ACTEW Corporation

Murrumbidgee Ecological Monitoring Program

Part 2: Burra Creek

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Executive Summary

ACTEW is committed to improving the security of the ACT water supply through the construction of an additional pumping structure and pipeline to abstract Murrumbidgee River water from a location near Angle Crossing (southern border of the ACT). The proposed pumping system will transfer water via an underground pipeline discharging into Burra Creek, and then by run of river flow into the Googong Reservoir. The system is being designed to enable pumping of up to 100 ML/d, and to be in operation around 2011. Abstraction at Angle Crossing and its subsequent transfer and release into Burra Creek will be dictated by the level of demand for the water, and by the availability of water in the Murrumbidgee River. The proposal is referred to as Murrumbidgee to Googong transfer project (M2G).

The hydrological change will noticeably increase the baseflow of Burra Creek and requires a meaningful assessment of the response of the river and its ecology through monitoring methods that can quantify these impacts.

This ecological monitoring program aims to determine the baseline river condition prior to water discharges into Burra Creek over a three year period, and then to continue monitoring after commencement to determine what changes are taking place that are attributable to water discharges from the Murrumbidgee River into Burra Creek.

The key aims of the sampling program were to:

1. *Determine the current macroinvertebrate community composition at key sites on Burra Creek and the nearby Queanbeyan River;*
2. *Provide ACTEW with river health assessments based on AUSRIVAS protocols at these key sites to determine how river health may be affected during and after the pipeline development and the subsequent discharges into Burra Creek;*
3. *Determine baseline periphyton data that will be used as a guide to monitor seasonal and temporal changes*
4. *Report on water quality from continuous and grab sample monitoring*

This report presents the findings from biological sampling of Burra Creek and the Queanbeyan River conducted in spring 2009. Sampling was completed in October 2009 and was based on ACT AUSRIVAS sampling protocols; but was extended to include multiple replicates from each site where specimens were identified to genus level, instead of family level.

The purpose of this protocol was to:

a) Determine biological signatures at each site prior to the commencement of pumping;

b) Potentially enable subtle changes to be detected if there are impacts associated with reduced flows.

The key results from the spring 2009 sampling of Burra Creek are as follows:

1. *Despite some surface flow, only one additional riffle in Burra Creek was suitable for sampling*
2. *AUSRIVAS assessments showed that:*

- *Both Queanbeyan River sites were "significantly impaired" (BAND –B)*
- *QBYN -2 showed an improved rating since autumn – probably due to increased flow downstream of the Burra Creek confluence*
- *The Burra control site was assessed as BAND –A "close to reference"*
- *The Burra sites downstream of the proposed discharge point were assessed as BAND – B and BAND – C*
- *Downstream of London Bridge, the site assessment was BAND –B, however, one of the replicates taken from this site resulted in a BAND – A assessment*

3. *Water Quality was good based on the available data. Changes are apparent from the continuous records in late October/early November, with strong correlations in most analytes with increased flow and/or water temperatures*
4. *Nutrient levels do not indicate enrichment in Burra Creek (as previously thought). Prolific filamentous algae (based on observational data) in the pools and shallow riffles are most likely a function of low flows and light not being limited rather than high nutrient loads. However, water quality samples taken after rainfall and surface runoff will provide better insight.*
5. *ANZECC & ARMCANZ (2000) Water quality guidelines were exceeded in Burra Creek and the Queanbeyan River. Dissolved oxygen extremes are related to high algae concentrations, depth of the riffle zone and minimal flow (upper Burra), while EC values, despite exceeding the guidelines were not outside the range of what is considered natural variation in Burra Creek. Nutrient levels were exceeded at both Queanbeyan River sites and at one Burra site, however these levels have not changed considerably (i.e. <5%) since autumn.*

It is recommended that the current sampling protocols remain as they are. However and additional investigation of the macroinvertebrate community responses to re-wetting in Burra Creek is recommended to help fill an important knowledge gap relating to hydrological changes. M2G water transfers to Burra creek will involve intermittent yet significant changes to flow over short periods of time.

List of abbreviations

ACT – Australian Capital Territory

ACTEW – ACTEW Corporation Limited

AFDM – Ash Free Dry Mass (periphyton)

ANZECC –Australian and New Zealand Environment and Conservation Council

ANOVA – Analysis of Variance (statistics)

APHA – American Public Health Association

ARMCANZ – Agriculture and Resource management Council of Australia and New Zealand

AUSRIVAS – Australian River Assessment System

BACI – Before After Control Impact

CMA – Catchment Management Authority

CRCFE – Cooperative Research Centre for Freshwater Ecology

EC – Electrical Conductivity

EIS – Environmental Impact Statement

EPA – Environmental Protection Authority

GL/a – Gigalitres per annum

GPS – Global positioning system

IBT- Inter-Basin Water Transfer

M2G – Murrumbidgee to Googong

MEMP – Murrumbidgee Ecological Monitoring Program

ML/d – Megalitres per day

NATA – National Association of Testing Authorities

NMDS – Non-metric Multidimensional Scaling (statistics)

NSW – New South Wales

NTU – Nephlelometric Turbidity Units

QA – Quality Assurance

QC – Quality Control

TN – Total Nitrogen

TP – Total Phosphorus

1 Introduction

The Murrumbidgee Ecological Monitoring Program (MEMP) was set up by ACTEW Corporation to evaluate the potential impacts of water abstraction from the Murrumbidgee River. It is being undertaken as part of the ACT water supply security infrastructure upgrade. The proposed timeline is to undertake sampling in spring and autumn over a three year period commencing in spring 2008.

There are four component areas being considered:

Part 1: Angle Crossing
Part 2: Burra Creek (discharge point for Angle Crossing abstraction)
Part 3: Murrumbidgee Pump Station
Part 4: Tantangara to Burrinjuck

This report focuses on Part 2: Burra Creek.

ACTEW is proposing to construct an additional pumping structure and pipeline to abstract water from the Murrumbidgee River from a location near Angle Crossing (southern border of the ACT). The proposed pumping system will transfer water from Angle Crossing through an underground pipeline into Burra Creek, and then transfer the water by run of river flows into the Googong Reservoir. The system is being designed to enable pumping of up to 100 ML/d, and to be in operation around 2011. Abstraction at Angle Crossing and the subsequent discharges to Burra Creek will be dictated by the level of demand for the water, and by the availability of water in the Murrumbidgee River. The proposal is referred to as Murrumbidgee to Googong project (M2G).

From the commencement of stream flow recording at the Burra Creek flow gauge in 1985 through to 2000, the mean daily flow was 14.5 ML/d, however over the next five years, flows have reduced substantially to a daily mean flow of just 1 ML/d. Since flow records began in 1985 a mean monthly flow of 100ML/d has only been exceeded 6 times with 100ML/d exceeded less than two percent of the time on a daily basis.

In light of the current low flow conditions in Burra Creek, it is expected that the increased flow will have several impacts on water quality, channel and bank geomorphology and the ecology of the system (Table 1). Some favourable ecological effects could be expected in the reaches of Burra Creek between the discharge point and downstream of the confluence of the Queanbeyan River. These effects include the increased utilisation of fish species and increased biodiversity in the macroinvertebrate communities. The impacts listed in Table 1 have been assessed by the relevant Government authorities and ACTEW and ACTEW's sub-consultants, through submission of Environmental Impact Statements (EIS) or similar assessments. One of the components of the EIS is to undertake an ecological monitoring program, for which this program is based.

Table 1. Potential impacts to Burra Creek following water discharges from the Murrumbidgee River.

Property	Possible impact	Source
Water Quality	- Increased turbidity from Murrumbidgee water which could decrease light penetration, resulting in lower macrophyte and algal growth.	Biosis, 2009.
	- The inter-basin transfer (IBT) of soft Murrumbidgee Water into the harder waters of Burra Creek are likely to change the natural biodiversity within Burra Creek.	Fraser, 2009.
	- Changes in water temperature could be expected from the IBT and increased turbidity. This may effect plant growth, nutrient uptake and dissolved oxygen levels.	Biosis, 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 increase the risk of the spread of disease.	Biosis, 2009; Davies *et al.* 1992.
	- Infilling from fine sediment transport could threaten the quality of the hyporhiec zone, which provides important habitat for macroinvertebrates in temporary streams.	Williams and Hynes, 1974; Brunke and Gonser, 1997.
	- The increased flow with improve longitudinal connectivity which potentially will provide fish with more breeding opportunities and range expansion, although this will be dependent on the proposed flow regime	Biosis, 2009.
Bank Geomorphology	-Bank failure from the initial construction phase and first releases. This could result in increased sedimentation, loss of riparian vegetation and increase erosion rates from bank instability	Skinner, 2009.
Channel Geomorphology	-Scouring of the river bed may result in a loss of emergent and submergent macrophyte species. This would result in a reduction of river bed stability and a change in macroinvertebrate diversity and dynamics.	Harrod, 1964.

1.1 Project objectives

The objectives of the Murrumbidgee Ecological Monitoring Program (MEMP) are to provide ACTEW with seasonal assessments of river health affected by the construction and operation of the new pipeline and discharge into Burra Creek.

Specifically, the aims of the project are to:

1. Provide seasonal "river health" reports in accordance with ACTEW water abstraction licence requirements;

2. Obtain baseline macroinvertebrate, water quality and periphyton data to ascertain whether the future discharges into Burra Creek from the Murrumbidgee River are likely to impact the ecology and ecological "health" of Burra Creek;

3. Establish baseline periphyton data that will be used as a guide to monitor seasonal and temporal changes

4. Report on water quality upstream and downstream of the discharge point in Burra Creek.

1.2 Project scope

The current ecological health of the sites monitored as part of the Burra Creek component of the Murrumbidgee Ecological Monitoring Program (MEMP) program has been estimated using ACT AUSRIVAS protocols for macroinvertebrate community data, combined with a suite of commonly used biological metrics and descriptors of community composition. The scope of this report is to convey the results from the spring 2009 sampling runs. Specifically, as outlined in the MEMP proposal to ACTEW Corporation (Ecowise, 2009*a*), this work includes:

- Sampling from autumn 2009;
- Macroinvertebrate sampling from riffle and edge habitats;
- Riffle and edge samples collected as per the ACT AUSRIVAS protocols;
- Macroinvertebrates counted and identified to the taxonomic level of genus;
- Riffle and edge samples assessed through the appropriate AUSRIVAS model;
- Some water quality measurements to be measured *in-situ*, and nutrient samples to be collected and analysed in Ecowise's NATA accredited laboratory.

Prior to the commencement of this program, Ecowise sought advice from independent industry experts on the sampling regime and study design required for a robust interpretation of the biological data collected. The communications began six months prior to the first sampling run and were adjusted from its original design due to difficulties in finding appropriate control sites. An additional site was added to this program because the exact location of the Burra Creek discharge point has yet to be finalised.

1.3 Rationale for using biological indicators

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

Periphyton is the matted 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 flows. This feature of rapid response makes them a valuable indicator of river health. Changes in total periphyton biomass and/or the live component of the periphyton (as determined by chlorophyll-a) can vary with changes in flow volume, so these variables are often used as indicators of river condition (Biggs, 1989; Whitton and Kelly, 1995; Biggs *et al.*, 1999). As changes in flow volume are expected with the proposed discharges from the Murrumbidgee River into Burra Creek, periphyton biomass and chlorophyll-a are included as biological indices.

2 Materials and Methods

2.1 Study sites

Macroinvertebrate community composition, periphyton assemblages and water quality were monitored at three control sites and four impact sites (which includes one provisional site until the exact discharge location is determined) on Burra Creek, Cassidy's Creek and the Queanbeyan River to obtain baseline ecological information prior to the construction and implementation of the Murrumbidgee to Googong (M2G) pipeline (Table 2; Figures 1 & 2).

To monitor for potential impacts to the ecological condition of Burra Creek, aquatic macroinvertebrates were sampled from two habitats (riffle and pool edges) and identified to family or genus level, to characterise each site. Periphyton was sampled in the riffle zones at each site and analysed for chlorophyll-a and Ash Free Dry Mass (AFDM) to provide estimates of the algal (autotrophic) biomass and total organic mass respectively (Biggs and Kilroy, 2000).

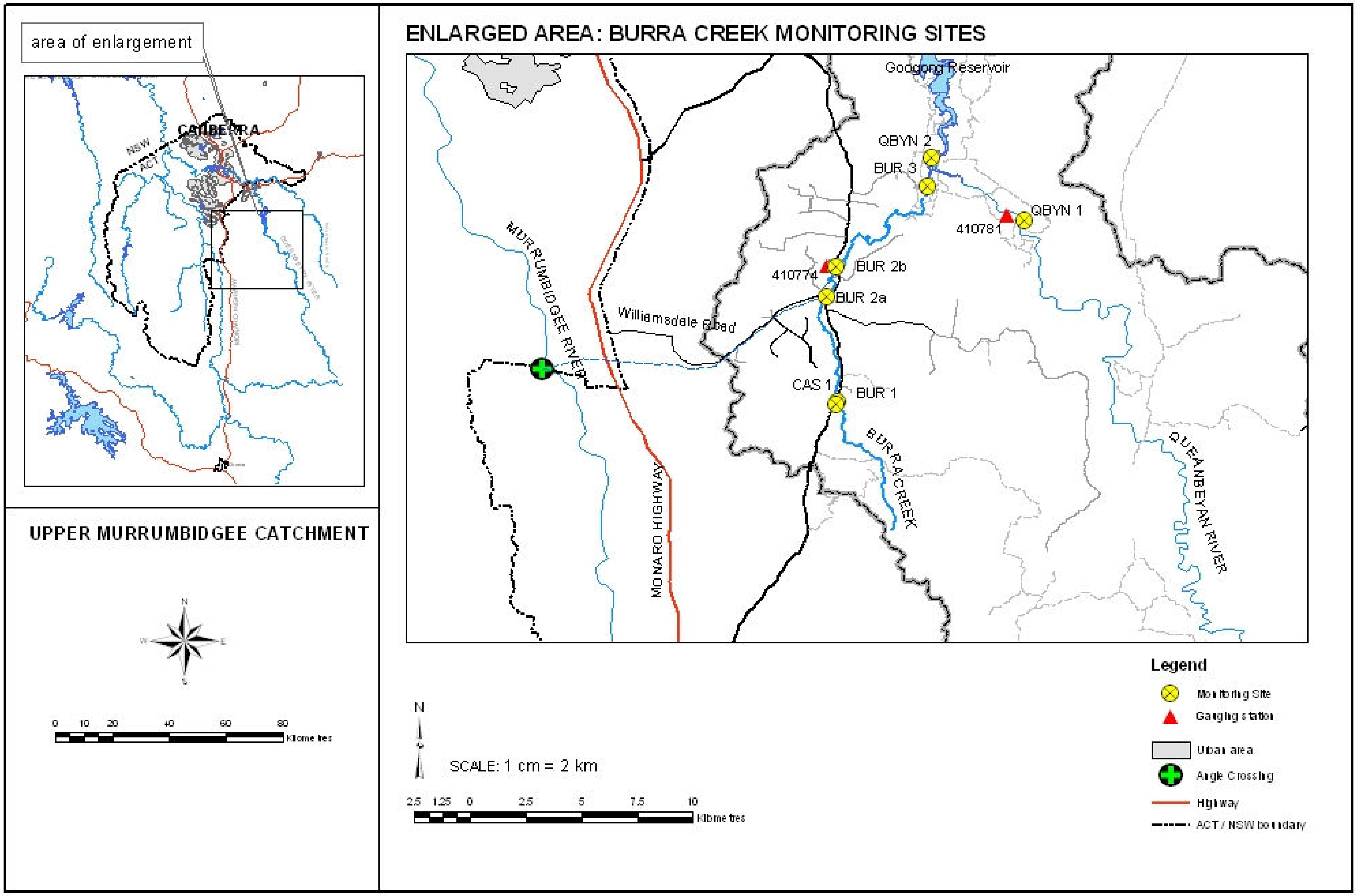
Both the riffle and edge habitats were sampled where available to provide a comprehensive assessment of each site and allow the flow related impacts to be distinguished from other disturbances. The reasoning behind this is that each habitat is likely to be effected in different ways. Riffle zones, for example, are often dry in Burra Creek because of its intermittent flow regime and are likely to be beneficially impacted by the additional flow through the channel; whereas the effects of increased flows on the macroinvertebrate assemblages in the pool/edge might not occur at the same magnitude and the effects may be less immediate. Further, due to the high number of no-flow days and the chain-of –ponds nature of Burra Creek, sampling the pool/edges allowed data collection when surface flow had ceased.

Table 2. Sampling site locations and details

Site Code	Location	Purpose	Latitude	Longitude
CAS 1	Cassidy's Creek, upstream Burra Creek confluence	Control site	-35° 35.918	149° 13.641
BUR 1	Burra Creek, upstream Cassidy Creek confluence	Control site	-35° 35.855	149° 13.666
BUR 2*a**	Burra Creek, downstream of Williamsdale Road Bridge	Impact site	-35° 33.326	149° 13.400
BUR 2*b**	Burra Creek, downstream of Burra Road Bridge	Impact site	-35° 35.571	149° 13.649
BUR 3	Burra Creek, downstream of London Bridge	Impact site	-35° 30.620	149° 15.861
QBYN 1	Queanbeyan River at Flynn's Crossing	Control site	-35° 31.459	149° 18.198
QBYN 2	Queanbeyan River, downstream of Burra Creek confluence	Impact site	-35° 29.937	149° 15.942

* Two options are given here because at the time of study design, the actual point of discharge into Burra Creek had yet to be confirmed.

Figure 1. Locality map showing monitoring sites and gauging stations



Bur 1.Looking upstream

Bur 2*a.* Downstream from Williamsdale Rd. bridge

Bur 2*b.* Downstream of Burra Road Bridge

Bur 3. Looking upstream towards London Bridge

Qbyn 1. Flynn's Crossing

Figure 2. Sites photographs: October 2009

Qbyn 2. Downstream of Burra Creek confluence (in the background indicated with a star).

Qbyn 2. Queanbeyan River at Burra Creek confluence.

Qbyn 2. Riffle substrate, showing proliferation of filamentous green algae

Figure 2 cntd. Site photographs taken in October 2009

2.2 Sampling details

Sampling occurred in October 2009. River flows during this period are indicated in Figure 2 (section 3.1). All sampling was carried out by AUSRIVAS accredited staff. Weather during sampling was fine with some surface moisture, following 13 rain days in October prior to sampling.

2.3 Hydrology and rainfall

Murrumbidgee River flows and rainfall for the sampling period were recorded at Ecowise gauging stations at Burra Road (410774, downstream of the Burra Road Bridge) and the Queanbeyan River (410781, upstream of Googong reservoir). Site locations and codes are given in Table 2 (below).

Table 3. Stream flow and water quality monitoring site locations

Site code	Location	Parameters*	Latitude	Longitude
410774	Burra Creek	WL, Q, pH, EC, DO, Temp, Turb	-35.5425	149.2279
410781	Queanbeyan River US of Googong Reservoir	WL, Q, pH, EC, DO, Temp, Turb	-35.5222	149.3005

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

2.4 Water quality

Baseline *in-situ* physico-chemical parameters including temperature, pH, electrical conductivity, turbidity and dissolved oxygen were recorded at each sampling site using a multiprobe Hydrolab® Minisonde 5*a* Surveyor. The Surveyor was calibrated in accordance with Ecowise QA procedures and the manufacturer's requirements prior to sampling. Additionally, grab samples were taken from each site in accordance with ACT AUSRIVAS protocols (Coysh *et al.*, 2000) for Hydrolab® verification and nutrient analysis. All samples were placed on ice, returned to the ECOWISE laboratory and analysed for nitrogen oxides (total NOx), total nitrogen (TN) and total phosphorus (TP) in accordance with the protocols outlined in APHA (2005). This information will assist in the interpretation of biological data and provide a basis to gauge changes that can potentially be linked to increased flow and potential changes in the Burra Creek system due to inter-basin water transfers from the donor (Murrumbidgee) system.

2.5 Macroinvertebrate sampling

Riffle and edge habitats were sampled for macroinvertebrates and analysed using the ACT Spring riffle and edge AUSRIVAS (Australian River Assessment System) protocols (Coysh *et al.*, 2000) during Spring (22nd and 23rd October) 2009. At each site, two samples were taken from the riffle habitat (flowing broken water over gravel, pebble, cobble or boulder, with a depth greater than 10cm; (Coysh *et al.*, 2000) using a framed net with 250 µm mesh size. Sampling began at the downstream end of each riffle. The net was held perpendicular to the substrate with the opening facing upstream. The stream bed directly upstream of the net opening was agitated by vigorously kicking, allowing dislodged invertebrates to be carried into the net by the current. The process continued, working upstream over 10 metres of riffle habitat. Samples were then preserved in 70% ethanol, clearly labelled with site code and date, then stored on ice and placed in a refrigeration unit until laboratory sorting commenced.

The edge habitat was also sampled according to the ACT AUSRIVAS protocols. Two samples were taken from the edge habitat. The nets and all other associated equipment were washed thoroughly between sampling events to remove any macroinvertebrates retained on them. Samples were collected by sweeping the collection net along the edge habitat at the sampling site; the operator worked systematically over a ten metre section covering overhanging vegetation, submerged snags, macrophyte beds, overhanging banks and areas with trailing vegetation. Samples were preserved on-site as described for the riffle samples.

Prior to 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 this assessment, so a Before – After / Control – Impact (BACI) design (Downes *et al.*, 2002) was adopted.

2.6 Periphyton

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

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

2.7 Data analysis

2.7.1 Water quality

Water quality parameters were examined for compliance with ANZECC & ARMCANZ (2000) water guidelines for healthy ecosystems in upland streams. Trend analyses of water quality parameters will be conducted at the end of the baseline collection period.

2.7.2 Macroinvertebrate communities

The macroinvertebrate data were examined separately for riffle and edge habitats. Replicates were examined individually (i.e. not averaged) at all sites because the aim is to examine within site variation as much as it is to describe patterns among sites at this stage. All multivariate analyses were performed using PRIMER version 6 (Clarke and Gorley, 2006). Univariate statistics were performed using R version 2.9.2 (R Development Core Team, 2009).

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

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

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

An analysis of similarities (ANOSIM) was performed on the data to test whether macroinvertebrate communities were statistically different upstream and downstream of the proposed discharge point. Sites were unable to be nested with location in the two-way design due to a lack of replication at several of the sites. Instead, a one-way analysis examined the differences between location (up and downstream of the proposed discharge point, using site as the unit of replication) and differences between systems (Burra and Queanbeyan).

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

2.7.3 AUSRIVAS assessment

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 influenced by non-human characters, e.g. altitude) are then compared to the observed fauna (O) and the ratio derived is used to indicate the extent of any impact (O/E). The ratio derived from this analysis is compiled into bandwidths (i.e. X, A-D; Table 4) which are used to gauge the overall health of particular site (Coysh *et al.* 2000). Data is presented using the AUSRIVAS O/E 50 ratio (Observed/Expected score for taxa with a >50% probability of occurrence) and the previously mentioned rating bands (Tables 4).

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

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

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

	RIFFLE	EDGE	
BAND	**O/E Band width**	**O/E band width**	**Explanation**
X	>1.14	>1.13	More diverse than expected. Potential enrichment or naturally biologically rich.
A	0.86-1.14	0.87-1.13	Similar to reference. Water quality and / or habitat in good condition.
B	0.57-0.85	0.61-0.86	Significantly impaired. Water quality and/ or habitat potentially impacted resulting in loss of taxa.
C	0.28-0.56	0.35-0.60	Severely impaired. Water quality and/or habitat compromised significantly, resulting in a loss of biodiversity.
D	0-0.27	0-0.34	Extremely impaired. Highly degraded. Water and /or habitat quality is very low and very few of the expected taxa remain.

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

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

2.7.5 Periphyton

Periphyton samples were collected from three sites (54 samples in total) as part of the field program. Unfortunately, the periphyton samples were lost following delivery to the Canberra laboratory during sample processing. As a result, there are no periphyton data to report for spring 2009.

2.8 Macroinvertebrate quality control procedures

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

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

All procedures were performed by AUSRIVAS accredited staff.

2.9 Licences and permits

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

Ecowise field staff maintains current ACT AUSRIVAS accreditation.

3 Results

3.1 Hydrology and rainfall

Burra Creek had 41 wet days in spring resulting in 205mm of rainfall (of which there was only an estimated 0.4 % runoff) in this three month period. This rainfall corresponded to an average flow for spring (September to November) of 0.62 ML/d, which was an order of magnitude higher than autumn's average of 0.05ML/d. The average flow in the Queanbeyan River (upstream of Googong Reservoir) during this period was 15.9 ML/d (Table 5). Rainfall in the central Googong catchment (Site 410781: Upstream Googong) in this period totalled 176 mm resulting in approximately 1.4 % runoff.

October was the wettest spring month with almost over 100 mm of rain falling in the Burra Creek catchment and 95 mm in the Googong catchment. Peak flows in both systems occurred in late October / early November (Figure 3). Burra Creek's maximum daily mean was 10.8 ML/d following 30 mm of rain in a 7 hour period two days after sampling ceased. Flows during the Burra Creek sampling on the 22nd of October (0.089 ML/d) were almost identical to the recorded flows of autumn (0.081ML/d).

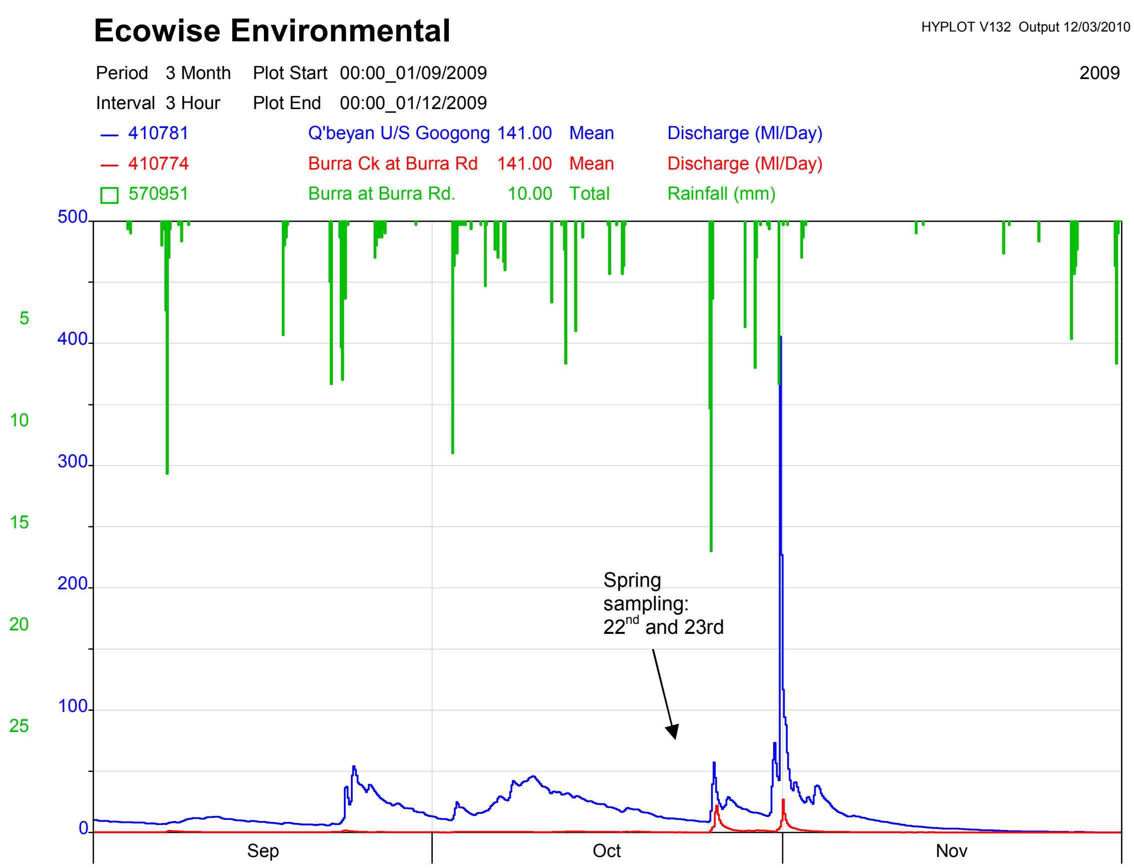


Figure 3. Spring hydrograph of Burra Creek and the Queanbeyan River*

*** Note the different scales on the y-axis are coloured coded to the parameters plotted**

Table 5. Monthly flow and rainfall statistics for spring 2009 at Burra Road (410774) and Queanbeyan River upstream of Googong reservoir (410781)

Station	Burra Creek		Queanbeyan River	
	Rainfall Total (mm)	Mean Flow (ML/d)	Rainfall Total (mm)	Mean Flow (ML/d)
September	68.6	0.34	63.8	13.4
October	106.6	0.98	95.4	25
November	29.4	0.55	16.4	9.2
Spring	204.6	0.62	175.6	15.9

3.2 Water quality

Surface water quality records were 76% complete for spring with 15 days lost between October 2nd – 16th for turbidity and pH due a lightening strike at Burra Creek station 410774 (Figure 4).

Data was logged for the entire spring period in the Quenbeyan River (410781) and is presented in Appendix A. Monthly water quality statistics for the Queanbeyan River are presented in Table 6.

Daily average water temperature in Burra Creek ranged from 8 – 26 °C over the spring period. Monthly mean temperatures steadily increased over spring (Table 6), but diurnal variation between daily minimums and maximums were low (between <1 and 5 °C).

Turbidity was below ANZECC & ARMCANZ (2000) guidelines for 90% of the spring records. Daily means increased to >25 NTU for 8 days in late October and early November as a result of steady rainfall over this time.

pH was consistent throughout the month with a daily averages ranging from 7.8-8. Minimum pH was slightly higher than during autumn as were the daily maximums.

Electrical conductivity decreased slightly over spring which was correlated to average day low records. Increases towards the end of November were related also to a reduction of mean daily flows. Daily means ranged from 450 - 715 µs/cm for the period.

Dissolved oxygen (% saturation) was low for spring, with daily maximums reaching 65% in early November. Diurnal variation increased with decreasing flows and varied by as little as 10% during the periods of springs highest flows (in late October). Daily maximum D.O. levels were equal to or greater than the lower limits of the ANZECC guidelines (i.e. ≥ 90%) for 18% of the time in spring, while the maximum D.O recorded for the period was 107%, still below the upper limits of the guidelines.

Grab sample results for Burra Creek and the Quenbeyan River are summarised in Table 7. Nutrient concentrations exceeded the recommended guidelines (ANZECC & ARMCANZ, 2000) at three of the five sites sampled (namely: BUR 2b, QBYN 1 and QBYN 2 (Table 7). Data were not collected in Burra creek in autumn because all sites were dry, however the TN concentrations at QBYN 1 & 2 were 5 % and 13 % higher than they were in autumn; while TP was 36 % and 40 % higher, respectively but the concentrations remained within the guidelines. Dissolved oxygen was outside of the guidelines at all sites expect QBYN 2 - the upper limit was exceeded at QBYN 1, while in Burra Creek, all values were below the lower limits for healthy ecosystems. Electrical conductivity was outside the upper limits of the guidelines in Burra Creek. The point should be made, that being a limestone stream with a high proportion of groundwater contributing to surface water flows, these values are not outside the natural variation in the system. The guidelines constructed by ANZECC & ARMCANZ (2000) were produced for upland perennial streams rather than systems (i.e.) with naturally high EC. Burra creek receives a high proportion of its surface flow from groundwater, so the high observed EC is expected and the values are not outside the natural variation of the system.

Table 6. Monthly water quality statistics from Burra Creek (410774) and the Queanbeyan River (410781)

Station	Burra Creek				Queanbeyan River			
Analyte	temp. °C	EC us/cm	pH	Turbidity NTU	temp. °C	EC us/cm	pH	Turbidity NTU
September	10.8	682	7.9	0.3	11.8	91.2	7.9	3.6
October	12.9	608	7.9	0.8	14.2	104.5	7.8	11.6
November	19.8	548	7.7	21	21.2	119.4	8.3	13.6
Spring	14.5	612	7.8	7.3	15.7	105	8	8.6

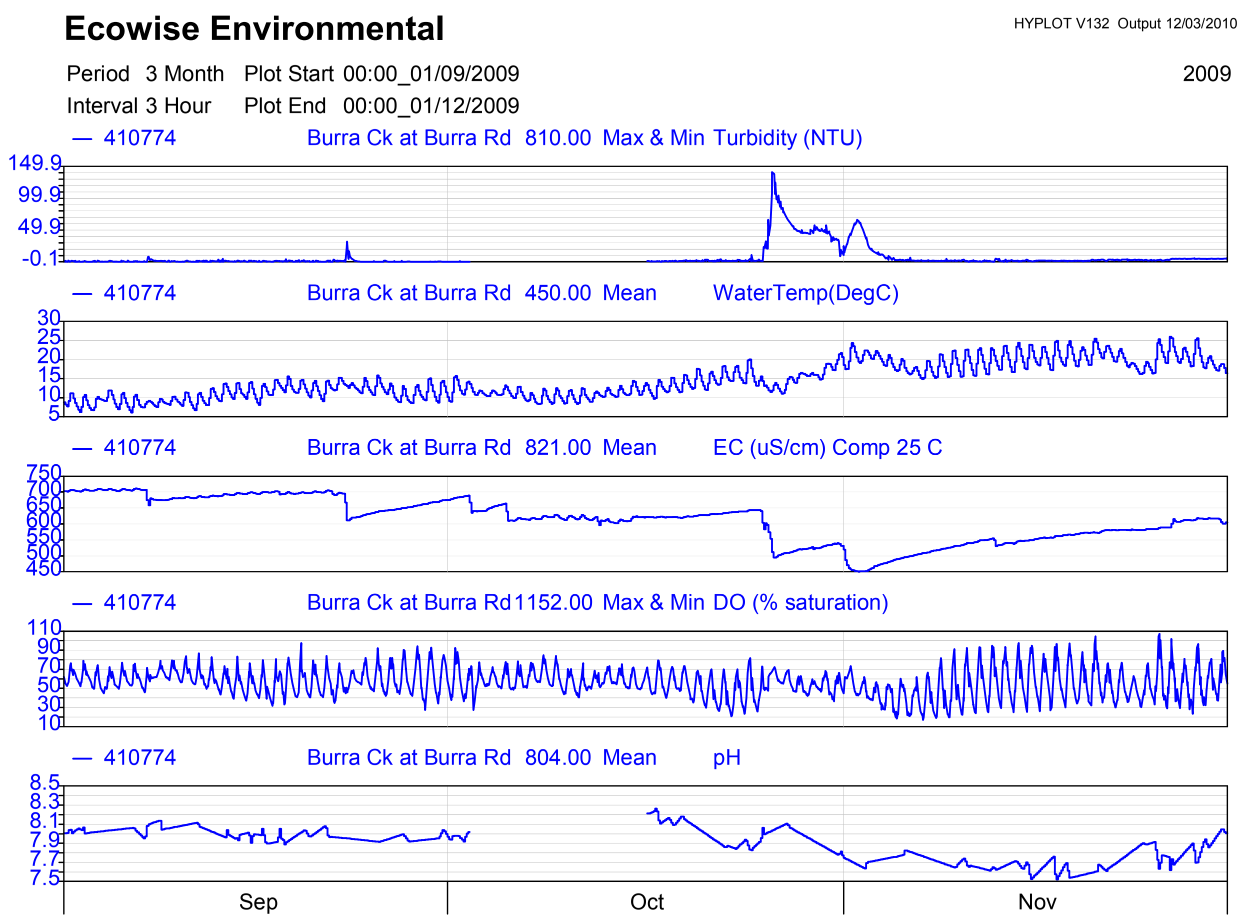


Figure 4. Water quality records from Burra Creek during Spring 2009

Missing turbidity (810) and pH (804) data from 2nd -16th October was due sensor malfunction from a lightening strike.

Table 7. In-situ water quality results: spring 2009

(ANZECC & ARMCANZ guidelines are in red). Yellow cells indicate values outside guidelines.

Refer to Table 2 for site location details.

*** Riffle dry; not sampled**

Location	Site	Time	Temp. (°C)	EC (µs/cm) (30-350)	Turbidity (NTU) (2-25)	pH (6.5-8)	D.O. (% Sat.) (90-110)	D.O. (mg/L)	Alkalinity	NOX (mg/L) (0.015)	Nitrate (mg/L)	Nitrite (mg/L)	Total Phosphorus (mg/L) (0.02)	Total Nitrogen (mg/L) (0.25)
Control sites	Cas 1	*	*	*	*	*	*	*	*	*	*	*	*	*
	Bur 1	*	*	*	*	*	*	*	*	*	*	*	*	*
	Qbyn 1	11.30	20.2	110	3	7.9	124.3	10.47	42.7	<0.01	<0.01	<0.01	0.02	0.39
Downstream sites	Bur 2a†	11.20	15.2	610	5	6.9	70.9	7.1	265	<0.01	<0.01	<0.01	0.02	0.22
	Bur 2b†	12.40	18.1	630	2	7.6	75	6.6	264	<0.01	<0.01	<0.01	0.04	0.42
	Bur 3	14.40	24.8	610	1	7.7	141.6	11.05	204	<0.01	<0.01	<0.01	0.02	0.24
	Qbyn 2	09.30	16.3	130	5.7	7.1	101.4	9.25	50.6	<0.01	<0.01	<0.01	0.02	0.37

3.3 Macroinvertebrate communities

Riffle samples were not taken from CAS 1, BUR 2a and BUR 2b due to the absence of available habitat at these sites. While water quality data are available for BUR 2a and BUR 2b, there was not sufficient habitat to collect a representative macroinvertebrate sample. Samples were taken from the EDGE habitat at all of the sampling sites. However, replication was not possible for CAS 1, BUR 2a or BUR 2b, again owing to limited sampling area.

An inventory of macroinvertebrate taxa collected in spring 2009 are presented in **Appendix B**.

The ANOSIM analysis detected significant differences in riffle macroinvertebrate communities between sites (R=0.991; *P*=0.01). Two –way analysis (with sites nested in location) was not performed on this data set because the lack of site replication within location. Pair-wise comparisons between sites followed the global R-test since there were significant differences detected between sites (**Appendix C**). All pair-wise combinations were highly significant. The R statistic of 1 between each pair indicates all replication with each site is more similar to each other than any of the replicates taken from any of the other sites (Clarke and Warwick, 2001). The relationship between these sites suggests that there are two main groups split at 40% similarity (Figure). The first group contains both Queanbeyan River sites while the second contains BUR 3 (downstream of London Bridge) (Figure 6) indicating the dissimilarities observed between the communities is likely a function of the river system they belong to rather than their assigned location (i.e. up- or downstream). However, the results from QBYN 1 and 2 are consistent with the results generated from the autumn 2009 analysis showing a clear separation of these sites in the NMDS plot (Figure 7).

The edge communities formed two main clusters (Figure 8 and 9) at 42% similarity. The ANOSIM test for differences between locations (H_0: no difference in macroinvertebrate communities between locations) showed that there was a significant separation of upstream (control) and downstream (impact) sites (R=0.59; *P*=0.02). However, the intermediate R-statistic of 0.59 indicates that there is considerable overlap between locations. This can be seen in Figure 8, where the position of some of the downstream sites shows that they are closer to the upstream sites. For example, QBYN 2 is closer to BUR 1 and QBYN 1 than other downstream sites. The similarity ellipses super imposed over the groups suggests that much of the variation in the community assemblages is due to which river / stream they were collected from rather than their assignment to a "location", as was suggested for the riffle samples.

3.3.1 Riffles

The most diverse riffle site was QBYN 1with 32 genera and 22 families collected (Figure 5). BUR 3 had 22 families and 28 genera while QBYN 2 had 16 families representing 19 genera. BUR 3 was dominated both in diversity and richness by opportunistic taxa such as Simuliidae and Chironomids. The chironomids were a particularly diverse group and made up ~62% of the total abundance at BUR 3. Other taxa that characterised this site include: *Dinotoperla sp.* (Gripopterygidae: Plecoptera) and *Platynectes sp.* (Dytiscidae: Coleoptera). Generally BUR 3 had low EPT diversity and relative abundance, with five genera representing this group of taxa with *Dinotoperla sp.* being the most abundant taxa of the group. BUR 3 also had a high diversity in the Coleopteran families: Dytiscidae and Hydrophilidae. Dytiscidae and Hydrophilidae were absent at both Queanbeyan sites. Below the Burra Creek confluence at QBYN 2 there was a decline in the number of different taxa recovered from the samples (Figure 5). EPT diversity was higher than BUR 3, although *Dinotoperla sp.* was considerably less abundant and was restricted to one or two individuals in only one of the subsamples.

The upstream control site samples from QBYN 1 contained three unique taxa, which have high SIGNAL scores (8): *Ulmerophlebia sp.* (Leptophlebiidae: Ephemeroptera), *Psyllobetina sp.* (Hydrobiosidae: Trichoptera) and *Illiesoperla sp.* (Gripopterygidae: Plecoptera). Coleopterans were represented only in the family Elmidae but in relatively high numbers; numerically the samples were dominated by (in order of highest to lowest abundance): Orthocladiinae, Chironominae and Tanypodinae. Downstream of the Burra Creek confluence Orthocladiinae accounted for ~82% of the total number of macroinvertebrates in each sample.

3.3.2 Edges

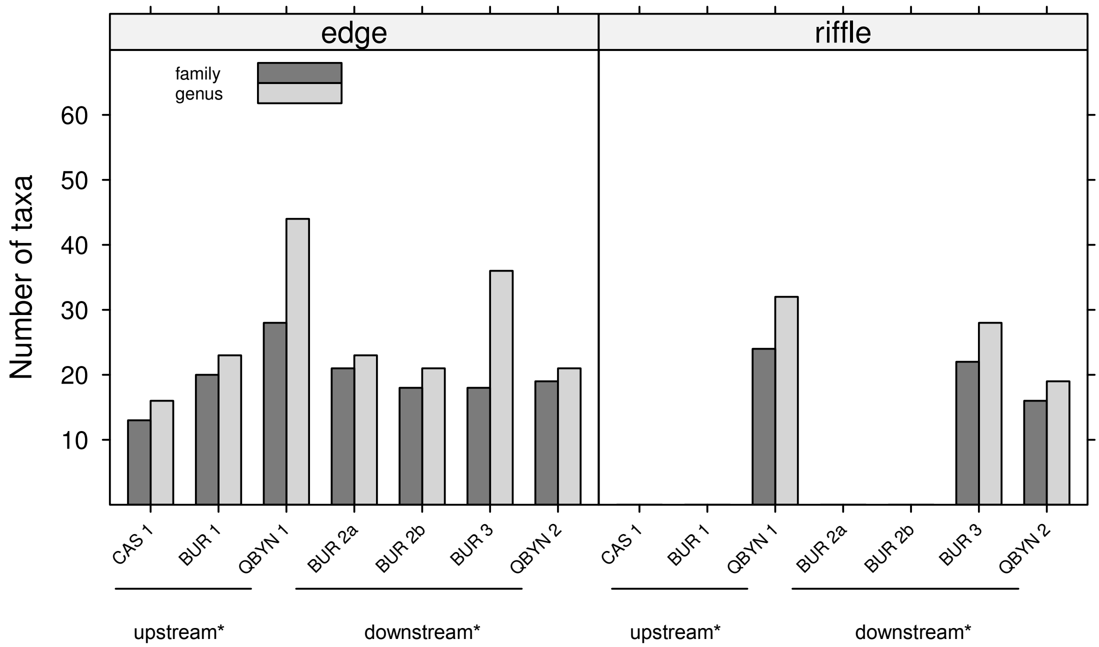
The composition of the edge communities was very similar across all sites. Orthocladiinae larvae were numerically dominant across all sites ranging from 250 individuals (CAS 1) to 2000 (BUR 2b). Diversity was highest at QBYN 1, which is consistent with the results from autumn 2009; although the number of families (28) and genera (44) (Figure 9) were 25 and 38 % fewer than were collected in autumn.

EPT taxa were absent from the samples taken at CAS 1. At this site, Chironomids, Oligochaetes, Corixidae and Dytiscidae contributed to 80% of the total abundance. Despite is proximity to CAS 1, the macroinvertebrate community at BUR 1 was very different to the assemblage in Cassidy Creek (Figures 7 & 8). Family richness was higher at BUR 1 compared to CAS 1 (Figure 9) with the main difference between the two sites was the presence of several EPT taxa collected at BUR 1 and the absence of Acarina (SIGNAL = 6), Atyidae (Decapoda) at CAS 1.

Downstream of the proposed discharge point at BUR 2a and 2b, the community assemblages were almost identical in terms of both richness (Figure 9) and abundances. The high similarity percentage (72 %) is reflected in the proximity of both sits to each other in the NMDS plot (Figure 9). The results from the SIMPER analysis suggest that the taxa best discriminating these two sites were *Dinotoperla sp*. (Gripopterygidae: Plecoptera) and *Atalophlebia* sp. (Leptophlebiidae: Ephemeroptera), present at BUR 2a but not at BUR 2b. There were also more Orthocladiinae (Chironomidae: Diptera) at BUR 2b.

BUR 3 was characterised by high abundances of *Dinotoperla sp*. (Gripopterygidae: Plecoptera) and relatively high diversity in the Mayfly (Ephemeroptera), Caddisfly (Trichoptera) and diving beetle (Dytiscidae) groups.

In the Queanbeyan River, there was an increase in the average similarity between QBYN 1 and 2 since autumn by 22 %. Despite the increase in average daily flows in spring, there was a loss of several flow dependant taxa at QBYN 2 including *Baetis sp., Cloeon sp*. (Baetidae: Ephemeroptera) and *Jappa sp*.(Leptophlebiidae: Ephemeroptera); while other taxa separating the two Queanbeyan sites were *Dinotoperla sp*. (Gripopterygidae: Plecoptera), *Micronecta sp* (Corixidae: Hemiptera) and *Simulium sp.* (Simuliidae: Diptera) – all of which were absent at QBYN 1.



***of the potential discharge point**

Figure 5. Taxonomic richness at family and genus level for riffle and edge habitats, spring 2009

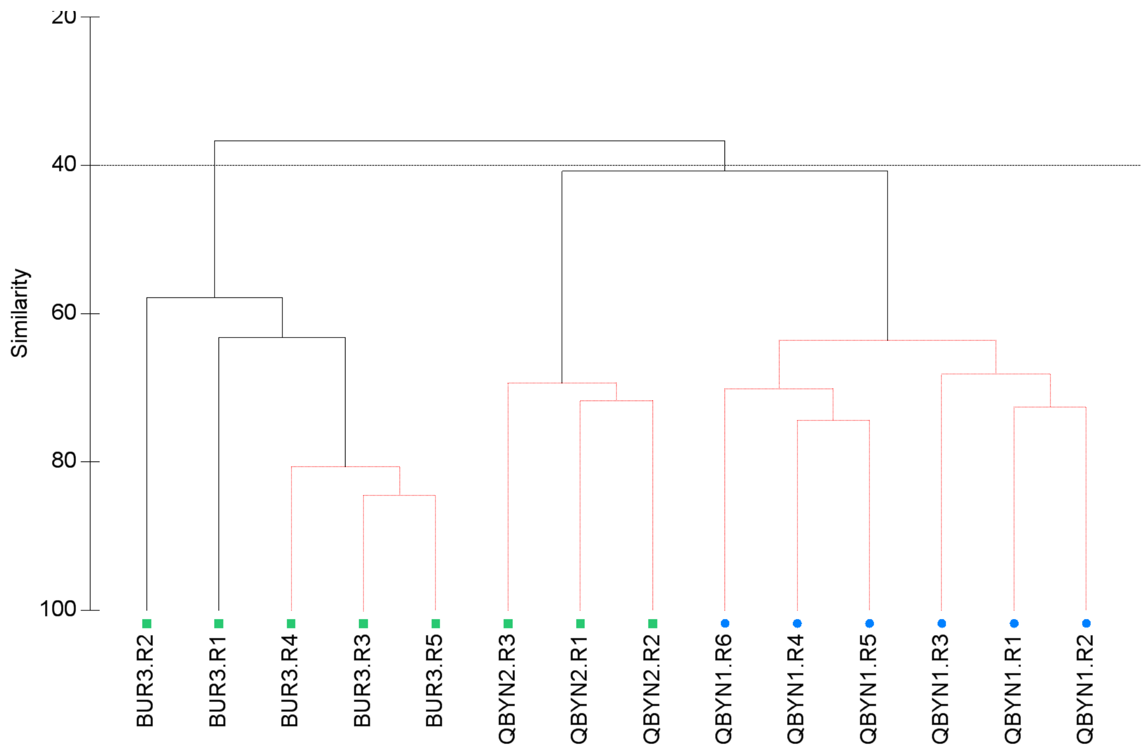


Figure 6. Cluster analysis for spring riffle samples.

Blue circles represent upstream control sites, green squares are the downstream impact site. Red lines indicate significant groups determined by the SIMPROF analysis

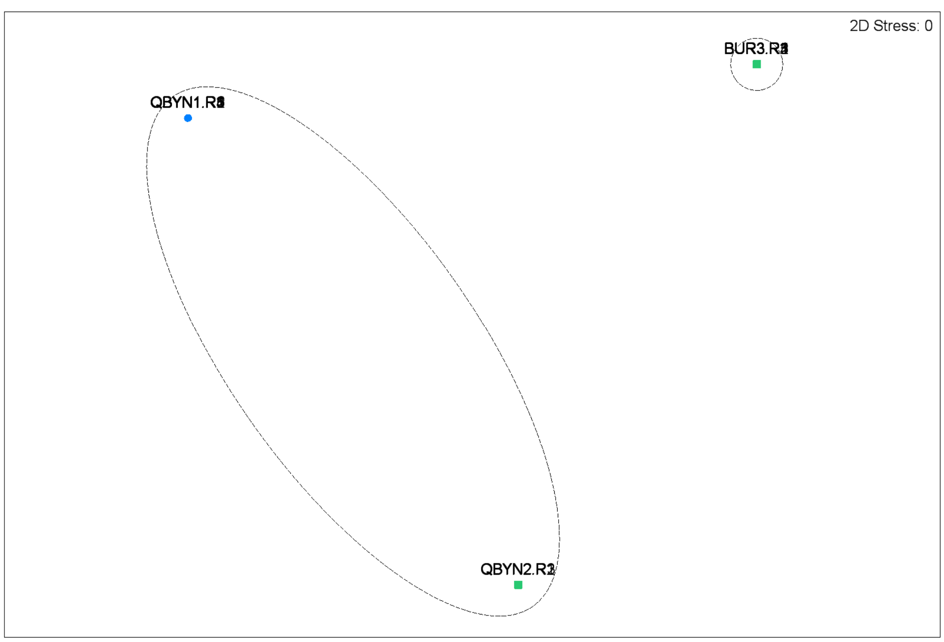


Figure 7. Non-metric multidimensional scaling of spring riffle samples Blues circles represent upstream control sites, green squares are the downstream impact site. Dashed ellipses represent 40% similarity groups

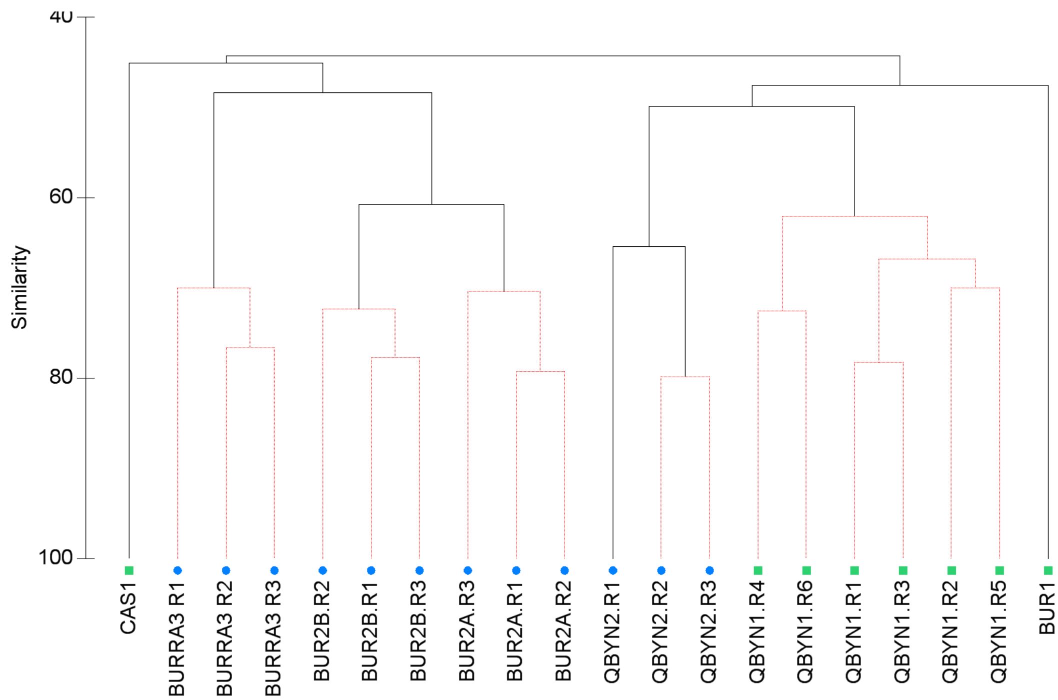


Figure 8. Cluster analysis for spring edge samples.

Blue circles indicate upstream control site, green squares are the downstream impact site. Red lines indicate significant groups determined by the SIMPROF analysis.

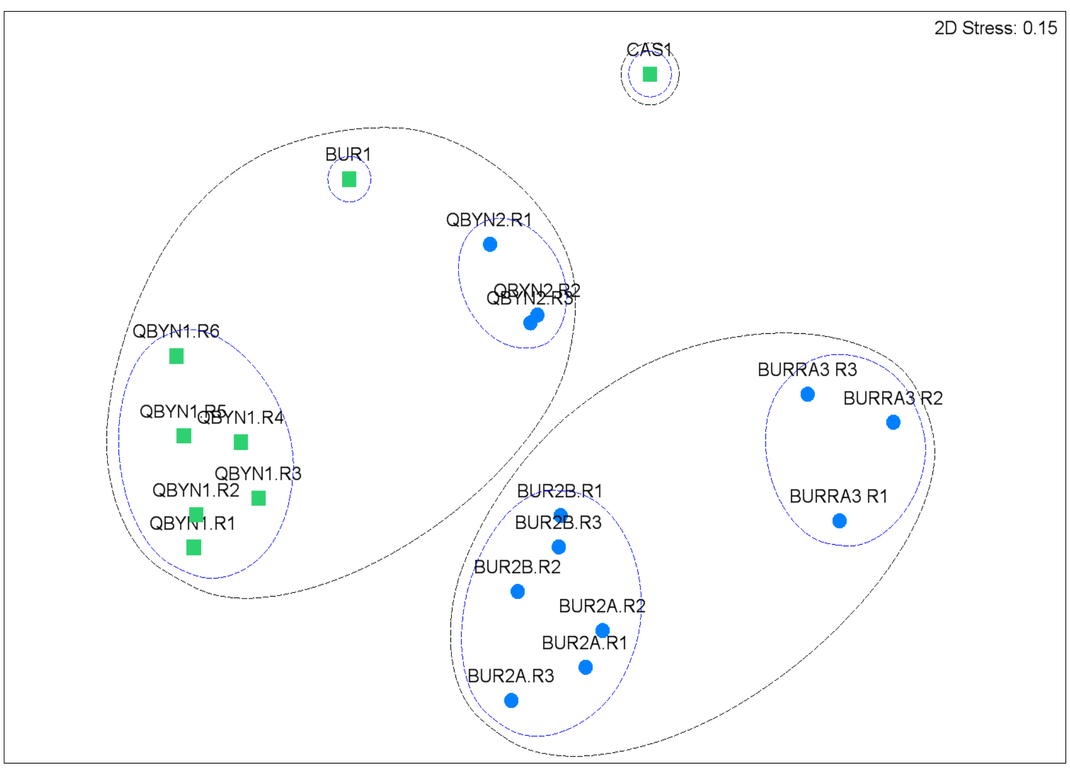


Figure 9. Non-metric multidimensional scaling of spring edge samples. Black ellipses represent 40% similarity groups; blue ellipses represent 60% similarity groups. Both are superimposed from the cluster analysis in Figure 8.

3.4 AUSRIVAS assessment

There was a slight improvement in the overall river health assessment at QBYN 2 (downstream, of the Burra Creek confluence). The autumn assessment of Band C – "*Severely impaired*" improved to Band B – "*significantly impaired*", giving it the same assessment as the upstream control site (QBYN 1) (Table 8; Figure 10). There was no change in the edge assessment at either site since autumn. The remaining sites were not sampled in autumn so seasonal comparisons are unavailable at this stage.

AUSRIVAS assessments were limited to the edge habitat only at the following sites: CAS 1; BUR 1; BUR 2a and BUR 2b. BUR 1 was the only site assessed as Band A –"*close to reference"* CAS 1 and BUR 2a were both assessed as B – "*significantly impaired*", while BUR 2b was considered to be Band C – "*Severely impaired*". Taxa predicted to occur with >50% probability, but absent from the samples are presented in **Appendix D**. The list of taxa missing but predicted is similar across of these sites. Baetid, Caenid and Leptophlebiidae mayflies are commonly missing as are Leptoceridae Caddisflies. Corixidae (SIGNAL = 2) were missing from site BUR 2a and from one subsample at BUR 2b.

BUR 3 was the only additional site with riffle habitat available for sampling. The overall site assessment was Band B – "*significantly impaired".* The riffle and edge samples at BUR 3 both contained 1 subsample which was considered Band A –*"close to reference"*. Where both habitats were assessed (QBYN 1 & 2 and BUR 3), QYN 1 was the only site where the habitat assessments differed. The edge was assessed as Band A – "*close to reference*", while the riffle, as already stated, was Band B – "*significantly impaired*". The number of taxa predicted to occur at QBYN 1, but were missing from the samples ranged from 3-6 in the riffle samples (**Appendix D**).

QBYN 2 recorded the most missing taxa (7), which were predicted to occur with >50% probability. Among the taxa that were not collected were the highly sensitive Elmidae (SIGNAL =7), Glossosomatidae (SIGNAL =9) and Conoesucidae (SIGNAL =7). Hydropsychidae (SIGNAL =6)) was missing from all sites except QBYN 2. There was a general trend across all the Burra Creek samples that taxa with higher SIGNAL scores were either present in all samples or missing from all samples, while taxa with lower sensitivities (e.g. Corixidae and Chironominae) were missing from only a few of the subsamples at a given site.

Table 8. AUSRIVAS and SIGNAL scores for spring 2009

SITE	Rep.	SIGNAL-2		AUSRIVAS O/E score		AUSRIVAS Band		Overall habitat assessment		Overall site assessment
		Riffle	*Edge*	*Riffle*	*Edge*	*Riffle*	*Edge*	*Riffle*	*Edge*	
CAS 1	1	*na*	*3.71*	*na*	*0.66*	*na*	**B**	*na*	**B**	**B**
BUR 1	1	*na*	*4.50*	*na*	*0.94*	*na*	**A**	*na*	**A**	**A**
BUR 2a	1	*na*	*4.71*	*na*	*0.78*	*na*	**B**	*na*	**B**	**B**
	2	*na*	*4.71*	*na*	*0.78*	*na*	**B**			
	3	*na*	*4.71*	*na*	*0.78*	*na*	**B**			
BUR 2b	1	*na*	*3.4*	*na*	*0.58*	*na*	**C**	*na*	**C**	**C**
	2	*na*	*3.4*	*na*	*0.58*	*na*	**C**			
	3	*na*	*3.4*	*na*	*0.58*	*na*	**C**			
BUR 3	1	*4.38*	*4.29*	*0.70*	*0.78*	**B**	**B**	**B**	**B**	**B**
	2	*4.38*	*3.86*	*0.70*	*0.78*	**B**	**B**			
	3	*4.50*	*4.13*	*0.88*	*0.89*	**A**	**A**			
	4	*4.56*	*na*	*0.79*	*na*	**B**	*na*			
	5	*4.50*	*na*	*0.70*	*na*	**B**	*na*			
QBYN 1	1	*4.89*	*4.8*	*0.83*	*1.17*	**B**	**X**	**B**	**A**	**B**
	2	*5*	*4.5*	*1.01*	*0.93*	**A**	**A**			
	3	*4.63*	*4.44*	*0.73*	*1.05*	**B**	**A**			
	4	*5.13*	*4.8*	*0.73*	*1.17*	**B**	**X**			
	5	*4.89*	*4.44*	*0.83*	*1.05*	**B**	**A**			
	6	*5*	*4.89*	*0.73*	*1.05*	**B**	**A**			
QBYN 2	1	*5.22*	*4.14*	*0.92*	*0.89*	**A**	**B**	**B**	**B**	**B**
	2	*5.10*	*3.5*	*0.83*	*0.76*	**B**	**B**			
	3	*4.5*	*3.86*	*0.83*	*0.83*	**B**	**B**			

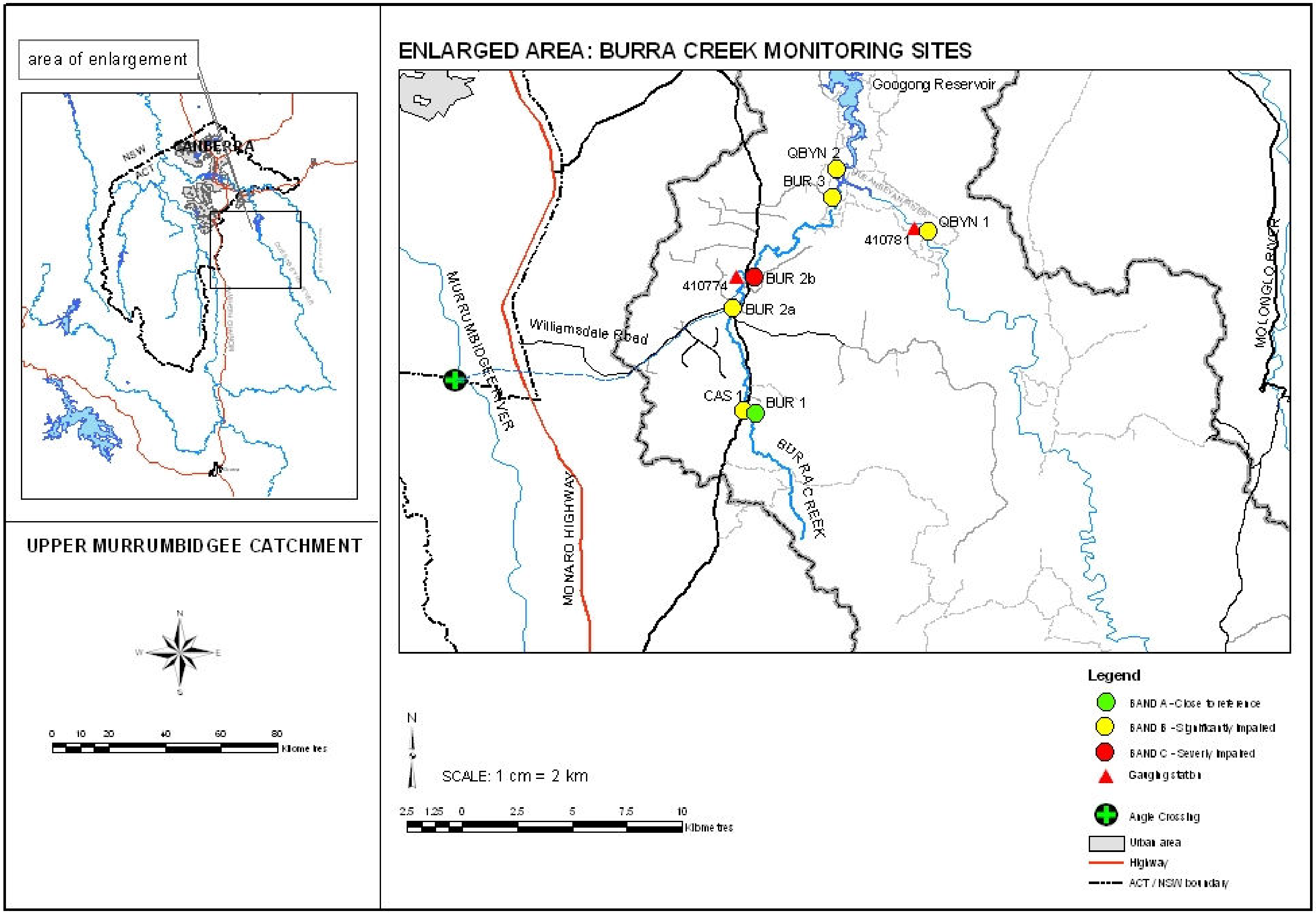


Figure 10. Location map showing the spatial distribution of the AUSRIVAS habitat assessments for autumn 2009.

Note: only QBYN 1 & 2 and BUR 3 are based on both he riffle and edge assessments, while the remaining sites are based on the edge assessments.

4 Discussion

4.1 River health and patterns in macroinvertebrate community assemblages

The results of the spring 2009 sampling program show that five of the sites sampled are considered to be "*significantly impaired*" (BAND B), including both control and impact sites. One of the sites (BUR 1) was assessed as "*close to reference condition*" (BAND A), while the final site (BUR 2b) was assessed as "*severely impaired*" (BAND C) (Table 8; Figure 9).

Despite these assessments, the riffle habitats all contained one subsample with a BAND A assessment. The difference between the assigned BAND B and the BAND A subsamples was between 1 and 3 families at each site (**Appendix C**) ranging from otherwise common tax such as Acarina (SIGNAL =6) and Chironominae (SIGNAL =3) to more sensitive taxa, such as Gripopterygidae (SIGNAL =8). These results suggest that habitat availability and/or quality are the main determinates of the site assessment because even though pollution sensitive taxa were missing from some of the samples, they were not entirely absent from the site. For example, Elmidae was missing from 2 and 1 of the subsamples at QBYN 1 and 2 respectively and Leptophlebiidae at QBYN 1 from sample.

Leptophlebiidae (SIGNAL =8), Elmidae (SIGNAL =7) and Gripopterygidae (SIGNAL =8) were recorded at QBYN 2 for the first time, indicating a response to increasing stream flows and resulting in a slight improvement in the condition of the riffle zone at QYBN 2 (Table 9; Figure 10) since autumn. However, the absence of the highly sensitive Glossosomatidae at QBYN 2 in all of the samples might suggest that some threshold of water quality tolerance has been crossed, which, given the generally good status of the water quality data (Table 7) is likely to be the slightly elevated water temperate. However, the lack of quality substrate (large rocks) (Gooderham and Tsyrlin, 2005) is also likely to be a limiting factor to their absence, and the absence of Psephenidae (SIGNAL =6) which are usually absent in loosely packed and sandy substrates such as the substrate qualified at QBYN 2.

As noted in section 3.4, there was a general trend across all the Burra Creek samples that taxa with higher SIGNAL scores were either present in all samples or missing from all samples, while taxa with lower sensitivities (e.g. Corixidae and Chironominae) were missing from only a few of the subsamples at a given site. For example, this observation is highlighted in the riffle samples of BUR 3 and in several of the edge samples (**Appendix C**) where Elmidae, Hydropsychidae and Leptophlebiidae were all missing from the predictions of the AUSRIVAS model. This phenomenon can best be explained in relation to naturally occurring dissimilarities between perennial and intermittent streams (Boulton, 1989; Boulton and Lake, 1992; Miller and Golladay, 1996; Del Rosario and Resh, 2000) and the predictions made by the AUSRIVAS model.

Williams and Hynes (1977) note that taxa in temporary streams can generally be divided into three main groups: 1) permanent stream forms (not well adapted to life in temporary streams); 2) those that occur in both lotic and lentic waters and 3) taxa "which are highly adapted and often restricted to temporary waters". While AUSRIVAS predictions based on physical information can result in similar taxa expected to occur within different stream types (i.e. intermittent and perennial), disparities in macroinvertebrate communities are related to system – specific differences such as water chemistry and the disturbance and flows regimes, resulting in adaptations to cope with these differences (Wallace, 1990). The AUSRIVAS model does not take the degree of flow permanence into account which could result in erroneous predictions by the model and lead to misleading outputs. It is therefore advised that caution should be given to the AUSRIVAS outputs for the Burra Creek riffle sites.

The edge habitat samples from CAS 1 and in the middle and upper sections of Burra Creek had variable AUSRIVAS assessments, ranging from BAND C at BUR 2b to BAND A at BUR 1 (Table 8; Figure 10).

There was a considerable amount of overlap in the faunal composition of these sites, with the main differences being a complete absence of EPT taxa at CAS 1 and BUR 2b. Gastropod diversity was relatively high and were in high numbers at BUR 2a and 2b, most likely reflecting an abundant food supply (Wood and Petts, 1994) and a tolerance to low oxygen concentrations.

BUR 1 was more similar in its macroinvertebrate assemblages to the Queanbeyan River sites than to other Burra Creek sites (Figure 9), which could be related to either similar physico-chemical properties between BUR 1 and QBYN 1 & 2 or similar riparian and substrate composition compared to the Burra Creek sites or a combination of both factors. Upper Burra Creek has different water chemistry than the sites further downstream, which are more comparable to the Queanbeyan River; especially EC, pH and alkalinity (based on summer event sampling 3 months after the spring sampling).

The impaired condition at CAS 1, BUR 2a and BUR 2b are likely to be a function of the degree of isolation of each pool/edge and their life span. Longer standing pools, such as the sites in question (*Pers. obs.*) are likely to be dominated by species that are tolerant to long term hypoxic conditions and higher temperatures (e.g. Larned *et al.*, 2010) such as: Dytiscidae; Chironomids, Oligochaeta and Gastropods. This is further supported by the low average SIGNAL-2 scores at CAS 1 and BUR 2b in particular (Table 8).

One caveat to note regarding these results is the fact that at CAS 1 and BUR 1 only 1 replicate and 1 subsample were possible due to habitat restrictions. Based on the variation observed in the subsamples from other sites it is possible that the assessments given here over-estimate the condition compared to an assessment based on multiple replicates and sub-samples. Underestimations are unlikely because the final assessment is limited by the lowest Band assigned to a given site. As an example, at QBYN 2, the first subsample was given a Band A, while the following subsamples all resulted in Band B. Therefore, if a similar pattern were to be assumed of BUR 1 for example, the current assessment could be misleading if current patterns of within site variation are not taken into account.

5 Conclusions

One of the limiting factors in this assessment was the lack surface water in the upper reaches of Burra Creek. Recent rainfall events prior to and post sampling, re-wetted the Creek bed but only to the extent that one additional site (BUR 3) could be sampled.

The current assessment indicates that the majority of sites are significantly impaired and one site being severely impaired, with several taxa predicted to occur, not be collected in the samples. The evidence from the communities collected at these sites suggest that at the impaired edge sites, the impacts to the communities are likely to be low dissolved oxygen, either because most of the surface water is from upwelling groundwater, and/or due to a lack of surface flow resulting in low atmospheric exchange with the water column.

The sites considered to be BAND A or B had higher richness in the EPT fauna and had a higher proportion of highly sensitive taxa with SIGNAL scores of 7 or above. In the pools this might indicate recent connectivity between pools and riffles, which increased oxygen levels and facilitated in dispersal between habitats. In the riffles, the BAND B assessment is a conservative estimate because at least one of the subsamples at each of the riffle sites results in a BAND A assessment. The samples all contained highly sensitive taxa, indicating that variation in substrate availability and in some cases patchy distributions of some taxa are the likely cause of these impaired assessments rather than poor water.

The main grouping structure determined by the multivariate analysis show distinct groupings of sites according to their membership to either the perennial or intermittent streams (Queanbeyan River and Burra Creek respectively). Disparities between the community assemblages are probably due to adaptations to the natural flow regime of each river type. One of the likely implications relating to the ecology of Burra Creek with the proposed M2G project is that the natural balance of the system is will be disrupted if flow permanence increases beyond natural variation. Studies have shown macroinvertebrate communities tend towards the communities in perennial systems with varying degrees of flow permanence (e.g. Smith and Wood, 2002). In Burra creek this could mean an increase in filter feeders and flow dependant taxa with might lead to a loss of taxa adapted to the natural ecological dynamics of Burra Creek and could pave the way for invasions of non-native species.

6 Recommendations

A condition stated in the Burra Creek monitoring proposal (section 1) is that the program is to be adaptive and that the methods, sites, and analysis in previous runs be reviewed so the objectives of ACTEW are being met satisfactorily. Based on the current round of sampling the following recommendations are made:

1) Despite the presence of surface water following spring rainfall, there appear to be minimal riffle habitat available for sampling in the mid-lower reaches of Burra Creek and QBYN- 2. It is unlikely that two replicates will be possible for the duration of the project given that off-season site visits did not find suitable replacements. It is suggested therefore, that QBYN 1 also be reduced to a single replicate to keep the sampling in-line with the other sites. This will allow for more robust statistical testing (Quinn and Keough, 2002) in the long term and also reduce the risk of non-comparable samples because of differences in sampling effort.

2) Given the importance of the pool/edge habitats in Burra Creek it is recommended that edge water samples are included in the sampling regime. This will add to the data set considerabley and allow analyses to be conducted in lieu of riffle samples during dry periods.

3) The importance of the hyporhiec zone (HZ) as a refuge for over-summering taxa, and during periods of drought is highlighted by several authors (Hynes, 1970; Williams and Hynes, 1977; Boulton, 1989) and its importance within the Burra Creek system is poorly understood. The proposed M2G transfer has the potential to change the substratum, surface water quality and potentially the groundwater quality within the system which could in turn impact upon the hyporhiec fauna. We recommend collecting baseline survey data of hyporheic community at each site. This information will allow ACTEW to make informed decisions regarding this component of the ecosystem, but would mean an expansion to the scope of the project to include such sampling.

Adding the HZ to the existing program as a third habitat (i.e. riffle, pool/edge, and hyporhiec zone) would also mean that even in periods when there is no surface flow, there would be the opportunity to collect representative data from a given site. This would require a period of intensive sampling in the early stages to develop a comprehensive baseline of existing taxa (Hancock, *Pers. Comm.*). One advantage of this approach, however, is that Ecowise has already collected samples from the hyporheic zone in Burra Creek as part of an ActewAGL funded R &D program to investigate the suitability of hyporheic communities for indicating the ecological health of ephemeral streams; so the potential for these protocols to be explored could be done so with minimal additional cost.

4) Baseline data are now available for Burra Creek. Although this information will provide seasonal assessments on a site specific basis, it lacks the ability to make inferences relating to the dynamics of the macroinvertebrate communities in Burra Creek, especially in relation to:

- Seasonal patterns in community turnover (outside of the standard autumn/spring AUISRIVAS sampling);
- Responses to various flow regimes, including large spates and increasing number of flow days since re-wetting (this would involve event based sampling on top of any additional sampling that may or may not be deemed necessary)

A comprehensive understanding of this system in relation to changing flow would involve a more intensive sampling regime, but would provide ACTEW with a more detailed assessment which would fill a large knowledge gap existing in this system.

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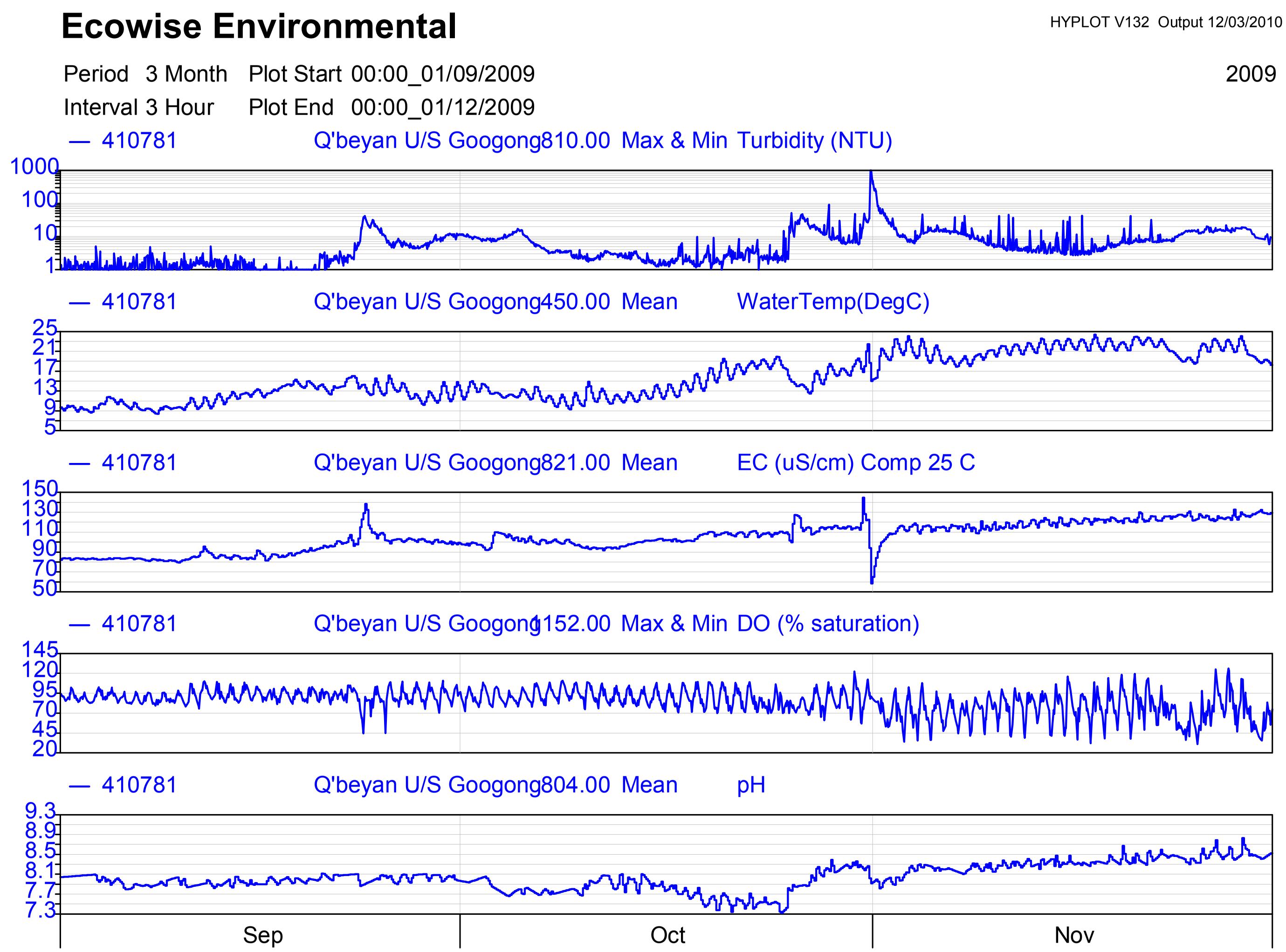
A P E N D I C E S

Appendix A –

Continuous water quality results for the Queanbeyan River upstream of Googong reservoir (410781)

Appendix A. Continuous water quality results for Spring 2009 in the Queanbeyan River (410781)



Appendix B
Taxonomic inventory of macroinvertebrates collected in the Queanbeyan River sites: Spring 2009

Appendix E. Taxonomic inventory of **EDGE** macroinvertebrates collected in spring 2009

CLASS Order	Family *Subfamily*	Genus	CAS 1	BUR 1	BUR 2a	BUR 2b	BUR 3	QBYN 1	QBYN 2
Acarina	sp.		✓	✓	✓	✓	✓	✓	
AMPHIPODA	Ceinidae	sp.	✓						
Coleoptera	Brentidae	sp.					✓		
Coleoptera	Dytiscidae	Antiporus			✓	✓	✓	✓	
Coleoptera	Dytiscidae	Hyphydrus					✓		
Coleoptera	Dytiscidae	Lancetes					✓		
Coleoptera	Dytiscidae	Megaporus					✓		
Coleoptera	Dytiscidae	Necterosoma	✓				✓		
Coleoptera	Dytiscidae	Platynectes					✓	✓	✓
Coleoptera	Dytiscidae	Sternopriscus	✓	✓	✓	✓	✓	✓	✓
Coleoptera	Hydrochidae	Hydrochus		✓		✓			
Coleoptera	Hydrophilidae	Berosus				✓			
Coleoptera	Hydrophilidae	sp.		✓	✓		✓		
Collembola	sp.						✓		
Decapoda	Atyidae	Paratya		✓				✓	✓
Decapoda	Parastacidae	Cherax			✓				
Decapoda	Parastacidae	Euastacus						✓	
Diptera	Ceratopogonidae	Ceratopoginae	✓	✓	✓	✓	✓	✓	✓
Diptera	Ceratopogonidae	Forcipomyiinae					✓		
Diptera	*Chironominae*	*Chironominae*	✓	✓	✓	✓	✓	✓	✓
Diptera	Culicidae	Culix	✓				✓		
Diptera	*Orthocladiinae*	*Orthocladiinae*	✓	✓	✓	✓	✓	✓	✓
Diptera	Psychodidae	sp.							
Diptera	Simuliidae	Austrosimulium			✓			✓	
Diptera	Simuliidae	Cnephia							
Diptera	Simuliidae	Simulium			✓			✓	
Diptera	Stratiomyidae	Odontomyia	✓	✓	✓	✓	✓		
Diptera	*Tanypodinae*	*Tanypodinae*	✓	✓	✓	✓	✓	✓	✓
Diptera	Tipulidae	Tipulidae			✓	✓	✓		
Ephemeroptera	Baetidae	Cloeon		✓				✓	
Ephemeroptera	Baetidae	sp.		✓			✓	✓	
Ephemeroptera	Caenidae	Tasmanocoenis						✓	✓
Ephemeroptera	Leptophlebiidae	Atalophlebia		✓	✓			✓	
Ephemeroptera	Leptophlebiidae	Jappa							✓
Ephemeroptera	Oniscigastridae	Tasmanophlebia		✓				✓	
GASTROPODA	Ancylidae	Ferrissia	✓						✓
GASTROPODA	Lymnaeidae	Pseudosuccinea			✓	✓	✓	✓	
GASTROPODA	Lymnaeidae	sp.			✓				
GASTROPODA	Physidae	Physa			✓	✓	✓	✓	✓

CLASS Order	Family *Subfamily*	Genus	CAS 1	BUR 1	BUR 2a	BUR 2b	BUR 3	QBYN 1	QBYN 2
GASTROPODA	Physidae	Physa acuta			✓			✓	
GASTROPODA	Planorbidae/physidae	sp.			✓	✓	✓	✓	✓
Hemiptera	Corixidae	Micronecta	✓			✓	✓	✓	
Hemiptera	Corixidae	sp.					✓	✓	
Hemiptera	Gelastocoridae	sp.		✓					
Hemiptera	Mesoveliidae	mesovelia		✓					
Hemiptera	Notonectidae	Enithares	✓				✓		
Hemiptera	Notonectidae	Paranisops	✓			✓		✓	
Hemiptera	Notonectidae	sp.				✓	✓		
Hemiptera	Veliidae	Drepanovelia		✓			✓		
HIRUDINEA	Richardsonianidae	sp.		✓					
Lepidoptera	Pyralidae	sp.							✓
Megaloptera	Sialidae	Stenosialis						✓	
Odonata	Aeschnidae	Brevyistyla	✓			✓		✓	
Odonata	Coenagrionidae	Ischnura							✓
Odonata	Gomphidae	Austrogomphus							✓
Odonata	Lestidae	Austrolestes					✓	✓	
Odonata	Zygoptera	sp.		✓	✓	✓	✓	✓	✓
OLIGOCHAETA	sp.		✓	✓	✓	✓	✓	✓	✓
Plecoptera	Gripopterygidae	Dinotoperla			✓		✓	✓	
Plecoptera	Gripopterygidae	sp.			✓	✓		✓	
Trichoptera	Ecnomidae	Ecnomus		✓				✓	✓
Trichoptera	Hydrobiosidae	Psyllobetina						✓	
Trichoptera	Hydroptilidae	Hellyethira		✓			✓		✓
Trichoptera	Hydroptilidae	Oxyethira					✓		✓
Trichoptera	Leptoceridae	Notalina					✓	✓	✓
Trichoptera	Leptoceridae	Oecetis						✓	✓
Trichoptera	Leptoceridae	Triplectides		✓				✓	
Turbellaria	Dugesiidae	sp.						✓	✓

Appendix E (cntd). Taxonomic inventory of **RIFFLE** macroinvertebrates collected in spring 2009

CLASS Order	Family *Subfamily*	Genus	BUR 3	QBYN 1	QBYN 2
Acarina	sp.		✓	✓	✓
BIVALVIA	Sphaeriidae	sp.			✓
Cladocera	sp.			✓	
Coleoptera	Curculionidae	sp.	✓		
Coleoptera	Dytiscidae	Antiporus	✓		
Coleoptera	Dytiscidae	Platynectes	✓		
Coleoptera	Dytiscidae	sp.	✓		
Coleoptera	Elmidae	Austrolimnius		✓	✓
Coleoptera	Elmidae	Simsonia			✓
Coleoptera	Hydraenidae	Hydraena	✓		
Coleoptera	Hydrophilidae	Paracymus	✓		
Coleoptera	Hydrophilidae	sp.	✓		
COLLEMBOLA				✓	
Copepoda	Cyclopoida	sp.	✓	✓	
Diptera	Ceratopogonidae		✓	✓	✓
Diptera	*Chironominae*		✓	✓	✓
Diptera	Dolichopodidae	sp.	✓	✓	
Diptera	*Orthocladiinae*		✓	✓	✓
Diptera	Psychodidae	sp.	✓		
Diptera	Simuliidae	Austrosimulium	✓	✓	✓
Diptera	Simuliidae	Simulium	✓	✓	✓
Diptera	Stratiomyidae	Odontomyia	✓		
Diptera	Tabanidae	sp.		✓	
Diptera	*Tanypodinae*		✓	✓	✓
Diptera	Tipulidae	sp.	✓	✓	✓
Ephemeroptera	Baetidae	Baetis	✓	✓	✓
Ephemeroptera	Caenidae	Tasmanocoenis	✓	✓	✓
Ephemeroptera	Leptophlebiidae	Jappa			✓
Ephemeroptera	Leptophlebiidae	Ulmerophlebia		✓	✓
Gastropoda	Lymnaeidae	Pseudosuccinea	✓	✓	
Gastropoda	Lymnaeidae	sp.		✓	
Gastropoda	Physidae	Physa	✓	✓	
Odonata	Epiproctophora	sp.		✓	
Oligochaeta	sp.		✓	✓	✓
Plecoptera	Gripopterygidae	Dinotoperla	✓	✓	✓
Plecoptera	Gripopterygidae	Illiesoperla		✓	
Plecoptera	Gripopterygidae	Trinotoperla	✓		
Temnocephalida	Temnocephalidae	Temnocephala		✓	
Trichoptera	Ecnomidae	Ecnomus			✓
Trichoptera	Hydrobiosidae	Ulmerochorema		✓	✓
Trichoptera	Hydropsychidae	Cheumatopsyche		✓	✓
Trichoptera	Hydroptilidae	Hellyethira	✓	✓	
Turbellaria	Dugesiidae	Dugesia		✓	

Appendix C - ANOSIM output for riffle and edge samples

Appendix C. ANOSIM output for riffle and edge samples

ANOSIM
Analysis of Similarities

One-Way Analysis

RIFFLE

Global Test
Sample statistic (Global R): 0.991
Significance level of sample statistic: 0.1%
Number of permutations: 999 (Random sample from 168168)
Number of permuted statistics greater than or equal to Global R: 0

Pairwise Tests

Groups	R Statistic	Significance Level %	Possible Permutations	Actual Permutations	Number >= Observed
b3, q1	1	0.2	462	462	1
b3, q2	1	1.8	56	56	1
q1, q2	1	1.2	84	84	1

EDGE

TESTS FOR DIFFERENCES BETWEEN # location GROUPS
(using # site groups as samples)
Global Test
Sample statistic (Global R): 0.529
Significance level of sample statistic: 0.1%
Number of permutations: 999 (Random sample from 125970)
Number of permuted statistics greater than or equal to Global R: 0

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

Appendix F. Macroinvertebrates predicted to occur with >50% probability by the AUSRIVAS model but were absent from the samples for the edge and riffle habitats. Number in cells represents their given probability of occurrence at a given site. Blank cells indicate they were collected at this site.

Edge

SITE		Oligochaeta	Ceratopogonidae	Baetidae	Leptophlebiidae	Caenidae	Corixidae	Gripopterygidae	Leptoceridae	
	SIGNAL SCORE	2	4	5	8	4	2	8	6	TOTAL NUMBER OF MISSING TAXA
CAS 1	1			0.62	0.83	0.94		0.64	0.88	5
BUR 1	1					0.94		0.66		2
BUR 2a	1			0.62		0.94	0.5		0.88	4
	2			0.62		0.94	0.5		0.88	4
	3			0.62		0.94	0.5		0.88	4
BUR 2b	1			0.63	0.85	0.94		0.69	0.89	5
	2			0.63	0.85	0.94		0.69	0.89	5
	3			0.63	0.85	0.94	0.44	0.69	0.89	6
BUR 3	1	1			0.85	0.94			0.88	4
	2			0.63	0.85	0.94			0.88	4
	3			0.63	0.85	0.94				3
QBYN 1	1						0.46			1
	2		0.63				0.46	0.68		3
	3							0.68		1
	4									0
	5							0.68		1
	6		0.63							1
QBYN 2	1			0.62	0.84		0.46	0.67		4
	2			0.62			0.46	0.67	0.89	4
	3			0.62	0.84		0.46	0.67	0.89	5

Appendix F (cntd). Macroinvertebrates predicted to occur with >50% probability by the AUSRIVAS model but were absent from the samples for the edge and riffle habitats. Number in cells represents their given probability of occurrence at a given site.

Riffle

SITE	SIGNAL	Sphaeriidae	Acarina	Elmidae	Psephenidae	Tipulidae	Ceratopogonidae	Tanypodinae	Chironominae	Baetidae	Leptophlebiidae	Caenidae	Gripopterygidae	Hydrobiosidae	Glossosomatidae	Hydropsychidae	Conoesucidae	TOTAL NUMBER OF MISSING TAXA
		5	6	7	6	5	4	4	3	5	8	4	8	8	9	6	7	
BUR 3	1		0.77	0.93						0.65	0.83	0.87				0.54		**6**
	2		0.77	0.93		0.5					0.83	0.87				0.54		**6**
	3			0.93		0.5					0.83					0.54		**4**
	4			0.93		0.5					0.83	0.87				0.54		**5**
	5			0.93		0.5				0.65	0.83	0.87				0.54		**6**
QBYN 1	1	0.58		0.91			0.51			0.68						0.51		**5**
	2	0.58								0.68						0.51		**3**
	3	0.58		0.91			0.51				0.76	0.86				0.51		**6**
	4	0.58					0.51			0.68		0.86				0.51		**5**
	5	0.58		0.91			0.51			0.68						0.51		**5**
	6	0.58		0.91			0.51			0.68		0.86				0.51		**6**
QBYN 2	1			0.94	0.52								0.89		0.57		0.52	**5**
	2				0.52			0.69	0.93				0.89	0.51	0.57		0.52	**7**
	3				0.52			0.69							0.57		0.52	**4**