemeroptera, Plecoptera and Trichoptera (EPT) taxa which were collected in both the edge and riffle habitats is shown in Figure 6-8, separated to show family and genus taxonomic levels. Overall, while some between site variations is apparent, the number of EPT taxa recorded from upstream and downstream sites in spring 2012 was similar. This was the case for both the edge and the riffle habitats, and with respect to both taxonomic levels.

This trend also held with respect to taxa richness (Figure 6-9). Figure 6-9 shows that MUR 935 recorded one of the lowest taxonomic richness scores for family level, however scored the highest taxonomic richness score for genus level. This demonstrates the value of assessing macroinvertebrate community data based on a number of taxonomic levels.

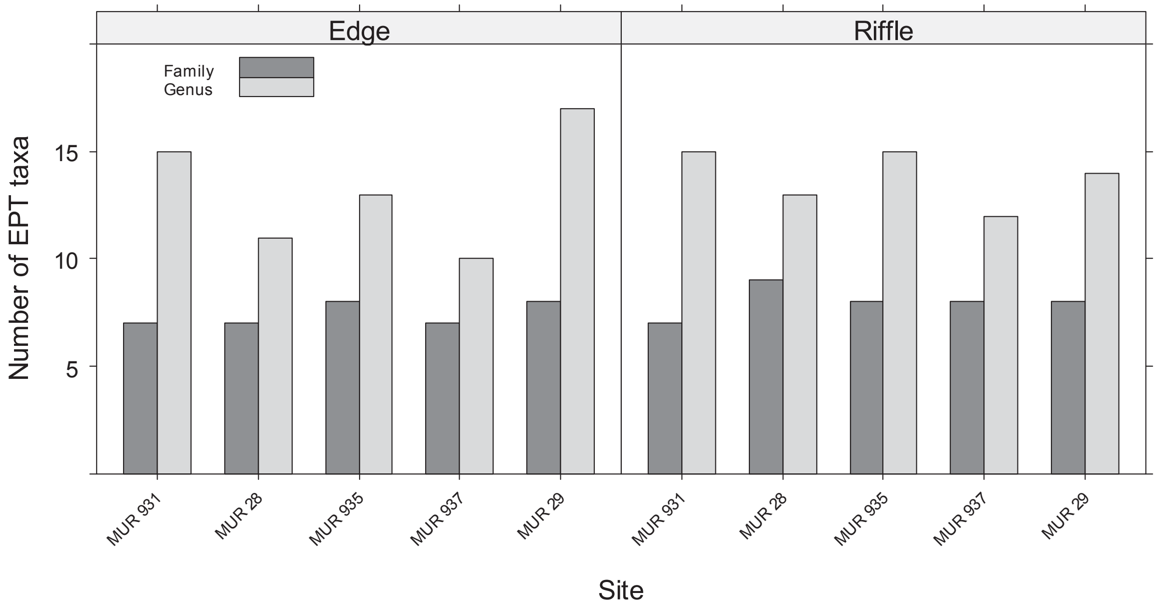

Figure 6-8 Number of EPT taxa in the edge and riffle habitats

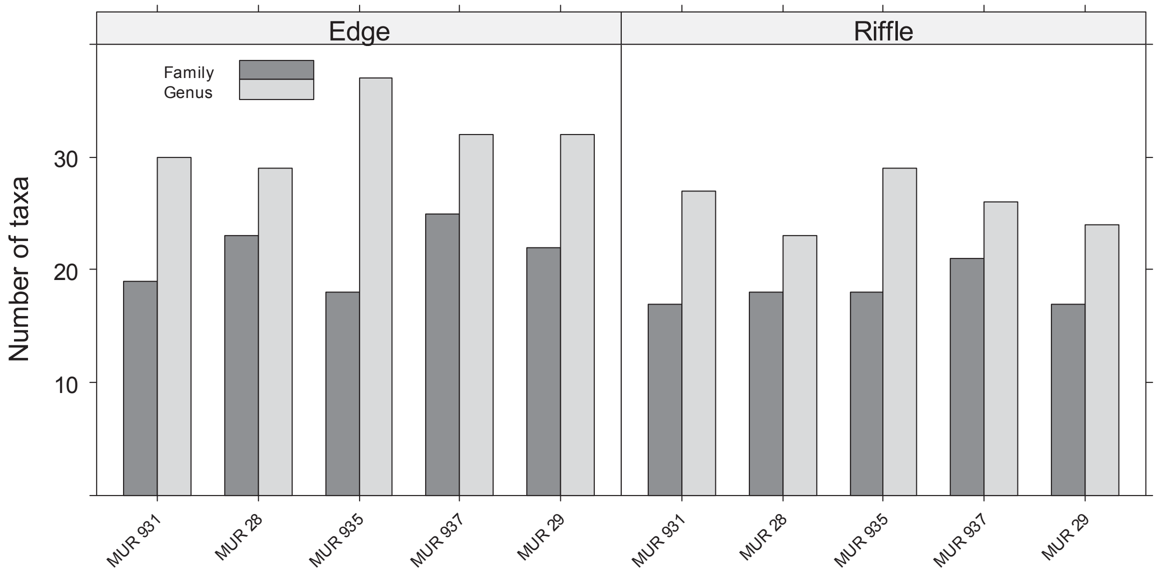

Figure 6-9 Number of unique taxa in the edge and riffle habitats

6.6 Discussion

6.6.1 Water quality

Water quality results based on *in-situ* readings and grab samples combined with the data from the continuous monitoring station data showed no impact by the Murrumbidgee Pump Station upon the Murrumbidgee Rivers water quality. The water quality monitoring data showed a high level of compliance with the ANZECC & ARMCANZ (2000) guidelines.

The only breach of the ANZECC & ARMCANZ (2000) guidelines for dissolved oxygen (DO) occurred during the *in-situ* reading during sampling at MUR 935. This reading of 89.1 % saturation is slightly below the minimum range of 90 % saturation but more importantly represented a drop of 12.4 % D.O. saturation compared to the site upstream (MUR 28). This was most likely due to the water from the Cotter River having a reduced D.O. concentration to that of the Murrumbidgee River and the mixing of the two just upstream of MUR 935.

pH exceeded the upper limits of the ANZECC & ARMCANZ (2000) guidelines at all sampling sites. While those exceedances were only slightly outside the guideline range, these were the highest pH readings recorded since the inception of the MEMP. The higher pH readings are very similar to those recorded in autumn 2012. In autumn it is likely the increased pH was related to groundwater contributions; however in this sampling event, the most likely factor causing these slightly higher values is runoff following recent rainfall events.

Total nitrogen (TN) concentration exceeded guideline levels at all sites and total phosphorus (TP) exceeded guideline levels at all sites with the exception of MUR 29. Although there are some small increases in TP at MUR 28 & 29, possibly from urban tributaries, the pattern shows that concentrations are dissipating downstream, potentially from the uptake of nutrients by the system. This trend indicates that the main source of nutrients pushing concentrations above guideline levels is upstream of the MPS and that the elevated TN and TP are not due to factors associated with the MPS operation.

6.6.2 Periphyton

The periphyton results show there was no detectable impact from the MPS pumping schedule on periphyton production and biomass. This is demonstrated through the non-significant results from the ANOVA between upstream and downstream sites for both chlorophyll-a and AFDM. These non-significant results are not surprising considering the intra-site variability in the replicates.

The farthest downstream site, MUR 29 has chlorophyll-a concentrations which are well in excess of MUR 935 & 937. These elevated chlorophyll-a levels were also present at this site in autumn 2012. This is likely due to the fact that the riffle habitat is shallow and has reduced flow velocities compared to the riffle habitats at the other upstream MPS sites. Shallow riffles allow for better light penetration and ideal conditions for photosynthesis and it also means that periphyton is less susceptible to scouring due to high flows. The AFDM concentrations were most elevated at MUR 931 & 29. Both these sites recorded higher detrital matter through the riffle habitat which could have contributed to this result.

The comparison of the chlorophyll-a results from spring 2012 to spring 2011 shows that, with the exception of MUR 931, concentrations have increased at all sites. In comparison to this, AFDM concentrations, with the exception of MUR 937, have reduced at all sites. This reduction could be linked to the flows which were present prior to sampling. During spring 2011 there were no significant high flow events prior to sampling, when compared to the high flow event approximately four weeks prior to sampling during spring 2012. The most likely scenario to explain this pattern is that the high flow event in 2012 removed the detritus from the periphyton matrix at most sites (hence the reduction in AFDM), allowing colonisation by algae and the elevated TN and TP, combined with persistent flows over the riffle zones post that event would also have helped promote algal growth (Biggs and Close, 1989; Jowett and Biggs, 1997).

6.6.3 AUSRIVAS and macroinvertebrate assemblages

The results from the spring 2012 macroinvertebrate sampling round do not indicate a significant difference between sites located upstream of the MPS in comparison to those located downstream in terms of composition, diversity or the occurrence of pollution sensitive versus pollution-tolerant taxa. This was the case for both riffle and edge habitat results.

There were some differences detected with respect to abundances between upstream and downstream sites. The total estimated abundance of macroinvertebrates upstream of the MPS was highly reduced in comparison to the total estimated abundance of macroinvertebrates downstream. The main taxa contributing to this result was black fly larvae (Simuliidae, SIGNAL=5). Simuliids are filter feeders and are prefer fast flowing waters (Gooderham and Tsyrlin, 2005). Simuliids were dominant in the riffle habitat at all MPS sites but were in much greater abundances at the downstream sites. This could potentially be explained by the higher velocity readings at the downstream sites due to contributions from the Cotter River and also the Bendora Scour Valve which may provide ideal flow conditions.

In the overall habitat classification all riffle sites were classified as Band-B, or “significantly impaired.” Replicates were consistently assessed as Band-B with a small proportion of Band-A replicates throughout the sites. Across all sites, every replicate was predicted to contain Glossosomatidae (SIGNAL=9), Conoesucidae (SIGNAL=7) and Psephenidae (SIGNAL=6) but these three taxa were absent. These taxa have also been predicted to occur but absent from all replicates in spring 2009 and 2011 (no spring 2010 data available), with the exception of one replicate which contained Glossosomatidae and one replicate which contained Conoesucidae, both in spring 2009.

There was a slight increase in the SIGNAL-2 score for the upstream sites in the riffle habitat since spring 2011. This increase is likely due to the increase in the number of sensitive taxa collected. This is corroborated by increases in both the number of EPT families collected and the number of EPT genera collected, with EPT proportions of up to 30% being recorded in spring 2012 (an increase from 18% in spring 2011). These increases in sensitive taxa abundances could be due to the high abundance of Hydropsychidae (SIGNAL=6) collected at the furthest upstream site, MUR 931. The high abundances found at MUR 931 is unusual given Hydropsychids inhabit a wide range of streams and rivers and can be found attached to rocks and large woody debris (Gooderham and Tsyrlin, 2005). This suggests that any of the MPS sites would be equally suitable for this family. Previous studies have shown that there is an antagonistic relationship between Hydropsychidae and Simuliids (Hemphill, 1988; Zhang *et al.*, 1998) and the high abundances of Simuliids in this study, may at least in part explain the lower abundance or absence of Hydropsychids.

The overall habitat classification for the edge show all sampled classified as Band-B, or “significantly impaired,” with the exception of MUR 935 which was Band-A, or “similar to reference.” Most replicates were consistently assessed as Band-A with a small proportion of replicates assessed as Band-B across the sites. In the previous two spring sampling runs, 2011 and 2009, all overall habitat assessments have been assessed as Band-B, “significantly impaired.” This shows the only change in overall habitat assessments for the edge habitat is at MUR 935, where the site has increased to Band-A, “similar to reference.” The SIGNAL-2 scores from spring 2012 are very similar to those recorded in spring 2011, which is to be expected when the overall assessments are also very similar.

6.7 Conclusions and Recommendations

This component aims to assess the impact on the Murrumbidgee River in response to the water abstraction at the Murrumbidgee Pump Station. The results from the water quality, periphyton and macroinvertebrate analysis indicates that the pump station is having no impact upon the health of the Murrumbidgee River. However, there is evidence that the increased flows occurring downstream of the Cotter River from the ECD, and Bendora Scour Valve are increasing the abundances of certain macroinvertebrates collected at the downstream sites. It is recommended that the pumping schedule and Cotter Dam release schedule are made available to GHD to aid interpretation of the data and more accurately assess potential impacts.

Part 4 - Tantangara to Burrinjuck

7. Tantangara to Burrinjuck

7.1 Summary of sampling and river condition

Sampling occurred between the 5th and the 15th of November. Maximum temperature during that time ranged from 19 to 29°C with rainfall on the 7th, 8th and 9th. This rainfall delayed sampling by 1 day due to rising water levels, which created difficulties in site access. Flows during this time were variable across the Murrumbidgee River, while there was a single small release from Tantangara Reservoir for this period on the 3rd of November.

The Bendora scour valve was operational prior to sampling of MUR 28 and was turned off on the 14th of November so that sampling could be completed. This site also had the only missed sample with only a single edge sample, due to limited habitat available for sampling with access to the edge slightly upstream of the riffle zone inhibited by the flows.

Sampling at MUR 15 returned to the usual site with lower flows and permissions from landowners enabling access. This site, which is slightly downstream of the alternate sampling used in autumn 2012, offers a better quality riffle habitat with a more stable substrate and provides safer access for GHD sampling staff.

Edge habitat at MUR 1, 2 & 3 were highly silted during this period, with sediments at MUR 3 producing a strong effluent scent due to access by grazing stock. There were numerous heavily eroded sections at MUR 9 with high levels of sediment deposits and bank slumping's in the edge habitat. A number of sites have shown evidence of sand deposition and movement through the system, especially at MUR 12, 15 & 22. These are likely the result of rain events during 2012, particularly the March and October events, and have likely been slowly moving downstream.

Full site summaries are shown in APPENDIX D.

7.2 Hydrology and rainfall

Figure 7-1 shows flow levels during the spring period at the four monitoring stations on the Murrumbidgee River. Rainfall recorded at Lobb's Hole (570985) is also shown and is considered to be representative of the region. Table 7-1 shows the monthly flow and rainfall statistics at all sites, however, there is no rain gauge located at Mt. MacDonald.

The highest flows during the season occurred in mid-October after consecutive rainfall events, with flows peaking at over 20,000 ML/d at Hall's Crossing (410777). Smaller rain events also occurred including one in late September and another in November which delayed sampling of some sites. The high flows in November at the downstream Murrumbidgee sites were due to the combined effect of the November rain event and the small water release from Tantangara Dam. The resulting wet conditions made access to some sites too dangerous and sampling was delayed by up to four days.

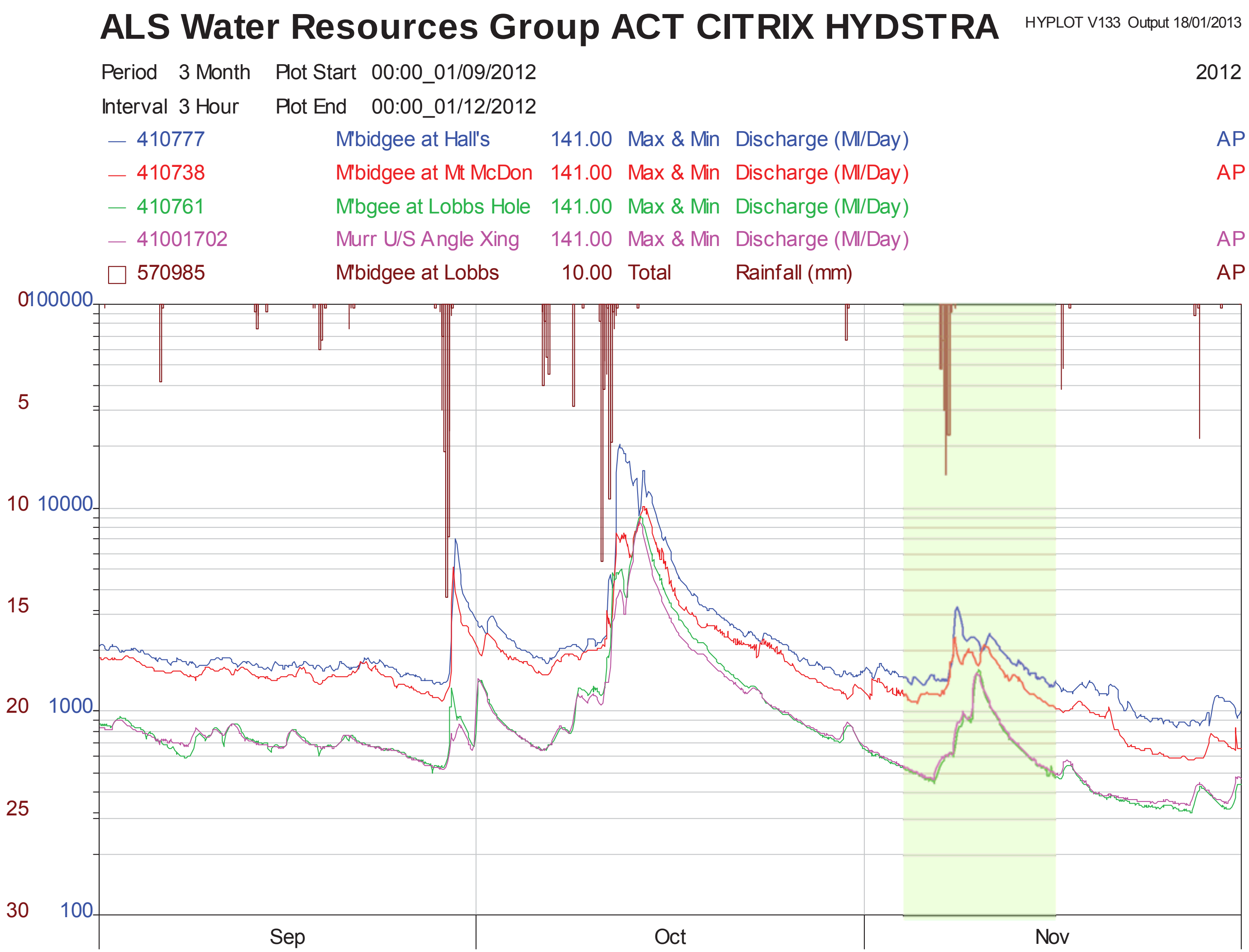

Figure 7-1 Spring hydrograph of the Murrumbidgee River flows (log scale) and rainfall

Note: Green shading indicates sampling period

Table 7-1 Average monthly flow and rainfall statistics for spring 2012

Site Location	September Average Flow (ML/d)	October Average Flow (ML/d)	November Average Flow (ML/d)	Total Rainfall (mm)
Upstream Angle Crossing (41000270)	716	1,690	559	163.2
Lobb's Hole (410761)	724	1,870	541	165
Mt. MacDonald (410738)	1,620	2,740	1,100	-
Hall's Crossing (410777)	1,870	3,820	1,420	123.8

7.3 Water quality

7.3.1 Grab samples and in-situ parameters

The results from the lab-analysed grab samples and the *in-situ* measured parameters are located in (Table 7-2). Water temperatures during spring 2012 ranged from 15.0°C at MUR 1 to 22.3°C at MUR 937. Turbidity levels were within the ANZECC & ARMCANZ (2000) guidelines at all sites during spring sampling, while electrical conductivity was within the guidelines for all sites with the exception of MUR 1, 2 & 3 in Zone 1, at which EC was below the guideline levels. TSS were highest at MUR 6, MUR 12 and MUR 15, all within Zone 2. Exceedances of the upper guideline trigger value (ANZECC & ARMCANZ, 2000) for pH was observed at MUR 16, 18, at most sites in Zone 3 and all sites in Zone 4. This pattern of increased pH does not appear to be linked to any M2G operations as, with the exception of MUR 22, 23 & 27, it follows the general trend of increasing pH levels from MUR 16 downstream to MUR 37.

In spring 2012, Dissolved Oxygen (DO) levels were slightly below the guidelines for majority of the sites across Zones 1 to 3. DO levels were within the recommended range at all Zone 4 sites. The DO concentrations are lower than those recorded in spring 2011 (ALS, 2012), however, the levels are still quite high with a minimum DO concentration of 82.9% at MUR 12. Alkalinity was lowest at Zone 1 sites and increased noticeably between MUR 9 and MUR 12. The highest levels of alkalinity were observed at Zone 3 and Zone 4 sites.

Nutrient concentrations along the Murrumbidgee River were elevated at all sites downstream of MUR 3. Concentrations of total nitrogen were above the ANZECC & ARMCANZ (2000) trigger value at all sites downstream of MUR 4, with the exception of MUR 22 & 23 (Table 7-2). The most significant increases in nitrogen occur at MUR 31 with total nitrogen rising to 1.0 mg/L and NO_x increasing to 0.650 mg/L which is more than 200 times higher than NO_x levels at MUR 30. The only exceedances in the guideline levels (ANZECC & ARMCANZ, 2000) for NO_x occurred in Zone 4. The results are comparable to previous sampling events with the lowest nitrogen levels observed in Zone 1 and increased nitrogen levels observed at the Zone 4 sites. Total Phosphorus levels were lowest at Zone 1 sites but did not appear to follow any consistent pattern across the other zones. Table 7-2 shows that total phosphorus levels were above the ANZECC & ARMCANZ (2000) trigger value at all sites downstream of MUR 3, with the exception of MUR 29 and the highest levels of Total Phosphorus were observed at Zone 2 and Zone 3 sites. Ammonia levels were highest at MUR 4 and MUR 19 and generally lowest at Zone 3 sites (Table 7-2).

A PCA was conducted to assist in the detection of pattern in multivariate water quality between Zones. The first two Principal Components (PCs) explain approximately 74.4% of the variation in water quality between the samples. PC1 is characterised by low EC, alkalinity, pH, turbidity and temperature. PC2 is characterised by low NO_x, ammonia and DO. The PCA plot in Figure 7-2 shows clear separation of the sites for Zone 1 and Zone 4 but no clear separation between Zones 2 & 3. Separation of the Zones along the PC1 axis indicates that Zone 1 sites have the lowest levels of EC, alkalinity, pH, turbidity and temperature while Zone 2 & 3 have intermediate levels of the parameters and Zone 4 have the highest levels of these parameters. Separation of the Zones along the PC2 axis show that NO_x, ammonia and DO are generally lowest within Zones 2 & 3, moderate in Zone 1 and highest in Zone 4. The full output of the PCA can be viewed in Appendix G.

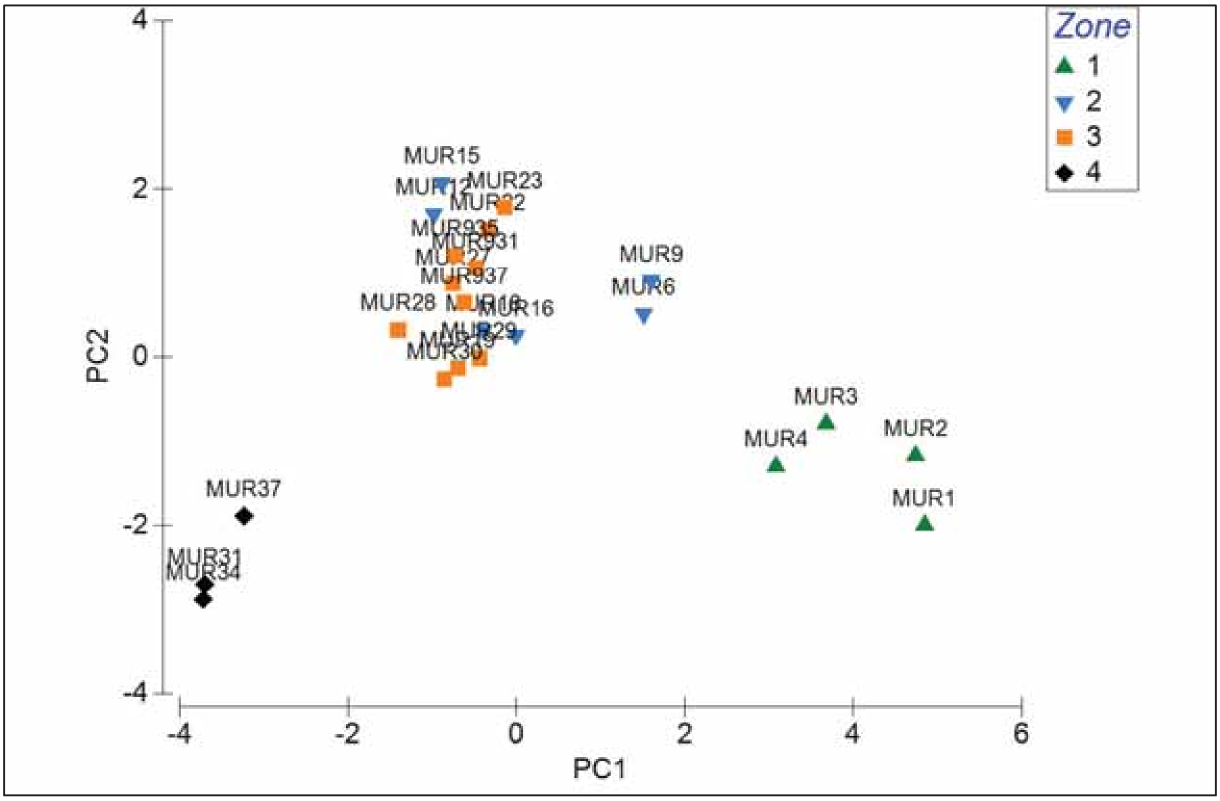

Figure 7-2 Principal Component Analysis (PCA) indicating differences in water quality between Murrumbidgee River sites

7.3.2 Continuous water quality monitoring

The water quality parameters measured at the three continuous water quality monitoring stations, upstream Angle Crossing (41001702), Lobb's Hole (4100761) and Hall's Crossing (410777), all followed similar seasonal trends during spring as seen in Figure 7-3, Figure 7-4 and Figure 7-5, respectively. Water quality parameters responded as expected to both the small and larger rain events during spring, showing recovery back to baseline condition as the higher flows receded. Turbidity fluctuated throughout the season at all three gauging stations, with distinct peaks observed during periods of high flow. Turbidity remained fairly low at Lobb's Hole throughout spring with a maximum reading of only 100 NTU. The highest levels of turbidity were observed at Hall's Crossing where the maximum for spring was around 3000 NTU. At Angle Crossing, in addition to some more marked peaks, a series of small peaks were observed between Mid-October and late-November. In contrast, the levels at Hall's Crossing and Lobb's Hole remained more constant but the few peaks were more abrupt and the levels were more extreme relative to the base-flow conditions.

EC followed a similar pattern at Lobb's Hole and Angle Crossing with a few distinct peaks and a troughs and a general increase towards the end of November. Levels of EC were more variable at Hall's Crossing with several small fluctuations in addition to the marked peaks. Temperature was consistent across all stations and increased throughout the season towards the beginning of summer. DO levels show the natural diurnal trend across the three stations throughout the period. However, the Hall's Crossing DO readings show pronounced periods of uncharacteristically low levels of DO which appear to be related to periods of higher flow.

Table 7-2 In-situ water quality results from Tantangara to Burrinjuck during spring 2012

ANZECC guidelines are in red bold parentheses, yellow cells indicate values outside of ANZECC and ARMCANZ (2000) guidelines, orange cells indicate value is on the cusp of the guideline

	Site	Date	Time	Temp. (°C)	EC (µs/cm) (30-350)	Turbidity (NTU) (2-25)	TSS mg/L	pH (6.5-8)	D.O.(% Sat.) (90-110)	D.O. (mg/L)	Alkalinity (mg/L)	NOx (mg/L) (0.015)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L) (0.02)	TN (mg/L) (0.25)
Zone 1	MUR 1	5/11/2012	11:25	15.0	20.3	4.5	3	7.45	91.6	9.25	13	0.011	0.009	< 0.002	0.004	0.01	0.17
	MUR 2	5/11/2012	13:50	16.0	23.6	3.3	4	7.58	87.2	8.61	15	0.01	0.008	< 0.002	0.003	0.01	0.15
	MUR 3	5/11/2012	16:30	18.0	27.9	5.7	5	7.63	87.7	8.31	16	0.005	0.003	< 0.002	0.003	0.01	0.19
	MUR 4	5/11/2012	15:30	18.9	32.8	6.8	7	7.66	90.4	8.41	18	0.004	0.002	< 0.002	0.005	0.02	0.21
Zone 2	MUR 6	6/11/2012	10:50	18.8	53.7	10.1	18	7.71	85.5	7.96	26	0.004	0.002	< 0.002	0.002	0.03	0.27
	MUR 9	6/11/2012	13:10	19.7	51.1	8.5	10	7.71	86.6	7.95	26	0.003	0.001	< 0.002	< 0.002	0.03	0.26
	MUR 12	6/11/2012	14:45	19.6	103.2	15.9	21	7.63	82.9	7.59	43	0.002	< 0.001	< 0.002	0.002	0.04	0.34
	MUR 15	7/11/2012	10:30	19.7	113.3	12.7	18	7.81	84.9	7.74	47	0.002	< 0.001	< 0.002	< 0.002	0.04	0.28
	MUR 16	12/11/2012	10:15	18.6	117.8	10.8	11	8.15	88.2	8.25	46	0.003	0.001	< 0.002	0.003	0.03	0.31
	MUR 18	12/11/2012	15:45	19.9	112.9	12.7	13	8.05	87.2	7.94	45	0.003	0.001	< 0.002	0.004	0.03	0.30
Zone 3	MUR 19	12/11/2012	14:20	20.5	114.0	12.7	11	8.07	91.0	8.17	45	0.003	0.001	< 0.002	0.005	0.03	0.30
	MUR 22	7/11/2012	13:45	19.6	123.7	9.5	10	7.93	86.8	7.94	52	0.004	0.002	< 0.002	< 0.002	0.02	0.23
	MUR 23	7/11/2012	15:10	19.9	125.7	8.6	11	7.82	84.1	7.66	52	0.002	< 0.001	< 0.002	< 0.002	0.02	0.23
	MUR 27	15/11/2012	15:45	21.2	123.9	10.8	14	7.94	87.2	7.76	50	0.004	0.002	< 0.002	0.002	0.02	0.31
	MUR 931	15/11/2012	10:05	20.9	122.7	8.6	11	8.06	90.0	8.04	49	0.003	0.001	< 0.002	< 0.002	0.02	0.30
	MUR 28	14/11/2012	9:35	19.9	130.8	13.0	10	8.16	101.5	9.26	51	0.003	0.001	< 0.002	< 0.002	0.02	0.33
	MUR 935	14/11/2012	11:20	20.1	126.1	11.7	11	8.17	89.1	8.08	49	0.003	0.001	< 0.002	< 0.002	0.02	0.32
	MUR 937	15/11/2012	13:00	22.3	96.6	8.3	9	8.25	97.1	8.44	39	0.004	0.002	< 0.002	< 0.002	0.02	0.26
	MUR 29	14/11/2012	13:50	21.8	110.1	10.2	8	8.28	96.0	8.42	43	0.004	0.002	< 0.002	0.002	0.01	0.28
	MUR 30	13/11/2012	16:00	22.1	115.1	11.4	9	8.39	97.7	8.52	45	0.003	0.001	<0.002	0.003	0.02	0.28
Zone 4	MUR 31	13/11/2012	14:45	21.8	156.0	11.2	9	8.37	99.4	8.72	52	0.65	0.648	0.002	0.003	0.03	1.00
	MUR 34	13/11/2012	10:05	20.0	167.9	13.7	14	8.37	101.6	9.23	58	0.50	0.497	0.003	0.004	0.03	0.91
	MUR 37	13/11/2012	12:40	21.7	161.5	11.1	11	8.46	98.2	8.63	57	0.29	0.287	0.003	0.003	0.02	0.69

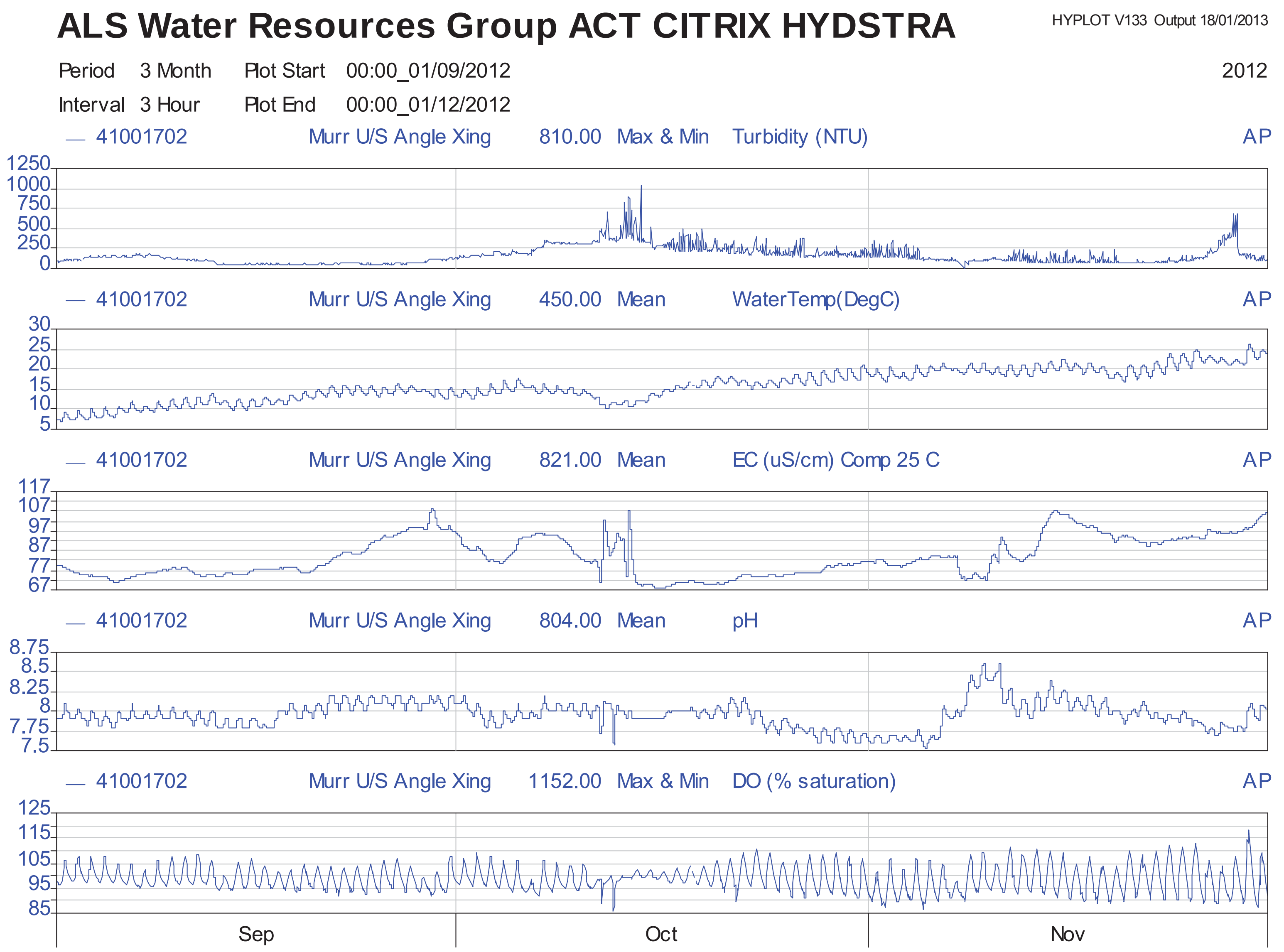

Figure 7-3 Continuous water quality results recorded upstream of Angle Crossing (41000270) in spring 2012

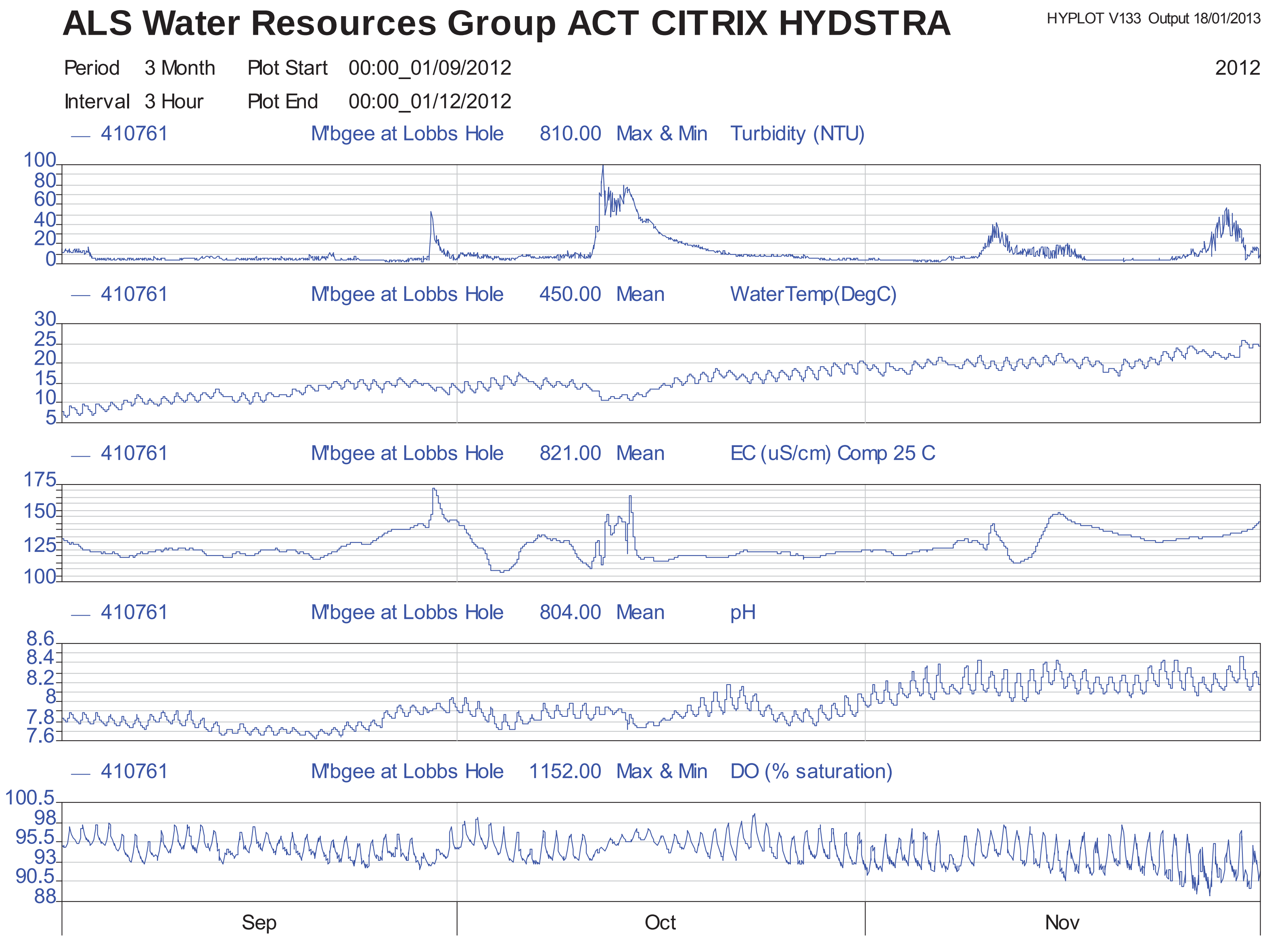

Figure 7-4 Continuous water quality results for Lobb's Hole (410761) in spring 2012

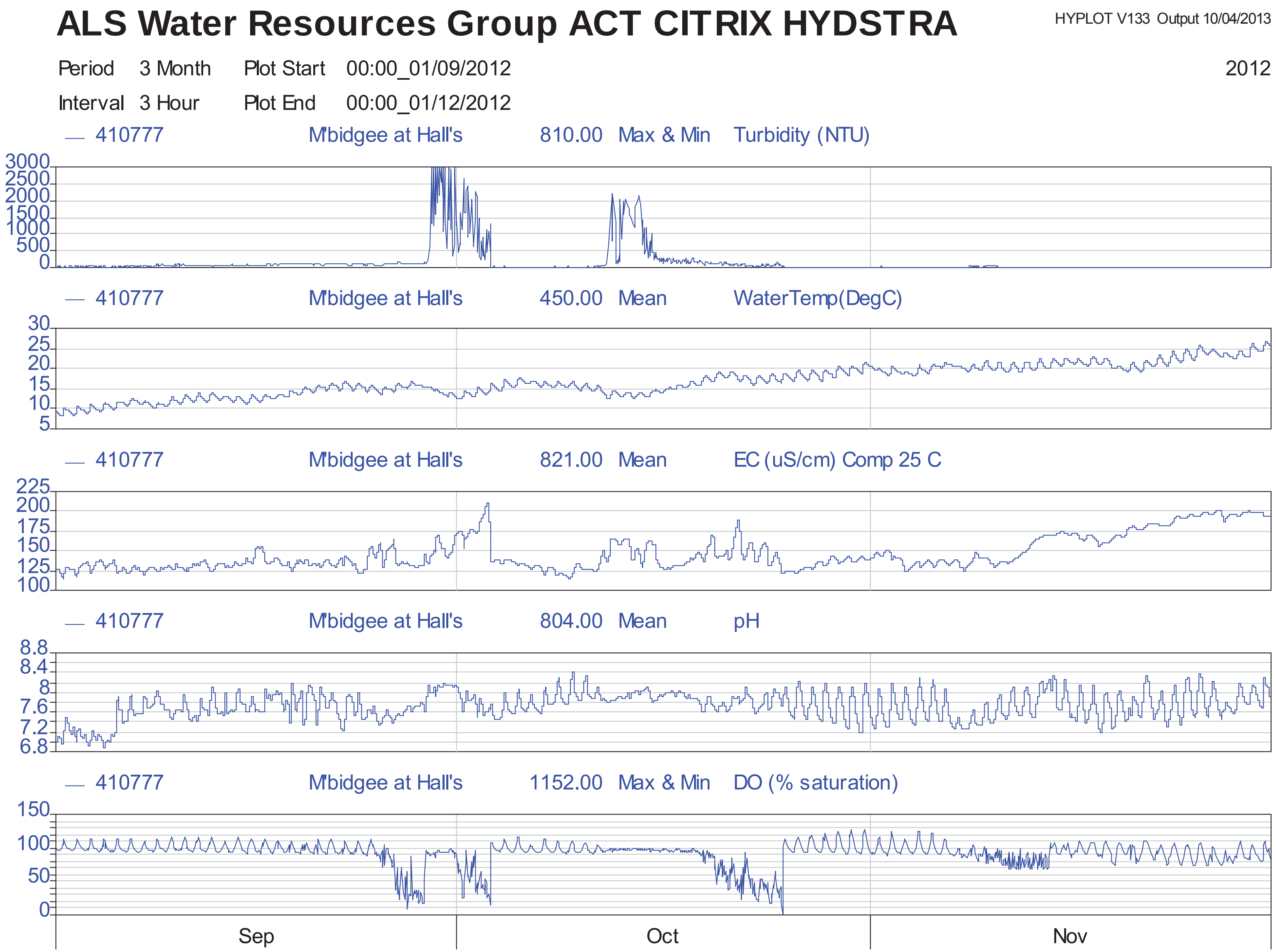

Figure 7-5 Continuous water quality results for Hall's Crossing (410777) in spring 2012

7.4 Macroinvertebrates

7.4.1 Community assemblages

7.4.1.1 Riffle habitat

MDS and cluster diagrams were generated to examine any multivariate patterns in macroinvertebrate community between sites and zones. The MDS plot for riffle samples (Figure 7-6) indicates several groups within the data. The samples collected from Zone 4 were grouped with Zone 3 sites and MUR 12, MUR 15, MUR 16 and MUR 18 from Zone 2. MUR 2 and MUR 3 from Zone 1 sites were grouped together but MUR 4 from this Zone was most strongly related to MUR 6 and MUR 9 from Zone 2. The riffle sample collected from MUR 1 is separated from all other samples within the MDS plot.

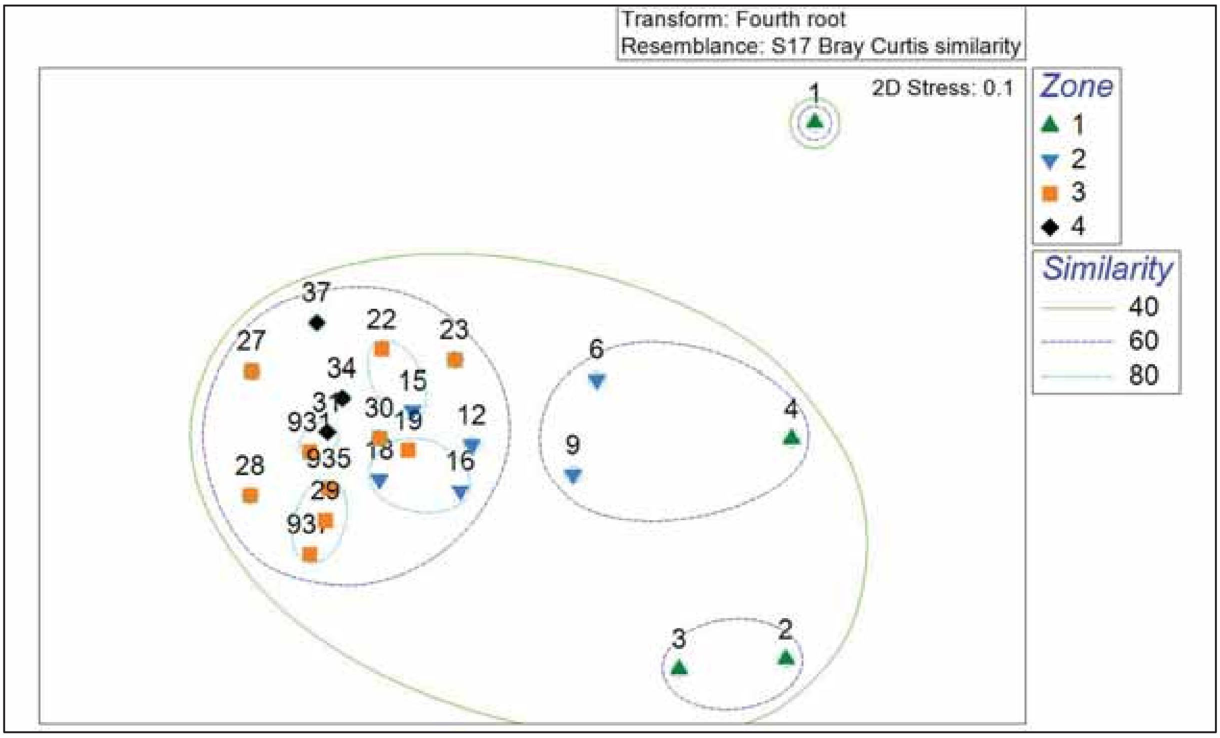

Figure 7-6 Non-metric multidimensional scaling of family level data for the spring 2012 riffle samples

The cluster diagram (Figure 7-7) provides a slightly different picture with all Zone 1 sites, except MUR 1, grouped together with Zone 2 sites MUR 6 and MUR 9. As was seen in the MDS, riffle sample collected at MUR 1 was separated from all other samples with only approximately 40% similarity between this and the most closely related sample. SIMPROF indicates that there is no separation within the remaining riffle samples. All Zone 2, Zone 3 and Zone 4 samples are within this group and there is a minimum similarity of 70% between these samples.

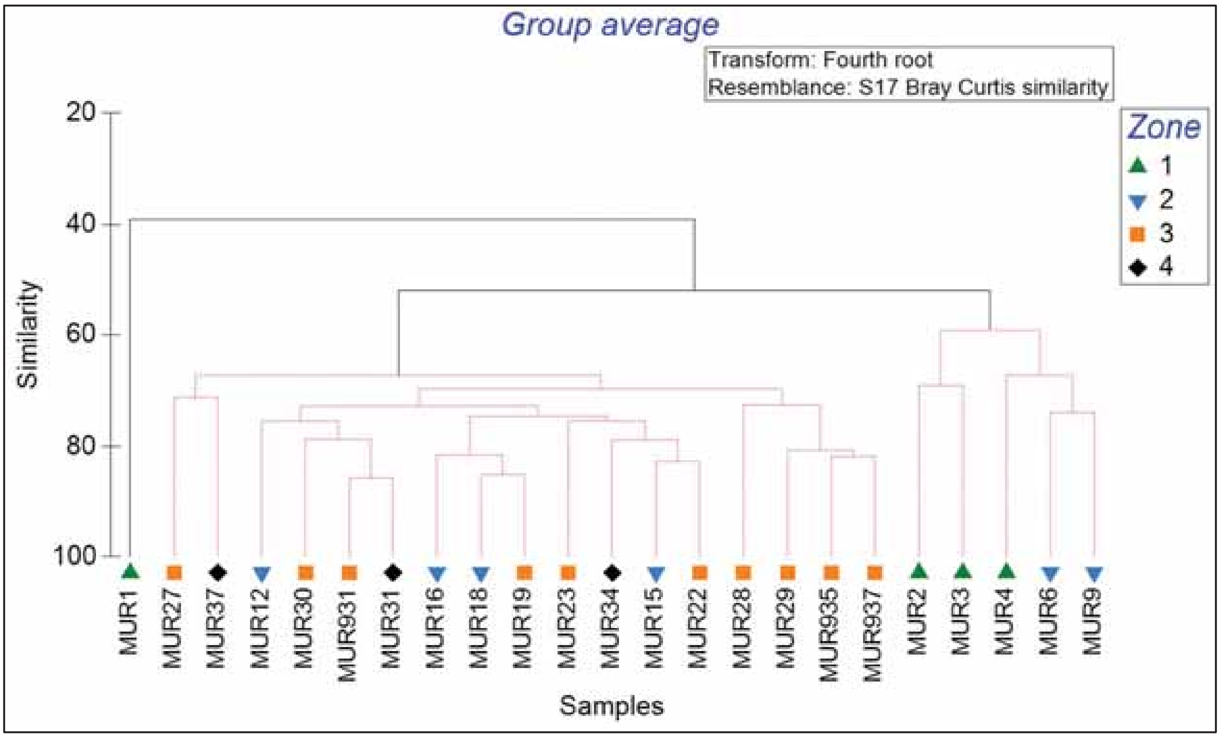

Figure 7-7 Cluster analysis of family level data for the spring riffle samples. Branches marked in red denote significant groupings based on SIMPROF

PERMANOVA analysis determined that there was a significant difference ($p<0.05$) in the spring 2012 samples collected from riffle habitat between some zones. The results of multiple comparisons testing (Table 7-3) indicated that riffle samples collected from Zone 1 sites were significantly different to all other Zones. The macroinvertebrate community was also significantly different for Zone 2 sites compared to Zones 3 and 4. Community assemblage was not found to differ between Zone 3 and Zone 4 sites. The full PERMANOVA output is presented in Appendix H.

Table 7-3 *p*-values for multiple comparisons between Zones for riffle macroinvertebrates. Significant *p*-values are highlighted in red ($p < 0.05$)

Zone	1	2	3
1			
2	0.0100		
3	0.0013	0.0066	
4	0.0276	0.0331	0.5089

SIMPER was used to determine the average similarity in the macroinvertebrate community between and within zones (Table 7-4). The similarity in community composition of riffle samples was generally much higher than between zones. Intra-zone variability ranged between 52.40% and 74.67% compared to inter-zone variability which ranged between 39.75% and 72.09%. Within-zone variability was generally higher than between-zone variability which suggests that there are some differences between Zones despite the inconclusive picture displayed in the MDS and cluster. The lowest between-zone similarity is between Zones 1 and 4. The highest between-zone similarity is between Zones 3 and 4.

Table 7-4 Average similarity in riffle macroinvertebrate samples between and within zone groups

Zone	1	2	3	4
1	52.40%			
2	51.93%	71.04%		
3	43.14%	67.20%	70.25%	
4	39.75%	68.09%	72.09%	74.67%

SIMPER also isolated the taxa that differ most strongly between riffle samples collected from different Zones. The five taxa that contribute most to differences are presented for all pairwise combinations of Zones for which there were significant differences detected by PERMANOVA. The contribution of each of these taxa is quite low (4% to 10%) which indicates that the differences between zones are due to the combined differences in many taxa.

The key taxa contributing most to differences between Zone 1 and Zone 2 are Simuliidae, Oligochaeta, Talitridae, Glossomatidae and Hydroptilidae (Table 7-5). Simuliidae, Oligochaeta, Chironominae and Hydroptilidae were higher and Talitridae and Glossosomatidae were lower, on average, in Zone 2 riffle samples compared to Zone 1 riffle samples. Numbers of Simuliidae, Hydropsychidae and Hyptoptilidae were higher and Gripopterygidae and Glossosomatidae were lower in Zone 3 compared to Zone 1) (Table 7-6). Between Zone 1 and Zone 4, Hydropsychidae and Simuliidae were most abundant in Zone 4 samples and levels of Gripopterygidae, Leptophlebiidae and Tanypodinae were higher in Zone 1 (Table 7-7). Between Zone 2 and Zone 3, Simuliidae and Hydropsychidae numbers were higher in Zone 3 and Gripopterygidae, Tanypodinae and Oligochaeta were higher in Zone 2 (Table 7-8). When comparing Zone 2 and Zone 4, Hydropsychidae and Simuliidae were found in higher numbers from Zone 4 riffle samples and Leptophlebiidae, Gripopterygidae and Tanypodinae were higher in Zone 1 (Table 7-9) samples.

Table 7-5 Major differentiating taxa between Zone 1 and Zone 2 riffle samples

Family	Av abundance		Contribution to group differences (%)
	Zone 1	Zone 2	
Simuliidae	1.19	4.32	5.97
Oligochaeta	2.78	5.39	5.19
Talitridae	2.22	0.00	4.67
Glossosomatidae	2.85	0.66	4.58
Hydroptilidae	0.00	2.18	4.33

Table 7-6 Major differentiating taxa between Zone 1 and Zone 3 riffle samples

Family	Av abundance		Contribution to group differences (%)
	Zone 1	Zone 3	
Simuliidae	1.19	5.85	7.55
Gripopterygidae	4.07	0.67	5.90
Hydropsychidae	0.69	3.86	5.70
Glossosomatidae	2.85	0.00	4.42
Hydroptilidae	0.00	2.57	4.32

Table 7-7 Major differentiating taxa between Zone 1 and Zone 4 riffle samples

Family	Av abundance		Contribution to group differences (%)
	Zone 1	Zone 4	
Hydropsychidae	0.69	4.61	6.52
Simuliidae	1.19	5.11	6.35
Gripopterygidae	4.07	0.67	5.68
Leptophlebiidae	3.81	1.00	4.99
Tanypodinae	2.83	0.00	4.50

Table 7-8 Major differentiating taxa between Zone 2 and Zone 3 riffle samples

Family	Av abundance		Contribution to group differences (%)
	Zone 2	Zone 3	
Hydropsychidae	1.56	3.86	8.18
Gripopterygidae	2.86	0.67	7.36
Simuliidae	4.32	5.85	7.32
Tanypodinae	2.25	0.63	5.59
Oligochaeta	5.39	4.40	5.03

Table 7-9 Major differentiating taxa between Zone 2 and Zone 4 riffle samples

Family	Av abundance		Contribution to group differences (%)
	Zone 2	Zone 4	
Hydropsychidae	1.56	4.61	9.74
Leptophlebiidae	3.81	1.00	9.48
Gripopterygidae	2.86	0.67	7.67
Tanypodinae	2.25	0.00	7.26
Simuliidae	4.32	5.11	4.69

The bubble plots in Figure 7-8 to Figure 7-15 portray the pattern in Simuliidae, Gripopterygidae, Hydropsychidae, Oligochaeta, Leptophlebiidae, Talitridae, Glossosomatidae and Tanypodinae, respectively. Simuliidae were generally low or absent for sites further upstream and present in the largest numbers at downstream sites including MUR 935, MUR 937 and MUR 29 (Figure 7-8). Gripopterygidae numbers were generally higher in riffle samples at the furthest upstream sites and decreased downstream of MUR 12 (Figure 7-9). Numbers of Hydropsychidae were highest at Zone 3 sites including MUR 931 and low or absent from sites upstream of MUR 12 (Figure 7-10). The lowest numbers of Oligochaeta were collected in riffle samples from MUR 23 and MUR 28 as well as those from the Zone 1 sites and the highest number were collected from MUR 12 and MUR 29 (Figure 7-11). Leptophlebiidae were found in the highest numbers at MUR 2, MUR 3 and MUR 9 (Figure 7-12).

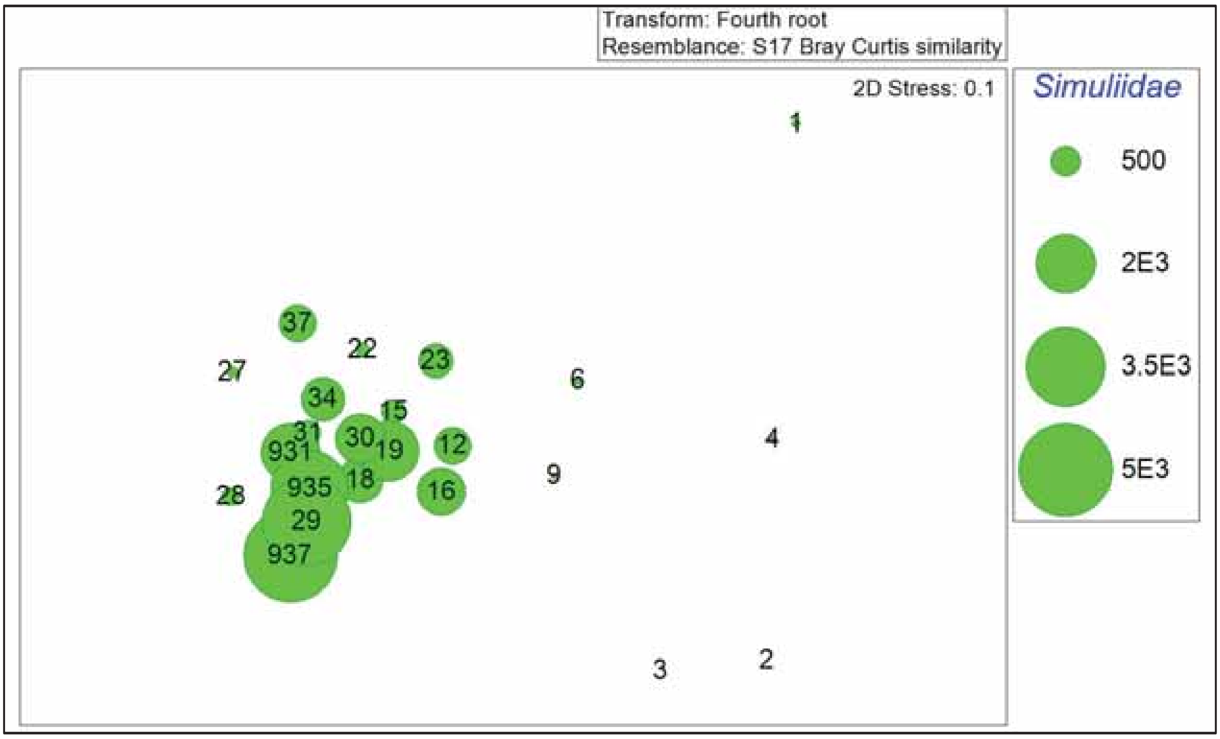

Figure 7-8 Bubble plot indicating relative abundance of Simuliidae between riffle samples

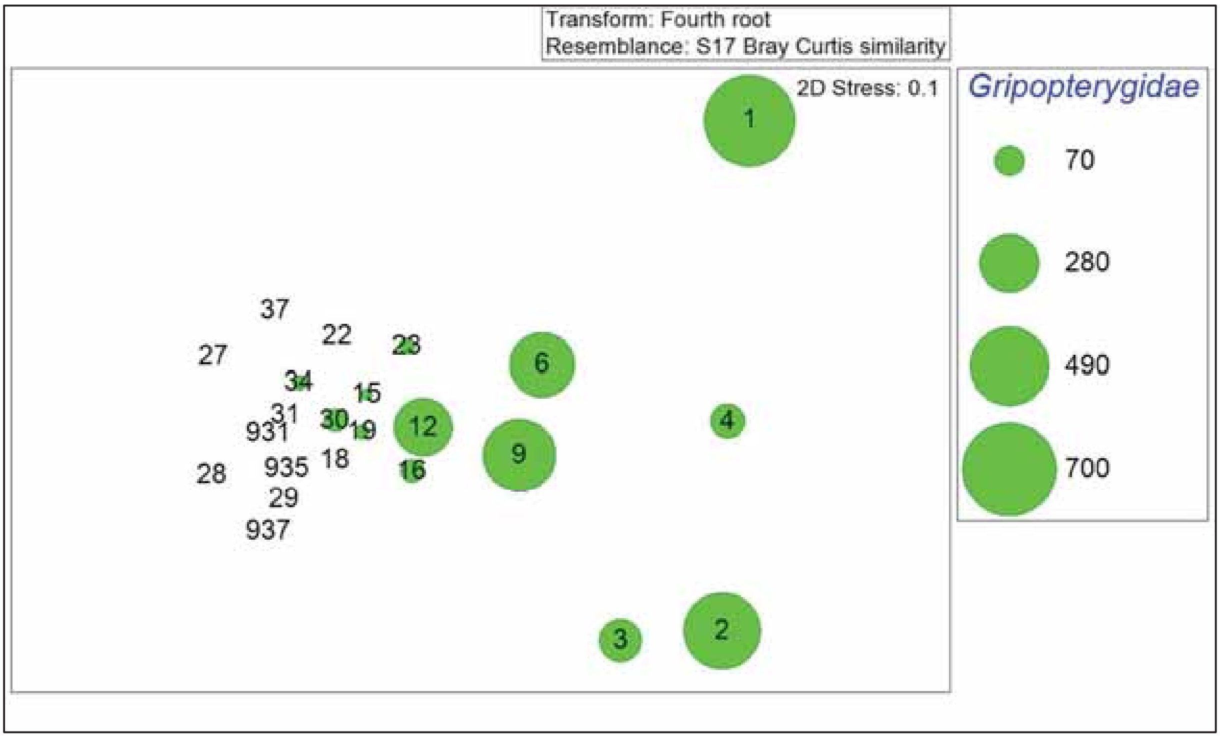

Figure 7-9 Bubble plot indicating relative abundance of Gripopterygidae between riffle samples

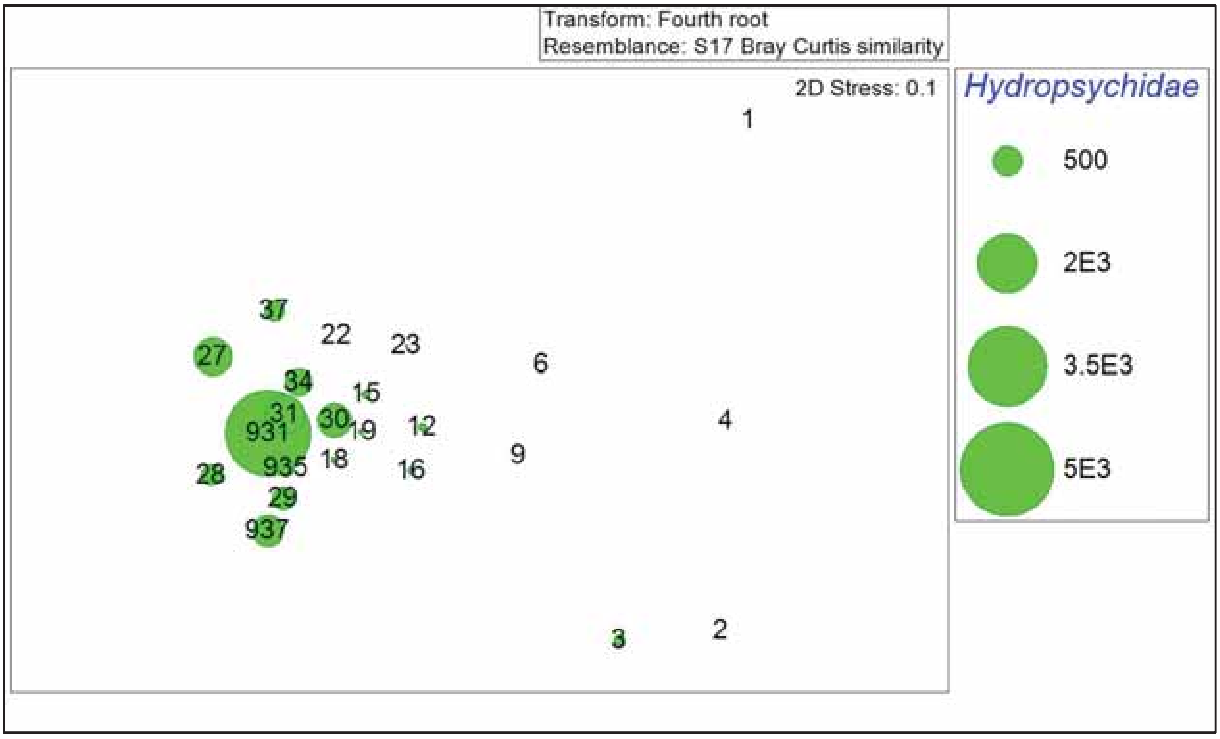

Figure 7-10 Bubble plot indicating relative abundance of Hydropsychidae between riffle samples

Figure 7-11 Bubble plot indicating relative abundance of Oligochaeta between riffle samples

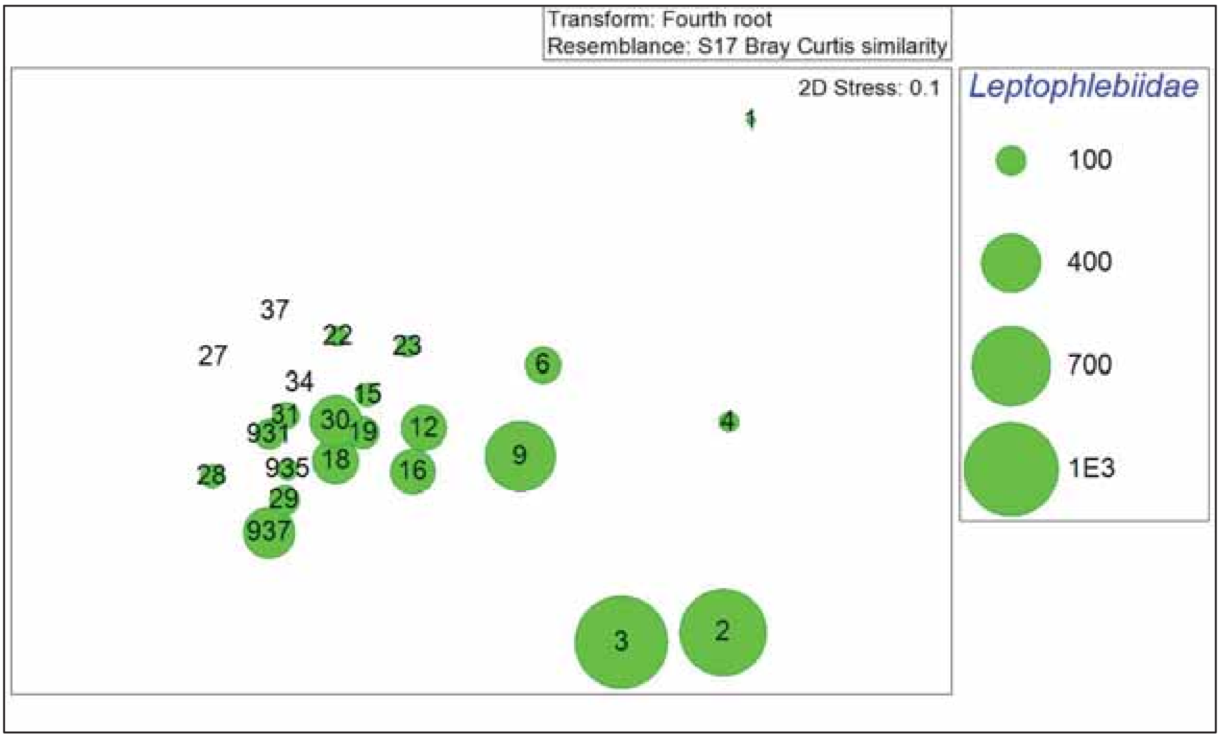

Figure 7-12 Bubble plot indicating relative abundance of Leptophlebiidae between riffle samples

Talitridae were only present at MUR 1, MUR 3 and MUR 4, within Zone 1 (Figure 7-13). Glossosomatidae were only collected from sites between MUR 2 and MUR 9 (Figure 7-14). There were no consistent patterns in Tanypodinae between sites except that none were found downstream of MUR 23 (Figure 7-15).

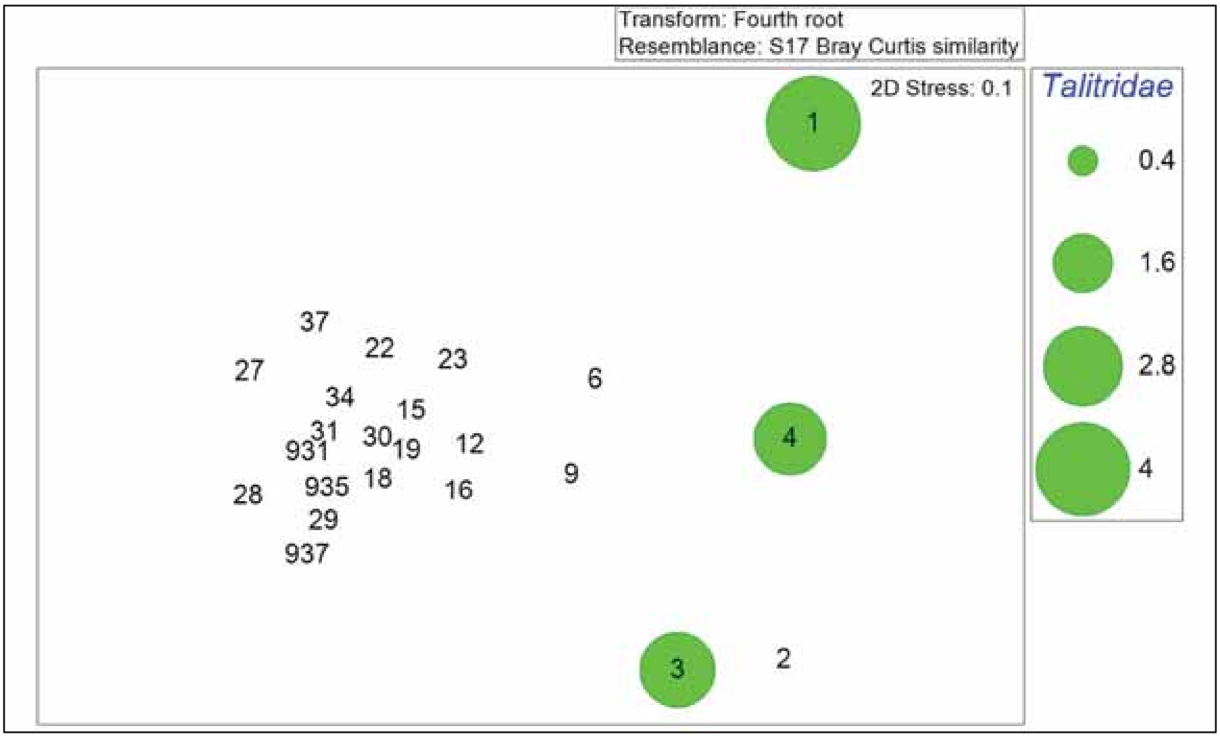

Figure 7-13 Bubble plot indicating relative abundance of Talitridae between riffle samples

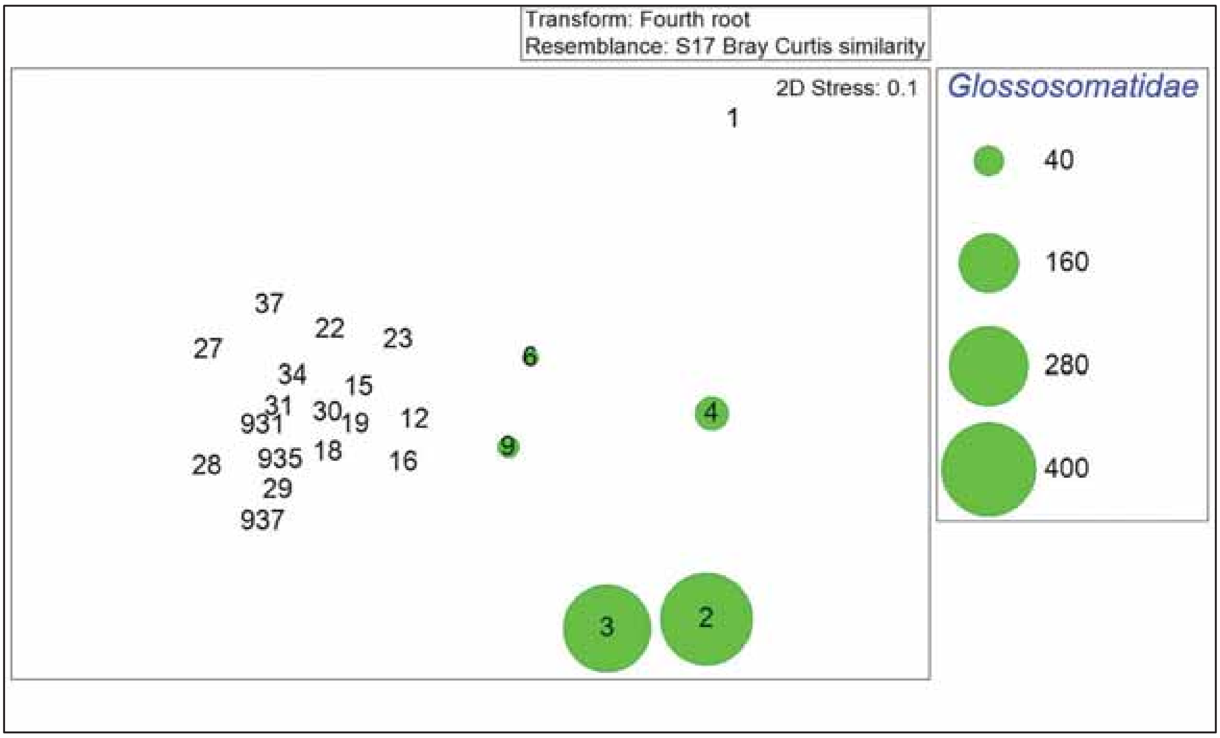

Figure 7-14 Bubble plot indicating relative abundance of Glossosomatidae between riffle samples

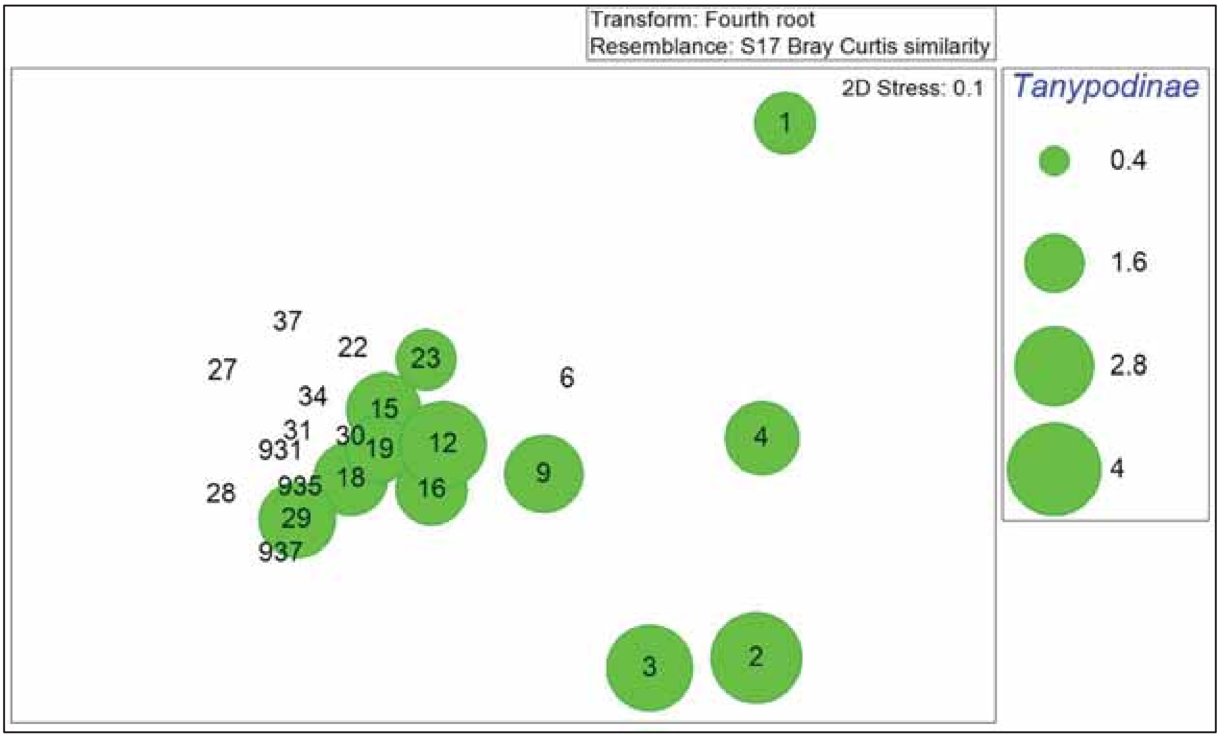

Figure 7-15 Bubble plot indicating relative abundance of Tanypodinae between riffle samples

7.4.1.1 Edge habitat

The MDS plot in Figure 7-16 shows the similarity in macroinvertebrate community composition between edge samples collected from the Murrumbidgee River sites. This plot shows a similar story to that seen for riffle samples with Zone 1 sites exhibiting high intra-zone variation and no clear separation between Zones 2 and 3 or between Zones 3 and 4. However, the overlayed clusters indicate that the minimum similarity between edge samples is around 45%. This suggests that the community is a minimum of 45% similar between sites.

The accompanying cluster diagram (Figure 7-17) shows that MUR 6 and MUR 9 are more strongly linked to Zone 1 sites MUR 2, 3 and 4 than they are to their fellow Zone 2 sites. This indicates that the macroinvertebrate community of MUR 6 and MUR 9 are more akin to that observed in Zone 1 sites although the average similarity within this group is only around 63%. The furthest upstream site MUR 1 was separated from all other sites. The Zone 4 sites are only approximately 60% similar to each other and are more strongly linked to some sites from Zone 2 and Zone 3 than they are to each other. In general, Zone 2 and Zone 3 edge samples are intermingled and no clear pattern is evident except that edge samples from MUR 15 to MUR 19 are clustered together with a similarity of approximately 70%.

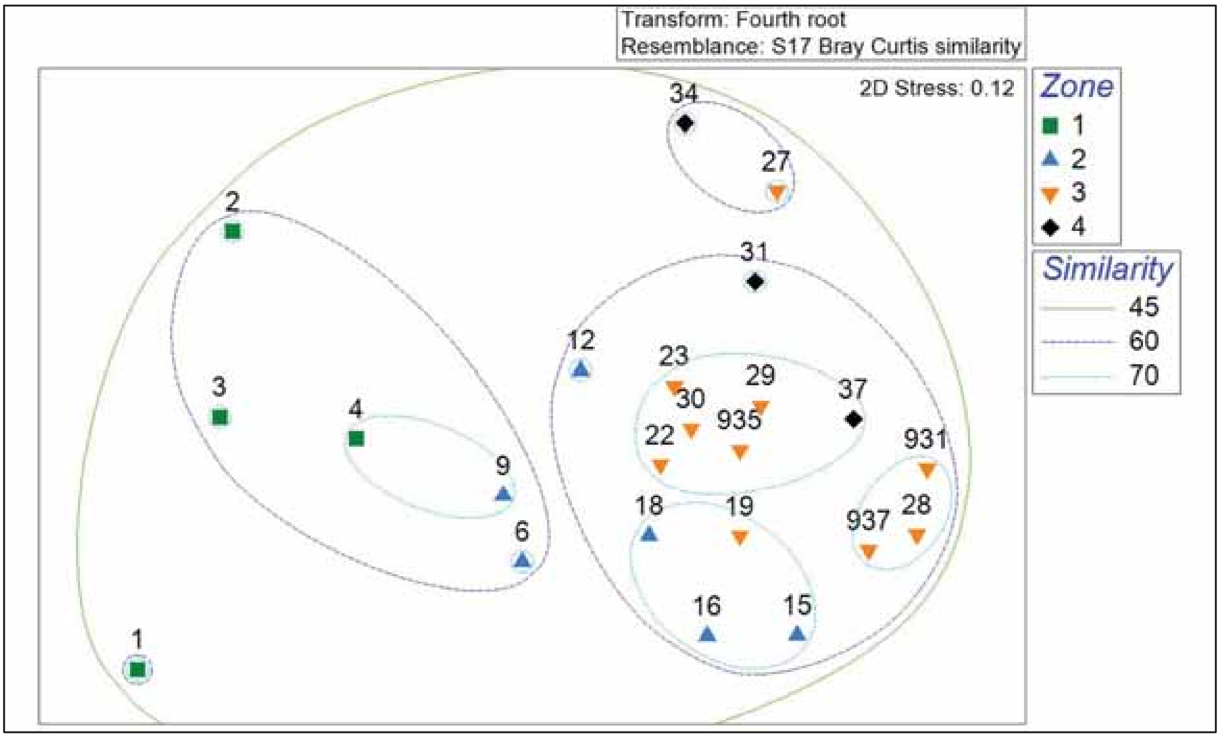

Figure 7-16 Non-metric multidimensional scaling of family level data for the spring edge samples

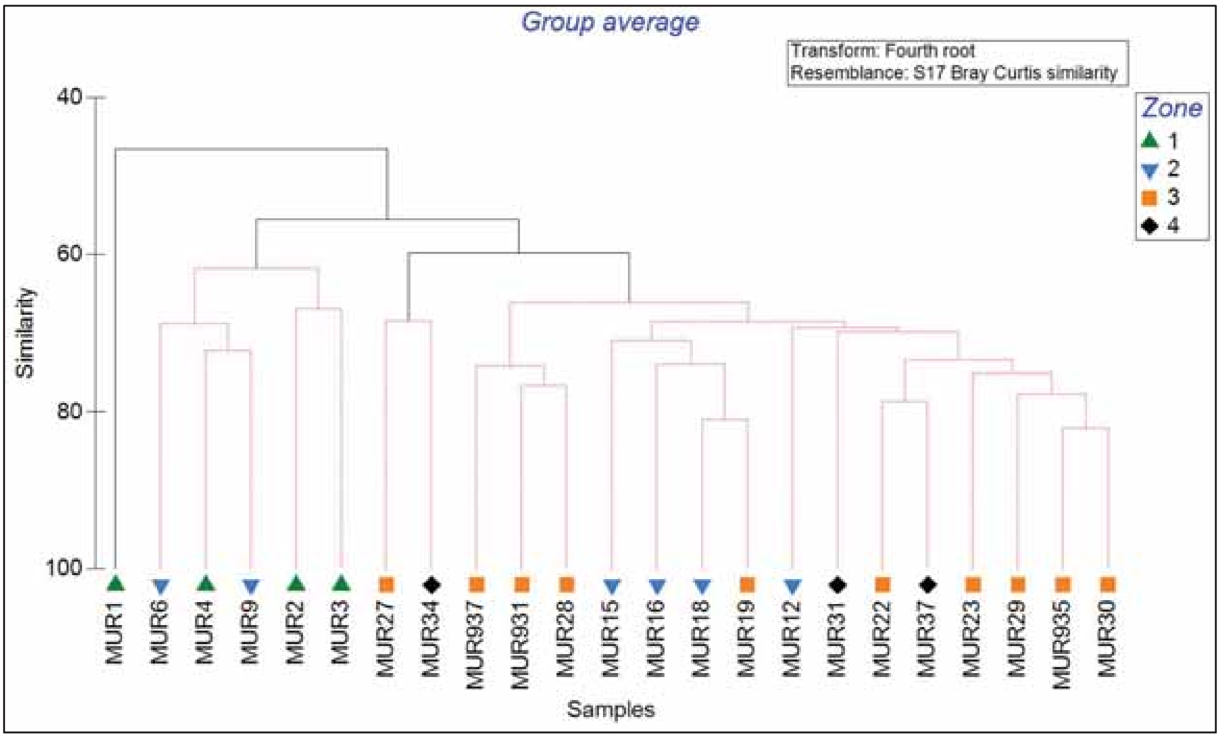

Figure 7-17 Cluster analysis of family level data for the spring edge samples. Branches marked in red denote significant groupings based on SIMPROF

PERMANOVA analysis identified significant ($p<0.05$) differences in the multivariate macroinvertebrate community of edge habitat between some zones. The results of multiple comparisons testing (Table 7-10) indicated that edge samples collected from Zone 1 and Zone 2 sites were significantly different to each other and to all other Zones. Community assemblage was not found to differ between Zone 3 and Zone 4 sites. The full PERMANOVA output is presented in Appendix H.

Table 7-10 *p*-values for multiple comparisons between Zones for edge macroinvertebrates. Significant p-values are highlighted in red ($p < 0.05$).

Zone	1	2	3
1			
2	0.0047		
3	0.0011	0.0101	
4	0.0301	0.0123	0.3339

SIMPER provided an estimate of within-zone and between-zone similarity for edge samples (Table 7-11). This table shows that between-zone similarity was, in some cases, only slightly lower than within-zone similarity. This suggests that despite the results of PERMANOVA, the differences between Zones are tenuous. The taxa contributing most to differences in the edge macroinvertebrate community between Zones are outlined in Table 7-12 to Table 7-16. Most individual taxa contributed less than 10% to the differences between Zones and many taxa were identified as contributing approximately the same amount to the differences. Corixidae and Caenidae were found to occur in lower numbers and Gripopterygidae in higher numbers for edge samples collected from Zone 1 compared to those from Zones 2, 3 and 4. Baetidae were found to be highest in abundance at Zone 2 sites followed by Zone 4 and lowest in number in Zones 1 and 3. Larger numbers of Hydroptilidae were found in Zone 1 compared to Zone 3. Simuliidae and Leptoceridae were highest in number at Zone 3 sites when compared to Zone 2 sites.

Table 7-11 Average similarity in edge macroinvertebrate samples between and within zone groups

Zone	1	2	3	4
1	62.3%			
2	54.1%	67.8%		
3	48.6%	65.8%	69.2%	
4	47.1%	58.9%	66.6%	63.3%

Table 7-12 Major differentiating taxa between Zone 1 and Zone 2 edge samples

Family	Av abundance		Contribution to group differences (%)
	Zone 1	Zone 2	
Talitridae	3.51	0.00	9.23
Caenidae	0.40	2.52	5.54
Hydroptilidae	0.00	1.61	4.21
Baetidae	2.10	2.36	3.97
Calamoceratidae	1.55	0.00	3.91

Table 7-13 Major differentiating taxa between Zone 1 and Zone 3 edge samples

Family	Av abundance		Contribution to group differences (%)
	Zone 1	Zone 3	
Talitridae	3.51	0.00	8.05
Gripopterygidae	3.74	0.66	7.22
Hydroptilidae	0.00	2.61	5.99
Caenidae	0.40	2.82	5.51
Corixidae	1.79	3.77	4.86

Table 7-14 Major differentiating taxa between Zone 1 and Zone 4 edge samples

Family	Av abundance		Contribution to group differences (%)
	Zone 1	Zone 4	
Gripopterygidae	3.74	0.00	7.90
Talitridae	3.51	0.00	7.29
Corixidae	1.79	4.84	6.47
Caenidae	0.40	3.41	6.22
Baetidae	2.10	2.23	3.63

Table 7-15 Major differentiating taxa between Zone 2 and Zone 3 edge samples

Family	Av abundance		Contribution to group differences (%)
	Zone 2	Zone 3	
Gripopterygidae	2.45	0.66	7.81
Baetidae	2.36	1.92	5.73
Corixidae	2.99	3.77	5.10
Simuliidae	1.58	2.15	4.90
Leptoceridae	0.78	1.43	4.83

Table 7-16 Major differentiating taxa between Zone 2 and Zone 4 edge samples

Family	Av abundance		Contribution to group differences (%)
	Zone 2	Zone 4	
Gripopterygidae	2.45	0.00	7.67
Ecnomidae	0.00	1.96	6.21
Corixidae	2.99	4.84	6.06
Baetidae	2.36	2.23	5.81
Oligochaeta	3.53	4.65	4.67

The bubble plots in Figure 7-18 to Figure 7-27 portray the change in relative abundance of Caenidae, Hydroptilidae, Corixidae, Simuliidae, Leptoceridae, Baetidae, Ecnomidae, Oligochaeta and Talitridae, respectively. Caenidae, Hydroptilidae, Simuliidae and Corixidae were generally higher at the sites further downstream. Ecnomidae were observed only at a few select sites, generally those in Zones 3 or 4. Talitridae were only found at Zone 1 sites while Gripopterygidae were absent from most Zone 3 and Zone 4 sites. Baetidae were collected in largest numbers at MUR 12 followed by MUR 34 but there was no clear pattern in Baetidae throughout the Zones.

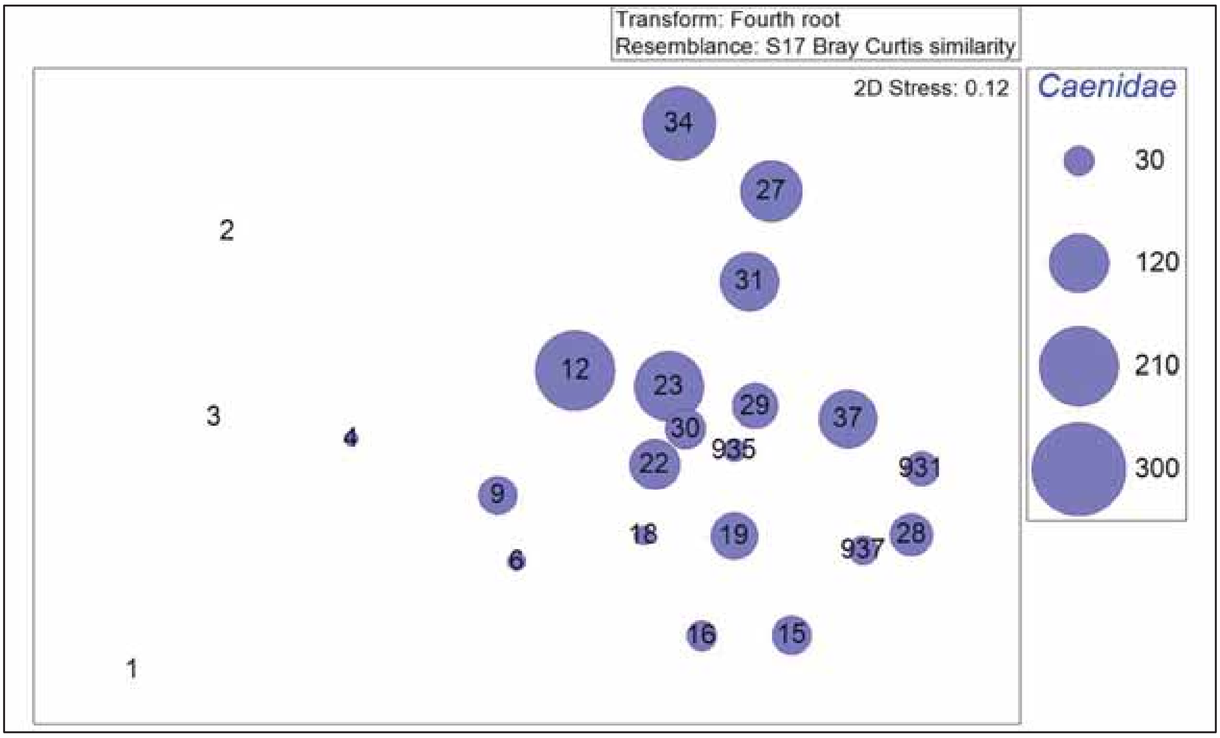

Figure 7-18 Bubble plot indicating relative abundance of Caenidae between edge samples

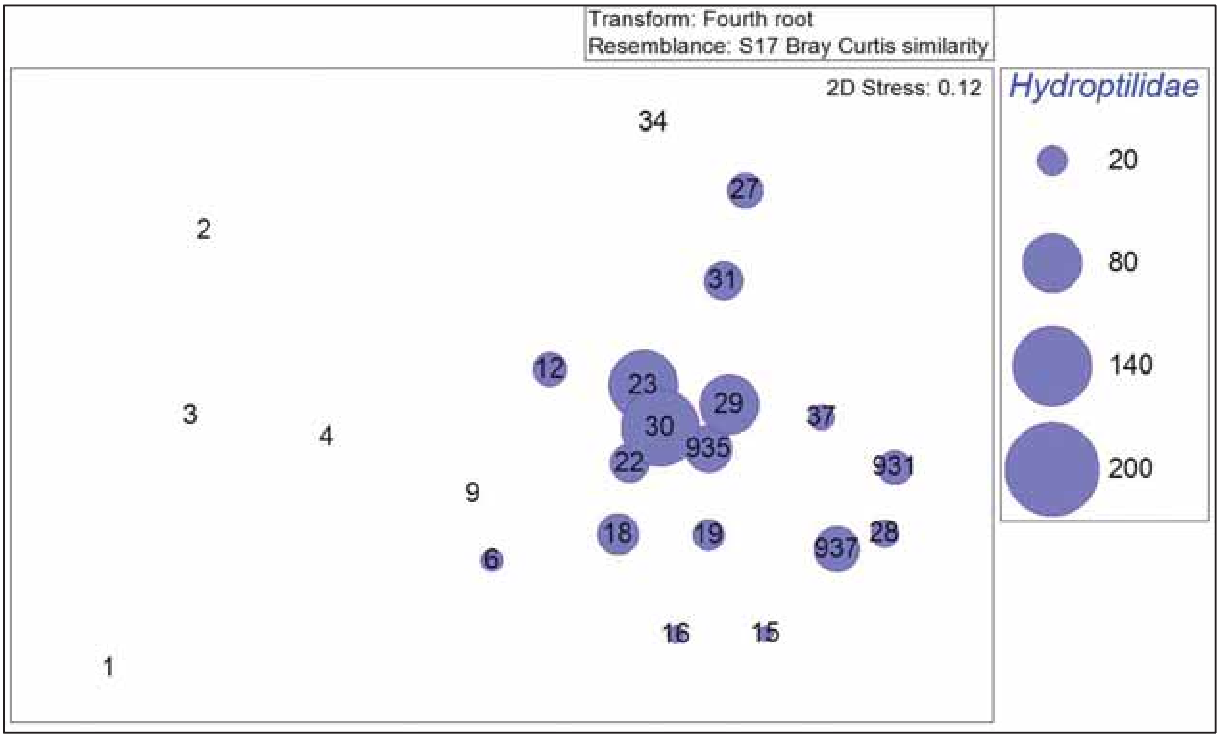

Figure 7-19 Bubble plot indicating relative abundance of Hydroptilidae between edge samples

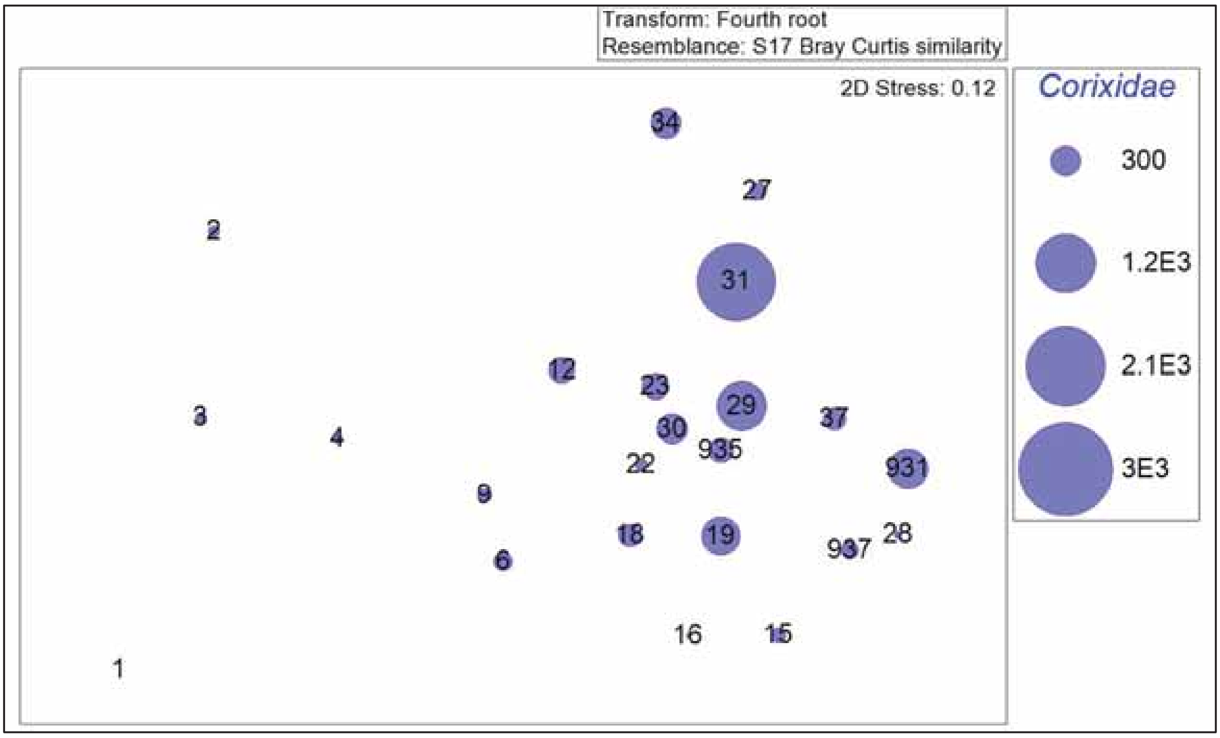

Figure 7-20 Bubble plot indicating relative abundance of Corixidae between edge samples

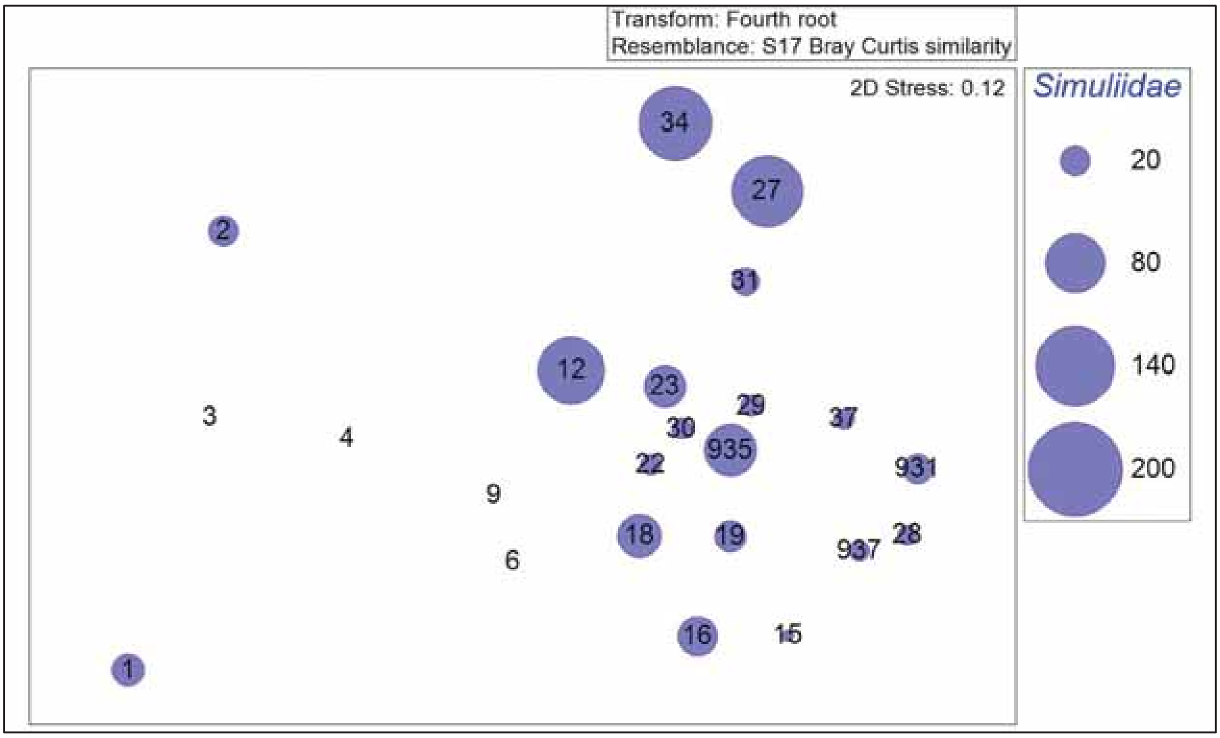

Figure 7-21 Bubble plot indicating relative abundance of Simuliidae between edge samples

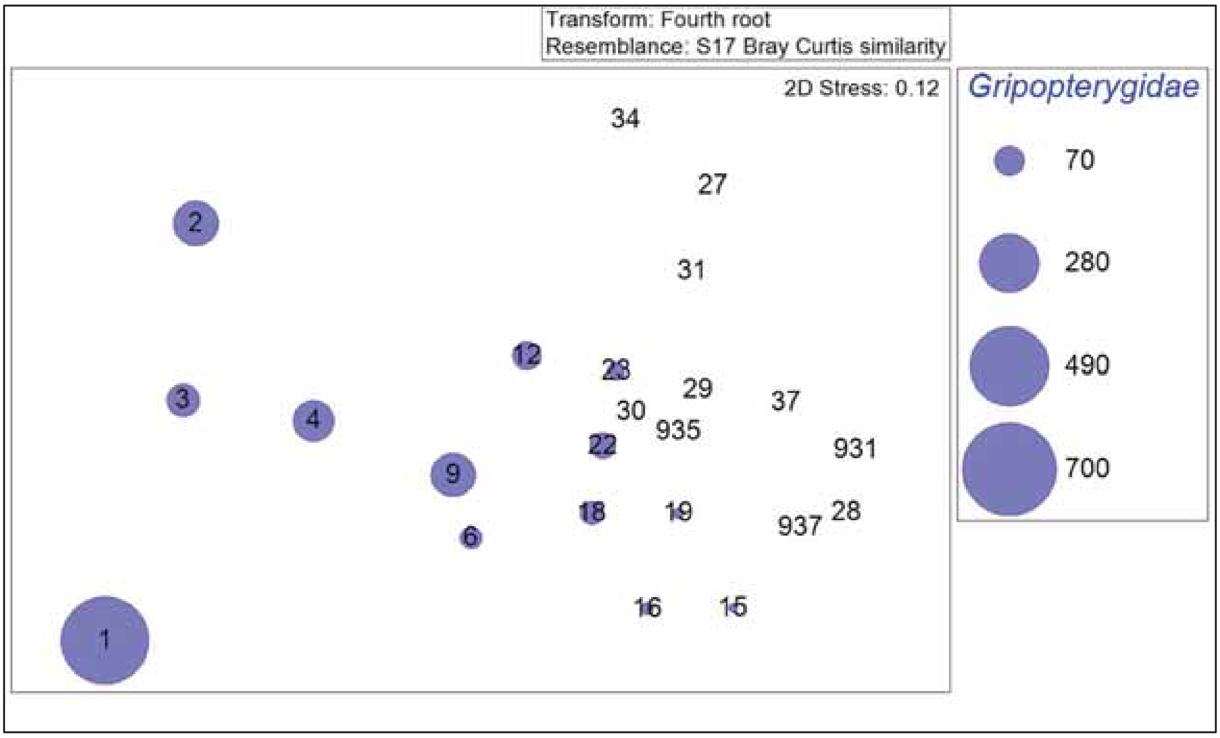

Figure 7-22 Bubble plot indicating relative abundance of Gripopterygidae between edge samples

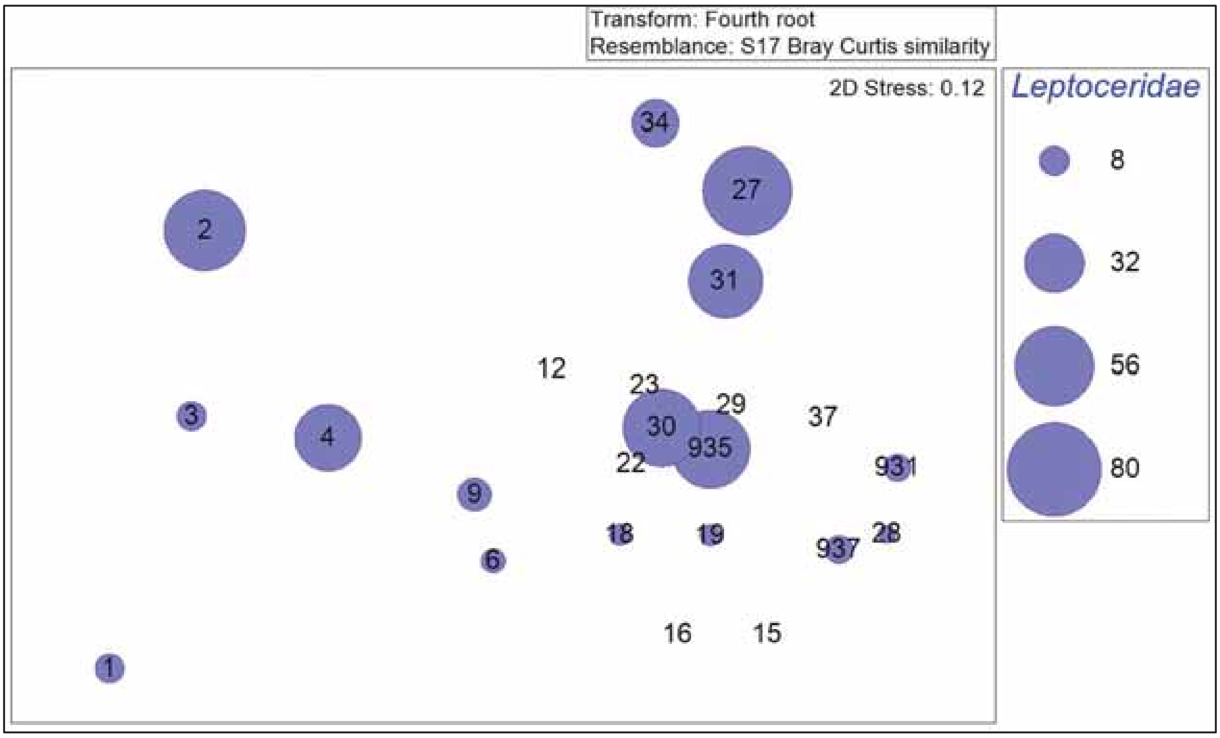

Figure 7-23 Bubble plot indicating relative abundance of Leptoceridae between edge samples

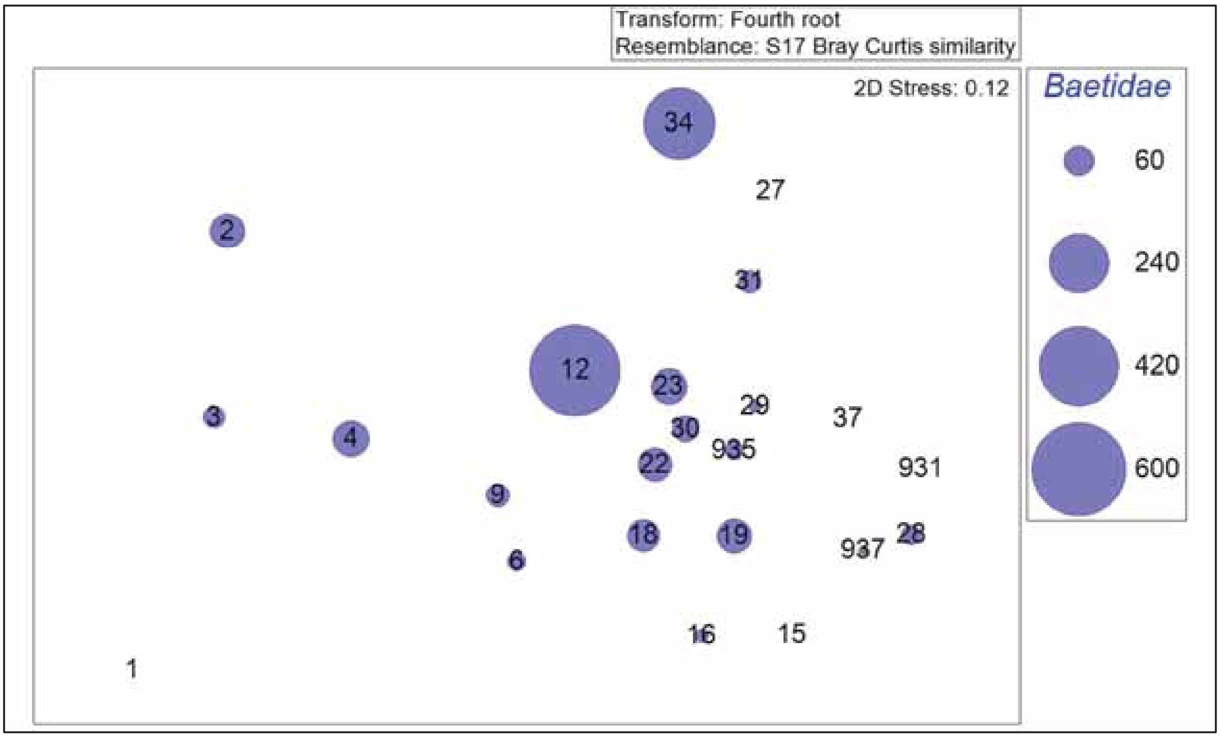

Figure 7-24 Bubble plot indicating relative abundance of Baetidae between edge samples

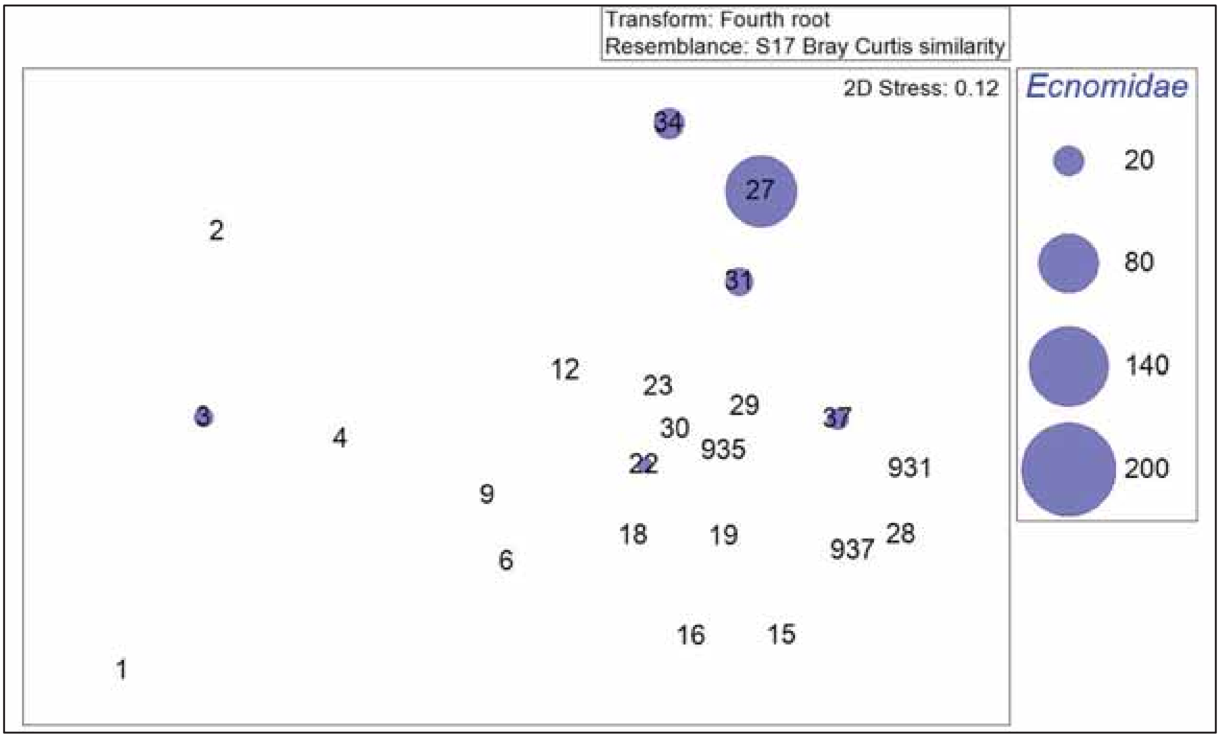

Figure 7-25 Bubble plot indicating relative abundance of Ecnomidae between edge samples

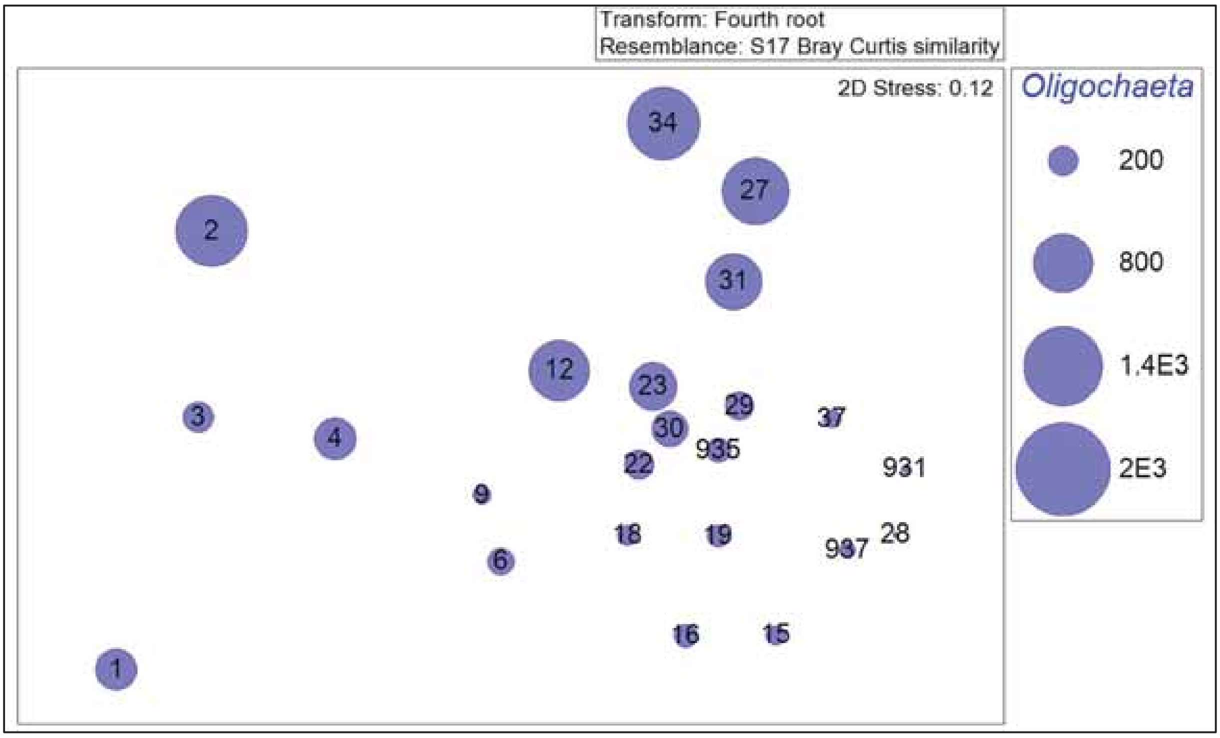

Figure 7-26 Bubble plot indicating relative abundance of Oligochaeta between edge samples

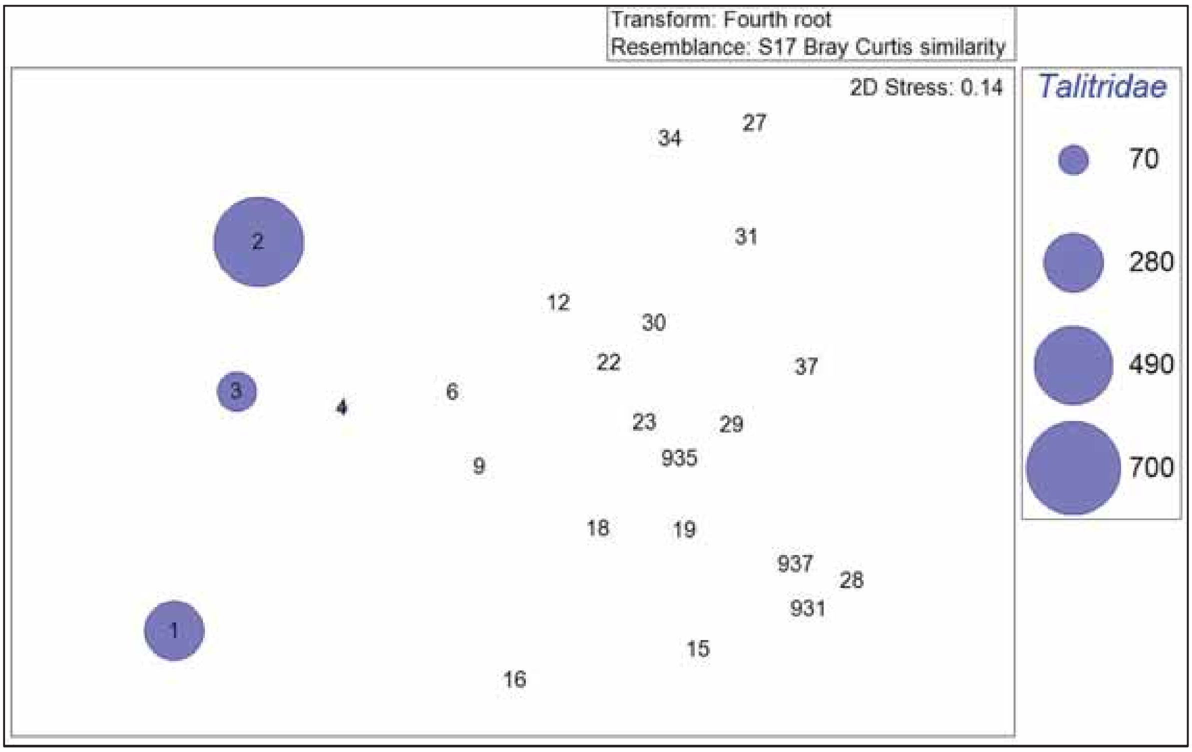

Figure 7-27 Bubble plot indicating relative abundance of Talitridae between edge samples

7.4.2 Univariate Indices

Abundance, richness, EPT richness and OCD richness were calculated for Murrumbidgee River sites. The histogram in Figure 7-28 shows total richness and EPT richness for each site. For riffle samples total richness was highest at MUR 4 followed by MUR 2, MUR 3 and MUR 6. Total richness was lowest in riffle samples from MUR 34 and MUR 29. Richness was generally higher at sites upstream of MUR 12 but did not appear to vary with any consistency between MUR 12 and MUR 37. The proportion of total richness comprised of EPT richness within riffle samples was highest at MUR 2 and lowest at MUR 15. Within edge samples, the total proportion of EPT richness relative to total richness was highest at MUR 1 and lowest at MUR 31. The percentage of total abundance made up of EPT taxa and OCD taxa have been calculated and are presented as EPT relative abundance and OCD relative abundance.

Kruskal-Wallis was used to test for differences in abundance, richness, EPT richness, EPT relative abundance and OCD relative abundance between zones. Output for all Kruskal-Wallis analyses can be viewed in Appendix I. For riffle samples no significant difference ($p>0.05$) was detected in abundance, total richness, EPT richness or OCD richness between zones. However, a significant ($p<0.05$) difference was detected in EPT relative abundance and OCD relative abundance of riffle samples between zones. A non-parametric multiple comparisons test indicated significant differences ($p<0.05$) in the EPT relative abundance within riffle samples between Zone 1 and both Zones 2 and Zone 4.

The means plot in Figure 7-29 shows that % EPT abundance was highest on average at Zone 1 compared to Zones 2 and 4. However, the standard errors around these means are quite high indicating a lot of within-zone variation as was seen earlier with the multivariate community. OCD relative abundance was found to differ significantly ($p<0.05$) between riffle samples of Zone 1 and both Zones 2 and 4 (Table 7-18). The means plot (Figure 7-29) indicates that OCD relative abundance was lowest, on average, within Zone 1 when compared to Zones 2 and 4.

For edge samples, Kruskal-Wallis tests indicated no significant difference ($p>0.05$) in abundance, EPT richness, EPT relative abundance or OCD relative abundance between zones. A significant difference ($p<0.05$) was detected in total richness of edge samples between the Zones. However, despite differences that were found in the overall model, the multiple comparisons test did not detect any pair-wise differences in richness between zones (Table 7-19).

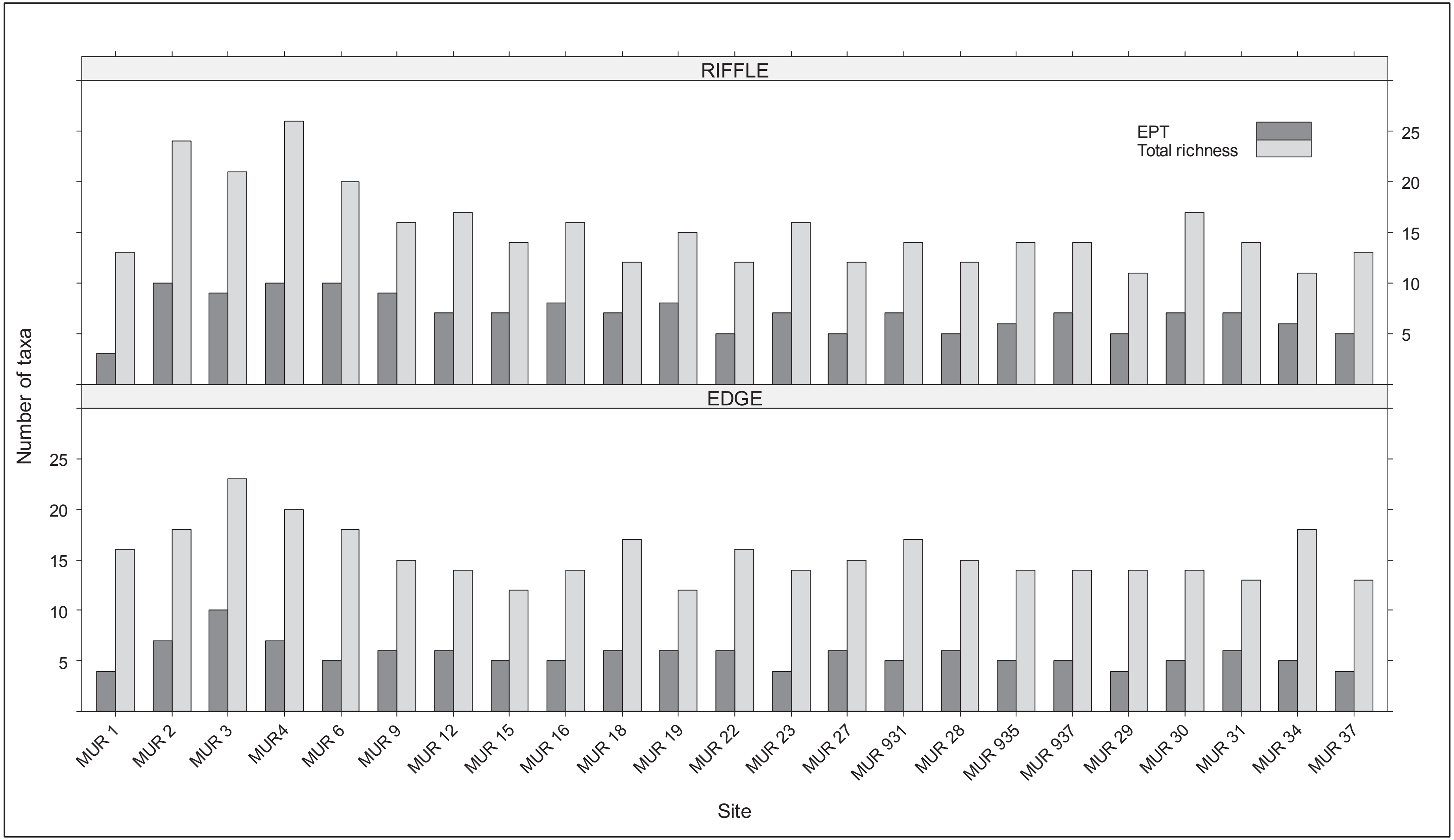

Figure 7-28 Total and EPT richness relative to total richness across Murrumbidgee River sites

Table 7-17 Multiple comparisons in EPT relative abundance for riffle samples between Zones

Zone	1	2	3
1			
2	0.0274		
3	0.1188	1.0000	
4	0.0239	1.0000	1.0000

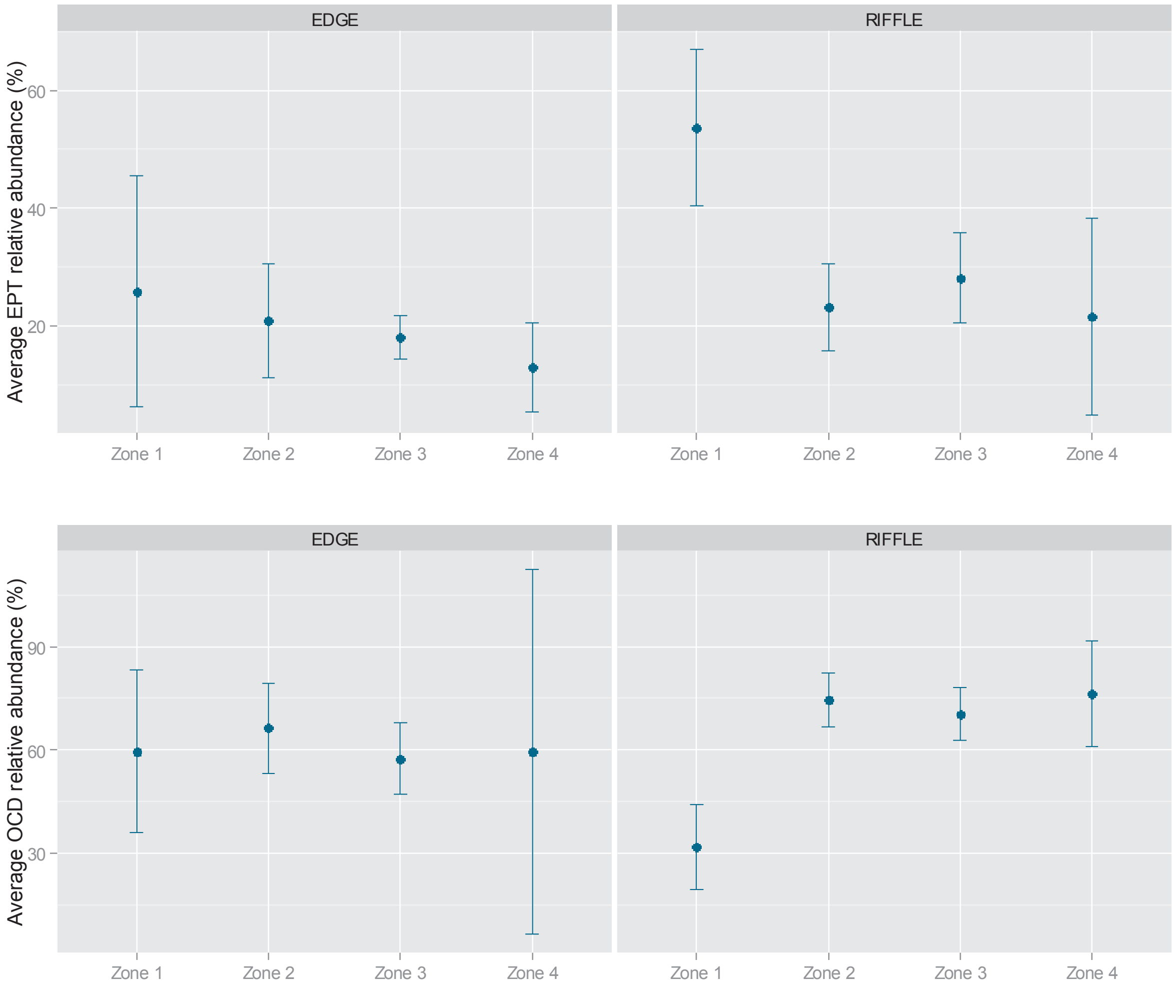

Figure 7-29 Mean EPT relative abundance and OCD relative abundance across Zones for riffle and edge habitats. Error bars indicate 95% confidence intervals

Table 7-18 Multiple comparisons in OCD relative abundance for riffle samples between Zones

Zone	1	2	3
1			
2	0.04		
3	0.05	1.00	
4	0.03	1.00	1.00

Table 7-19 Multiple comparisons in Total Richness for edge samples between Zones

Zone	1	2	3
1			
2	0.16		
3	0.07	1.00	
4	0.18	1.00	1.00

The SIGNAL-2, O/E50 (AUSRIVAS based ratio) and AUSRIVAS bands are provided in Table 7-20. This table shows that average SIGNAL-2 generally ranged between 4.38 (MUR 37) and 5.75 (MUR 2) from the riffle habitat and between 3.75 (MUR 34) and 5.13 (MUR 1) from the edge habitat. AUSRIVAS bands for individual habitats were either X, A or B indicating “above reference”, “reference”, or “significantly impaired” conditions, respectively. The AUSRIVAS band was generally higher for edge samples compared to riffle samples, which might reflect a higher resistance of edge taxa to the impacts of rainfall events. The overall site assessment indicated bands of A for sites between MUR 2 and MUR 16, MUR 23, MUR 27 and sites MUR 30 to MUR 34. All other sites received a B rating overall. Kruskal-Wallis and non-parametric multiple comparisons test were used to formally test for differences in SIGNAL-2 and O/E50 between Zones.

Table 7-20 AUSRIVAS and SIGNAL-2 scores for spring 2012

= nearly outside the experience of the model

Zone	Site	Location	SIGNAL-2		AUSRIVAS O/E50 score		AUSRIVAS BAND		Overall Site Assessment
			Riffle	Edge	Riffle	Edge	Riffle	Edge	
1	MUR 1	D/S Tantangara Reservoir	5.44	5.13	0.63	0.70	B	B	**B**
	MUR 2	Yaouk Bridge	5.75	5.00	1.14	0.93	X	A	**A**
	MUR 3	Bobeyan Road Bridge	5.46	4.89	0.97	1.05	A	A	**A**
	MUR 4	Camp ground off Bobeyan Road	5.54	4.91	0.98	1.21	A	X	**A**
2	MUR 6	D/S STP Pilot Creek Road	5.67	4.20	0.90	1.11	A	A	**A**
	MUR 9	Murrells Crossing	5.62	4.55	0.97	1.22	A	X	**A**
	MUR 12	Through Bredbo township	4.92	4.40	1.10	1.11	A	A	**A**
	MUR 15	Near Colinton - Bumbalong Road	5.06	4.42	1.10	1.13	A	A	**A**
	MUR 16	The Willows - Near Michelago	4.88	4.40	0.92	1.07	A	A	**A**
	MUR 18	U/S Angle Crossing	4.99	4.58	0.78	1.00	B	A	**B**
3	MUR 19	D/S Angle Crossing	5.21	4.35	0.80	1.02	B	A	**B**
	MUR 22	Tharwa Bridge	5.00	4.44	0.71	1.00	B	A	**B**
	MUR 23	Point Hut Crossing	5.32	4.29	0.99	0.98	A	A	**A**
	MUR 27	Kambah Pool	4.80	4.13	0.79	0.89	B	A	**A**
	MUR 931	"Fairvale" ~4km U/S of the Cotter Confluence	4.98	4.35	0.74	0.93	B	A	**B**
	MUR 28	U/S Cotter River confluence	4.99	3.85	0.82	0.85	B	B	**B**
	MUR 935	Casuarina sands	4.95	4.22	0.74	1.00	B	A	**B**
	MUR 937	Mt. MacDonald ~5km D/S of the Cotter Confluence	5.09	4.32	0.74	0.93	B	A	**B**
	MUR 29	Uriarra Crossing	4.82	3.99	0.69	0.87	B	A	**B**
	MUR 30	U/S Molonglo Confluence	5.36	4.22	0.86	1.00	A	A	**A**
4	MUR 31	D/S Molonglo Confluence	4.78	4.25	0.87	0.89	A	A	**A**
	MUR 34	Halls Crossing	4.78	3.75	0.87	0.89	A	A	**A**
	MUR 37	Boambolo	4.38	3.86	0.63	0.78	B	B	**B**

For the riffle samples, SIGNAL-2 was found to be significantly different between Zones 1 and 4 (Table 7-21). The means plot shows that SIGNAL-2 was significantly higher at Zone 1 sites compared to Zone 4 sites (Figure 7-30).No significant difference was detected in O/E50 from riffle samples between Zones.

SIGNAL-2 was found to differ significantly ($p<0.05$) between Zones for edge samples. The multiple comparisons results indicate that SIGNAL-2 was significantly different between Zone 1 and both Zones 3 and 4 (Table 7-22). However, there was no significant difference detected in SIGNAL-2 of edge samples between Zone 1 and Zone 3 or any other combination of zones. The means plot in Figure 7-30 indicates that SIGNAL-2 was highest in Zone 1 and declined in a downstream direction. However, this plot also indicates the high variation, particularly within Zone 4. A significant ($p<0.05$) difference was also detected in O/E50 of edge samples between Zones. Further analysis showed that O/E (Figure 7-30) shows that O/E50 was highest in edge samples collected from Zone 2 and lowest within Zone 4. This plot also highlights the high variation within the Zone 1 samples.

Table 7-21 Multiple comparisons in SIGNAL-2 for riffle samples between Zones

Zone	1	2	3
1			
2	0.7387		
3	0.1543	1.0000	
4	0.0031	0.1139	0.2560

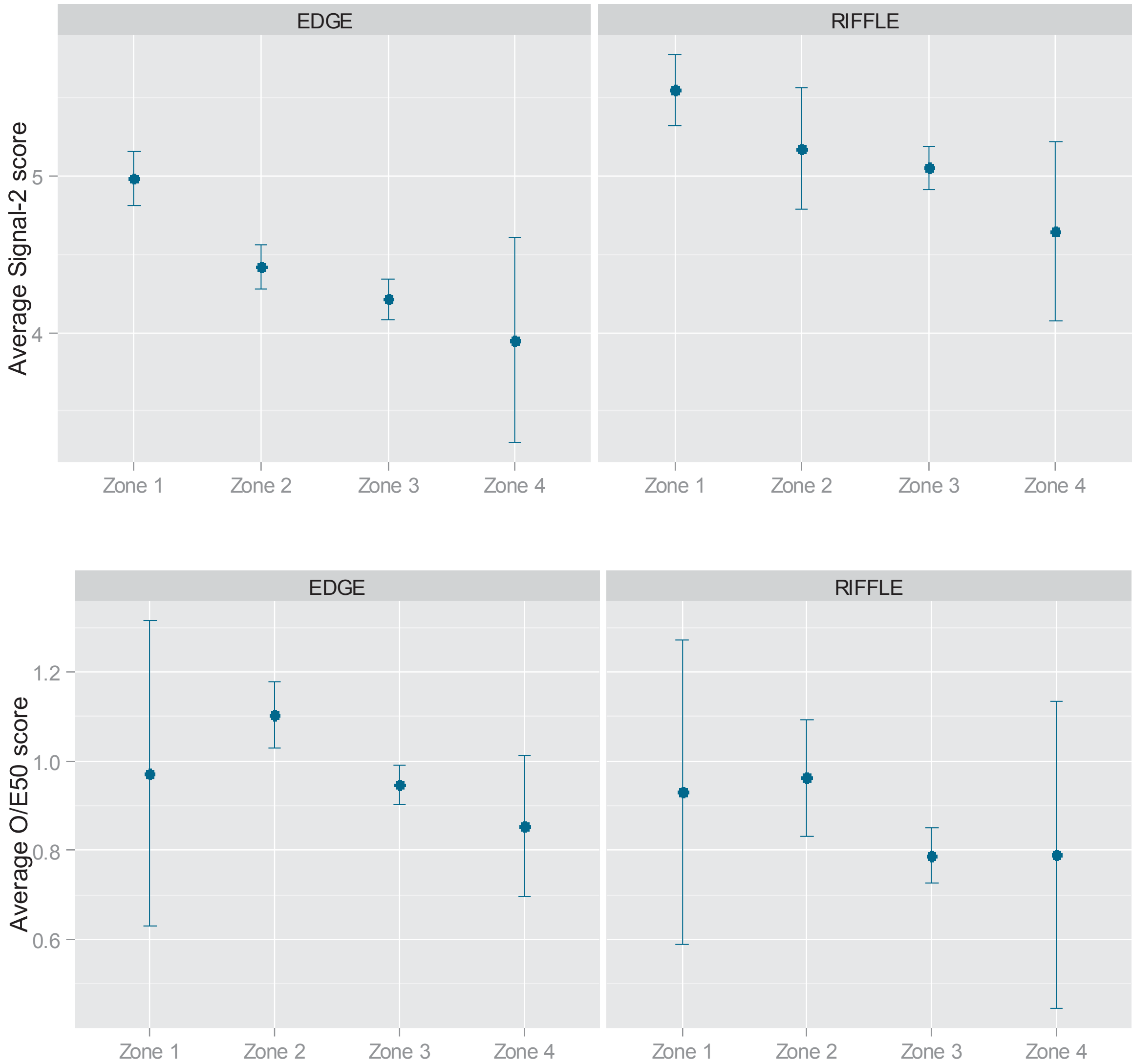

Figure 7-30 Means plot of SIGNAL-2 and O/E50 score between Zones and in riffle and edge habitats. Error bars are 95% confidence intervals

Table 7-22 Multiple comparisons in SIGNAL-2 for edge samples between Zones

Zone	1	2	3
1			
2	0.71		
3	0.01	0.59	
4	0.005	0.18	1.00

Table 7-23 Multiple comparisons in O/E50 for edge samples between Zones

Zone	1	2	3
1			
2	0.71		
3	1.00	0.05	
4	0.85	0.01	1.00

7.5 Discussion

7.5.1 Water quality

The water quality grab samples showed that electrical conductivity is slightly below the ANZECC & ARMCANZ (2000) guideline range at MUR 1, 2 & 3, all located within Zone 1. This is not a concern as these sites have typically fallen outside the recommended range in previous seasons and electrical conductivity is generally lower in the upland reaches of rivers. There was some elevation of the pH values occurring downstream of Zone 1, which was probably a response to runoff from the recent rain and the slight increases in electrical conductivity in the middle to lower sections of the catchment. This trend does not appear to be related to the M2G operations because there were exceedances occurring both upstream and downstream of Angle Crossing.

In-situ readings of dissolved oxygen (DO) returned the largest number of sites for which DO levels were recorded below the ANZECC & ARMCANZ (2000) guidelines since the inception of the MEMP. These lower DO values could be a result of reduced macrophyte and algae levels, increased organic matter or a combination of these and other factors at each site or across the whole upper Murrumbidgee Catchment. Also during spring, the continuous gauging station at Hall's Crossing recorded two periods of reduced DO concentrations which coincided with the two main high flow events. The lower DO readings during the events are likely due to the deposition of fine sediments which got washed downstream with the high flows and accumulated around the probe reducing oxygen availability.

The deposition of fine sediment around the probe would also explain the extreme turbidity values recorded during the high flows at Hall's Crossing. It is expected that there will be some exceedances of the ANZECC & ARMCANZ (2000) guidelines during high flow events. Continuous monitoring at upstream Angle Crossing also shows elevated turbidity readings throughout the period. This site has been prone to turbidity issues in the past due to the nature of the substrate consisting of sand and fine sediment, with these spring readings unlikely to be accurate. The turbidity issues at upstream Angle Crossing have been discussed in more detail previously in section 4.6.

The grab samples showed a considerable elevation of nutrient levels across Zones 2, 3 & 4. This elevation is not season specific and has been recorded in previous sampling runs during both autumn and spring. All sites in Zone 2 & 4 exceed the ANZECC & ARMCANZ (2000) trigger values, while a majority of sites Zone 3 also show exceedances. The source of the nutrients entering the system in Zones 1, & 2 is likely a result of runoff from the dominant land use type within the catchment, agriculture. Total nitrogen concentrations drop below ANZECC & ARMCANZ (2000) trigger values at MUR 22 & 23, which could be related to the slow dissipating trend combined with these reaches having a higher proportion of macrophytes taking up higher proportions of nutrients. The subsequent increase above the trigger values below MUR 23 could be related to the input of urban streams and retarding basins, such as Point Hut Pond which drains into the Murrumbidgee River directly downstream of MUR 23.

Nutrient levels spike significantly in Zone 4 which consists of sites downstream of the Molonglo Confluence. These nutrient increases include a spike in the NO_x concentrations to more than 40 times the ANZECC & ARMCANZ (2000) trigger value, an increase to the total nitrogen to 4 times the trigger value and a further increase to the total phosphorus. The increased nutrients are coming from the Lower Molonglo Water Quality Control Centre (LMWQCC) which discharges into the Molonglo River approximately two kilometres upstream of the confluence.

7.5.2 Macroinvertebrates

Differences in the macroinvertebrate community were seen between sites but the differences between Zones were not as clear cut as for the water quality data. The macroinvertebrate community was seen to change at points along the Murrumbidgee River but these changes did not always correspond to a change in Zone. Zone 1 sites were noticeably separated from other Zones; however there was more intra-site variability within this Zone than any other.

There were discrepancies between the results of PERMANOVA and the MDS / Cluster diagrams. PERMANOVA indicated significant differences in the macroinvertebrate community (both edge and riffle) between all pairwise combinations of zones except for Zones 2 and 3, whereas the MDS and Cluster plots showed weak separation, if any, according to Zone. This disparity can be explained by considering how these methods work. PERMANOVA uses the information provided from all sites within a Zone to calculate a combined 'average' for the macroinvertebrate community and attempts to compare this 'average' to that calculated for the other Zones. The MDS and Cluster plots on the other hand display each site separately and thus are more reflective of the variation that exists within each Zone. This method indicated that differences between sites often occurred as a gradient of change along the Murrumbidgee River and these changes often spanned multiple Zones.

Multivariate analysis was used to distinguish the taxa which contributed most to changes in the macroinvertebrate community between Zones. These taxa contributed less than 10% to the differences between Zones and many taxa were identified as contributing around the same amount to the differences. This suggests that the perceived differences between Zones were due to a series of small changes in many taxa which were likely each affected by a diverse range of sources such as flow, landuse, physical site differences, inputs from tributaries and water quality at a local site level rather than larger changes at a Zone level.

Patterns were quite similar to previous sampling events with more noticeable changes in the community downstream of MUR 9. This mirrored the change in water quality that was observed following MUR 9 with increased EC and increased total nitrogen and total phosphorus observed at MUR 12. Differences were generally more pronounced between the furthest upstream and furthest downstream sites with little differentiation made within the central sites. The bubble plots highlighted some of these gradients along the Murrumbidgee River. Simuliidae and Hydropsychidae were detected in higher numbers at sites further downstream. These two taxa are known to prefer higher flow conditions and, thus, their increase in the downstream Murrumbidgee River sites is not surprising as these flows are generally higher. Members of the Trichopteran family Ecnomidae were found only at MUR 3, MUR 27, MUR 31, MUR 34 and MUR 37. The higher prevalence of Ecnomidae at Zone 3 and Zone 4 sites is not expected as these animals generally live within slow flowing waters (Dean, St Clair and Cartwright, 2004); however, this family was only observed in Edge samples where flow would be reduced. Furthermore, Ecnomidae are often observed foraging in areas of fine sediment deposition for detritus (Gooderham and Tsyrlin, 2002). Thus, as several of the Zone 3 and Zone 4 sites were observed to have large deposits of fine silts (see section 7.1) this may have contributed to the presence of Ecnomids at these sites.

In general, there were higher numbers of the sensitive family Gripopterygidae found at sites further upstream which corresponds to the generally improved water quality observed at these sites.

The amphipod - Talitridae are generally found on land but are frequently washed into rivers (Gooderham and Tsyrlin, 2002) as probably occurred here during one of the rainfall events. Thus, the restriction of their presence in samples from MUR 1, MUR 3 and MUR 4 is not informative.

Oligochaeta, which are known to thrive in high nutrient environments (Gooderham and Tsyrlin, 2002), did not follow any consistent pattern across the sites. The highest numbers of Oligochaeta were observed at MUR 34, MUR 2 and MUR 27. In spring 2012, Oligochaeta did not mirror patterns in the measured nutrients, which indicates that other factors such as the degree of sediment deposition may be more important in explaining their distribution.

Other tolerant taxa, Corixidae, Hydroptilidae and Caenidae, increased in number at the sites downstream of MUR 4 but there was no consistent trend in these taxa across Zones 2, 3 and 4. This reflects the results of formal statistical analysis which generally indicated no significant differences between the lower Zones. The reduced numbers of these tolerant taxa at Zone 1 sites is presumably another example of the macroinvertebrate community responding to improved water quality within this zone.

For the riffle samples SIGNAL-2 was found to be significantly higher within Zone 1 compared to Zone 4 but O/E50 scores were not statistically different. For edge samples, SIGNAL-2 was found to be significantly different in Zone 1 compared to both Zones 3 and 4. EPT abundance was also found to be higher at Zone 1 compared to Zones 3 and 4 and the abundance of tolerant taxa (OCD taxa) was lower at Zone 1 compared to Zone 3. This means that the a larger proportion of abundance collected within Zone 1 were made up of more sensitive animals from the EPT group and few members of the tolerant groups were collected from this zone when compared to other zones. This is in keeping with the superior water quality results within this Zone as well as the results of previous sampling events.

Taxa richness was moderate across the zones and EPT richness, at least for riffle samples, constituted a fairly large portion of total richness. This suggests positive health within the system. The overall site assessment based on AUSRIVAS was either an A or B banding. Across the zones, 13 A grades and 10 B grades were achieved which indicates that despite the recent heavy flow events, the health of Murrumbidgee River sites in spring 2012 was improved compared to the autumn 2012 and spring 2011 sampling events. Based on this result, there is no reason to suggest that the health of the macroinvertebrate community has been compromised by the abstraction of water associated with the M2G project or the MPS. Although higher numbers of sensitive taxa and higher O/E50 was often observed in Zone 1 especially when compared to Zones 2 and 3, these patterns are in line with the conclusions made from the pre-abstraction sampling events. Given the amount of water received across the region particularly in the lead up to sampling it is doubtful that the small amount extracted as part of the M2G commissioning would have had an obvious effect. Thus, this conclusion should be made based on the results of multiple sampling events, preferably in the absence of extreme flows.

7.6 Conclusion and recommendations

Water quality changed considerably across spring and most physical/chemical parameters such as DO, EC and pH fluctuated in accordance with the major rainfall events. Although the changes in rainfall and differences in flows throughout the Murrumbidgee River make it difficult to compare individual levels of these parameters across sites, multivariate analysis identified the overall trends in water quality between the four Zones, which are more easily interpreted. The overall trend was generally that of lower EC, alkalinity, temperature and turbidity at the sites furthest upstream and higher nitrogen at the sites furthest downstream. The higher nitrogen at Zone 4 sites is attributed to differences in landuse and the fact that these sites experience the culmination of multiple river inputs. Phosphorus was found to be highest at MUR 12 and MUR 15 within Zone 2 and similar spikes of nitrogen were also observed at these sites. This reinforces previous conclusions that there is an localised input of nutrients into the system between MUR 9 and MUR 12, which is probably be the Bredbo River.. As has been seen previously, Zone 1 sites had considerably improved water quality compared to the other three zones which is a reflection of the landuse in this region.

Although differences in water quality were fairly clear between sites and zones these changes did not translate to any consistent differences in macroinvertebrates between Zones. As was seen for previous events, the patterns between environmental variables and the macroinvertebrates do not appear to match up precisely. Changes in the macroinvertebrate community were observed at Zone 1 sites but no clear separation of Zone 4 sites was observed as has sometimes been the case. However, in spring 2012, the water quality in Zone 4 was not seen to clearly distinguished from Zones 2 and 3, except for the aforementioned spike in nitrogen.

There was a complex combination of taxa which differed between sites generally along a gradual gradient of localised change rather than with strict adherence to the Zone boundaries. The particular taxa distinguished indicated that the changes in water quality are not solely responsible for the differences in macroinvertebrates. As has previously been shown, there were changes along the Murrumbidgee River of taxa such as Simuliidae and Hydropsychidae which respond to flow. Numbers of these taxa were highest at Zone 4 sites and other sites which are downstream of the Cotter and Molonglo confluence. The consistency of this pattern with previous sampling events suggests that the extraction at Angle Crossing and MPS has had no considerable impact on the macroinvertebrates of the Murrumbidgee River. The specific changes in macroinvertebrates that could be linked to water quality including increased numbers of sensitive taxa such as Gripopterygidae at the sites furthest upstream and higher numbers of the tolerant taxa Corixidae and Caenidae at sites with poorer water quality (generally those further downstream).

AUSRIVAS banding indicated that overall health in Murrumbidgee River is generally good between Tantangara and Burrinjuck reservoirs. There were some key differences in SIGNAL-2, O/E50 and OCD abundance between sites but these patterns did not usually hold true for the entire Zone. Differences generally presented as a gradient of change that spanned across zone boundaries and, thus, localised differences in water quality and landuse and inputs from joining tributaries have been suggested as possible sources of variation within the data. Richness was moderate for most sites but EPT richness was fairly high indicating that there are several more sensitive taxa living within the study area. The AUSRIVAS bands, richness, EPT richness and SIGNAL-2 results are comparable to previous sampling results and indeed, in many cases, the AUSRIVAS bands are improved. This suggests that the water extraction has not had a negative impact upon the downstream sites of the Murrumbidgee River.

Considering all the data, there is no indication that patterns in macroinvertebrate community have changed due to difference in flows now that abstraction has commenced. The patterns in the macroinvertebrate community and water quality were reminiscent of previous sampling events. However, given that a large amount of rainfall has been received over spring 2012, this will need to be confirmed over a number of sampling events. Although a brief comparison has been made to historical data, a formal review of all historical data should be conducted to quantitatively identify temporal differences in the data between the spring 2012 (post extraction) and previous (pre-extraction) sampling events. Such a review could utilise techniques such as RELATE which seeks to identify similarities (or differences) between two multivariate patterns (i.e. the pattern of data observed in an MDS plot).

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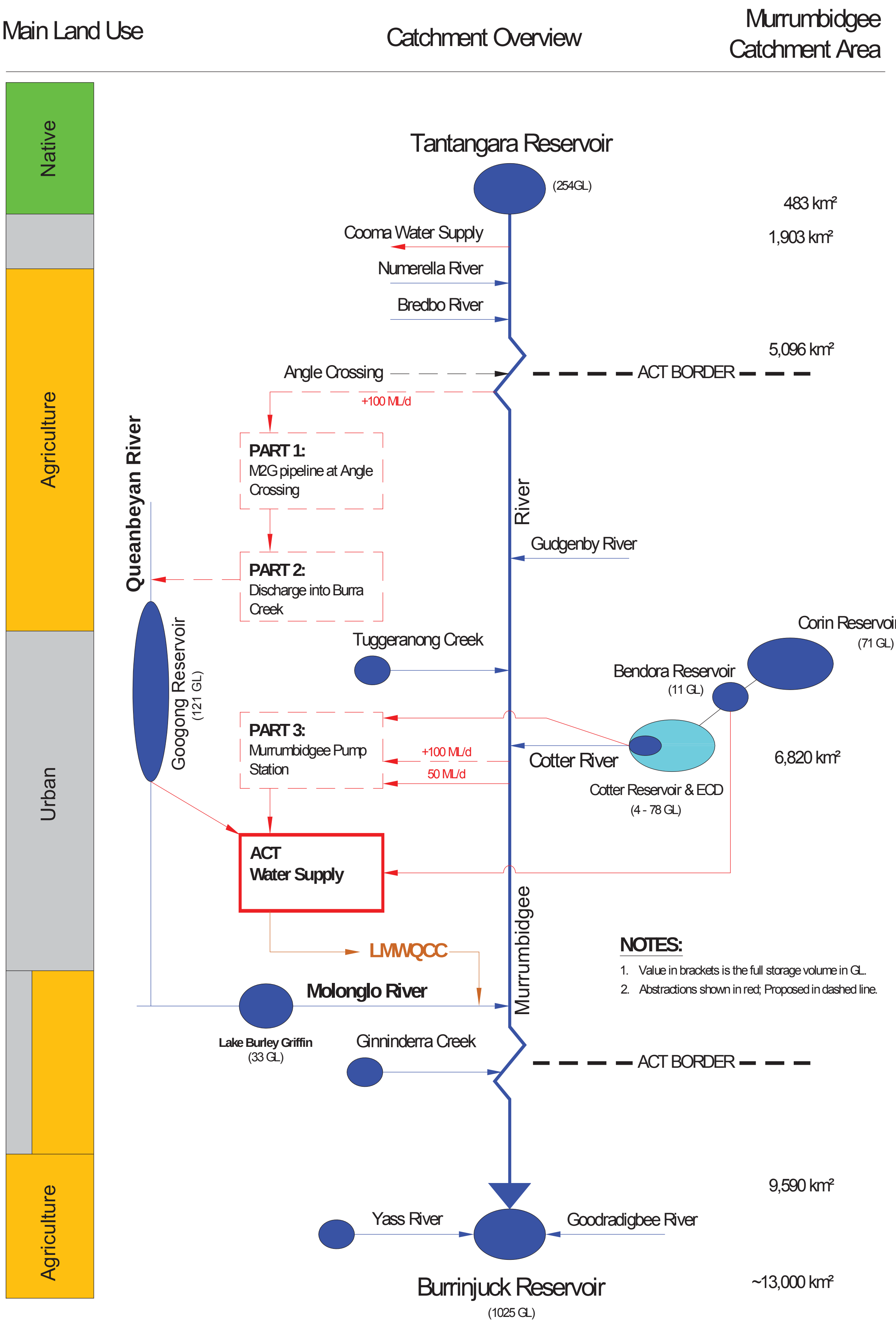
Appendices

Appendix A - Schematic representation of the Murrumbidgee Catchment and ACTEW Waters' major projects

Appendix A. Overview of ACTEW Water's major projects



Appendix B - Conceptual framework of the effects of reduced flow

Appendix B Summary of the effects of reduced flows on various habitat conditions and macroinvertebrate communities (Dewson, 2007)*.

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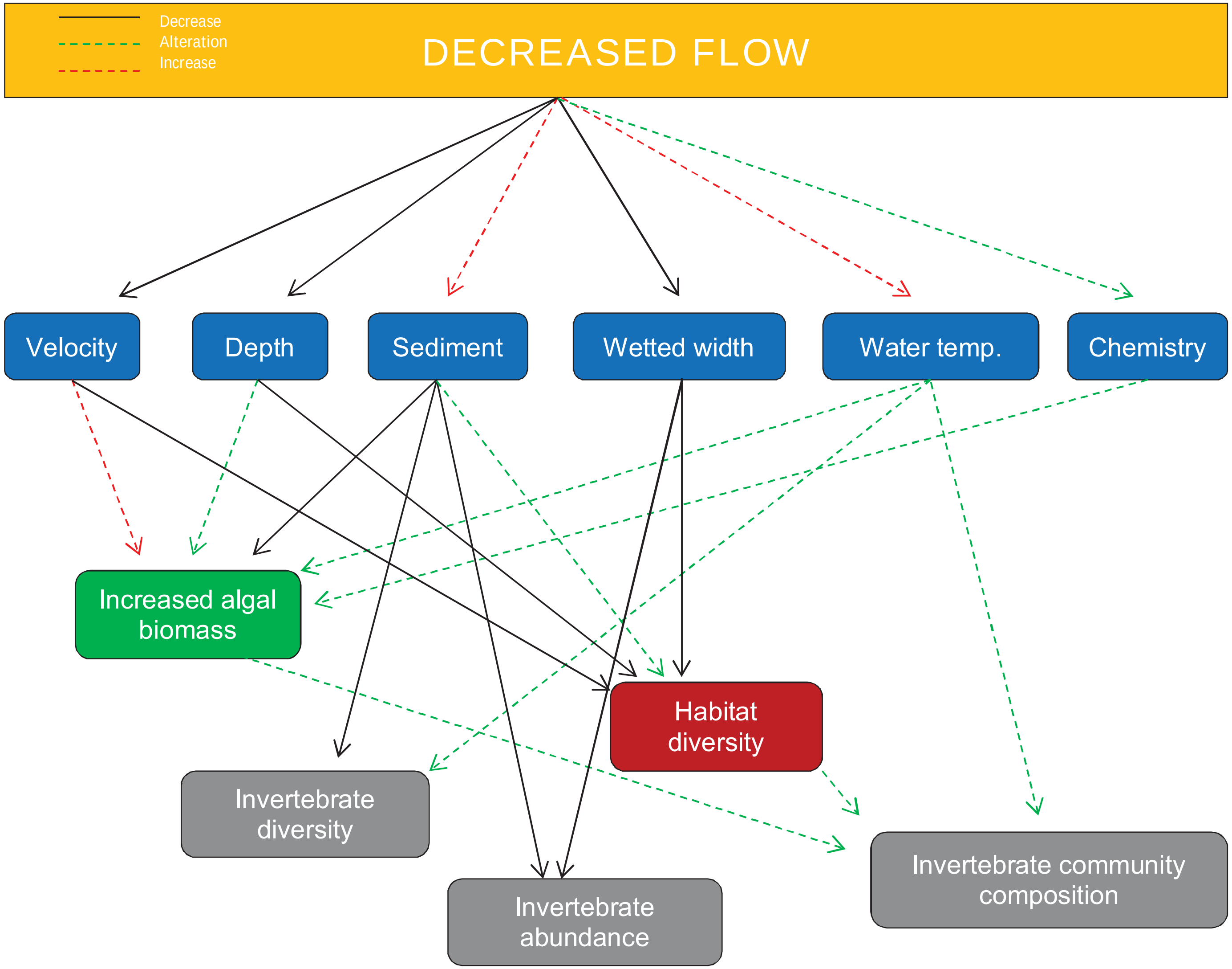


Appendix C – QA/QC Results

Appendix C QA/QC results for spring 2012

		Site Code	BUR2A		MUR15		MUR16		MUR18		MUR19		MUR28		MUR935		MUR937		MUR937		MUR3		MUR12	
		Habitat	Riffle		Edge		Edge		Edge		Riffle		Riffle		Riffle		Riffle		Edge		Edge		Riffle	
		Replicate	1		1		2		1		2		2		1		2		1		1		1	
		QSN	MEMP11/12		MEMP11/26		MEMP11/31		MEMP11/34		MEMP11/37		MEMP11/49		MEMP11/51		MEMP11/56		MEMP11/57		MEMP11/68		MEMP11/75	
		Date Collected	29/10/2012		6/11/2012		12/11/2012		12/11/2012		12/11/2012		13/11/2012		14/11/2012		15/11/2012		15/11/2012		5/11/2012		6/11/2012	
		Replicate	1	QA	1	QA	1	QA	3	QA	1	QA	2	QA	3	QA	1	QA	1	QA	1	QA	1	QA
Order	**Family**	**Genus**																						
Acarina	Acarina	Acarina											1	1	1	1					1	1	1	1
Amphipoda	Talitridae	sp.																			1	1		
Bivalvia	Sphaeriidae	sp.			1	1															1	1		
Coleoptera	Elmidae	Simsonia																	1	1				
Coleoptera	Gyrinidae	sp.									1	1												
Coleoptera	Scirtidae	sp.	1	1																				
Decapoda	Parastacidae	Cherax	1	1																				
Diptera	Ceratopogonidae	Ceratopoginae									1	1							1	1				
Diptera	Ceratopogonidae	sp.																			1	1	1	1
Diptera	Chironomidae	sp.																			1	1	1	1
Diptera	Chironominae	sp.	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Diptera	Empididae	sp.							1	1									1	1			1	1
Diptera	Orthocladiinae	sp.	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Diptera	Simuliidae	Austrosimulium	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1				
Diptera	Simuliidae	sp.			1		1	1	1	1	1	1	1	1	1	1	1	1	1	1			1	1
Diptera	Tanypodinae	sp.	1	1	1	1	1	1					1	1							1	1	1	1
Diptera	Tipulidae	sp.					1	1	1	1					1	1	1	1	1	1				
Diptera	sp.																							
Ephemeroptera	Baetidae	Baetidae Genus 1	1	1					1	1		1	1	1					1	1				
Ephemeroptera	Baetidae	Baetidae Genus 2	1	1							1	1	1	1	1	1	1	1						
Ephemeroptera	Baetidae	Centroptilum sp	1	1																				
Ephemeroptera	Baetidae	sp.	1	1			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Ephemeroptera	Caenidae	Irapacaenis			1	1	1	1	1	1							1	1						
Ephemeroptera	Caenidae	Tasmanocoenis	1	1	1	1	1	1	1	1			1	1			1	1	1	1				
Ephemeroptera	Caenidae	sp.			1	1	1	1	1	1					1	1			1	1			1	1
Ephemeroptera	Coloburiscidae	sp.																					1	1
Ephemeroptera	Leptophlebiidae	Atalophlebia	1	1			1	1																
Ephemeroptera	Leptophlebiidae	Austrophlebiodes											1	1			1	1						
Ephemeroptera	Leptophlebiidae	Jappa	1	1			1	1			1	1												
Ephemeroptera	Leptophlebiidae	Nousia	1																					
Ephemeroptera	Leptophlebiidae	Ulmerophlebia	1	1																				
Ephemeroptera	Leptophlebiidae	sp.	1	1	1	1	1	1	1	1	1	1	1	1			1	1	1	1	1	1	1	1
Gastropoda	Ancylidae	Ferrissia															1	1						
Gastropoda	Physidae	sp.																			1	1		
Gastropoda	Planorbidae/physidae	sp.					1	1																
Gastropoda	sp.																				1	1		
Hemiptera	Corixidae	Micronecta			1	1	1	1	1	1									1	1				
Hemiptera	Corixidae	sp.							1	1											1	1		
Hemiptera	Notonectidae	Enithares					1	1																
Hemiptera	Notonectidae	sp.																			1	1		
Nematomorpha	Gordiidae	sp.																					1	1
Odonata	Zygoptera	sp.																			1	1		
Oligochaeta	Oligochaeta	Oligochaeta	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

		Site Code	BUR2A		MUR15		MUR16		MUR18		MUR19		MUR28		MUR935		MUR937		MUR937		MUR3		MUR12	
		Habitat	Riffle		Edge		Edge		Edge		Riffle		Riffle		Riffle		Riffle		Edge		Edge		Riffle	
		Replicate	1		1		2		1		2		2		1		2		1		1		1	
		QSN	MEMP11/12		MEMP11/26		MEMP11/31		MEMP11/34		MEMP11/37		MEMP11/49		MEMP11/51		MEMP11/56		MEMP11/57		MEMP11/68		MEMP11/75	
		Date Collected	29/10/2012		6/11/2012		12/11/2012		12/11/2012		12/11/2012		13/11/2012		14/11/2012		15/11/2012		15/11/2012		5/11/2012		6/11/2012	
		Replicate	1	QA	1	QA	1	QA	3	QA	1	QA	2	QA	3	QA	1	QA	1	QA	1	QA	1	QA
Order	Family	Genus																						
Plecoptera	Gripopterygidae	Dinotoperla	1	1	1	1			1	1	1	1	1	1										
Plecoptera	Gripopterygidae	Eunotoperla													1	1								
Plecoptera	Gripopterygidae	Illiesoperla									1	1												
Plecoptera	Gripopterygidae	sp.					1	1													1	1	1	1
Trichoptera	Atriplectididae	sp.																			1	1		
Trichoptera	Calamoceratidae	sp.																			1	1		
Trichoptera	Conoesucidae	sp.																			1	1		
Trichoptera	Ecnomidae	Ecnomus	1	1																				
Trichoptera	Ecnomidae	sp.																			1	1		
Trichoptera	Hydrobiosidae	sp.													1	1					1	1	1	1
Trichoptera	Hydrobiosidae	Taschorema	1	1																				
Trichoptera	Hydrobiosidae	Ulmerochorema																1						
Trichoptera	Hydrobiosidae	sp.									1	1					1	1						
Trichoptera	Hydropsychidae	Asmicridea									1	1					1	1						
Trichoptera	Hydropsychidae	Cheumatopsyche											1	1			1	1						
Trichoptera	Hydropsychidae	sp.			1	1							1	1	1	1	1	1					1	1
Trichoptera	Hydroptilidae	Hellyethira			1	1	1	1	1	1									1	1				
Trichoptera	Hydroptilidae	Hydroptila											1	1	1	1	1	1	1	1				
Trichoptera	Hydroptilidae	sp.					1	1	1	1				1	1	1								
Trichoptera	Hydroptilidae	Oxyethira					1	1	1	1					1	1				1				
Trichoptera	Leptoceridae	Notalina																	1	1				
Trichoptera	Leptoceridae	Triplectides																	1	1				
Trichoptera	Leptoceridae	sp.																			1	1		
Trichoptera	Philorheithridae	sp.																			1	1		
Trichoptera	sp.												1		1	1			1	1			1	1
Turbellaria	Dugesiidae	sp.																			1	1		
		Percent Taxa Correct	94.70%		93.30%		100.00%		100%		94.70%		94.70%		100%		95.50%		95.20%		100%		100%	
		Pass/Fail	Pass		Pass		Pass		Pass		Pass		Pass		Pass		Pass		Pass		Pass		Pass	

Appendix D - Site summary sheets

Part 1 – Angle Crossing

MUR15

Bumbalong Road
7/11/2012 10:30 am

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	TSS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
19.7	113.3	12.7	18	7.81	84.9	7.74

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
47	0.002	< 0.001	< 0.002	< 0.002	0.040	0.28

Daily Flow: 480 ML/day

Recorded at the closest station (410050) - located on the Murrumbidgee River at Billilingra. (Source: www.water.nsw.gov.au)

Compared to current flow:

Spring 2011: ↓ Autumn 2012: ↑

AUSRIVAS Results

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

Riffle Habitat

- Small patches of filamentous algae within the riffle habitat
- Little sand deposition within the riffle
- Dominant substrate was cobble

Dominant Taxa

- None

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Gripopterygidae
- Leptophlebiidae
- Hydrobiosidae
- Glossosomatidae

Additional Comments

- Few macrophytes observed
- Large sand deposits within the reach
- Extensive periphyton coverage on stable habitat

Edge Habitat

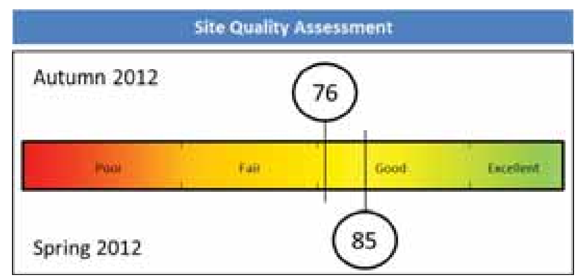
- Dominant trailing bank vegetation was wood debris from inundated shrubs

Dominant Taxa

- Corixidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae



MUR16

The Willows – Near Michelago
12/11/2012 10:15 am

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	TSS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
18.6	117.8	10.8	11	8.15	88.2	8.25

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
46	0.003	0.001	< 0.002	0.003	0.031	0.31

Daily Flow: 620 ML/day

Recorded at the closest station (410050), located on the Murrumbidgee River at Billilingra. (Source: www.water.nsw.gov.au)

Compared to current flow:

Spring 2011: ↓ Autumn 2012: ↑

AUSRIVAS Results

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

Riffle Habitat

- Dominant substrate was cobble

Dominant Taxa

- Simuliidae
- Chironomidae
- Hydropsychidae
- Coloburiscidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Coloburiscidae
- Glossosomatidae
- Gripopterygidae
- Hydrobiosidae

Edge Habitat

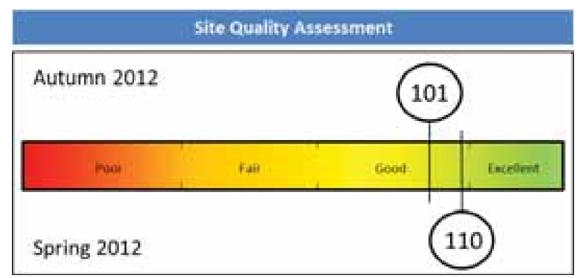
- Dominant trailing bank vegetation was overhanging native shrubs and wood debris

Dominant Taxa

- None

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Gripopterygidae
- Leptophlebiidae
- Hydrobiosidae



Additional Comments

- Flows elevated compared to usual sampling level
- Evident lack of macrophytes which are usually present at this site, specifically *Myriophyllum sp.*

MUR18

Upstream Angle Crossing
12/11/2012 12:45 pm

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	TSS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
19.9	112.9	12.7	13	8.05	87.2	7.94

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
45	0.003	0.001	< 0.002	0.004	0.034	0.30

Daily Flow: 760 ML/day

Recorded at the closest station (41001702), located on the Murrumbidgee River at upstream Angle Crossing.

Compared to current flow:

Spring 2011: ↓ Autumn 2012: ↓

AUSRIVAS Results

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

Riffle Habitat

- Dominant substrate was cobble

Dominant Taxa

- Baetidae
- Gripopterygidae
- Acarina
- Simuliidae
- Chironomidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae
- Gripopterygidae
- Coloburiscidae
- Hydrobiosidae

Additional Comments

- Sections of erosion on the upper left hand bank
- Filamentous algae attached to terrestrial plant roots in the shallow edges

Edge Habitat

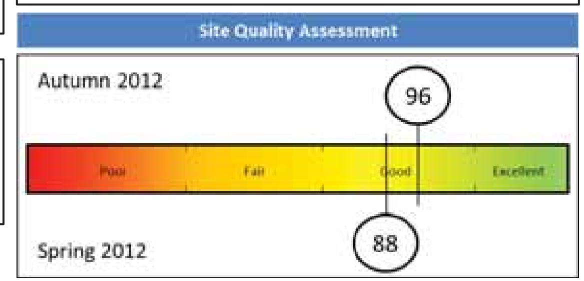
- Macrophytes limited to the edge habitat
- Better quality edge habitat inaccessible on the opposite bank due to deep channel
- Dominant trailing bank vegetation was overhanging native shrubs and wood debris

Dominant Taxa

- Gripopterygidae
- Corixidae
- Chironomidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Gripopterygidae



MUR19

Downstream Angle Crossing
12/11/2012 2:20 pm

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	TSS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
20.5	114.0	12.7	11	8.07	91.0	8.17

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
45	0.003	0.001	< 0.002	0.005	0.032	0.30

Daily Flow: 760 ML/day

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

Compared to current flow:

Spring 2011: Autumn 2012:

AUSRIVAS Results

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

Riffle Habitat

- *Myriophyllum sp.* abundant within the riffle zone
- Dominant substrate was cobble

Dominant Taxa

- Simuliidae
- Gripopterygidae
- Baetidae
- Leptophlebiidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae
- Hydrobiosidae
- Gripopterygidae

Additional Comments

- M2G construction completed
- Adult stoneflies present in large numbers
- Revegetation of the right hand bank recently undertaken with weed spraying underway during sampling
- Dirt road leading to the crossing is likely increasing the sediment load at this site

Edge Habitat

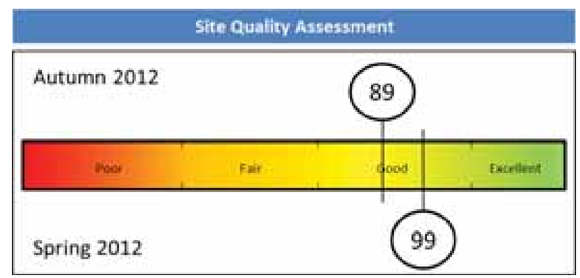
- Dominant trailing bank vegetation was native shrubs and wood debris

Dominant Taxa

- Corixidae
- Gripopterygidae
- Chironomidae
- Leptoceridae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Gripopterygidae



MUR23

Point Hut Crossing
7/11/2012 3:10 pm

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	TSS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
19.9	125.7	8.6	11	7.82	84.1	7.66

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
52	0.002	< 0.001	< 0.002	< 0.002	0.022	0.23

Daily Flow: 600 ML/day

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

Compared to current flow:

Spring 2011:  Autumn 2012: 

AUSRIVAS Results

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

Riffle Habitat

- Patches of *Myriophyllum sp.* and filamentous algae in the riffle zone
- Dominant substrate was cobble

Dominant Taxa

- Simuliidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae
- Gripopterygidae
- Hydrobiosidae

Edge Habitat

- Dominant trailing bank vegetation was macrophytes (*Phragmites australis* and *Eleocharis sp.*)

Dominant Taxa

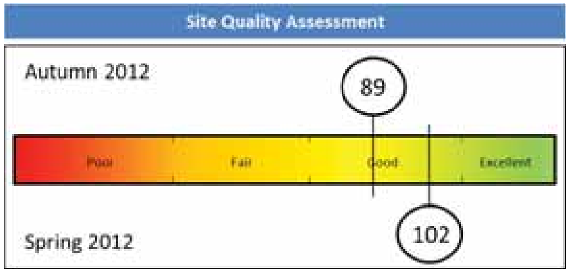
- Corixidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae
- Gripopterygidae

Additional Comments

- Small areas of erosion on the left hand bank
- Sand deposits within the reach



MUR28

Upstream Cotter River Confluence
14/11/2012   9:35 am

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	TSS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
19.9	130.8	13.0	10	8.16	101.5	9.26

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
51	0.003	0.001	< 0.002	< 0.002	0.026	0.33

Daily Flow:

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

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

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

The variation in flows down the Cotter River limit the comparability of this site's flow between seasons, which is further complicated by the operation of the Bendora Scour Valve.

AUSRIVAS Results

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

Riffle Habitat

- Dominant substrate was boulder

Dominant Taxa

- Chironomidae
- Baetidae
- Simuliidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae
- Coloburiscidae
- Hydrobiosidae

Edge Habitat

- Limited edge habitat available, resulting in only a single edge sample

Dominant Taxa

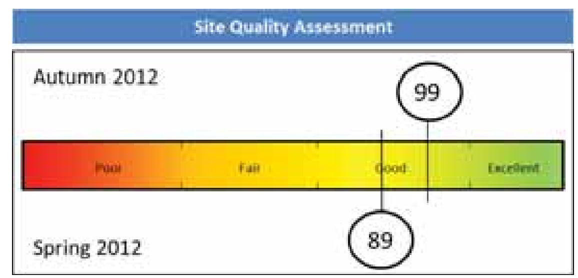
- Chironomidae
- Corixidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae
- Gripopterygidae

Additional Comments

- Bendora Scour Valve was on prior to sampling
- The Murrumbidgee Pump Station is currently recirculating water down the Cotter River, downstream of the Enlarged Cotter Dam
- Very few macrophytes
- Periphyton growth very high except in the path of the scour valve due to its operation



Part 2 – Burra Creek

BUR1a

Burra Native
29/10/2012 2:25 pm

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	TSS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
22.2	117.8	14.6	3	7.57	88.7	7.73

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
27	0.005	0.002	0.003	0.006	0.022	0.44

Daily Flow: 5.4 ML/day

Recorded at the closest station (410774), located on Burra Creek at Burra Road.

Compared to current flow:

Spring 2011: 

Autumn 2012: 

AUSRIVAS Results

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

Riffle Habitat

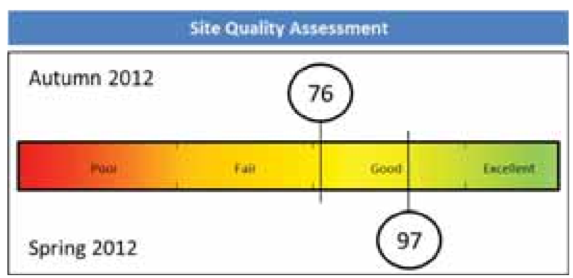
- Very shallow
- Dominant substrate was cobble

Dominant Taxa

- Leptophlebiidae
- Hydrobiosidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae
- Hydrobiosidae



Edge Habitat

- Dominant trailing bank vegetation was *Kunzea sp.*
- Limited habitat available resulting in the collection of only a single edge sample

Dominant Taxa

- Leptoceridae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Telephlebiidae
- Gripopterygidae
- Leptophlebiidae

Additional Comments

- High level of erosion on the right hand bank
- Some deposition of sand on the inside of the bend on the left hand bank
- Blackberry regrowth evident
- Adult dragon and damselflies common

BUR1c

Upstream Williamsdale Road
29/10/2012 12:10 pm

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	TSS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
18.8	365.7	9.3	11	8.04	93.6	8.73

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
144	0.056	0.054	0.002	0.006	0.015	0.39

Daily Flow: 5.4 ML/day

Recorded at the closest station (410774), located on Burra Creek at Burra Road.

Compared to current flow:

Spring 2011:  Autumn 2012: 

AUSRIVAS Results

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

Riffle Habitat

- Dominant substrate was pebble

Dominant Taxa

- Hydrobiosidae
- Leptophlebiidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Hydrobiosidae
- Leptophlebiidae
- Gripopterygidae

Edge Habitat

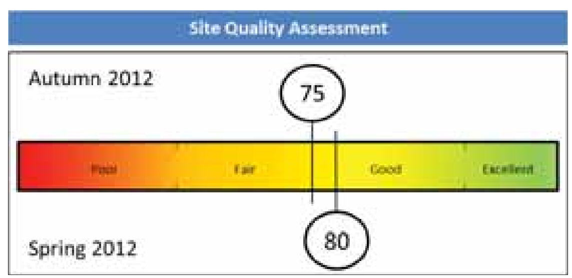
- Dominant trailing bank vegetation was macrophytes (*Eleocharis sp.*)

Dominant Taxa

- Leptophlebiidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae
- Gripopterygidae
- Hydrobiosidae



Additional Comments

- Reduction in silt deposition in comparison to previous seasons

BUR2a

Downstream Williamsdale Road
29/10/2012 10:15 am

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	TSS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
14.7	435.4	1.5	5	7.99	87.6	8.85

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
179	0.20	0.198	0.002	0.005	0.013	0.49

Daily Flow: 5.4 ML/day

Recorded at the closest station (410774), located on Burra Creek at Burra Road.

Compared to current flow:

Spring 2011: 

Autumn 2012: 

AUSRIVAS Results

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

Riffle Habitat

- Dominant substrate was cobble

Dominant Taxa

- Gripopterygidae
- Simuliidae
- Chironomidae
- Caenidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae
- Gripopterygidae
- Hydrobiosidae

Edge Habitat

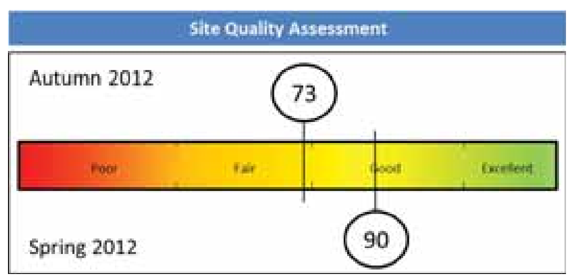
- *Gambusia holbrooki* abundant within the edge habitat
- Dominant trailing bank vegetation was macrophytes (mainly *Phragmites australis*)

Dominant Taxa

- Corixidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae
- Hydrobiosidae
- Coloburiscidae



Additional Comments

- Infrequent patches of filamentous algae
- Evidence of M2G / natural high flow releases – flattened riparian grasses

BUR2b

Downstream Burra Road
30/10/2012 3:00 pm

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	TSS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
21.7	448.4	5.6	5	8.16	101.7	8.96

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
182	0.060	0.058	0.002	0.006	0.014	0.38

Daily Flow: 5.3 ML/day

Recorded at the closest station (410774), located on Burra Creek at Burra Road.

Compared to current flow:

Spring 2011:  Autumn 2012: 

AUSRIVAS Results

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

Riffle Habitat

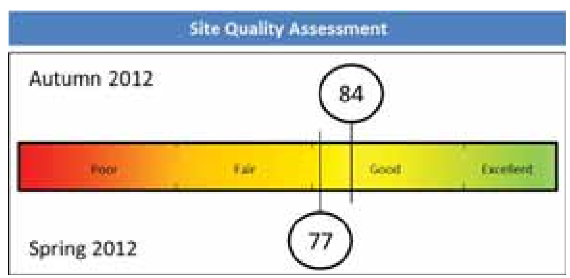
- Dominant substrate was cobble

Dominant Taxa

- Chironomidae
- Simuliidae
- Hydrobiosidae
- Leptophlebiidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Hydrobiosidae
- Leptophlebiidae
- Gripopterygidae



Edge Habitat

- Dominant trailing bank vegetation was macrophytes (mainly *Phragmites australis* and *Typha sp.*)

Dominant Taxa

- Corixidae
- Baetidae
- Leptophlebiidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae
- Hydrobiosidae
- Gripopterygidae

Additional Comments

- Large scale colonisation of the *Typha sp.* by macroinvertebrates (mainly black fly larvae [Simuliidae])
- Small bank collapse from elevated flow

BUR2c

Upstream London Bridge
30/10/2012 1:00 pm

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	TSS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
20.5	439.8	3.4	< 2	8.12	102.3	9.16

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
184	0.051	0.049	< 0.002	0.002	0.009	0.32

Daily Flow: 5.3 ML/day

Recorded at the closest station (410774), located on Burra Creek at Burra Road.

Compared to current flow:

Spring 2011: ↓ Autumn 2012: ↓

AUSRIVAS Results

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

Riffle Habitat

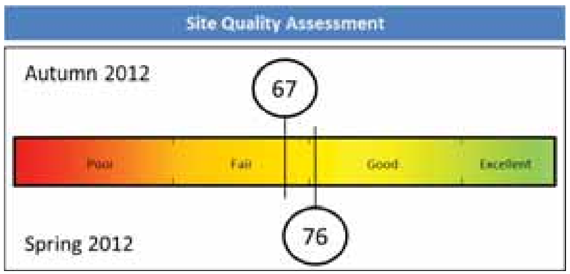
- Dominant substrate was cobble

Dominant Taxa

- Hydrobiosidae
- Simuliidae
- Baetidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Gripopterygidae
- Hydrobiosidae
- Leptophlebiidae



Edge Habitat

- Sediment in the edge zone had smelt anoxic
- Dominant trailing bank vegetation was macrophytes (*Typha sp.*, *Eleocharis sp.* and *Isolepis habra*)

Dominant Taxa

- Chironomidae
- Leptophlebiidae
- Leptoceridae
- Gripopterygidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae
- Gripopterygidae

Additional Comments

- Significant bank erosion on the left hand bank
- Sections of scour through the centre of the channel
- Some small sections of undercutting present directly upstream of the site

QBYN1

Flynn's Crossing
30/10/2012 10:50 am

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	TSS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
19.7	108.7	6.7	4	8.14	102.0	9.31

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
47	0.003	0.001	< 0.002	0.004	0.021	0.32

Daily Flow: 90 ML/day

Recorded at the closest station (410781), located on the Queanbeyan River, upstream of Googong Dam.

Compared to current flow:

Spring 2011: 

Autumn 2012: 

AUSRIVAS Results

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

Riffle Habitat

- Possible blue-green algae proliferation in the riffle zone
- Dominant substrate was cobble

Dominant Taxa

- Simuliidae
- Gripopterygidae
- Leptophlebiidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae
- Gripopterygidae

Edge Habitat

- Dominant trailing bank vegetation was wood and overhanging *Kunzea sp.*

Dominant Taxa

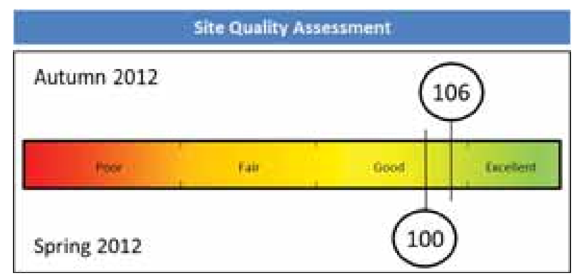
- Leptoceridae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Gripopterygidae
- Telephlebiidae

Additional Comments

- Some isolated erosion on the upper right hand bank
- Few macrophytes in re



Part 3 – Murrumbidgee Pump Station

MUR931

Fairvale
15/11/2012 10:05am

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	TSS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
20.9	122.7	8.6	11	8.06	90.0	8.04

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
49	0.003	0.001	< 0.002	< 0.002	0.026	0.30

Daily Flow: 520 ML/day

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

Compared to current flow:

Spring 2011: 

Autumn 2012: 

Riffle Habitat

- Dominant substrate was bedrock

Dominant Taxa

- Simuliidae
- Hydropsychidae
- Chironomidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae
- Hydrobiosidae
- Gripopterygidae
- Coloburiscidae

Edge Habitat

- Dominant trailing bank vegetation was blackberry

Dominant Taxa

- Chironomidae
- Leptophlebiidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

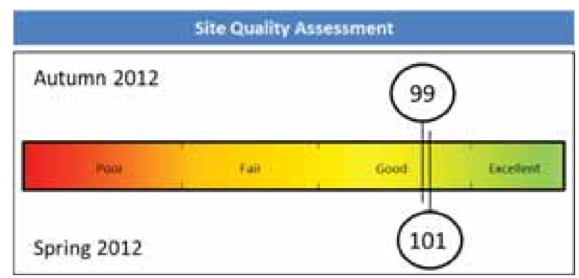
- Leptophlebiidae

AUSRIVAS Results

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

Additional Comments

- Some small sand deposits on the left hand bank
- Large amounts of logs and wood debris deposited along the right hand bank



MUR28

Upstream Cotter River Confluence
14/11/2012 9:35 am

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	TSS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
19.9	130.8	13.0	10	8.16	101.5	9.26

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
51	0.003	0.001	< 0.002	< 0.002	0.026	0.33

Daily Flow:

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

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

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

The variation in flows down the Cotter River limit the comparability of this site's flow between seasons, which is further complicated by the operation of the Bendora Scour Valve.

AUSRIVAS Results

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

Riffle Habitat

- Dominant substrate was boulder

Dominant Taxa

- Chironomidae
- Baetidae
- Simuliidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae
- Coloburiscidae
- Hydrobiosidae

Edge Habitat

- Limited edge habitat available, resulting in only a single edge sample
- Dominant trailing bank vegetation was wood debris

Dominant Taxa

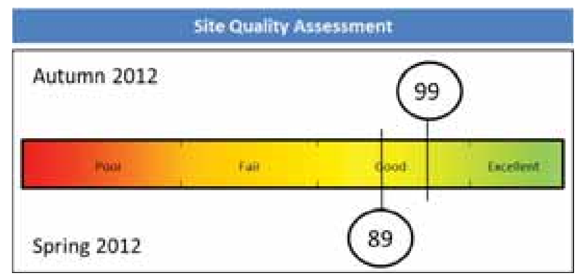
- Chironomidae
- Corixidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae
- Gripopterygidae

Additional Comments

- Bendora Scour Valve has been on for over a week, was turned down, but not completely off, for sampling
- The Murrumbidgee Pump Station is currently recirculating water down the Cotter River, downstream of the Enlarged Cotter Dam
- Very few macrophytes
- Periphyton growth very high except in the path of the scour valve due to its operation



MUR935

Casuarina Sands
14/11/2012 11:20 am

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	TSS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
20.1	126.1	11.7	11	8.17	89.1	8.08

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
49	0.003	0.001	< 0.002	< 0.002	0.026	0.32

Daily Flow:

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

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

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

The variation in flows down the Cotter River limit the comparability of this site's flow between seasons, which is further complicated by the operation of the Bendora Scour Valve.

AUSRIVAS Results

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

Riffle Habitat

- Small patches of filamentous algae in the riffle zone
- Dominant substrate was boulder

Dominant Taxa

- Glossosomatidae
- Simuliidae
- Baetidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae
- Hydrobiosidae
- Gripopterygidae
- Glossosomatidae
- Coloburiscidae

Edge Habitat

- Dominant trailing bank vegetation was wood and *Casuarina sp.*

Dominant Taxa

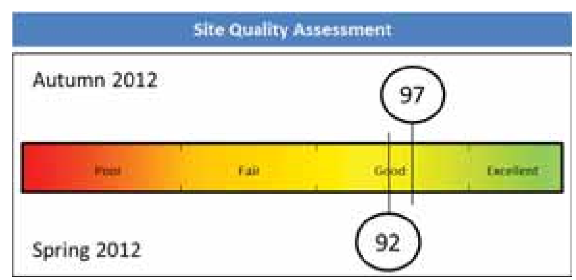
- Notonectidae
- Atyidae
- Corixidae
- Leptophlebiidae
- Chironomidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae

Additional Comments

- Large deposits of sand on the right hand bank
- Small areas of erosion on the left hand bank
- Few macrophytes observed at the site



MUR937

Mt. MacDonald
15/11/2012 1:00 pm

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	TSS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
22.3	96.6	8.3	9	8.25	97.1	8.44

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
39	0.004	0.002	< 0.002	< 0.002	0.021	0.26

Daily Flow: 1100 ML/day

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

Compared to current flow:

Spring 2011: ↓ Autumn 2012: ↑

AUSRIVAS Results

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

Riffle Habitat

- Dominant substrate was cobble

Dominant Taxa

- Leptophlebiidae
- Chironomidae
- Hydrobiosidae
- Simuliidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae
- Gripopterygidae
- Hydrobiosidae
- Philorheithridae
- Glossosomatidae

Edge Habitat

- Limited edge habitat available, 2 samples still possible
- Carp present in the edge habitat
- Dominant trailing bank vegetation was wood debris

Dominant Taxa

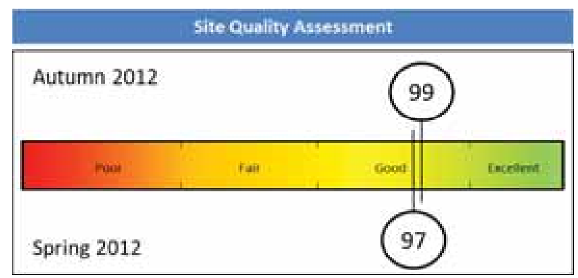
- Corixidae
- Chironomidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae

Additional Comments

- High periphyton growth in slow flowing areas
- Small areas of erosion on the left hand bank
- Significant sand deposition on the right hand bank



MUR29

Uriarra Crossing
14/11/2012 1:50 pm

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	TSS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
21.8	110.1	10.2	8	8.28	96.0	8.42

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
43	0.004	0.002	< 0.002	0.002	0.019	0.28

Daily Flow: 1200 ML/day

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

Compared to current flow:

Spring 2011:  Autumn 2012: 

AUSRIVAS Results

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

Riffle Habitat

- Simuliids (black fly larvae) abundant within the riffle habitat, visible in large numbers on the substrate
- Riffle habitat in good condition covering large portion of the site
- Dominant substrate was cobble

Dominant Taxa

- Chironomidae
- Simuliidae
- Leptophlebiidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Hydrobiosidae
- Leptophlebiidae

Additional Comments

- Vegetation still recovering from the high flow events
- Very little inflow from Uriarra Creek, directly upstream of the site

Edge Habitat

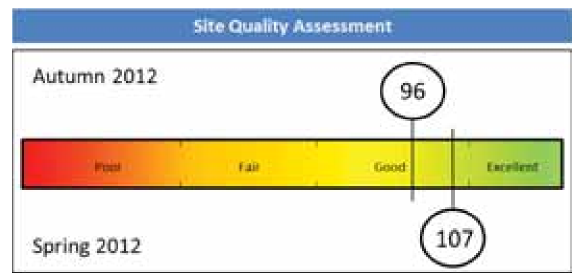
- *Gambusia holbrooki* present in the edge habitat
- Edge habitat in poor condition
- Dominant trailing bank vegetation was wood debris and macrophytes (*Juncus sp.*)

Dominant Taxa

- Corixidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae
- Telephlebiidae



Part 4 – Tantangara to Burrinjuck

MUR1

Downstream Tantangara Reservoir
Zone 1: Tantangara - Cooma
5/11/2012 11:25 am

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	TSS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
15.0	20.3	4.5	3	7.45	91.6	9.25

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
13	0.011	0.009	< 0.002	0.004	0.013	0.17

Daily Flow: 400 ML/day

Recorded at the closest station (41000260), located on the Murrumbidgee River at Yaouk. (Source: www.water.nsw.gov.au)

Compared to current level:

Spring 2011: ↓ Autumn 2012: ↓

AUSRIVAS Results

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

Riffle Habitat

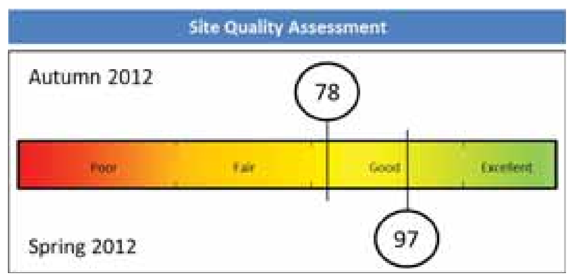
- Dominant substrate was boulder

Dominant Taxa

- Chironomidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Gripopterygidae
- Hydrobiosidae



Edge Habitat

- Edge habitat is highly silted
- Dominant trailing bank vegetation was macrophytes and grasses

Dominant Taxa

- Gripopterygidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Gripopterygidae
- Leptophlebiidae
- Philorheithridae

Additional Comments

- Flowing, small release from Tantangara Dam
- Submerged vegetation is dominated by a single species, *Eriocaulon sp.*
- Large wood debris downstream of bridge, but absent upstream

MUR2

Yaouk Bridge
Zone 1: Tantangara - Cooma
5/11/2012 1:50 pm

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	TSS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
16.0	23.6	3.3	4	7.58	87.2	8.61

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
15	0.010	0.008	< 0.002	0.003	0.014	0.15

Daily Flow: 400 ML/day

Recorded at the closest station (41000260), located on the Murrumbidgee River at Yaouk. (Source: www.water.nsw.gov.au)

Compared to current level:

Spring 2011:   Autumn 2012:

AUSRIVAS Results			
	Spring 2011	Autumn 2012	Spring 2012
Riffle Habitat	A	A	X
Edge Habitat	X	A	A
Overall Site Assessment	A	A	A

Riffle Habitat

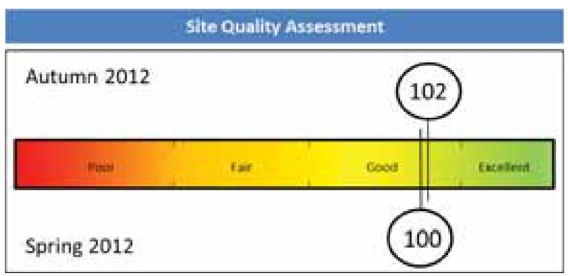
- Large riffle zone
- Dominant substrate was cobble

Dominant Taxa

- Leptophlebiidae
- Coloburiscidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Coloburiscidae
- Leptophlebiidae
- Glossosomatidae
- Gripopterygidae



Edge Habitat

- Restricted access to edge zone due to private property access limitations
- Macrophytes in the edge habitat colonised by macroinvertebrates
- Dominant trailing bank vegetation was macrophytes and grasses

Dominant Taxa

- Amphipoda
- Chironomidae
- Leptophlebiidae
- Corixidae
- Leptoceridae
- Gripopterygidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae
- Gripopterygidae

Additional Comments

- Small patches of filamentous algae
- Adult dragon flies present

MUR3

Bobeyan Road Bridge
Zone 1: Tantangara - Cooma
5/11/2012 4:30 pm

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	TSS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
18.0	27.9	5.7	5	7.63	87.7	8.31

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
16	0.005	0.003	< 0.002	0.003	0.017	0.19

Daily Flow: 400 ML/day

Recorded at the closest station (41000260), located on the Murrumbidgee River at Yaouk. (Source: www.water.nsw.gov.au)

Compared to current level:

Spring 2011: 

Autumn 2012: 

AUSRIVAS Results

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

Riffle Habitat

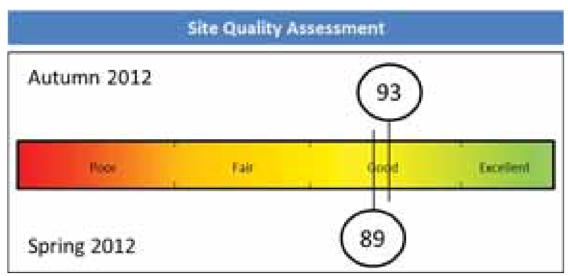
- Dominant substrate was cobble

Dominant Taxa

- Leptophlebiidae

Sensitive Taxa (SIGNAL-2 ≥)

- Coloburiscidae
- Leptophlebiidae
- Glossosomatidae
- Hydrobiosidae
- Gripopterygidae



Edge Habitat

- Edge habitat covered in silt and sludge, with the scent of sewerage
- Dominant trailing bank vegetation was macrophytes (mainly *Eleocharis sp.* and *Nymphaea sp.*)

Dominant Taxa

- Baetidae
- Leptoceridae
- Leptophlebiidae
- Corixidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae
- Gripopterygidae
- Philorheithridae

Additional Comments

- Direct stock access to river channel,
- Trout present

MUR4

Bobeyan Road Camp Ground
Zone 1: Tantangara - Cooma
5/11/2012 3:30 pm

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	TSS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
18.9	32.8	6.8	7	7.66	90.4	8.41

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
18	0.004	0.002	< 0.002	0.005	0.021	0.21

Daily Flow: 400 ML/day

Recorded at the closest station (41000260), located on the Murrumbidgee River at Yaouk. (Source: www.water.nsw.gov.au)

Compared to current level:

Spring 2011: ↓ Autumn 2012: ↓

AUSRIVAS Results

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

Riffle Habitat

- Dominant substrate was cobble

Dominant Taxa

- Coloburiscidae
- Amphipoda
- Chironomidae
- Leptophlebiidae
- Gripopterygidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Coloburiscidae
- Leptophlebiidae
- Gripopterygidae
- Hydrobiosidae
- Telephlebiidae

Edge Habitat

- Edge habitat highly silted, with an anaerobic scent
- Dominant trailing bank vegetation was macrophytes (*Eleocharis sp.* and *Phragmites australis*)

Dominant Taxa

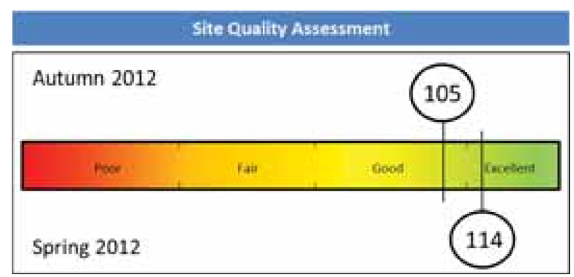
- Corixidae
- Leptoceridae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Gripopterygidae
- Coloburiscidae

Additional Comments

- Flow high compared to previous sampling level



MUR6

D/S Cooma STP, Pilot Creek Road
Zone 2: Cooma – Angle Crossing
6/11/2012 10:50 am

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	TSS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
18.8	53.7	10.1	18	7.71	85.5	7.96

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
26	0.004	0.002	< 0.002	0.002	0.034	0.27

Daily Flow: 300 ML/day

Recorded at the closest station (410033), located on the Murrumbidgee River at Mittagang. (Source: www.water.nsw.gov.au)

Compared to current flow:

Spring 2011:  Autumn 2012: 

AUSRIVAS Results

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

Riffle Habitat

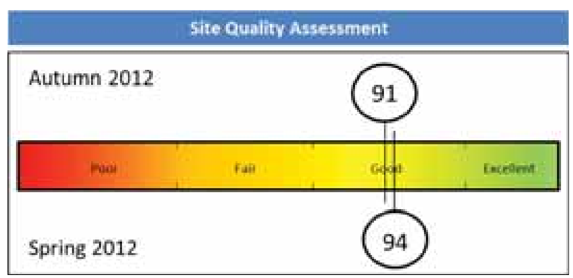
- Dominant substrate was cobble

Dominant Taxa

- Gripopterygidae
- Chironomidae

Sensitive Taxa (SIGNAL-2 ≥ 8)

- Coloburiscidae
- Hydrobiosidae
- Leptophlebiidae
- Gripopterygidae



Edge Habitat

- Edge habitat highly silted
- Dominant trailing bank vegetation was macrophytes (*Phragmites australis*)

Dominant Taxa

- Chironomidae
- Corixidae
- Leptoceridae
- Gripopterygidae
- Leptophlebiidae
- Baetidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae
- Gripopterygidae

Additional Comments

- Areas of erosion on the upper right hand bank and the upper left hand bank
- Newly graded track on the left hand bank could be contributing to the sediment load of the site

MUR9

Murrells Crossing
Zone 2: Cooma – Angle Crossing
6/11/2012 1:10 pm

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	TSS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
19.7	51.1	8.5	10	7.71	86.6	7.95

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
26	0.003	0.001	< 0.002	< 0.002	0.030	0.26

Daily Flow: 300 ML/day

Recorded at the closest station (410033), located on the Murrumbidgee River at Mittagang. (Source: www.water.nsw.gov.au)

Compared to current flow:

Spring 2011: ↓ Autumn 2012: ↓

AUSRIVAS Results

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

Riffle Habitat

- Small patches of filamentous algae in the riffle zone
- High proportion of sand within the riffle habitat
- The riffle zone has been scoured through the centre of the channel
- Riffle zone is present where the old bridge has collapsed
- Dominant substrate was cobble

Dominant Taxa

- None

Sensitive Taxa (SIGNAL-2 ≥ 8)

- Gripopterygidae
- Hydrobiosidae
- Leptophlebiidae

Edge Habitat

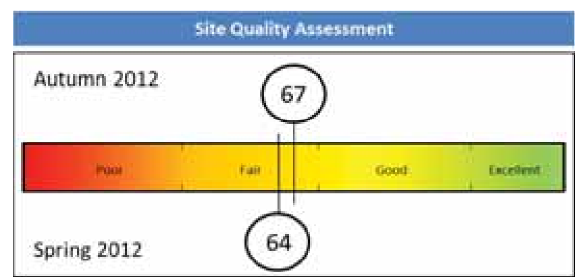
- Edge habitat in poor condition
- Some silt deposition in the edge habitat
- Dominant trailing bank vegetation was macrophytes (*Juncus sp.* and *Carex sp.*)

Dominant Taxa

- Corixidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Hydrobiosidae
- Gripopterygidae
- Leptophlebiidae



Additional Comments

- Adult mayflies present
- Bank slumping on the right hand bank with high levels of erosion on the left hand bank upstream of the bridge
- Crossing and dirt pile possibly contributing to the sediment load particularly during rainfall events

MUR12

Bredbo
Zone 2: Cooma – Angle Crossing
6/11/2012 2:45 pm

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	TSS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
19.6	103.2	15.9	21	7.63	82.9	7.59

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
43	0.002	< 0.001	< 0.002	0.002	0.048	0.34

Daily Flow: 440 ML/day

Recorded at the closest station (410050), located on the Murrumbidgee River at Billilingra. (Source: www.water.nsw.gov.au)

Compared to current flow:

Spring 2011: ↓ Autumn 2012: ↑

AUSRIVAS Results

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

Riffle Habitat

- Some silt deposits in the riffle zone
- Shallow riffle zone
- Dominant substrate was cobble

Dominant Taxa

- Chironomidae
- Gripopterygidae
- Baetidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae
- Hydrobiosidae
- Gripopterygidae

Additional Comments

- Slower moving areas are highly silted
- Small patches of filamentous algae
- Large sand deposits throughout the reach

Edge Habitat

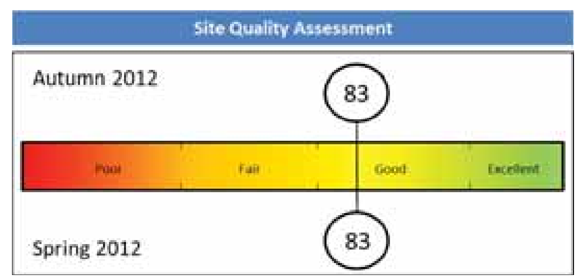
- Dominant trailing bank vegetation was macrophytes

Dominant Taxa

- Chironomidae
- Corixidae
- Gyrinidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae



MUR15

Bumbalong Road
Zone 2: Cooma – Angle Crossing
7/11/2012 10:30 am

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	TSS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
19.7	113.3	12.7	18	7.81	84.9	7.74

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
47	0.002	< 0.001	< 0.002	< 0.002	0.040	0.28

Daily Flow: 480 ML/day

Recorded at the closest station (410050), located on the Murrumbidgee River at Billilingra. (Source: www.water.nsw.gov.au)

Compared to current flow:

Spring 2011: 

Autumn 2012: 

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

Riffle Habitat

- Small patches of filamentous algae within the riffle habitat
- Little sand deposition within the riffle
- Dominant substrate was cobble

Dominant Taxa

- None

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Gripopterygidae
- Leptophlebiidae
- Hydrobiosidae
- Glossosomatidae

Additional Comments

- Large sand deposits within the reach
- Extensive periphyton coverage on stable habitat

Edge Habitat

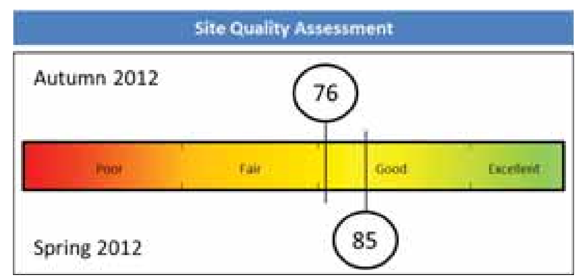
- Dominant trailing bank vegetation was wood debris from inundated shrubs

Dominant Taxa

- Corixidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae



MUR16

The Willows – Near Michelago
Zone 2: Cooma – Angle Crossing
12/11/2012 10:15 am

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	TSS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
18.6	117.8	10.8	11	8.15	88.2	8.25

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
46	0.003	0.001	< 0.002	0.003	0.031	0.31

Daily Flow: 620 ML/day

Recorded at the closest station (410050), located on the Murrumbidgee River at Billilingra. (Source: www.water.nsw.gov.au)

Compared to current flow:

Spring 2011: 

Autumn 2012: 

Riffle Habitat

- Dominant substrate was cobble

Dominant Taxa

- Simuliidae
- Chironomidae
- Hydropsychidae
- Coloburiscidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Coloburiscidae
- Glossosomatidae
- Gripopterygidae
- Hydrobiosidae

Edge Habitat

- Dominant trailing bank vegetation was overhanging native shrubs and wood debris

Dominant Taxa

- Corixidae
- Gripopterygidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

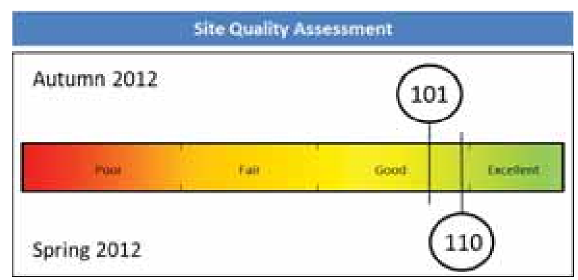
- Gripopterygidae
- Leptophlebiidae
- Hydrobiosidae

AUSRIVAS Results

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

Additional Comments

- Flows elevated compared to usual sampling level
- Evident lack of macrophytes which are usually present at this site, specifically *Myriophyllum sp.*



MUR18

Upstream Angle Crossing
Zone 2: Cooma – Angle Crossing
12/11/2012 12:45 pm

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	TSS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
19.9	112.9	12.7	13	8.05	87.2	7.94

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
45	0.003	0.001	< 0.002	0.004	0.034	0.30

Daily Flow: 760 ML/day

Recorded at the closest station (41000270), located on the Murrumbidgee River at upstream Angle Crossing.

Compared to current flow:

Spring 2011:  Autumn 2012: 

AUSRIVAS Results

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

Riffle Habitat

- Dominant substrate was cobble

Dominant Taxa

- Baetidae
- Gripopterygidae
- Acarina
- Simuliidae
- Chironomidae

Sensitive Taxa (SIGNAL-2 ≥ 8)

- Leptophlebiidae
- Gripopterygidae
- Coloburiscidae
- Hydrobiosidae

Additional Comments

- Sections of erosion on the upper left hand bank
- Filamentous algae attached to terrestrial plant roots in the shallow edges

Edge Habitat

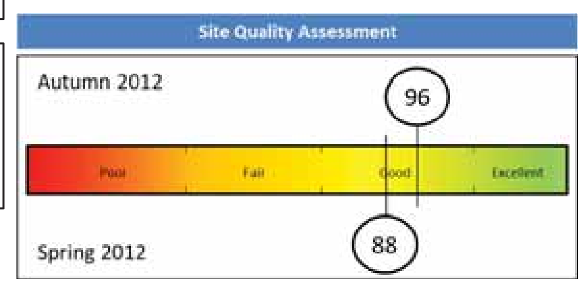
- Macrophytes limited to the edge habitat
- Better quality edge habitat inaccessible on the opposite bank due to deep channel
- Dominant trailing bank vegetation was overhanging native shrubs and wood debris

Dominant Taxa

- Gripopterygidae
- Corixidae
- Chironomidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Gripopterygidae



MUR19

Downstream Angle Crossing
Zone 3: Angle Crossing - LMWQCC
12/11/2012 2:20 pm

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	TSS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
20.5	114.0	12.7	11	8.07	91.0	8.17

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
45	0.003	0.001	< 0.002	0.005	0.032	0.30

Daily Flow: 760 ML/day

Recorded at the closest station (41000270), located on the Murrumbidgee River at upstream Angle Crossing.

Compared to current flow:

Spring 2011: ⇩ Autumn 2012: ⇩

AUSRIVAS Results

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

Riffle Habitat

- *Myriophyllum sp.* abundant within the riffle zone
- Dominant substrate was cobble

Dominant Taxa

- Simuliidae
- Gripopterygidae
- Baetidae
- Leptophlebiidae

Sensitive Taxa (SIGNAL-2 ≥ 8)

- Leptophlebiidae
- Hydrobiosidae
- Gripopterygidae

Edge Habitat

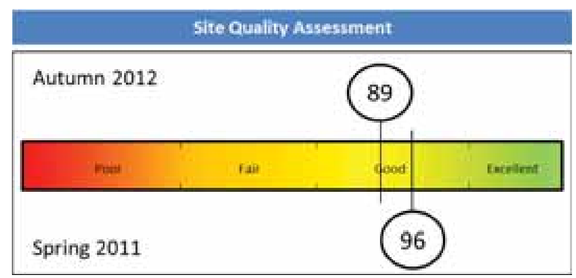
- Dominant trailing bank vegetation was native shrubs and wood debris

Dominant Taxa

- Corixidae
- Gripopterygidae
- Chironomidae
- Leptoceridae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Gripopterygidae



Additional Comments

- M2G construction completed
- Adult stoneflies present in large numbers
- Revegetation of the right hand bank recently undertaken with weed spraying underway during sampling
- Dirt road leading to the crossing is likely increasing the sediment load at this site

MUR22

Tharwa Bridge
Zone 3: Angle Crossing - LMWQCC
7/11/2012 1:45 pm

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	TSS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
19.6	123.7	9.5	10	7.93	86.8	7.94

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
52	0.004	0.002	< 0.002	< 0.002	0.023	0.23

Daily Flow: 600 ML/day

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

Compared to current flow:

Spring 2011:

Autumn 2012:

AUSRIVAS Results

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

Riffle Habitat

- Poor riffle habitat
- Dominant substrate was sand

Dominant Taxa

- Simuliidae
- Baetidae
- Chironomidae

Sensitive Taxa (SIGNAL-2 ≥ 8)

- Leptophlebiidae
- Gripopterygidae
- Hydrobiosidae

Additional Comments

- Large sand deposits throughout the reach
- Silt settled in slow flowing areas
- Little stable substrate available

Edge Habitat

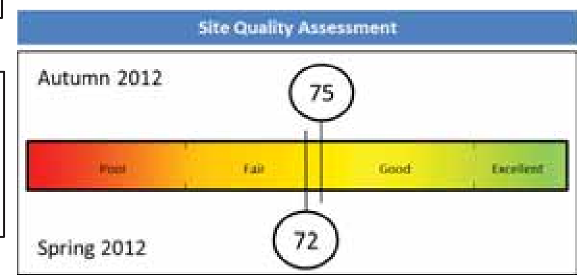
- Dominant trailing bank vegetation was macrophytes (*Phragmites australis*)

Dominant Taxa

- Chironomidae
- Corixidae
- Leptoceridae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae
- Gripopterygidae



MUR23

Point Hut Crossing
Zone 3: Angle Crossing - LMWQCC
7/11/2012 3:10 pm

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	TSS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
19.9	125.7	8.6	11	7.82	84.1	7.66

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
52	0.002	< 0.001	< 0.002	< 0.002	0.022	0.23

Daily Flow: 600 ML/day

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

Compared to current flow:

Spring 2011: ↓ Autumn 2012: ↑

Riffle Habitat

- Patches of *Myriophyllum sp.* and filamentous algae in the riffle zone
- Dominant substrate was cobble

Dominant Taxa

- Simuliidae

Sensitive Taxa (SIGNAL-2 ≥ 8)

- Leptophlebiidae
- Gripopterygidae
- Hydrobiosidae

Edge Habitat

- Dominant trailing bank vegetation was macrophytes (*Phragmites australis* and *Eleocharis sp.*)

Dominant Taxa

- Corixidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

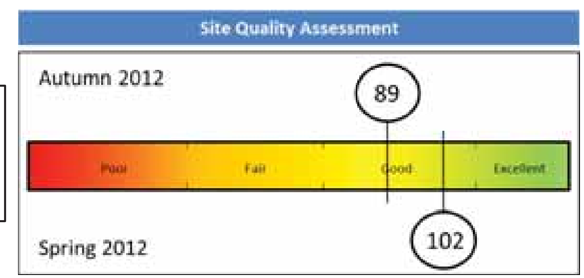
- Leptophlebiidae
- Gripopterygidae

AUSRIVAS Results

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

Additional Comments

- Small areas of erosion on the left hand bank
- Sand deposits within the reach



MUR27

Kambah Pool
Zone 3: Angle Crossing - LMWQCC
15/11/2012   3:45 pm

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	TSS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
21.2	123.9	10.8	14	7.94	87.2	7.76

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
50	0.004	0.002	< 0.002	0.002	0.028	0.31

Daily Flow: 520 ML/day

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

Compared to current flow:

Spring 2011: 

Autumn 2012: 

AUSRIVAS Results

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

Riffle Habitat

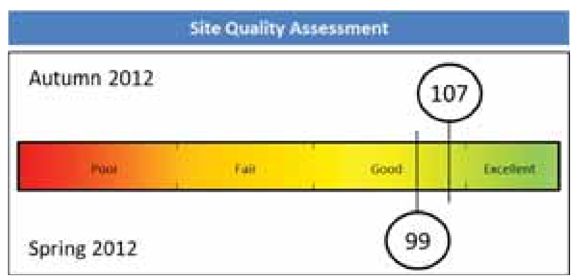
- Wood debris throughout the riffle zone
- Dominant substrate was bedrock

Dominant Taxa

- Chironomidae
- Hydropsychidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae
- Gripopterygidae
- Glossosomatidae



Edge Habitat

- Dominant trailing bank vegetation was macrophytes (*Phragmites australis*)

Dominant Taxa

- Gripopterygidae
- Corixidae
- Chironomidae
- Gastropoda

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Gripopterygidae
- Leptophlebiidae

Additional Comments

- Small sections of erosion on both upper banks
- Bare bank areas colonised by weeds and pasture grasses

MUR931

Fairvale
Zone 3: Angle Crossing - LMWQCC
15/11/2012   10:05 am

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	TSS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
20.9	122.7	8.6	11	8.06	90.0	8.04

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
49	0.003	0.001	< 0.002	< 0.002	0.026	0.30

Daily Flow: 520 ML/day

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

Compared to current flow:

Spring 2011:    Autumn 2012: 

AUSRIVAS Results

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

Riffle Habitat

- Reduced rubble in the edge habitat due to the higher proportion of bedrock in the riffle habitat
- Dominant substrate was bedrock

Dominant Taxa

- Simuliidae
- Hydropsychidae
- Chironomidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae
- Hydrobiosidae
- Gripopterygidae
- Coloburiscidae

Additional Comments

- Some small sand deposits on the left hand bank
- Large amounts of logs and wood debris deposited along the right hand bank

Edge Habitat

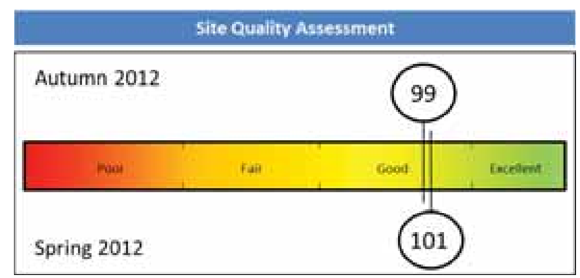
- Dominant trailing bank vegetation was wood debris

Dominant Taxa

- Chironomidae
- Leptophlebiidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae



MUR28

Upstream Cotter River Confluence
Zone 3: Angle Crossing - LMWQCC
14/11/2012 9:35 am

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	TSS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
19.9	130.8	13.0	10	8.16	101.5	9.26

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
51	0.003	0.001	< 0.002	< 0.002	0.026	0.33

Daily Flow:

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

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

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

The variation in flows down the Cotter River limit the comparability of this site's flow between seasons, which is further complicated by the operation of the Bendora Scour Valve.

AUSRIVAS Results

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

Riffle Habitat

- Dominant substrate was boulder

Dominant Taxa

- Chironomidae
- Baetidae
- Simuliidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae
- Coloburiscidae
- Hydrobiosidae

Additional Comments

- Bendora Scour Valve has been on for over a week, was turned down, but not completely off, for sampling
- The Murrumbidgee Pump Station is currently recirculating water down the Cotter River, downstream of the Enlarged Cotter Dam
- Very few macrophytes
- Periphyton growth very high except in the path of the scour valve due to its operation

Edge Habitat

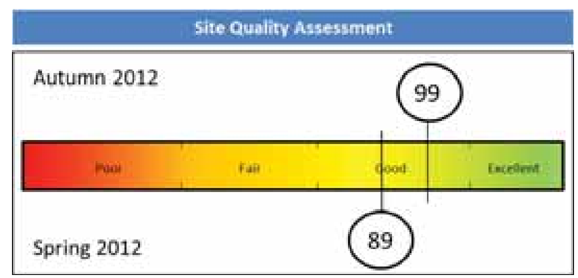
- Limited edge habitat available, resulting in only a single edge sample
- Dominant trailing bank vegetation was wood debris

Dominant Taxa

- Chironomidae
- Corixidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae
- Gripopterygidae



MUR935

Casuarina Sands
Zone 3: Angle Crossing - LMWQCC
14/11/2012 11:20 am

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	TSS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
20.1	126.1	11.7	11	8.17	89.1	8.08

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
49	0.003	0.001	< 0.002	< 0.002	0.026	0.32

Daily Flow:

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

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

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

The variation in flows down the Cotter River limit the comparability of this site's flow between seasons, which is further complicated by the operation of the Bendora Scour Valve.

AUSRIVAS Results

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

Riffle Habitat

- Small patches of filamentous algae in the riffle zone
- Dominant substrate was boulder

Dominant Taxa

- Glossosomatidae
- Simuliidae
- Baetidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae
- Hydrobiosidae
- Gripopterygidae
- Glossosomatidae
- Coloburiscidae

Edge Habitat

- Limited edge habitat due to inability to cross the channel, 2 samples still possible
- Dominant trailing bank vegetation was wood and *Casuarina sp.*

Dominant Taxa

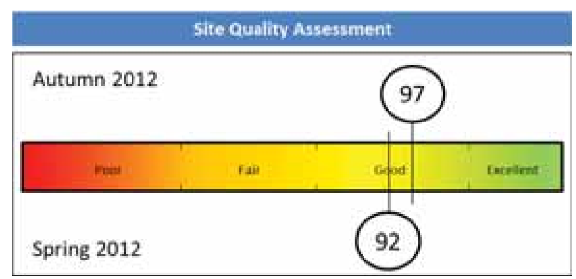
- Notonectidae
- Atyidae
- Corixidae
- Leptophlebiidae
- Chironomidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae

Additional Comments

- Large deposits of sand on the right hand bank
- Small areas of erosion on the left hand bank
- Few macrophytes observed at the site



MUR937

Mt. MacDonald
Zone 3: Angle Crossing - LMWQCC
15/11/2012 1:00 pm

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	TSS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
22.3	96.6	8.3	9	8.25	97.1	8.44

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
39	0.004	0.002	< 0.002	< 0.002	0.021	0.26

Daily Flow: 1100 ML/day

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

Compared to current flow:

Spring 2011: 

Autumn 2012: 

AUSRIVAS Results

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

Riffle Habitat

- Dominant substrate was cobble

Dominant Taxa

- Leptophlebiidae
- Chironomidae
- Hydrobiosidae
- Simuliidae

Sensitive Taxa (SIGNAL-2 ≥ 8)

- Leptophlebiidae
- Gripopterygidae
- Hydrobiosidae
- Philorheithridae
- Glossosomatidae

Additional Comments

- High periphyton growth in slow flowing areas
- Small areas of erosion on the left hand bank
- Significant sand deposition on the right hand bank

Edge Habitat

- Limited edge habitat available, 2 samples still possible
- Carp present in the edge habitat
- Dominant trailing bank vegetation was wood debris

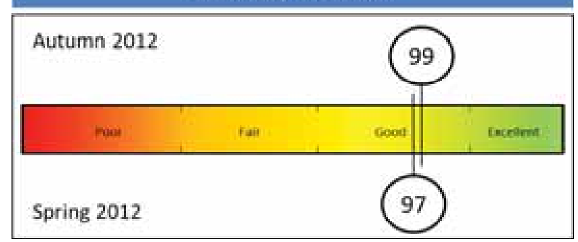
Dominant Taxa

- Corixidae
- Chironomidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae

Site Quality Assessment



MUR29

Uriarra Crossing
Zone 3: Angle Crossing - LMWQCC
14/11/2012 1:50 pm

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	TSS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
21.8	110.1	10.2	8	8.28	96.0	8.42

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
43	0.004	0.002	< 0.002	0.002	0.019	0.28

Daily Flow: 1200 ML/day

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

Compared to current flow:

Spring 2011: ↓ Autumn 2012: ↑

AUSRIVAS Results

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

Riffle Habitat

- Simuliids (black fly larvae) abundant within the riffle habitat, visible in large numbers on the substrate
- Riffle habitat in good condition covering large portion of the site
- Dominant substrate was cobble

Dominant Taxa

- Chironomidae
- Simuliidae
- Leptophlebiidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Hydrobiosidae
- Leptophlebiidae

Additional Comments

- Vegetation still recovering from the high flow events
- Very little inflow from Uriarra Creek, directly upstream of the site

Edge Habitat

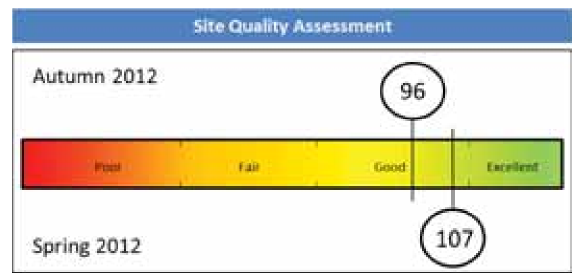
- *Gambusia holbrooki* present in the edge habitat
- Edge habitat in poor condition
- Dominant trailing bank vegetation was wood debris and macrophytes (*Juncus sp.*)

Dominant Taxa

- Corixidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae
- Telephlebiidae



MUR30

Camp Sturt
Zone 3: Angle Crossing - LMWQCC
13/11/2012 4:00 pm

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	TSS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
22.1	115.1	11.4	9	8.39	97.7	8.52

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
45	0.003	0.001	< 0.002	0.003	0.02	0.28

Daily Flow: 1400 ML/day

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

Compared to current flow:

Spring 2011: ↓ Autumn 2012: ↓

AUSRIVAS Results

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

Riffle Habitat

- Dominant substrate was cobble

Dominant Taxa

- Hydropsychidae
- Leptophlebiidae
- Baetidae
- Chironomidae
- Simuliidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae
- Hydrobiosidae
- Telephlebiidae

Edge Habitat

- Limited edge habitat available due to inability to cross the channel
- Dominant trailing bank vegetation was macrophytes (*Paspalum sp.*)

Dominant Taxa

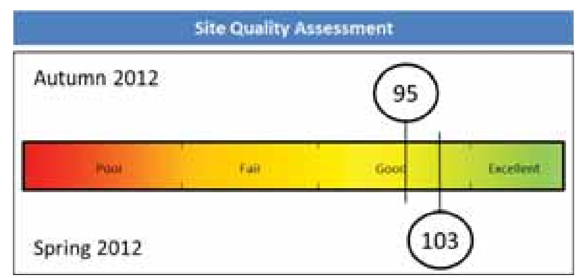
- Leptoceridae
- Corixidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae

Additional Comments

- Significant periphyton growth
- Large sections of wood debris still present from previous high flow events



MUR31

D/S Molonglo River Confluence
Zone 4: LMWQCC - Burrinjuck
13/11/2012 2:45 pm

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	TSS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
21.8	156.0	11.2	9	8.37	99.4	8.72

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
52	0.65	0.648	0.002	0.003	0.03	1.00

Daily Flow: 1700 ML/day

Recorded at the closest station (410777), located on the Murrumbidgee River at Hall's Crossing.

Compared to current flow:

Spring 2011: 

Autumn 2012: 

Riffle Habitat

- Dominant substrate was cobble

Dominant Taxa

- Chironomidae
- Baetidae
- Simuliidae

Sensitive Taxa (SIGNAL-2 ≥ 8)

- Hydrobiosidae
- Leptophlebiidae

Edge Habitat

- Silt deposition in edge zone
- Dominant trailing bank vegetation was wood debris

Dominant Taxa

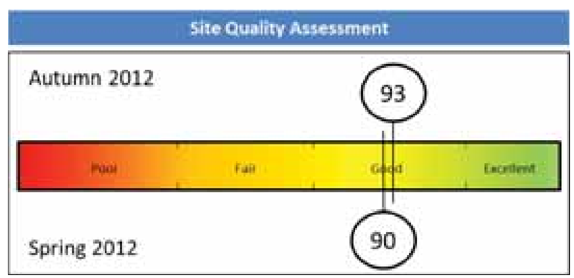
- Corixidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae

AUSRIVAS Results

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



Additional Comments

- Large sand deposits throughout the reach
- Establishment of grasses on deposited sand
- Reduced recovery of vegetation to high flow events compared to other sites with little regrowth present
- Significant periphyton cover

MUR34

Halls Crossing
Zone 4: LMWQCC - Burrinjuck
13/11/2012 10:05 am

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	TSS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
20.0	167.9	13.7	14	8.37	101.6	9.23

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
58	0.50	0.497	0.003	0.004	0.03	0.91

Daily Flow: 1700 ML/day

Recorded at the closest station (410777), located on the Murrumbidgee River at Hall's Crossing.

Compared to current flow:

Spring 2011:

Autumn 2012:

Riffle Habitat

- Terrestrial plant roots encroaching on the edge of the riffle zone
- Dominant substrate was cobble

Dominant Taxa

- Hydropsychidae

Sensitive Taxa (SIGNAL-2 ≥ 8)

- Gripopterygidae
- Hydrobiosidae

Edge Habitat

- Carp present in the edge habitat
- Thick periphyton on infrequent stable habitat
- Dominant trailing bank vegetation was wood and pushed over *Casuarina sp.*

Dominant Taxa

- Chironomidae
- Leptoceridae
- Corixidae

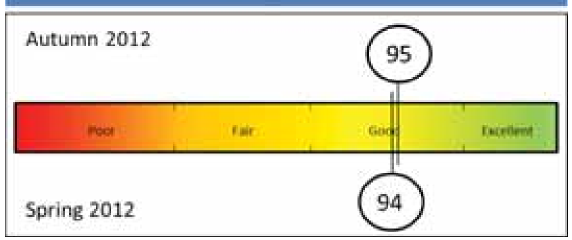
Sensitive Taxa (SIGNAL-2 ≥ 7)

- Gripopterygidae

AUSRIVAS Results

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

Site Quality Assessment



Additional Comments

- Some erosion on right hand bank
- Few macrophytes observed
- Wood debris remaining along the banks, deposited after high flows

MUR37

Boambolo Road
Zone 4: LMWQCC - Burrinjuck
13/11/2012   12:40 pm

Temp. (°C)	EC (µs/cm)	Turbidity (NTU)	TSS (mg/L)	pH	D.O. (% Sat.)	D.O. (mg/L)
21.7	161.5	11.1	11	8.46	98.2	8.63

Alkalinity	NO_x (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ammonia (mg/L)	TP (mg/L)	TN (mg/L)
57	0.29	0.287	0.003	0.003	0.02	0.69

Daily Flow: 1700 ML/day

Recorded at the closest station (410777), located on the Murrumbidgee River at Hall's Crossing.

Compared to current flow:

Spring 2011:    Autumn 2012: 

AUSRIVAS Results

	Spring 2011	Autumn 2012	Spring 2012
Riffle Habitat	B	NS	B
Edge Habitat	C	B	B
Overall Site Assessment	C	B	B

Riffle Habitat

- Dominant substrate was sand

Dominant Taxa

- Simuliidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae

Edge Habitat

- Dominant trailing bank vegetation was wood debris

Dominant Taxa

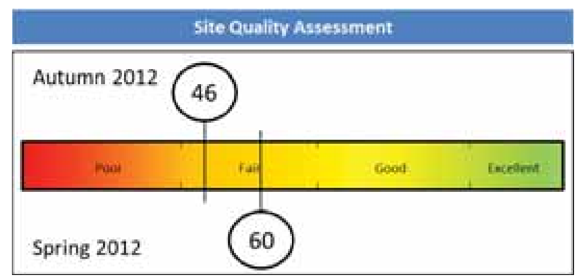
- Chironomidae
- Corixidae

Sensitive Taxa (SIGNAL-2 ≥ 7)

- Leptophlebiidae

Additional Comments

- Burrinjuck Reservoir level has dropped meaning the site is no longer inundated
- Carp present at the site
- Moderate bank erosion on both banks
- Direct stock access to the river
- Regrowth present on inundated vegetation
- No macrophytes were observed



Appendix E - Taxa predicted to occur with >50% probability but not collected

Appendix D Angle Crossing taxa predicted to occur but absent from the riffle

Site	Taxa	Acarina	Elmidae	Psphenidae	Ceratopogonidae	Tanypodinae	Tipulidae	Gripopterygidae	Glossosomatidae	Hydrobioside	Caenidae	Conoesucidae	Hydropsychidae	Total number of missing taxa
	SIGNAL	6	7	6	4	4	4	8	9	8	5	7	6	
MUR15			*0.92*											1
MUR15					*0.50*									1
MUR15	Riffle				*0.50*									1
MUR15			*0.92*		*0.50*	*0.75*								3
MUR15			*0.92*											1
MUR15			*0.92*		*0.50*	*0.75*								3
MUR16					*0.50*				*0.53*					2
MUR16			*0.93*		*0.50*	*0.71*			*0.53*					4
MUR16	Riffle	*0.76*	*0.93*		*0.50*				*0.53*				*0.84*	5
MUR16			*0.93*		*0.50*			*0.87*	*0.53*					4
MUR16			*0.93*		*0.50*			*0.87*	*0.53*					4
MUR16			*0.93*		*0.50*			*0.87*	*0.53*					4
MUR18		*0.81*	*0.95*	*0.57*			*0.59*	*0.91*	*0.64*			*0.60*		7
MUR18			*0.95*	*0.57*			*0.59*	*0.91*	*0.64*			*0.60*		6
MUR18	Riffle		*0.95*	*0.57*			*0.59*		*0.64*			*0.60*		5
MUR18		*0.81*	*0.95*	*0.57*		*0.65*	*0.59*		*0.64*	*0.54*		*0.60*		8
MUR18		*0.81*	*0.95*	*0.57*		*0.65*	*0.59*		*0.64*	*0.54*		*0.60*		8
MUR18		*0.81*	*0.95*	*0.57*			*0.59*		*0.64*	*0.54*		*0.60*		7
MUR19			*0.94*	*0.55*			*0.57*		*0.62*			*0.58*		5
MUR19			*0.94*	*0.55*		*0.66*	*0.57*		*0.62*			*0.58*		6
MUR19	Riffle		*0.94*	*0.55*			*0.57*		*0.62*	*0.53*	*0.88*	*0.58*		7
MUR19		*0.80*	*0.94*	*0.55*		*0.66*	*0.57*		*0.62*			*0.58*		7
MUR19		*0.80*	*0.94*	*0.55*		*0.66*	*0.57*		*0.62*	*0.53*		*0.58*		7
MUR19		*0.80*	*0.94*	*0.55*		*0.66*	*0.57*		*0.62*			*0.58*		7
MUR23				*0.51*			*0.52*		*0.55*			*0.51*		4
MUR23			*0.93*	*0.51*		*0.70*	*0.52*		*0.55*			*0.51*		6
MUR23	Riffle		*0.93*	*0.51*			*0.52*		*0.55*			*0.51*		5
MUR23				*0.51*		*0.70*	*0.52*		*0.55*	*0.50*		*0.51*		6
MUR23				*0.51*		*0.70*	*0.52*		*0.55*			*0.51*		5
MUR23				*0.51*					*0.55*			*0.51*	*0.54*	4
MUR28		*0.85*	*0.96*	*0.64*		*0.59*		*0.95*	*0.75*	*0.59*		*0.73*		8
MUR28				*064*		*0.59*			*0.75*	*0.59*		*0.73*		5
MUR28	Riffle		*0.96*	*0.64*				*0.95*	*0.75*			*0.73*		5
MUR28		*0.85*	*0.96*	*0.64*			*0.68*		*0.75*	*0.59*		*0.73*		7
MUR28			*0.96*	*0.64*			*0.68*		*0.75*	*0.59*		*0.73*		6
MUR28			*0.96*	*0.64*		*0.59*		*0.95*	*0.75*			*0.73*		6

Appendix D Angle Crossing taxa predicted to occur but absent from the edge

Site	Taxa	Gripopterygidae	Leptophlebiidae	Leptoceridae	Ceratopogonidae	Tanypodinae	Total number of missing taxa
	SIGNAL	8	8	6	4	4	
MUR15	Edge			*0.88*			1
MUR15				*0.88*			1
MUR15				*0.88*			1
MUR15				*0.88*			1
MUR15							0
MUR15				*0.88*			1
MUR16	Edge			*0.88*			1
MUR16				*0.88*			1
MUR16				*0.88*			1
MUR16				*0.88*	*0.65*		2
MUR16				*0.88*			1
MUR16				*0.88*	*0.65*		2
MUR18	Edge				*0.65*		1
MUR18					*0.65*	*0.97*	2
MUR18				*0.88*	*0.65*	*0.97*	3
MUR18						*0.97*	1
MUR18				*0.88*		*0.97*	2
MUR18							0
MUR19	Edge				*0.65*	*0.97*	2
MUR19			*0.82*		*0.65*	*0.97*	3
MUR19			*0.82*	*0.88*		*0.97*	3
MUR19							0
MUR19					*0.65*		1
MUR19				*0.88*			1
MUR23	Edge		*0.82*	*0.88*	*0.65*		3
MUR23			*0.82*		*0.65*	*0.97*	3
MUR23			*0.82*		*0.65*		2
MUR23				*0.88*			1
MUR23				*0.88*			1
MUR23				*0.88*	*0.65*		2
MUR28	Edge	*0.62*			*0.65*		2
MUR28		*0.62*				*0.97*	2
MUR28		*0.62*	*0.82*		*0.65*	*0.97*	4

Appendix D Burra Creek taxa predicted to occur but absent from the riffle

Site	Taxa	Sphaeriidae	Acarina	Elmidae	Ceratopogonidae	Simuliidae	Tanypodinae	Oligochaeta	Baetidae	Gripopterygidae	Caenidae	Hydropsychidae	Total number of missing taxa
	SIGNAL	5	6	7	4	5	4	2	5	8	5	6	
QBYN1	Riffle	*0.54*					*0.76*		*0.68*			*0.51*	4
QBYN1		*0.54*		*0.91*					*0.68*			*0.51*	4
QBYN1		*0.54*			*0.51*				*0.68*			*0.51*	4
QBYN1		*0.54*		*0.91*	*0.51*							*0.51*	4
QBYN1		*0.54*		*0.91*					*0.68*			*0.51*	4
QBYN1		*0.54*		*0.91*	*0.51*	*0.79*						*0.51*	5
BUR1a	Riffle	*0.59*		*0.90*								*0.50*	3
BUR1a		*0.59*	*0.7*	*0.90*						*0.82*		*0.50*	5
BUR1a		*0.59*		*0.90*						*0.82*		*0.50*	4
BUR1a		*0.59*	*0.7*	*0.90*					*0.69*	*0.82*	*0.86*	*0.50*	7
BUR1a		*0.59*	*0.7*	*0.90*					*0.69*	*0.82*	*0.86*	*0.50*	7
BUR1a		*0.59*		*0.90*					*0.69*		*0.86*	*0.50*	5
BUR1C	Riffle	*0.55*		*0.90*								*0.51*	3
BUR1C		*0.55*	*0.71*	*0.90*					*0.68*			*0.51*	5
BUR1C		*0.55*		*0.90*								*0.51*	3
BUR1C		*0.55*		*0.90*								*0.51*	3
BUR1C		*0.55*		*0.90*					*0.68*	*0.83*	*0.83*	*0.51*	5
BUR1C		*0.55*		*0.90*	*0.51*				*0.68*	*0.83*	*0.86*	*0.51*	7
BUR2A	Riffle	*0.57*		*0.90*								*0.51*	3
BUR2A		*0.57*		*0.90*								*0.51*	3
BUR2A		*0.57*		*0.90*								*0.51*	3
BUR2A		*0.57*		*0.90*						*0.82*		*0.51*	4
BUR2A		*0.57*		*0.90*						*0.82*			3
BUR2A		*0.57*		*0.90*									2
BUR2B	Riffle	*0.53*	*0.72*	*0.90*						*0.83*		*0.51*	5
BUR2B			*0.72*	*0.90*					*0.68*		*0.86*	*0.51*	5
BUR2B		*0.53*	*0.72*	*0.90*						*0.83*		*0.51*	5
BUR2B		*0.53*		*0.90*			*0.76*			*0.83*		*0.51*	5
BUR2B		*0.53*		*0.90*			*0.76*	*1.00*				*0.51*	5
BUR2B		*0.53*						*1.00*		*0.83*		*0.51*	4
BUR2C	Riffle	*0.52*		*0.90*								*0.52*	3
BUR2C		*0.52*		*0.90*			*0.76*					*0.52*	4
BUR2C		*0.52*					*0.76*						2
BUR2C		*0.52*		*0.90*								*0.52*	3
BUR2C		*0.52*	*0.73*									*0.52*	3
BUR2C		*0.52*		*0.90*								*0.52*	3

Appendix D Burra Creek taxa predicted to occur but absent from the edge

Site	Taxa	Elmidae	Acarina	Ceratopogonidae	Baetidae	Gripopterygidae	Leptoceridae	Corixidae	Total number of missing taxa
	SIGNAL	7	6	4	5	8	6	2	
QBYN1	Edge								*0*
QBYN1									*0*
QBYN1									*0*
QBYN1									*0*
QBYN1									*0*
QBYN1									*0*
BUR1A	Edge	*0.50*			*0.70*	*0.82*			*3*
BUR1A		*0.50*		*0.61*	*0.70*	*0.82*			*4*
BUR1A		*0.50*			*0.70*	*0.82*			*3*
BUR1C	Edge						*0.88*	*0.50*	*2*
BUR1C				*0.64*					*1*
BUR1C									*0*
BUR1C						*0.64*			*1*
BUR1C						*0.64*		*0.50*	*2*
BUR1C						*0.64*		*0.50*	*2*
BUR2A	Edge								*0*
BUR2A									*0*
BUR2A									*0*
BUR2A							*0.89*		*1*
BUR2A									*0*
BUR2A							*0.89*		*1*
BUR2B	Edge	*0.50*				*0.81*			*2*
BUR2B		*0.50*				*0.81*			*2*
BUR2B		*0.50*					*0.90*		*2*
BUR2B		*0.50*	*0.63*			*0.81*	*0.90*		*4*
BUR2B		*0.50*	*0.63*			*0.81*			*3*
BUR2B		*0.50*	*0.63*			*0.81*	*0.90*		*4*
BUR2C	Edge								*0*
BUR2C									*0*
BUR2C									*0*
BUR2C						*0.69*			*1*
BUR2C						*0.69*			*1*
BUR2C						*0.69*			*1*

Appendix D Murrumbidgee Pump Station taxa predicted to occur but absent from the riffle

Site	Taxa	Acarina	Elmidae	Psphenidae	Leptophlebiidae	Tanypodinae	Tipulidae	Gripopterygidae	Glossosomatidae	Hydrobioside	Caenidae	Conoesucidae	Hydropsychidae	Total number of missing taxa
	SIGNAL	6	7	6	8	4	4	8	9	8	5	7	6	
MUR 931			0.97	0.68		0.57		0.97	0.80			0.78		6
MUR 931		0.86	0.97	0.68	0.97	0.57		0.97	0.80			0.78		8
MUR 931	Riffle			0.68	0.97	0.57		0.97	0.80	0.62		0.78		7
MUR 931			0.97	0.68		0.57			0.80			0.78		5
MUR 931		0.86		0.68			0.73	0.97	0.80			0.78		6
MUR 931				0.68	0.97	0.57		0.97	0.80	0.62		0.78		7
MUR 28		0.85	0.96	0.64		0.59		0.95	0.75	0.59		0.73		8
MUR 28				064		0.59			0.75	0.59		0.73		5
MUR 28	Riffle		0.96	0.64				0.95	0.75			0.73		5
MUR 28		0.85	0.96	0.64			0.68		0.75	0.59		0.73		7
MUR 28			0.96	0.64			0.68		0.75	0.59		0.73		6
MUR 28			0.96	0.64		0.59		0.95	0.75			0.73		6
MUR 935				0.65		0.59		0.96	0.77			0.75		5
MUR 935			0.97	0.65			0.70	0.96	0.77			0.75		6
MUR 935	Riffle		0.97	0.65	0.96	0.59		0.96	0.77		0.88	0.75		8
MUR 935		0.83	0.97	0.65	0.96	0.59	0.70		0.77			0.75		8
MUR 935			0.97	0.65		0.59		0.96	0.77	0.60		0.75		7
MUR 935		0.83	0.97	0.65	0.96	0.59		0.96	0.77		0.88	0.75		9
MUR 937		0.82		0.65		0.61		0.96	0.74			0.73		6
MUR 937		0.82	0.96	0.65		0.61		0.96	0.74		0.88	0.73		9
MUR 937	Riffle	0.82	0.96	0.65		0.61	0.68	0.96	0.74			0.73		8
MUR 937		0.82	0.96	0.65		0.61		0.96	0.74			0.73		7
MUR 937		0.82		0.65		0.61	0.68	0.96	0.74	0.60		0.73		8
MUR 937			0.96	0.65		0.61	0.68	0.96	0.74			0.73		7
MUR 29		0.82	0.96	0.63		0.61		0.96	0.75	0.60		0.73		8
MUR 29			0.96	0.63		0.61		0.96	0.75	0.60		0.73		7
MUR 29	Riffle	0.82	0.96	0.63		0.61	0.68	0.96	0.75	0.60		0.73		9
MUR 29		0.82	0.96	0.63		0.61	0.68	0.96	0.75			0.73	0.58	9
MUR 29		0.82		0.63		0.61	0.68		0.75	0.60		0.73		7
MUR 29			0.96	0.63		0.61	0.68	0.96	0.75	0.60		0.73		8

Appendix D Murrumbidgee Pump Station taxa predicted to occur but absent from the edge

Site	Taxa	Ceratopogonidae	Tanypodinae	Leptophlebiidae	Gripopterygidae	Leptoceridae	Baetidae	Total number of missing taxa
	SIGNAL	4	4	8	8	6	5	
MUR 931	Edge		*0.97*		*0.62*		*0.62*	3
MUR 931		*0.65*	*0.97*				*0.62*	3
MUR 931		*0.65*	*0.97*		*0.62*			3
MUR 931		*0.65*						1
MUR 931						*0.88*	*0.62*	2
MUR 931		*0.65*	*0.97*		*0.62*		*0.62*	4
MUR 28	Edge	*0.65*			*0.62*			2
MUR 28			*0.97*		*0.62*	*0.88*		3
MUR 28		*0.65*	*0.97*	*0.82*	*0.62*	*0.88*		5
MUR 935	Edge				*0.62*			1
MUR 935			*0.97*		*0.62*			2
MUR 935		*0.65*	*0.97*		*0.62*			3
MUR 935		*0.65*			*0.62*			2
MUR 935		*0.65*			*0.62*			2
MUR 935		*0.65*			*0.62*			2
MUR 937	Edge		*0.97*					1
MUR 937		*0.65*	*0.97*					2
MUR 937		*0.65*	*0.97*			*0.88*		3
MUR 937		*0.65*				*0.88*		2
MUR 937		*0.65*	*0.97*		*0.62*			3
MUR 29	Edge	*0.65*			*0.62*	*0.88*		3
MUR 29		*0.65*	*0.97*		*0.62*	*0.88*		4
MUR 29		*0.65*	*0.97*	*0.82*				3
MUR 29					*0.62*			1
MUR 29		*0.65*	*0.97*	*0.82*	*0.62*		*0.62*	5

Appendix D Tantangara to Burrinjuck taxa predicted to occur but absent from the riffle

Site	Taxa	Ceratopogonidae	Sphaeriidae	Acarina	Elmidae	Scirtidae	Psphenidae	Tipulidae	Simuliidae	Tanypodinae	Baetidae	Chironominae	Leptophlebiidae	Caenidae	Gripopterygidae	Notonemouridae	Hydrobioside	Glossosomatidae	Hydropsychidae	Conoesucidae	Leptoceridae	Calocidae	Total number of missing taxa
	SIGNAL	4	5	6	7	6	6	5	5	4	5	3	8	4	8	6	8	9	6	7	6	9	
MUR 1	Riffle (Zone 1)				0.95	0.80					0.98	0.76		0.74		0.64	0.60	0.60			0.59	0.56	
MUR 2									0.59							0.51			0.51				
MUR 3				0.79					0.61								0.62			0.72			
MUR 4							0.61	0.68									0.61		0.56				
MUR 6	Riffle (Zone 2)						0.64	0.68		0.59							0.59		0.58				
MUR 9					0.97		0.66	0.71											0.59				
MUR 12			0.61		0.90																		
MUR 15		0.50			0.92					0.75													3
MUR 16		0.50																0.53					2
MUR 18				0.81	0.95		0.57	0.59							0.91			0.64		0.60			7
MUR 19	Riffle (Zone 3)			0.80	0.94		0.55	0.57		0.66							0.53	0.62		0.58			7
MUR 22					0.94		0.53	0.55		0.68					0.89			0.59	0.55				
MUR 23					0.51			0.52		0.70								0.55	0.50	0.51			6
MUR 27					0.94		0.54			0.67			0.87					0.60		0.55			
MUR 931					0.97		0.68			0.57					0.97			0.80		0.56			6
MUR 28				0.85	0.96		0.64			0.59					0.95		0.59	0.75		0.60			8
MUR 935				0.83	0.97		0.65	0.70		0.59			0.96					0.77		0.75			8
MUR 937				0.82			0.65			0.61					0.96			0.74		0.73			6
MUR 29				0.82	0.96		0.63			0.61					0.96		0.60	0.75		0.73			8
MUR 30					0.95		0.57	0.59		0.65								0.64					
MUR 31	Riffle (Zone 4)		0.56		0.91					0.80					0.83								
MUR 34			0.55		0.91					0.79			0.78										
MUR 37					0.94		0.53	0.57		0.68			0.89		0.91		0.54	0.61		0.59			

Appendix D Tantangara to Burrinjuck taxa predicted to occur but absent from the edge

Site	Taxa	Ceratopogonidae	Sphaeriidae	Elmidae	Scirtidae	Tanypodinae	Baetidae	Leptophlebiidae	Caenidae	Gripopterygidae	Hydrobioside	Glossosomatidae	Hydropsychidae	Conoesucidae	Leptoceridae	Total number of missing taxa
	SIGNAL	4	5	7	6	4	5	8	4	8	8	9	6	7	6	
MUR 1	Riffle (Zone 1)		*0.56*	*0.76*		*0.94*	*0.70*		*0.83*							5
MUR 2		*0.62*							*0.90*							2
MUR 3									*0.92*							1
MUR 4																0
MUR 6	Riffle (Zone 2)							*0.82*								1
MUR 9																0
MUR 12															*0.88*	1
MUR 15															*0.88*	1
MUR 16															*0.88*	1
MUR 18		*0.65*														1
MUR 19	Riffle (Zone 3)	*0.65*														1
MUR 22		*0.65*													*0.88*	2
MUR 23															*0.88*	1
MUR 27		*0.65*					*0.62*			*0.62*						3
MUR 931						*0.97*	*0.62*			*0.62*						3
MUR 28		*0.65*								*0.62*						2
MUR 935		*0.65*								*0.62*						2
MUR 937						*0.97*										1
MUR 29		*0.65*								*0.62*					*0.88*	3
MUR 30						*0.97*				*0.62*						2
MUR 31	Riffle (Zone 4)	*0.65*				*0.97*				*0.62*						3
MUR 34		*0.65*						*0.82*		*0.62*						2
MUR 37		*0.65*					*0.62*			*0.62*					*0.88*	4

Appendix F – Taxonomic Inventory

Appendix E Taxonomic inventory of macroinvertebrates collected in the riffle habitat at Murrumbidgee River sites

CLASS / Order	Family / subfamily	Genus	MUR1	MUR2	MUR3	MUR4	MUR6	MUR9	MUR12	MUR15	MUR16	MUR18	MUR19	MUR22	MUR23	MUR27	MUR931	MUR28	MUR935	MUR937	MUR29	MUR30	MUR31	MUR34	MUR37
ACARINA			■	■		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Amphipoda						■																			
	Eusiridae					■																			
	Talitridae		■		■	■																			
Coleoptera	Dytiscidae	*notriolus*																	■						
	Dytiscidae				■																				
	Elmidae	*Austrolimnius*								■					■					■					
		Coxelmis															■				■				
		Simsonia															■	■	■						
		Stetholus															■	■							
		sp.		■	■	■	■			■	■						■			■					
	Gyrinidae	*Aulonogyrus*																							
		Macrogyrus										■	■		■										
		sp.									■	■	■									■			■
	Hydrophilidae					■	■																		
	Psephenidae			■	■																				
	Scirtidae			■													■	■							■
Decapoda	Atyidae	*Paratya*																■							
	Palaemonidae	*Macrobrachium*									■						■								
	Parastacidae					■																			
Diptera	Ceratopogonidae	*Ceratopoginae*								■			■		■						■				
		sp.	■			■	■		■					■								■			■
	Chironomidae					■	■		■							■			■						
	Chironominae			■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	Dolichopodidae																			■					
	Empididae			■		■			■			■	■		■		■	■	■	■	■	■	■		
	Orthocladiinae		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	Simuliidae	*Austrosimulium*								■	■	■	■		■		■	■	■	■	■				
		sp.	■			■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	Tabanidae			■																					
	Tanypodinae		■	■	■	■		■	■	■	■	■	■		■		■	■	■		■				
	Tipulidae		■	■	■					■					■	■	■	■	■	■	■				

CLASS / Order	Family / subfamily	Genus	MUR1	MUR2	MUR3	MUR4	MUR6	MUR9	MUR12	MUR15	MUR16	MUR18	MUR19	MUR22	MUR23	MUR27	MUR931	MUR28	MUR935	MUR937	MUR29	MUR30	MUR31	MUR34	MUR37
Ephemeroptera						■								■				■							
	Baetidae	*Baetidae Genus 1*										■			■			■							
		Baetidae Genus 2									■	■	■		■		■	■	■	■	■				
		sp.		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	Caenidae	*Irapacaenis*									■	■	■		■		■	■	■	■					
		Tasmanocoenis								■	■	■	■		■		■	■	■	■	■				
		sp.		■	■	■	■	■	■	■	■	■	■	■	■	■		■	■	■	■	■	■	■	■
	Coloburiscidae			■	■	■	■	■	■	■	■		■												
Ephemeroptera	Leptophlebiidae	*Atalophlebia*									■														
		Jappa								■	■	■	■		■		■	■		■					
		sp.	■	■	■	■	■	■	■	■	■	■	■	■	■		■	■	■	■	■	■	■		
GASTROPODA	Ancylidae	*Ferrissia*																		■					
Gastropoda	Physidae	*Physa*													■										
Hemiptera	Corixidae	*Micronecta*									■		■						■						
		sp.					■								■										
HYDROZOA	Hydridae	*Hydra*																	■						
Lepidoptera	Crambidae														■										
Megaloptera	Corydalidae			■	■																				
Nematoda																		■							
Nematomorpha	Gordiidae								■					■								■	■		
Odonata	Gomphidae			■	■	■		■														■			
	Telephlebiidae					■																			
OLIGOCHAETA			■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Plecoptera			■			■										■		■							
	Gripopterygidae	*Dinotoperla*								■	■	■	■		■		■	■	■		■				
		Illiesoperla								■	■	■	■		■			■							
		sp.	■	■	■	■	■	■	■	■	■	■	■		■					■		■		■	
Trichoptera						■	■	■	■					■		■	■	■	■			■			
	Calamoceratidae					■																			
	Conoesucidae		■	■		■	■	■							■										
	Ecnomidae	*Ecnomus*								■	■	■	■				■				■				
		sp.			■	■	■					■			■	■							■		■
	Glossosomatidae			■	■	■	■	■																	

CLASS / Order	Family / subfamily	Genus	MUR1	MUR2	MUR3	MUR4	MUR6	MUR9	MUR12	MUR15	MUR16	MUR18	MUR19	MUR22	MUR23	MUR27	MUR931	MUR28	MUR935	MUR937	MUR29	MUR30	MUR31	MUR34	MUR37
Plecoptera	Hydrobiosidae	*Taschorema*								■	■		■		■										
		Ulmerochorema															■	■	■	■	■				
		sp.		■				■	■	■	■	■	■	■	■	■	■		■	■	■	■	■	■	
	Hydropsychidae	*Asmicridea*								■	■		■		■		■	■	■	■	■				
		Cheumatopsyche									■				■		■	■	■	■	■				
		sp.			■				■	■	■	■	■		■	■	■	■	■	■	■	■	■	■	■
	Hydroptilidae	*Hydroptila*									■	■	■				■	■	■	■	■				
		Oxyethira								■	■		■		■				■	■	■				
		sp.					■	■		■	■	■	■	■	■		■	■	■	■	■	■	■	■	■
	Leptoceridae	*Triplectides*										■													
		sp.		■	■																				
	Odontoceridae			■																					
	Philopotamidae	*Chimarra*																	■	■	■				
		sp.		■		■	■												■	■					
Turbellaria	Dugesiidae		■															■	■						
	Temnocephalidae		■		■																				

Appendix E Taxonomic inventory of macroinvertebrates collected in the edge habitat at Murrumbidgee River sites

CLASS / Order	Family / subfamily	Genus	MUR1	MUR2	MUR3	MUR4	MUR6	MUR9	MUR12	MUR15	MUR16	MUR18	MUR19	MUR22	MUR23	MUR27	MUR931	MUR28	MUR935	MUR937	MUR29	MUR30	MUR31	MUR34	MUR37
ACARINA																									
Amphipoda																									
	Ceinidae																								
	Eusiridae																								
	Talitridae																								
BIVALVIA																									
	Corbiculidae	*Corbicula*																							
	Sphaeriidae																								
Coleoptera	Dytiscidae	*Necterosoma*																							
		notriolus																							
		Platynectes																							
		Sternopriscus																							
		sp.																							
	Elmidae	*Austrolimnius*																							
		Coxelmis																							
		Simsonia																							
		Stetholus																							
		sp.																							
	Gyrinidae	*Macrogyrus*																							
		sp.																							
	Hydraenidae	*Hydraena*																							
		sp.																							
	Hydrophilidae	*Berosus*																							
		sp.																							
	Scirtidae																								
Copepoda																									
Decapoda	Atyidae	*Paratya*																							
		sp.																							
	Palaemonidae	*Macrobrachium*																							
		sp.																							
Diptera																									
	Ceratopogonidae	*Ceratopoginae*																							
		sp.																							
	Chironomidae																								
	Chironominae																								
	Dixidae																								
	Empididae																								
	Muscidae																								
	Orthocladiinae																								
	Psychodidae																								

CLASS / Order	Family / subfamily	Genus	MUR1	MUR2	MUR3	MUR4	MUR6	MUR9	MUR12	MUR15	MUR16	MUR18	MUR19	MUR22	MUR23	MUR27	MUR931	MUR28	MUR935	MUR937	MUR29	MUR30	MUR31	MUR34	MUR37
Diptera	Simuliidae	*Austrosimulium*								■	■	■	■		■		■	■	■	■	■				
		sp.	■	■					■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	Tabanidae																			■					
	Tanypodinae			■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■			■	■
	Tipulidae			■		■					■	■	■		■				■	■	■		■	■	
Ephemeroptera					■	■																			
	Baetidae	*Baetidae Genus 1*								■	■	■	■		■		■	■	■	■					
		Baetidae Genus 2											■					■		■	■				
		sp.		■	■	■	■	■	■	■	■	■	■	■	■		■	■	■	■	■	■	■	■	
	Caenidae	*Irapacaenis*								■	■	■	■		■		■	■	■	■					
		Tasmanocoenis								■	■	■	■		■		■	■	■	■	■				
		sp.				■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	Coloburiscidae					■				■															
	Leptophlebiidae	*Atalophlebia*									■		■		■		■		■	■	■				
		Jappa									■	■	■		■			■							
		sp.	■	■	■	■		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		■
GASTROPODA					■	■	■	■									■	■							
	Lymnaeidae		■	■			■												■						
	Physidae	*Physa*	■		■		■							■	■	■	■		■	■	■	■		■	■
	Planorbidae												■												
	Planorbidae/physidae										■														
Hemiptera	Corixidae	*Micronecta*								■	■	■	■		■		■	■	■	■	■				
		Sigara																	■		■				
		sp.		■	■	■	■	■	■			■	■	■	■	■	■		■	■	■	■	■	■	■
	Gerridae	*Rheumatometra*															■								
		sp.																			■				
	Hydrometridae	*Hydrometra*															■		■						
	Notonectidae	*Enithares*									■	■													
		sp.			■								■						■		■	■			
HYDROZOA	Hydridae	*Hydra*												■		■									
Lepidoptera	Crambidae														■										
Nematoda												■					■								
Odonata	Epiproctophora																			■					
	Synthemistidae		■																						
	Telephlebiidae	*Austroaeschna*																			■				
		sp.		■				■				■													
	Zygoptera				■	■	■																		
OLIGOCHAETA			■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Plecoptera			■			■		■																	
	Gripopterygidae	*Dinotoperla*								■	■	■	■		■		■			■	■				
		Illiesoperla													■										
		sp.	■	■	■	■	■	■	■	■	■	■		■	■										

CLASS / Order	Family / subfamily	Genus	MUR1	MUR2	MUR3	MUR4	MUR6	MUR9	MUR12	MUR15	MUR16	MUR18	MUR19	MUR22	MUR23	MUR27	MUR931	MUR28	MUR935	MUR937	MUR29	MUR30	MUR31	MUR34	MUR37
Trichoptera							■					■		■		■	■	■		■		■		■	
	Atriplectididae		■	■	■																				
	Calamoceratidae			■	■	■																			
	Conoesucidae			■	■																				
	Ecnomidae	*Ecnomus*								■					■		■								
		sp.			■									■		■	■		■				■	■	■
	Hydrobiosidae	*Taschorema*									■														
		Ulmerochorema																■							
		sp.			■			■	■	■											■				
	Hydropsychidae	*Asmicridea*													■		■								
		Cheumatopsyche										■						■	■						
		sp.								■					■	■	■	■	■	■				■	
	Hydroptilidae	*Hellyethira*								■	■	■	■		■		■	■	■	■	■				
		Hydroptila									■	■						■		■	■				
		Oxyethira								■	■	■	■		■					■					
		sp.					■		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		■
	Leptoceridae	*Notalina*								■		■	■							■	■				
		Oecetis																			■				
		Triaenodes															■			■					
		Triplectides										■	■				■	■	■	■	■				
		sp.	■	■	■	■	■	■				■	■		■	■	■		■	■		■	■	■	
	Philopotamidae				■															■					
Turbellaria	Dugesiidae		■		■																				

Appendix E Taxonomic inventory of macroinvertebrates collected in the riffle habitat at Burra Creek and Queanbeyan River sites

CLASS / Order	Family / subfamily	Genus	QBYN1	BUR1a	BUR1c	BUR2a	BUR2b	BUR2c
ACARINA			■	■	■	■	■	■
BIVALVIA	Sphaeriidae						■	
Coleoptera	Dytiscidae	*Platynectes*		■				
		sp.		■			■	
	Elmidae	*Austrolimnius*	■				■	■
		sp.	■					
	Gyrinidae	*Macrogyrus*				■		
	Hydraenidae	*Hydraena*		■				
	Scirtidae			■	■	■	■	■
Decapoda	Parastacidae	*Cherax*		■		■		
Diptera	Ceratopogonidae	*Ceratopoginae*	■	■	■	■	■	■
	Chironominae		■	■	■	■	■	■
	Empididae		■	■				
	Orthocladiinae		■	■	■	■	■	■
	Psychodidae					■		
	Simuliidae	*Austrosimulium*	■	■	■	■	■	■
		sp.	■	■	■	■	■	■
	Tanypodinae		■	■	■	■	■	■
	Tipulidae		■	■	■	■		■
Ephemeroptera	Baetidae	*Baetidae Genus 1*			■	■		
		Baetidae Genus 2		■		■		■
		Centroptilum sp				■		
		sp.	■	■	■	■	■	■
	Caenidae	*Tasmanocoenis*	■	■	■	■	■	■
		sp.	■	■	■	■	■	■
	Leptophlebiidae	*Atalophlebia*				■		
		Jappa			■	■	■	■
		Nousia				■		■
		Ulmerophlebia				■		
		sp.	■	■	■	■	■	■
GASTROPODA	Lymnaeidae				■			
	Physidae	*Physa*				■		
Hemiptera	Corixidae	*Micronecta*				■	■	■
Odonata	Gomphidae	*Hemigomphus*		■				
OLIGOCHAETA			■	■	■	■	■	■
Plecoptera	Gripopterygidae	*Dinotoperla*	■		■	■		
		Illiesoperla	■	■			■	
		sp.	■	■	■	■	■	■
Trichoptera	Ecnomidae	*Ecnomus*				■	■	■
		sp.						■
	Hydrobiosidae	*Taschorema*	■	■	■	■	■	■
		sp.	■	■	■	■	■	■
	Hydropsychidae	*Asmicridea*						■
		Cheumatopsyche				■		
		sp.				■		
	Hydroptilidae	*Oxyethira*	■		■		■	■
		sp.	■		■	■		■
	Leptoceridae	*Notalina*	■	■	■			
		Oecetis					■	
Turbellaria	Dugesiidae	*Dugesia*						■
		sp.		■				

Appendix E Taxonomic inventory of macroinvertebrates collected in the edge habitat at Burra Creek and Queanbeyan River sites

CLASS / Order	Family / subfamily	Genus	QBYN1	BUR1a	BUR1c	BUR2a	BUR2b	BUR2c
ACARINA								
BIVALVIA	Corbiculidae	*Corbicula*						
	Sphaeriidae							
Coleoptera	Dytiscidae	*Necterosoma*						
		Platynectes						
		Rhantus						
		Sternopriscus						
		sp.						
	Elmidae	*Austrolimnius*						
	Gyrinidae	*Macrogyrus*						
		sp.						
	Hydraenidae	*Hydraena*						
	Hydrophilidae	*Enochrus*						
		sp.						
	Scirtidae							
Decapoda	Atyidae	*Paratya*						
	Parastacidae	*Cherax*						
Diptera	Ceratopogonidae	*Ceratopoginae*						
	Chironominae							
	Dixidae	*Dixa*						
	Empididae							
	Orthocladiinae							
	Psychodidae							
	Simuliidae	*Austrosimulium*						
		sp.						
	Stratiomyidae	*Odontomyia*						
	Tanypodinae							
	Tipulidae							
Ephemeroptera	Baetidae	*Baetidae Genus 1*						
		Baetidae Genus 2						
		Centroptilum sp.						
		Cloeon						
		sp.						
	Caenidae	*Tasmanocoenis*						
		sp.						
	Leptophlebiidae	*Atalophlebia*						
		Jappa						
		Nousia						
		sp.						
GASTROPODA								
	Ancylidae	*Ferrissia*						
	Lymnaeidae							
	Physidae	*Physa*						
Hemiptera	Corixidae	*Micronecta*						
		Sigara						
		sp.						
	Notonectidae	*Enithares*						
		Paranisops						
	Veliidae	*Microvelia*						
Odonata	Aeshnidae	*Anax*						
	Coenagrionidae	*Ischnura*						
		sp.						
	Gomphidae	*Austrogomphus*						
		Hemigomphus						
		sp.						
	Telephlebiidae	*Spinaeschna*						
	Zygoptera							
OLIGOCHAETA								
Plecoptera	Gripopterygidae	*Dinotoperla*						
		Illiesoperla						
		sp.						
Trichoptera	Ecnomidae	*Ecnomus*						
		sp.						
	Hydrobiosidae	*Taschorema*						
		sp.						
	Hydropsychidae	*Cheumatopsyche*						
	Hydroptilidae	*Hellyethira*						

CLASS / Order	Family / subfamily	Genus	QBYN1	BUR1a	BUR1c	BUR2a	BUR2b	BUR2c
		Oxyethira						
Trichoptera	Hydroptilidae	*sp.*						
	Leptoceridae	*Notalina*						
		Oecetis						
		Triaenodes						
		Triplectides						
		sp.						

Appendix G – Tantangara to Burrinjuck - PCA output

Appendix G. PCA output

PCA
Principal Component Analysis

Data worksheet
Name: Data6
Data type: Environmental
Sample selection: All
Variable selection: All

Eigenvalues

PC	Eigenvalues	%Variation	Cum.%Variation
1	5.4	54.0	54.0
2	2.03	20.3	74.4
3	1.28	12.8	87.2
4	0.541	5.4	92.6
5	0.351	3.5	96.1

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

Variable	PC1	PC2	PC3	PC4	PC5
Water temp.	-0.342	0.114	0.260	0.393	-0.398
EC in-situ	-0.413	0.032	0.075	-0.025	0.404
pH lab	-0.376	0.215	0.245	0.001	0.186
D.O (% Sat.) in-situ	-0.207	-0.445	0.385	0.279	-0.370
Turbidity in-situ	-0.346	0.169	-0.378	0.292	-0.120
Alkalinity	-0.401	0.137	0.082	-0.014	0.453
Total Nox	-0.220	-0.539	-0.038	-0.486	-0.002
Ammonia	0.072	-0.510	-0.373	0.595	0.393
TP	-0.254	0.183	-0.640	-0.107	-0.336
TN	-0.357	-0.332	-0.138	-0.282	-0.142

Outputs
Plot: Graph6
Worksheet: Data7

Appendix H – Tantangara to Burrinjuck – PERMANOVA output

Permutational MANOVA

Resemblance worksheet
Name: Riffle Resem1
Data type: Similarity
Selection: All
Transform: Fourth root
Resemblance: S17 Bray Curtis similarity

Sums of squares type: Type III (partial)
Fixed effects sum to zero for mixed terms
Permutation method: Unrestricted permutation of raw data
Number of permutations: 9999

Factors

Name	Type	Levels
Zone	Fixed	4

PERMANOVA table of results

Source	df	SS	MS	Pseudo-F	P(perm)	Unique perms
Zone	3	7477.4	2492.5	4.4748	0.0001	9915
Res	19	10583	557			
Total	22	18060				

Details of the expected mean squares (EMS) for the model

Source	EMS
Zone	1*V(Res) + 5.3333*S(Zone)
Res	1*V(Res)

Construction of Pseudo-F ratio(s) from mean squares

Source	Numerator	Denominator	Num.df	Den.df
Zone	1*Zone	1*Res	3	19

Estimates of components of variation

Source	Estimate	Sq.root
S(Zone)	362.9	19.05
V(Res)	557	23.601

Resemblance worksheet
Name: Riffle Resem1
Data type: Similarity
Selection: All
Transform: Fourth root
Resemblance: S17 Bray Curtis similarity

Sums of squares type: Type III (partial)
Fixed effects sum to zero for mixed terms
Permutation method: Unrestricted permutation of raw data
Number of permutations: 9999

Factors

Name	Type	Levels
Zone	Fixed	4

PAIR-WISE TESTS

Term 'Zone'

Groups	t	P(perm)	Unique perms
2, 3	1.7492	0.0066	5684
2, 1	1.9248	0.01	210
2, 4	1.5772	0.0331	84
3, 1	2.9443	0.0013	1001
3, 4	0.96547	0.5089	286
1, 4	2.2606	0.0276	35

Denominators

Groups	Denominator	Den.df
2, 3	1*Res	14
2, 1	1*Res	8
2, 4	1*Res	7
3, 1	1*Res	12
3, 4	1*Res	11
1, 4	1*Res	5

Average Similarity between/within groups

	2	3	1	4
2	71.043			
3	67.2	70.252		
1	51.931	43.141	52.395	
4	68.087	72.092	39.754	74.671

PERMANOVA
Permutational MANOVA

Resemblance worksheet
Name: Edge Resem2)
Data type: Similarity
Selection: All
Transform: Fourth root
Resemblance: S17 Bray Curtis similarity

Sums of squares type: Type III (partial)
Fixed effects sum to zero for mixed terms
Permutation method: Unrestricted permutation of raw data
Number of permutations: 9999

Factors

Name	Type	Levels
Zone	Fixed	4

PERMANOVA table of results

Source	df	SS	MS	Pseudo-F	P(perm)	Unique perms
Zone	3	6970.1	2323.4	4.1602	0.0001	9909
Res	19	10611	558.47			
Total	22	17581				

Details of the expected mean squares (EMS) for the model

Source	EMS
Zone	1*V(Res) + 5.3333*S(Zone)
Res	1*V(Res)

Construction of Pseudo-F ratio(s) from mean squares

Source	Numerator	Denominator	Num.df	Den.df
Zone	1*Zone	1*Res	3	19

Estimates of components of variation

Source	Estimate	Sq.root
S(Zone)	330.92	18.191
V(Res)	558.47	23.632

Resemblance worksheet
Name: Edge Resem2)
Data type: Similarity
Selection: All
Transform: Fourth root
Resemblance: S17 Bray Curtis similarity

Sums of squares type: Type III (partial)
Fixed effects sum to zero for mixed terms
Permutation method: Unrestricted permutation of raw data
Number of permutations: 9999

Factors

Name	Type	Levels
Zone	Fixed	4

PAIR-WISE TESTS

Term 'Zone'

Groups	t	P(perm)	Unique perms
2, 3	1.5543	0.0101	5697
2, 1	2.1803	0.0047	210
2, 4	1.7138	0.0123	84
3, 1	2.9535	0.0011	1000
3, 4	1.0616	0.3339	286
1, 4	2.1077	0.0301	35

Denominators

Groups	Denominator	Den.df
2, 3	1*Res	14
2, 1	1*Res	8
2, 4	1*Res	7
3, 1	1*Res	12
3, 4	1*Res	11
1, 4	1*Res	5

Average Similarity between/within groups

	2	3	1	4
2	67.857			
3	65.834	69.251		
1	54.073	48.638	62.315	
4	58.955	66.669	47.112	63.343

Appendix I – Tantangara to Burrinjuck – Kruskal-Wallis output

Edge

Kruskal-Wallis ANOVA by Ranks; SIGNAL-2 by Zone. Kruskal-Wallis test: H (3, N= 23) =14.71964 p =.0021			
Zone	**Valid - N**	**Sum of - Ranks**	**Mean - Rank**
1	4	86.00000	21.50000
2	6	88.00000	14.66667
3	10	89.00000	8.90000
4	3	13.00000	4.33333

Multiple Comparisons p values (2-tailed); SIGNAL-2 by Zone. Kruskal-Wallis test: H (3, N= 23) =14.71964 p =.0021			
Zone	**1 - R:21.500**	**2 - R:14.667**	**3 - R:8.9000**
1			
2	0.711364		
3	0.010130	0.597966	
4	0.005519	0.187136	1.000000

Kruskal-Wallis ANOVA by Ranks; O/E50 by Zone. Kruskal-Wallis test: H (3, N= 23) =11.16678 p =.0109			
Zone	**Valid - N**	**Sum of - Ranks**	**Mean - Rank**
1	4	49.0000	12.25000
2	6	114.5000	19.08333
3	10	98.5000	9.85000
4	3	14.0000	4.66667

	Multiple Comparisons p values (2-tailed); O/E50 by Zone. Kruskal-Wallis test: H (3, N= 23) =11.16678 p =.0109		
Zone	**1 - R:12.250**	**2 - R:19.083**	**3 - R:9.8500**
1			
2	0.711364		
3	1.000000	0.050289	
4	0.859265	0.015878	1.000000

Kruskal-Wallis ANOVA by Ranks; Abundance by Zone. Kruskal-Wallis test: H (3, N= 23) =4.834783 p =.1843			
Zone	**Valid - N**	**Sum of - Ranks**	**Mean - Rank**
1	4	64.0000	16.00000
2	6	49.0000	8.16667
3	10	113.0000	11.30000
4	3	50.0000	16.66667

Kruskal-Wallis ANOVA by Ranks; Richness by Zone. Kruskal-Wallis test: H (3, N= 23) =7.843268 p =.0494			
Zone	**Valid - N**	**Sum of - Ranks**	**Mean - Rank**
1	4	81.5000	20.37500
2	6	64.0000	10.66667
3	10	103.0000	10.30000
4	3	27.5000	9.16667

Multiple Comparisons p values (2-tailed); Richness by Zone. Kruskal-Wallis test: H (3, N= 23) =7.843268 p =.0494		
1 - R:20.375	**2 - R:10.667**	**3 - R:10.300**
0.159517		
0.072251	1.000000	
0.182909	1.000000	1.000000

Kruskal-Wallis ANOVA by Ranks; EPT Richness by Zone. Kruskal-Wallis test: H (3, N= 23) =3.652258 p =.3015			
Zone	**Valid - N**	**Sum of - Ranks**	**Mean - Rank**
1	4	68.5000	17.12500
2	6	75.0000	12.50000
3	10	105.0000	10.50000
4	3	27.5000	9.16667

Kruskal-Wallis ANOVA by Ranks; EPT relative abundance by Zone. Kruskal-Wallis test: H (3, N= 23) =4.256884 p =.2350			
Zone	**Valid - N**	**Sum of - Ranks**	**Mean - Rank**
1	4	65.0000	16.25000
2	6	80.0000	13.33333
3	10	113.0000	11.30000
4	3	18.0000	6.00000

Kruskal-Wallis ANOVA by Ranks; OCD Richness by Zone. Kruskal-Wallis test: H (3, N= 23) =.1562236 p =.9843			
Zone	**Valid - N**	**Sum of - Ranks**	**Mean - Rank**
1	4	52.5000	13.12500
2	6	70.5000	11.75000
3	10	118.0000	11.80000
4	3	35.0000	11.66667

Kruskal-Wallis ANOVA by Ranks; OCD relative abundance by Zone. Kruskal-Wallis test: H (3, N= 23) =2.206616 p =.5306			
Zone	**Valid - N**	**Sum of - Ranks**	**Mean - Rank**
1	4	46.5000	11.62500
2	6	92.0000	15.33333
3	10	101.5000	10.15000
4	3	36.0000	12.00000

Riffle

Kruskal-Wallis ANOVA by Ranks; SIGNAL-2 by Zone. Kruskal-Wallis test: H (3, N= 23) =12.49931 p =.0059			
Zone	**Valid - N**	**Sum of - Ranks**	**Mean - Rank**
1	4	80.0000	20.00000
2	6	79.5000	13.25000
3	10	110.5000	11.05000
4	3	6.0000	2.00000

Multiple Comparisons p values (2-tailed); SIGNAL-2 by Zone. Kruskal-Wallis test: H (3, N= 23) =12.49931 p =.0059			
Zone	**1 - R:20.000**	**2 - R:13.250**	**3 - R:11.050**
1			
2	0.738721		
3	0.154270	1.000000	
4	0.003067	0.113922	0.255961

Kruskal-Wallis ANOVA by Ranks; O/E50 by Zone. Kruskal-Wallis test: H (3, N= 23) =6.459044 p =.0913			
Zone	**Valid - N**	**Sum of - Ranks**	**Mean - Rank**
1	4	61.00000	15.25000
2	6	99.50000	16.58333
3	10	87.00000	8.70000
4	3	28.50000	9.50000

Kruskal-Wallis ANOVA by Ranks; Richness by Zone. Kruskal-Wallis test: H (3, N= 23) =7.275978 p =.0636			
Zone	**Valid - N**	**Sum of - Ranks**	**Mean - Rank**
1	4	73.50000	18.37500
2	6	85.50000	14.25000
3	10	96.50000	9.65000
4	3	20.50000	6.83333

Kruskal-Wallis ANOVA by Ranks; EPT Richness by Zone. Kruskal-Wallis test: H (3, N= 23) =6.897390 p =.0752			
Zone	**Valid - N**	**Sum of - Ranks**	**Mean - Rank**
1	4	65.00000	16.25000
2	6	96.00000	16.00000
3	10	91.00000	9.10000
4	3	24.00000	8.00000

Kruskal-Wallis ANOVA by Ranks; EPT relative abundance by Zone. Kruskal-Wallis test: H (3, N= 23) =10.84457 p =.0126

Zone	Valid - N	Sum of - Ranks	Mean - Rank
1	4	85.0000	21.25000
2	6	53.0000	8.83333
3	10	119.0000	11.90000
4	3	19.0000	6.33333

Multiple Comparisons p values (2-tailed); EPT relative abundance by Zone. Kruskal-Wallis test: H (3, N= 23) =10.84457 p =.0126			
Zone	**1 - R:21.250**	**2 - R:8.8333**	**3 - R:11.900**
1			
2	0.027395		
3	0.118764	1.000000	
4	0.023890	1.000000	1.000000

Kruskal-Wallis ANOVA by Ranks; OCD Richness by Zone. Kruskal-Wallis test: H (3, N= 23) =6.461645 p =.0912			
Zone	**Valid - N**	**Sum of - Ranks**	**Mean - Rank**
1	4	67.5000	16.87500
2	6	66.5000	11.08333
3	10	127.0000	12.70000
4	3	15.0000	5.00000

Kruskal-Wallis ANOVA by Ranks; OCD relative abundance by Zone. Kruskal-Wallis test: H (3, N= 23) =10.36449 p =.0157			
Zone	**Valid - N**	**Sum of - Ranks**	**Mean - Rank**
1	4	10.0000	2.50000
2	6	86.0000	14.33333
3	10	129.0000	12.90000
4	3	51.0000	17.00000

Multiple Comparisons p values (2-tailed); OCD relative abundance by Zone. Kruskal-Wallis test: H (3, N= 23) =10.36449 p =.0157			
Zone	**1 - R:2.5000**	**2 - R:14.333**	**3 - R:12.900**
1			
2	0.041240		
3	0.057266	1.000000	
4	0.030740	1.000000	1.000000

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2						