Ecowise Environmental

ACTEW Corporation

Murrumbidgee Ecological Monitoring Program

Part 2: Burra Creek

Autumn 2009

Brisbane - Canberra - Melbourne - Sydney - Regional offices

CERTIFICATE OF APPROVAL FOR ISSUE OF DOCUMENTS

Report Title: Burra Creek Assessment autumn 2009

Document No: CN21106360-2009-002

Project Title: Murrumbidgee Ecological Monitoring Program

Document Status: Final Report

Date of Issue: 11/02/2010

Client: ACTEW Corporation

Cover photograph: Burra Creek Downstream of London Bridge Autumn 2009

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Document Revision Control

Version	**Description of Revision**	**Person Making Issue**	**Date**	**Approval**
1	Final Report	Phil Taylor	11/02/10	NM

Ecowise Australia Pty Ltd ABN 94 105 060 320

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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 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 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 establish 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. *Establish current macroinvertebrate community data 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. *Establish 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 autumn 2009. Sampling was completed in May 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) Establish biological signatures at each site prior to the commencement of pumping;
b) enable subtle changes to be detected if there are impacts associated with reduced flows.

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

- *All sites in Burra Creek were dry at the time of sampling so no assessment was possible*;*
- *Assessments of the Queanbeyan River sites show that the upstream control site was categorised as Band B "significantly impaired" and the site downstream of the Burra Creek confluence was Band C "severely impaired" by the ACT AUSRIVAS assessment;*
- *There were clear differences between upstream and downstream sites in macroinvertrate community assemblages based on ANOSIM results. There is evidence from the field observations to suggest that differences in habitat quality are the chief cause of these differences rather than water quality. Low flows may also be impacting on these assemblages, but large sediment deposits downstream of the Burra Creek confluence are likely to be driving these patterns;*
- *Water quality was generally good based on the available data for Burra Creek. Some changes are apparent towards the end of the season, with decreases in EC and temperature; these are expected naturally as ambient temperatures decrease and dilution effects become more important with an increasing contribution from groundwater;*
- *Most water quality parameters are at levels within ANZECC (Australian and New Zealand Conservation Council) guidelines. Nutrient concentrations exceeded guideline targets at both sites on the Queanbeyan River and D.O (% sat.) exceeded guideline values at the time of sampling at Flynn's Crossing on the Queanbeyan River;*
- *Improvements in macroinvertebrate communities may improve with increasing flows but is unlikely downstream of the Burra Creek confluence unless sediment is transported away by high natural flows.*

It is recommended that the current sampling protocols remain as they are for the next round of sampling, but a review of the sample sites and methodology will be required if Burra Creek remains dry.

*On subsequent visits, these sites remained dry.

List of abbreviations

ACT – Australian Capital Territory
ACTEW – ACTEW Corporation Limited
AFDM – Ash Fee Dry Mass (periphyton)
ANOVA – Analysis of Variance (statistics)
AUSRIVAS – Australian River Assessment System
CMA – Catchment Management Authority
CRCFE – Cooperative Research Centre for Freshwater Ecology
EIS – Environmental Impact Statement
EPA – Environmental Protection Authority
GL/a – Gigalitres per annum
GPS – Global positioning system
IBT- Inter-Basin Water Transfer
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
WAE – Water Allocation Entitlement

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 recording at the Burra Creek stream flow gauge in 1985 through to 2000, the mean daily flow was 14.5 ML/d, however over the last five years (in the current drought) flows have reduced substantially with a mean daily flow of just 1 ML/d. Since flow records began in 1985 a mean monthly flow of 100ML/d has only been exceeded six 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 beneficial ecological effects could be expected in the reaches of Burra Creek between the discharge point and downstream of the confluence of the Queanbeyan River including the increased utilisation of fish species and increased biodiversity in the macroinvertebrate communities. These 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 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 pose a 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 in order 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 AURIVAS 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 autumn 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 sort advice by 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 before it was finalised due to difficulties in finding appropriate control sites and. 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, Biggs *et al.*, 1999, Whitton and Kelly, 1995). As changes in flow volume are expected with the proposed changes in the flow regime in the Murrumbidgee River, 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 organisms 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	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.

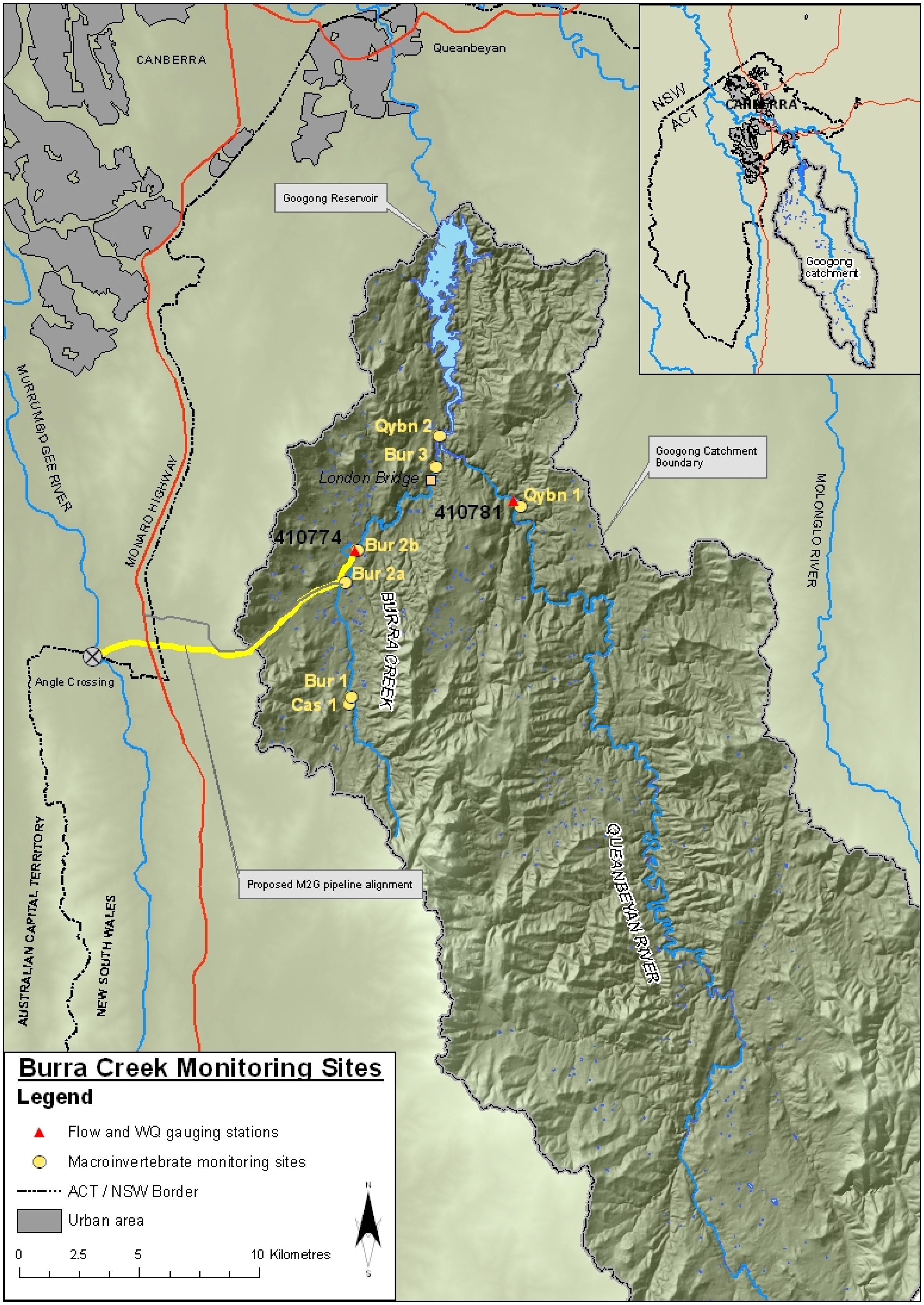

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Figure 1. Locality map showing monitoring sites and gauging stations

Bur 1.Looking upstream

Bur 2*b.* Looking upstream towards bridge

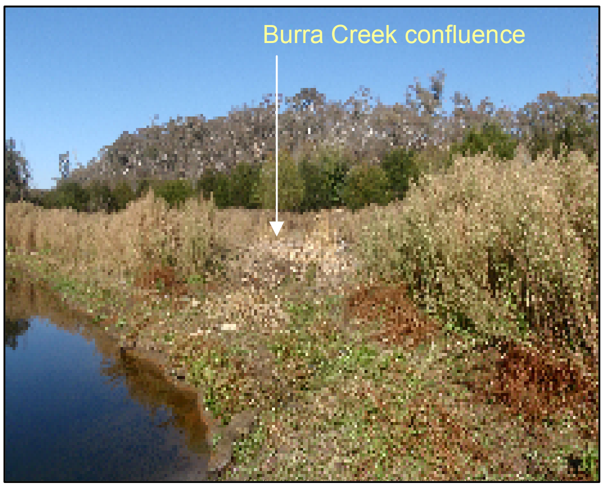
Bur 2*b.* Downstream of Burra Road Bridge

Bur 3. Looking upstream towards London Bridge

Qbyn 1. Flynn's Crossing

Figure 2. Sites photographs: May 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

Figure 2 cntd. Site photographs taken in May 2009

2.2 Sampling details

Sampling occurred in May 2009 with flows indicated in Figure 2 (section 3.1). All sampling was carried out by AUSRIVAS accredited staff. Weather during sampling was fine and dry.

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 autumn riffle and edge AUSRIVAS (Australian River Assessment System) protocols (Coysh *et al.*, 2000) during autumn (May 18th and 19th) 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 granted access 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 sampling sites selected for this project (Table 1, shown earlier) were sampled for periphyton in autumn 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 gm^{-2}), and chlorophyll-a. Samples for Ash Free Dry Mass (gm^{-2}) and chlorophyll-a analysis were filtered onto glass filters and frozen. Sample processing 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 (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. 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). The first 200 animals were identified (identification followed taxonomic keys published by Hawking (2000) and if 200 were identified before a cell had been completely analysed, identification continued until the animals within the entire cell were identified. Data was entered directly into electronic spreadsheets to eliminate errors associated with manual data transfer.

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

An analysis of similarities (ANOSIM) was performed on the data to test whether macroinvertebrate communities were statistically different upstream and downstream of the proposed discharge point. Sites were nested within location for the purposes of the analysis.

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

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

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

2.7.3 AUSRIVAS assessment

AUSRIVAS is a prediction system that uses macroinvertebrates to assess the biological health of rivers and streams. Specifically, the model uses site-specific information to predict the macroinvertebrate fauna Expected (E) to be present in the absence of environmental stressors. The expected fauna from sites with similar sets of predictor variables (physical and chemical characteristics influenced by non-human characters, e.g. altitude) are then compared to the Observed fauna (O) and the ratio derived is used to indicate the extent of any impact (O/E). The ratio derived from this analysis is compiled into bandwidths (i.e. X, A-D; Table 4) which are used to gauge the overall health of particular site (Coysh *et al.* 2000). Data is presented using the AUSRIVAS O/E 50 ratio (Observed/Expected score for taxa with a >50% probability of occurrence) and the previously mentioned rating bands (Tables 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 unreliability of the results.

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

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

	Riffle	Edge	
Band	**O/E bandwidth**	**O/E bandwidth**	**Explanation**
X	>1.12	>1.17	*More diverse than expected. Potential enrichment or naturally biologically rich.*
A	0.63- 0.87	0.82-1.17	*Similar to reference. Water quality and / or habitat in good condition.*
B	0.63-0.85	0.48-0.82	*Significantly impaired. Water quality and/or habitat potentially impacted resulting in loss of taxa.*
C	0.39-0.63	14-0.48	*Severely impaired. Water quality and/or habitat compromised significantly, resulting in a loss of biodiversity.*
D	0-0.39	0-0.14	*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

To test whether estimated biomass (as AFDM) and live content (Chlorophyll-a) were different between sites upstream and downstream of the proposed discharge point, t-tests were performed on Log_e-transformed data. Log transformation was necessary to meet the assumptions of normality. After the sample collection, six of the twelve samples were allocated for chlorophyll-*a* analysis, while the remaining six samples were used to estimate the total organic content of the periphyton sample by Ash Free Dry Mass (AFDM). Samples were then filtered onto individual glass filters.

Data were pooled within sites upstream and downstream because the current aim is to determine upstream (control) and downstream (impact) effects rather than site specific-effects. Data were back-transformed for graphical visualization.

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 maintain current ACT AUSRIVAS accreditation.

3 Results

3.1 Hydrology and rainfall

The average flow for autumn 2009 recorded at the Burra Road gauging station was 0.05 ML/d (discounting March when there were 31 no flow days). In the Quenbeyan River for the same period the average flow was 5.7 ML/d (Table 5). April was the wettest autumn month with almost 60 mm of rain recorded at the Burra Creek station, this did not generate much surface run off given that flows in Burra Creek were still nil, but probably contributed to groundwater recharge. The reoccurrence of flow in May without corresponding rainfall suggests a delay between the April rainfall, aquifer recharge and underground transport to the upwelling zone near the gauging station (Figure 2).

Sampling occurred approximately one month after the heaviest rainfalls in April (Figure 2). Surface flow in Burra Creek had re-commenced by this stage but was almost entirely groundwater sourced and was <0.1 ML/d for 71% of the month.

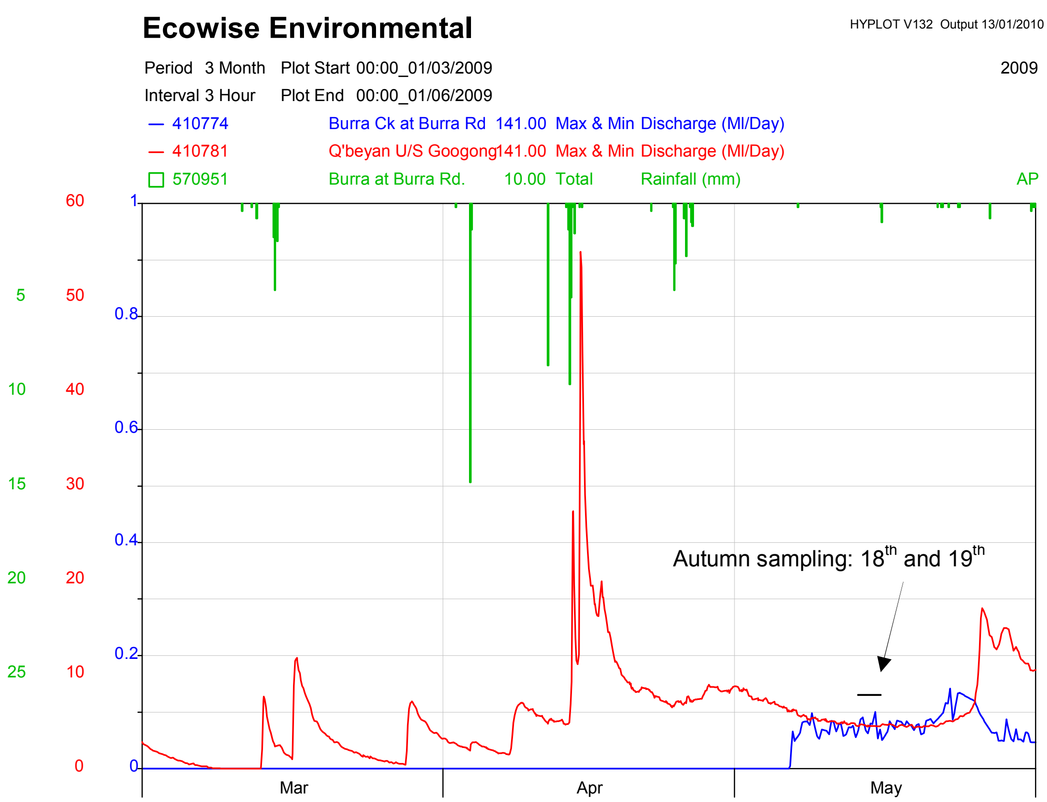


Figure 3. Autumn hydrograph of Burra Creek and the Queanbeyan River*

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

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

Site	Burra Creek		Queanbeyan River	
	Rainfall Total (mm)	Mean Flow (ML/d)	Rainfall Total (mm)	Mean Flow (ML/d)
March	10.0	0	12.8	2.3
April	58.8	0.04	59.8	8
May	4.2	0.06	8.4	7
Autumn	73.0	0.05	81.0	5.7

3.2 Water quality

Surface water quality was gauged for 26 days in autumn 2009 at Burra Road bridge (410774) (Figure 3). Data was available for the entire autumn period in the Quenbeyan River (410781) and is presented in **Appendix A.**

Water temperature in Burra Creek was consistent for the recorded period, with an average of 7 °C. Diurnal variation was low, with the daily maximums reaching between 2 and 3 degrees higher than the overnight low.

The average turbidity for the month was <1 NTU, well below ANZECC (2000) water quality guidelines. The maximum turbidity of 7.6 NTU was recorded at the commencement of surface water flow. Daily means show little variation for the period, with a maximum daily mean of 1.4 NTU and a minimum of 0.4 NTU. pH was consistent throughout the month with an average of 7.3 and recording a minimum of 6.9 and maximum of 7.5. Dissolved oxygen and electrical conductivity tended to decrease over the month of May. In the case of dissolved oxygen, the degree of diurnal variation reduced from afternoon maximums of 123% at the beginning of the month, to <70% by the end of the month. The average electrical conductivity in Burra Creek was 743 µs/cm but varied up to 60% of the mean value with maximum values exceeding 1000 µs/cm.

The grab sample results for the Quenbeyan River are summarised in Table 5.

As already stated, the designated sites for this program remained dry at the time of sampling so no grab samples were collected for this round of sampling. Nutrient levels in the Quenbeyan River were in excess of the recommended guidelines (ANZECC, 2000) (Table 6.) Total Nitrogen was exceeded at both sites, with the upstream site (Qbyn 1) downstream site (Qbyn 2) recording similarly high values (0.34 and 0.35 respectively). Total phosphorus was >50% higher than the guideline limits at the downstream site, while the upstream control remained within the guidelines. All other parameters were within the expected limits for lowland ecosystem health, except for dissolved oxygen (% saturation) at Qbyn 1 (upstream), which recorded 116.0% - exceeding the upper guideline limits of 110%.

3.3 Periphyton

Periphyton was not sampled in Burra Creek in autumn 2009 because all of the sites were dry.. The results from the Quenbeyan River sites do, however, show some differences between locations. The average ash free dry mass (AFDM) was not significantly different upstream (mean = 1062 mg/m^{-2}) and downstream (mean = 1083 mg/m^{-2}) of the Burra Creek confluence ($t_{10} = 0.246$, P=0.88); however, there were apparent differences in the chlorophyll-a content between these sites with the mean content upstream (mean = 11296 $\mu g/m^{-2}$) being an order of magnitude higher than Qbyn 2, downstream of the Burra creek confluence (mean = 11296 $\mu g/m^{-2}$) ($t_{10} = 6.79$, $P<0.001$) (Figure 4).

The lack of site replication limits the ability to correlate these data with physical habitat and water quality variables. However, field observations demonstrate obvious differences in the stability, heterogeneity and degree of sedimentation in the substrate between sites.

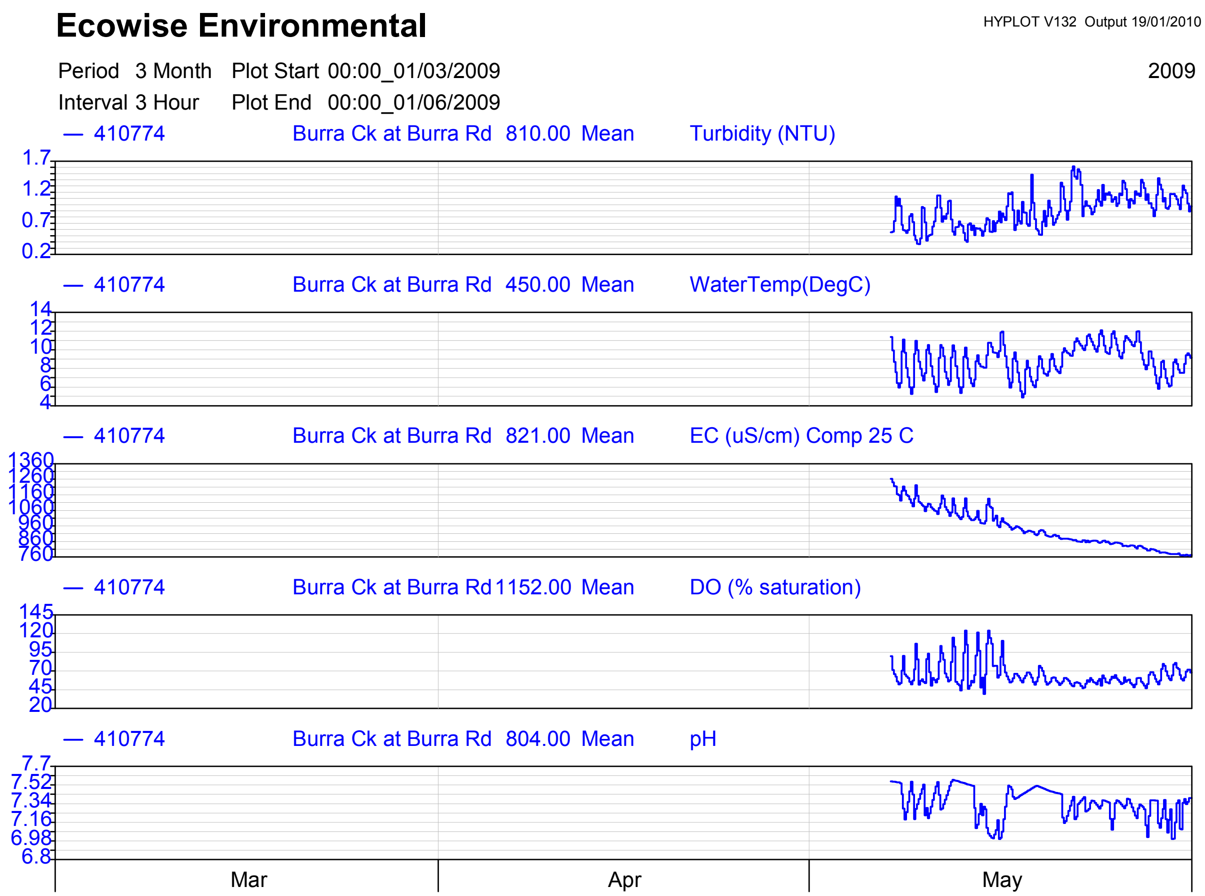


Figure 4. Water quality records from Burra Creek during autumn 2009

The missing data for March, April and the first two weeks in May were due to the absence of surface water in Burra Creek at this time

Table 6. *In-situ* water quality results from autumn 2009. (ANZECC guidelines are in red). Yellow cells indicate values outside ANZECC (2000) guidelines. Refer to Table 2 for site location details.

* Site dry

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)	Ammonia (mg/L)	TP (mg/L) (0.02)	TN (mg/L) (0.25)
Control sites	Cas 1	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	Bur 1	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	Qbyn 1	13.12	9.6	65	1.5	7.9	116.0	12.10	42	<0.01	<0.01	<0.01	<0.01	0.012	0.34
Impact sites	Bur 2a	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	Bur 2b	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	Bur 3	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	Qbyn 2	10.05	5.5	93	2.7	7.8	98.0	11.39	42	<0.01	<0.01	<0.01	<0.01	0.031	0.35

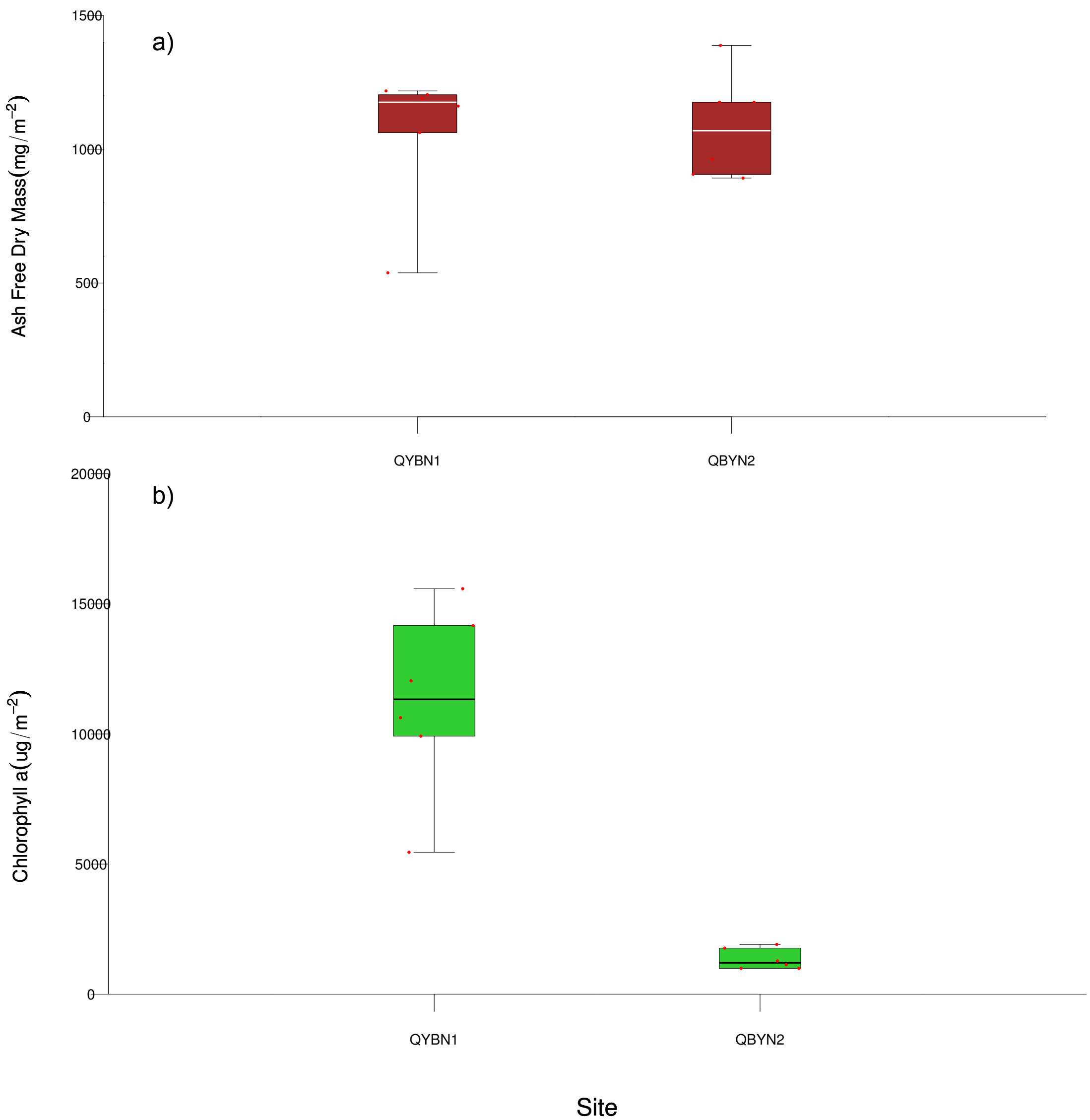


Figure 5. The distribution of a) ash fee dry mass (AFDM) and b) chlorophyll-a in the Queanbeyan River

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

3.4 Macroinvertebrate communities

Macroinvertebrate communities were not sampled in Burra Creek because all sites were dry at the time of sampling, including pool/edges that were present during the initial site visits. The sites on the Queanbeyan River were sampled, although only one replicate sample was possible at Qbyn 2 (downstream of the Burra Creek confluence) due to a lack of habitat.

The ANOSIM analysis detected highly significant differences in the riffle macroinvertebrate communities between the two sites on the Queanbeyan River (R= 0.99; P=0.036) and differences in the edge communities (R=1; P=.10)*. The high global R-statistic suggests that all the replicate samples within each site are more similar to one another than any of the replicates form other sites (Clarke and Warwick, 2001). This can be seen in the NMDS plots (Figures 6 and 8).

The NMDS solution in this case (Figures 6 and 8) is known as a "degenerate" solution, because all of the within site samples are tightly clustered and have collapsed onto a single point. This happens when all of the within –site dissimilarities are smaller than all of the between site dissimilarities (Anderson *et al.*, 2008). For the purpose of clarity, the relationships between and within sites is best determined through the cluster analysis for the riffle (Figure 5) and edge (Figure 6) habitats.

The differences in macroinvertebrate assemblages across sites and habitats can be seen in the taxonomic inventory presented in **Appendix C.** The inventory is presented as a presence/absence matrix which demonstrates several patterns between the two sites, and the habitats sampled within those sites. For example, Qbyn 1 has more taxa in both the riffle and edge habitats (Table 7); and most notable is the absence of Coleopterans (beetle larvae), lower mayfly and caddisfly diversity and absence of Plecopterans (stoneflies) downstream of the Burra Creek confluence.

3.4.1 Riffles

In total, 70 genera representing 37 families were collected from the upstream, control site on the Quenbeyan River (Qbyn 1) (Table 6). This site was characterized by high diversity in the Dipterans (true flies): Ceratopogonidae (SIGNAL= 4); s/f Chironominae (SIGNAL =3); s/f Orthocladiinae (SIGNAL =4) and Caddisfly family, Hydroptilidae (SIGNAL = 4). Elmidae (SIGNAL =7) (riffle beetles) were particularly abundant. Below the Burra Creek confluence there was a sharp decline in the number of different taxa recovered from the samples, with 29 genera in 17 families being collected. As noted previously, mayfly and caddisfly diversity was considerably lower, coleopterans were absent from the site, as were stoneflies. The other notable feature was the much fewer individuals at the downstream sites than at the upstream sites (~2200 individuals upstream *cf.* ~150 downstream) some groups of taxa (e.g. Leptoceridae: SIGNAL =6) were represented only by a single individual.

3.4.2 Edges

The edge samples were diverse at the downstream site, with 49 genera in 29 families being collected (Table 7). A total of 60 genera in 37 families were collected at Qbyn 1. The edge samples upstream were comprised of the level of diversity in the Dipteran families mentioned above, but in much lower numbers. At site Qbyn 2, downstream of the confluence, Orthocladiinae, Tanypodinae and Chironominae were present in high numbers; as were the numerically dominant Baetidae (SIGNAL =5), Leptophlebiidae (SIGNAL=8) and Caenidae (SIGNAL = (4) (all families of mayfly).

*The small number of replicates is reflected in the relatively large p-value; more replicates allows for a more sensitive test in PRIMER because the p-value is generated through re-sampling and as such is directly related to the number of distinct permutations. In this case ten. Therefore the p-value can never be more than 1 in 10, or 10%.

Table 7. Summary of metrics based on macroinvertebrate community data for autumn

	Edge		Riffle	
	Queanbeyan 1	Queanbeyan 2	Queanbeyan 1	Queanbeyan 2
Taxonomic richness – genus	60	49	70	29
Taxonomic richness – family	37	29	37	17
% sensitive taxa	/	/	25	11
% tolerant taxa	/	/	63	80

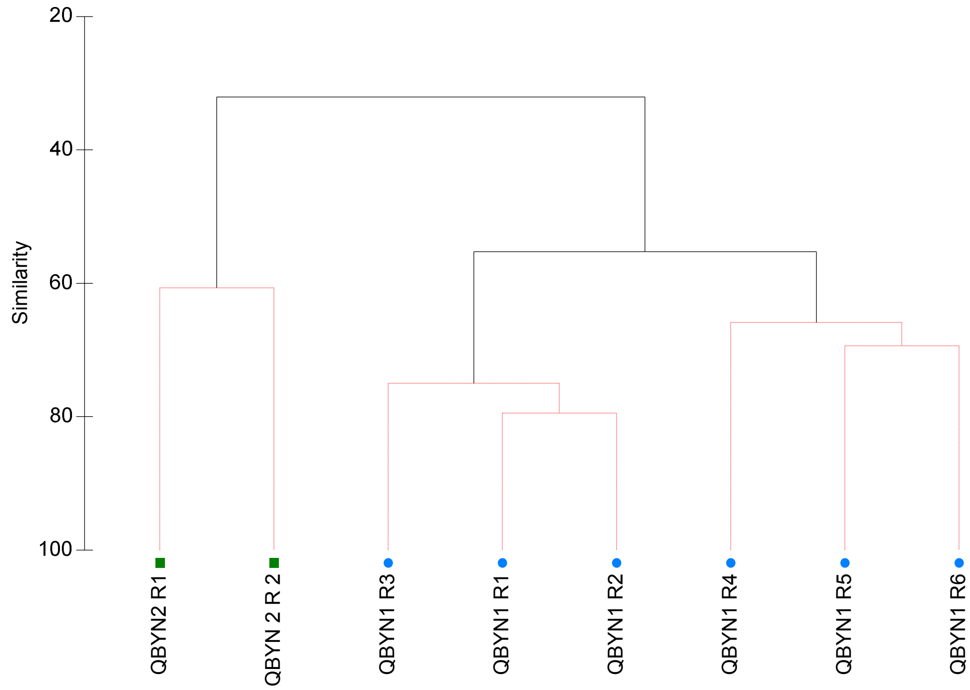


Figure 6. Cluster analysis for autumn riffle samples. Blue circles indicate upstream control site, green squares are the downstream impact site. Red lines indicate significant groups determined by the SIMPROF analysis.

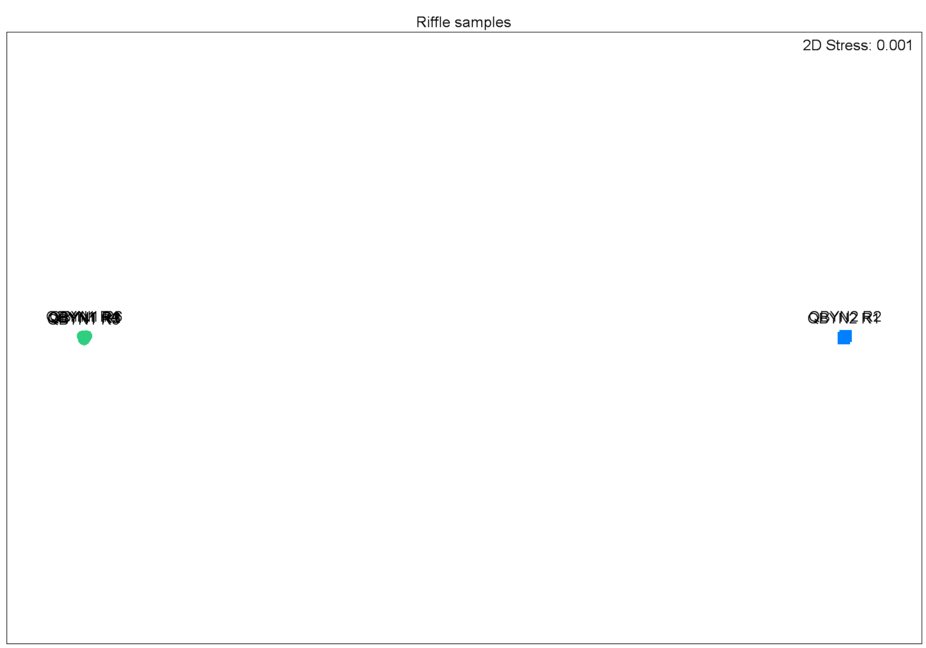


Figure 7. Non-metric multidimensional scaling of autumn riffle samples.

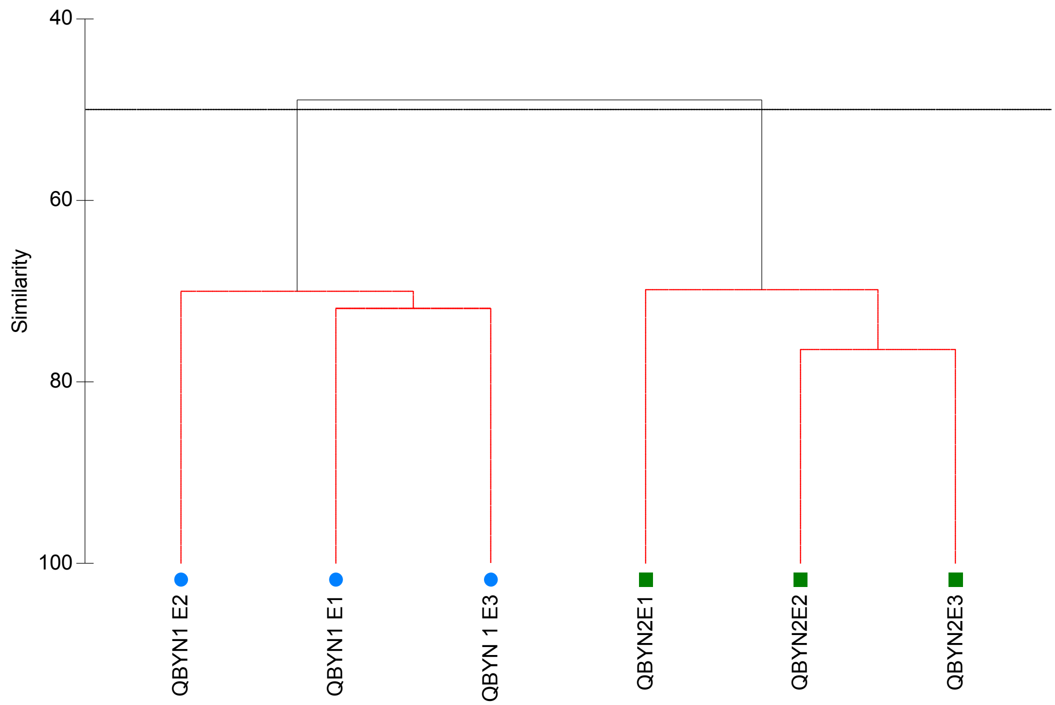


Figure 8. Cluster analysis for autumn edge samples. Blue circles indicate upstream control site, green squares are the downstream impact site. Red lines indicate significant groups determined by the SIMPROF analysis.

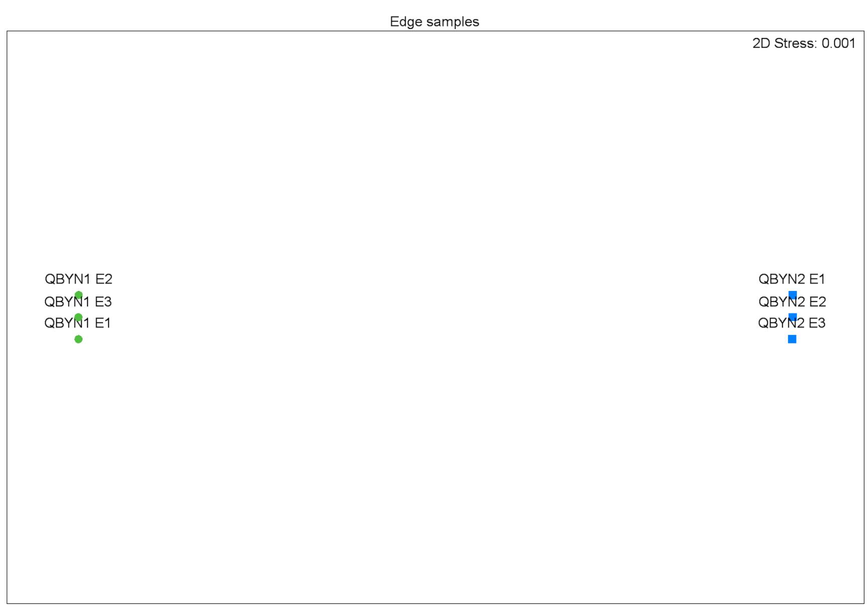


Figure 9. Non-metric multidimensional scaling of autumn edge samples

3.5 AUSRIVAS assessment

At both sites sampled in this assessment, the riffle zone had a lower health assessment band than the edge habitat. At Qbyn 1, the final assessment was Band B – *"significantly impaired"* and for Qbyn 2, downstream of the Burra Creek confluence the overall site assessment was Band C – *"severely impaired"*. There are two points to note regarding these assessments however: 1) At Qbyn 1, five of the six samples (83%) were assessed as Band A – *"close to reference"* and 2) The third sub-sample, which was assessed as Band B, only had one additional family missing, which was otherwise present in all the other sub-samples.

Taxa predicted to occur with >50% probability, but absent from the samples are presented in **Appendix D.**

Qbyn 2 recorded the most missing taxa (14), which were predicted to occur with >50% probability. This was almost double the number of taxa missing from the upstream control site. Among the taxa that were not collected were the highly sensitive Elmidae (SIGNAL =7), Leptophlebiidae (SIGNAL =8) and Hydrobiosidae (SIGNAL =8)); at the other end of the scale however the tolerant Hydrophilidae (SIGNAL =2) was also predicted but missing from the samples.

Glossosomatidae (SIGNAL =9) was missing from all subsamples except in sub-sample 5 at Qbyn 1. This is a highly sensitive caddisfly that is usually associated with a stony environment with cool, fast flowing water.

The edge habitat had a higher health assessment at both sites. Qbyn 2 had twice the missing taxa that Qbyn 1 recorded. Synlestidae (SIGNAL =7) and Conoesucidae (SIGNAL=7) were missing from all samples; while the highly sensitive, Gripopterygidae (SIGNAL =8) was absent only from Qbyn 2. Other missing taxa include: Ecnomidae (SIGNAL =4), Planorbidae (SIGNAL =2) and Leptophlebiidae (SIGNAL =8) from both sites.

Table 8. AUSRIVAS and SIGNAL scores for autumn

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	*5.43*	*4.50*	*0.90*	*0.93*	A	A	**B**	**A**	**B**
Qbyn 1	2	*5.36*	*4.00*	*0.90*	*0.93*	A	A			
Qbyn 1	3	*4.83*	*4.92*	*0.77*	*0.93*	B	A			
Qbyn 1	4	*5.36*	*na*	*0.90*	*na*	A	*na*			
Qbyn 1	5	*5.27*	*na*	*0.96*	*na*	A	*na*			
Qbyn 1	6	*5.21*	*na*	*0.90*	*na*	A	*na*			
Qbyn 2	1	*4.70*	*4.20*	*0.60*	*0.78*	C	B	**C**	**B**	**C**
Qbyn 2	2	*4.63*	*3.78*	*0.48*	*0.70*	C	B			
Qbyn 2	3	*na*	*4.20*	*na*	*0.78*	*na*	B			

4 Discussion

4.1 Water quality

Burra Creek was dry during the sampling run, so no grab samples were taken for this period. Surface water appeared in early May but was still at very low levels. The continuous water quality results during this period were relatively constant apart from a 35% decline in the daily average electrical conductivity. The steady reduction in EC is likely to be related to either dilution effects from increasing flows, decreasing water temperatures or a combination of both factors (Figure 3). This pattern was also evident in the Queanbeyan River (**Appendix A**).

Grab samples from the Queanbeyan River show that most analytes were within ANZECC (2000) water quality guidelines with the exception of Total Nitrogen (TN) and Total Phosphorus at Qbyn 2, and Dissolved Oxygen (% saturation) at Qbyn 1 (Table 6). Total Phosphorus levels were nearly three times that of the upstream site, suggesting that the source is either downstream of Qbyn 1 on the Queanbeyan River and/or enters via one of the Queanbeyan River tributaries. Verhoff *et al.* (1982) suggests that sediment transport is a major source of phosphorous in streams, so one possibility is that the high concentrations in the Queanbeyan River originated in Burra Creek and moved downstream attached to sediments from runoff and bank erosion. The large sediment deposits downstream of the Burra Creek tributary support this suggestion, as sedimentation loads are minimal just upstream of the confluence. Grab samples at a location upstream of the Burra Creek confluence will be required to confirm this.

4.2 River health and patterns in macroinvertebrate community assemblages

The AUSRIVAS river health assessment was limited to sites on the Queanbeyan River only. The upstream control site (Qbyn 1) appears to be in good ecological health, despite an overall site assessment of Band B, which was the result of a single family missing from a single sub-sample. Taxa present at this site are indicative of quality habitat and high quality water, and the number of taxa predicted to occur, but missing from the AUSRIVAS model, emphasizes the differences between the two sites (**Appendix D**).

Macroinvertebrate taxa such as Gripopterygidae (Plecoptera); Elmidae (Coleoptera); Glossosomatidae (Trichoptera) and Corydalidae (Megaloptera) all require medium to fast flowing cool, well oxygenated water (Gooderham and Tsyrlin, 2005). At Qbyn 2, all these taxa were absent, including the generally more pollution and silt tolerant Caenidae (Ephemeroptera). Simuliidae require relatively clean, silt free habitat (Zhang *et al.*, 1998) and although they were present at Qbyn 2, their abundance (~23 individuals) was an order of magnitude lower than found upstream. This is consistent with Bond *et al.* (2008) who suggests that the decline of such taxa is directly linked to the reduction and cessation of flows in river systems

Elmidae (the riffle beetle) were completely absent from site Qbyn 2. Elmidae appear to use the edge habitat as a refuge (Ecowise, 2009*b*) during periods of low flows and stress in riffle zones. Their absence at this site suggests that the edge habitat is also of poor quality, having little coarse particulate organic matter and almost no trailing vegetation (Figure 1). The evidence of absent taxa and taxa abundances between sites suggests that the apparent differences in habitat availability between sites are determining these different communities. Taxa richness at Qbyn 2 was less than half that recorded at Qbyn 1 (Table 7), which is a further reflection of the nature of the availability and heterogeneity of the substrate – generally a highly heterogeneous and stable habitat will support more taxa (Death and Winterbourn, 1995, Englund and Malmqvist, 1995), while competition will often limit diversity in restricted or contracting environments (Allan and Castillo, 2008, Stanley *et al.*, 1997).

The evidence from the macroinvertebrate data suggests that a combination of low flows and poor habitat quality downstream of the Burra Creek confluence are the main drivers of the poor river health assessment at this site.

5 Conclusions

A complete assessment of all the designated sampling sites was limited by several sites being dry in autumn 2009. This included pools in Burra Creek which usually contain surface water. The current assessment did show however, that the upstream control site on the Queanbeyan River and the downstream impact site have very different macroinvertebrate assemblages. Upstream, the ecological condition of the river is good, with most sensitive taxa predicted to occur being collected in the AUSRIVAS samples. Water quality was of a high standard, with the exception of slight nutrient enrichment, which might have contributed to a slight increase in filamentous algal growth. Downstream of the Burra Creek confluence, the macroinvertebrate communities lacked both tolerant and sensitive taxa, which were expected to occur, indicating a system under stress.

The water quality results from site Qbyn 2 are not suggestive of a degraded site (again, apart from slight nutrient enrichment). The most influential factor driving the predominantly tolerant species in the macroinvertebrate community is the high degree of sedimentation (~1.2m deep at one point) which is likely being deposited via Burra Creek, whose confluence is 180m upstream. Low flows are also likely to be causing problems at this site, with very shallow riffle zones and the edge habitat contracting. The combination of these factors will be influencing diurnal patterns in temperature and dissolved oxygen, and over prolonged periods will ultimately influence ecological processes at this site (Boulton, 2003).

Higher flow volumes might improve the depth, available habitat and water quality at Qbyn 2, but are unlikely to improve the quality of the substrate unless flows are high enough to transport the larger, coarser materials from further upstream.

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) Site selection for this program was based on a balanced statistical design of control and impact sites including tributaries to provide a degree of statistical independence (Downes *et al.*, 2002) from the main channels. Sites were chosen based on previous site visits to include both riffle and edge habitats to achieve comprehensive site assessments. At the time of sampling, however, all the Burra Creek sites were dry, including the pool/edges which previously contained some surface water. In the event that this trend continues, sites should be re-located based on further site assessments and should include permanent pools and / or macrophyte beds.

2) To pursue the source of the elevated TP levels below the Burra Creek confluence, further water quality samples will be required, downstream of Flynn's Crossing, but upstream of the confluence. Washpen Crossing would be a good option.

3) To provide a reliable assessment of any biological changes that might occur in Burra Creek resulting from increased flow discharged from the Murrumbidgee River, a basic understanding of natural spatial and temporal variation is required. The lead time given in this project provides ample time to achieve this. However, if Burra Creek remains dry and suitable alternative sites cannot be found (stated in "1" above) then further adaptations might be required, which move away from an RBA approach (i.e. AUSRIVAS). This might include, but not be limited to:

- Protocols similar to those by described by Wright (1984, 1992) which will allow sampling during periods of low or no surface flow, by targeting specific biotopes such as the prolific macrophyte flora in Burra Creek in the semi-permanent pools. This has been suggested previously by an anonymous reviewer (Anonymous, 2009) and might benefit the program by targeting different plant species which often have distinct faunal associations (e.g. Harrod, 1964).
- Consideration of the hyporheic fauna in Burra Creek. The hyporheic zone (sub-surface) has been shown to contain an abundant macroinvertebrate fauna (Williams and Hynes, 1974) which can serve as a refuge for macroinvertebrates in periods of drought and other environmental stressors. Adding the HZ to the existing program as a third habitat (i.e. riffle, pool/edge, and hyporhiec zone) would 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 hyporhiec 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.
- Adopting the above approaches, combined with AUSRIVAS assessments when possible in the framework of a multiple lines of evidence approach (Downes *et al.*, 2002, Lind *et al.*, 2007) will provide a tool to recognise deviations from background trends that can be used as evidence of for suspected impacts related to discharges into Burra Creek.

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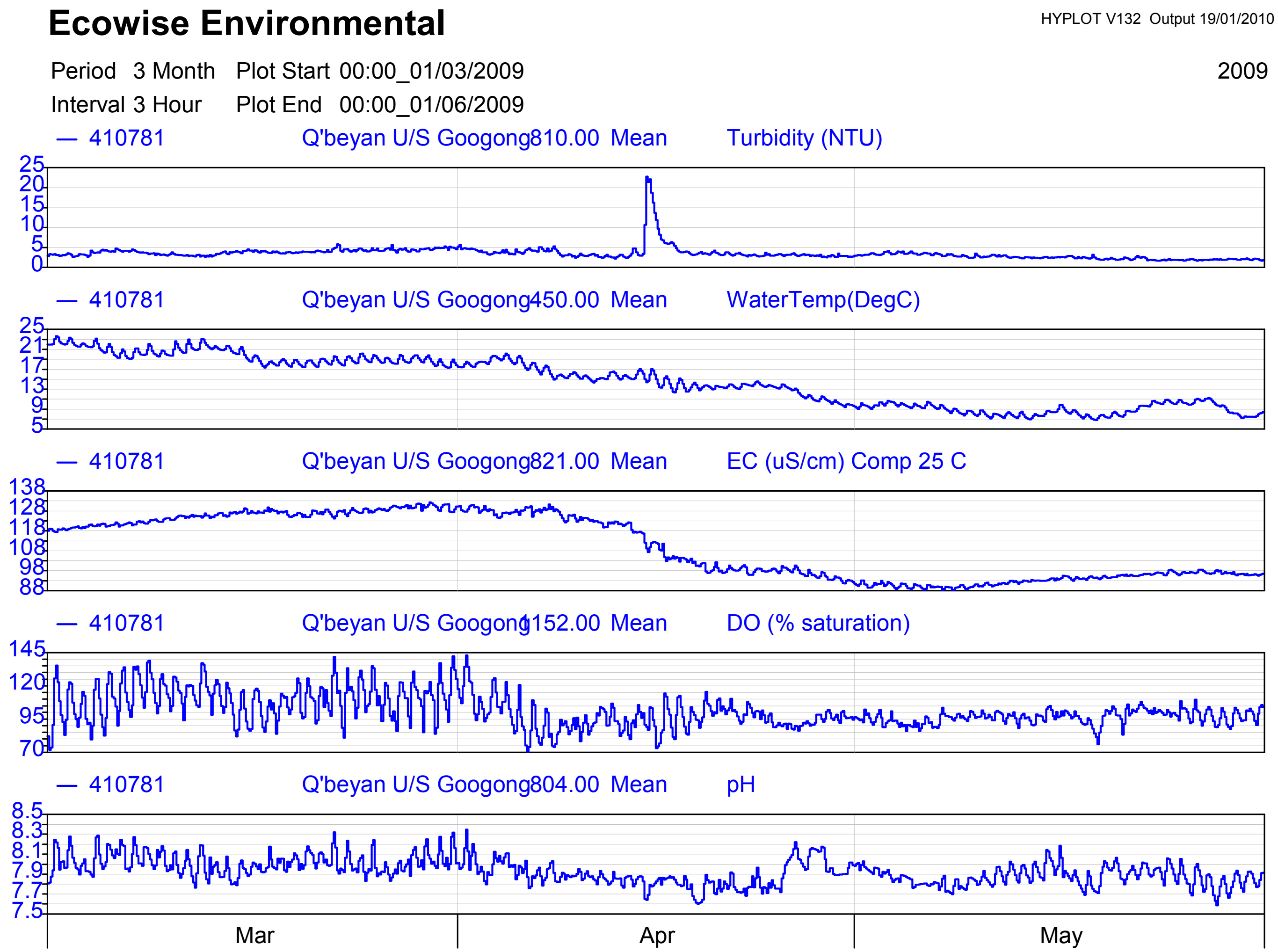
A P E N D I C E S

Appendix A –

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

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

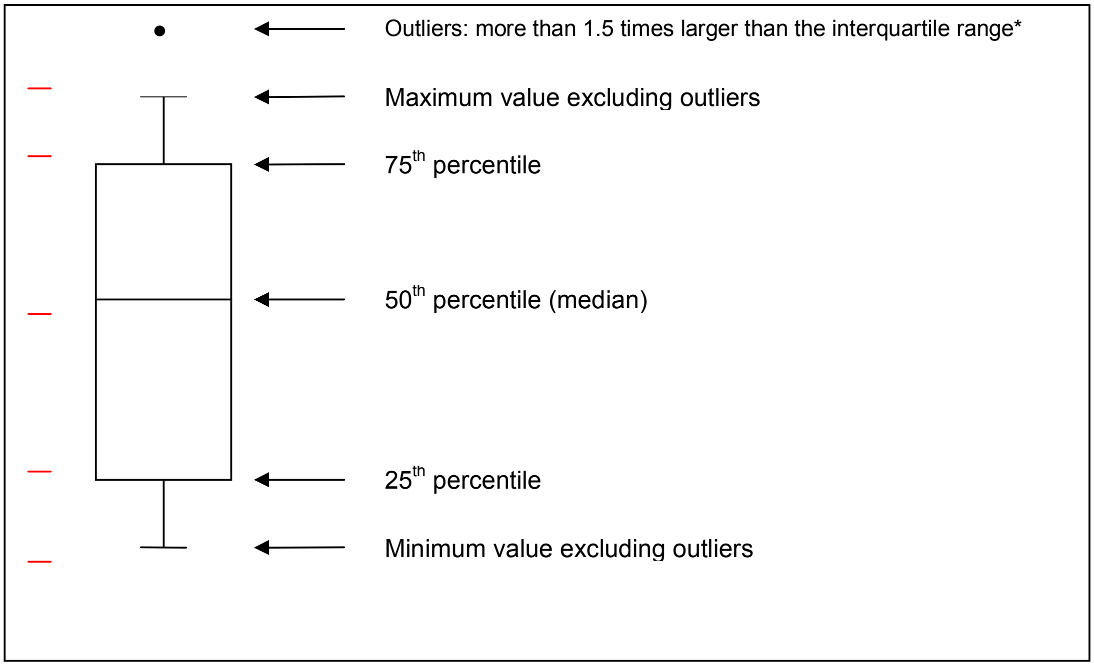


Appendix B –

Interpreting box and whisker plots

Appendix B. Interpreting box and whisker plots

Box and whisker plots are intended as an exploratory tool to help describe the distribution of a dataset. The red points on the inside of the plot area indicate the raw data values that make up the distribution portrayed in the boxplot. The plot below explains how the box and whisker plots should be read.



* The interquartile (IQR) range is the difference between the 25th and 75th percentile. This value is important when two sets of data are being compared. The closer the values are to the median, the smaller the IQR. Conversely, the more spread out the values are, the larger the IQR.

Appendix C
Taxonomic inventory of macroinvertebrates collected in the Queanbeyan River sites: autumn 2009

Appendix E. Taxonomic inventory of macroinvertebrates collected in the Queanbeyan River sites: autumn 2009

Order	Family	Genus	QBYN 1	QBYN 2	QBYN 1	QBYN 2
			Riffle	***Riffle***	***Edge***	***Edge***
Bivalvia	Corbiculidae	Corbicula	●			
Bivalvia	Sphaeriidae	Musculium (Sphaerium)				●
Bivalvia	Sphaeriidae	Pisidium			●	
Bivalvia	Sphaeriidae/ Corbiculidae	Sphaeriidae/ Corbiculidae	●	●	●	●
Cladocera	Cladocera	Cladocera			●	
Coleoptera	Dytiscidae	Dytiscidae				●
Coleoptera	Dytiscidae	Necterosoma				●
Coleoptera	Elmidae	Austrolimnius	●		●	
Coleoptera	Elmidae	Simsonia	●			
Coleoptera	Hydraenidae	Hydraena	●			
Coleoptera	Hydrophilidae	Hydrophilidae	●		●	
Coleoptera	Psephenidae	Sclerocyphon	●			
Coleoptera	Scirtidae	Scirtidae			●	●
Copepoda	Copepoda	Copepoda		●	●	●
Decapoda	Atyidae	Paratya	●		●	●
Diptera	Ceratopogonidae	Ceratopoginae	●		●	●
Diptera	Ceratopogonidae	Forcipomyiinae	●			●
Diptera	Ceratopogonidae	Ceratopogonidae	●	●	●	
Diptera	Chironominae	Cladotanytarsus	●	●	●	●
Diptera	Chironominae	Dicrotendipes	●		●	
Diptera	Chironominae	Chironominae	●			
Diptera	Chironominae	Polypedilum	●	●	●	●
Diptera	Chironominae	Tanytarsus	●	●	●	●
Diptera	Dolichopodidae	Dolichopodidae	●			
Diptera	Empididae	Empididae	●			
Diptera	Orthocladiinae	Cardiocladius	●	●	●	
Diptera	Orthocladiinae	Corynoneura	●	●	●	●
Diptera	Orthocladiinae	Cricotopus	●	●	●	●
Diptera	Orthocladiinae	Eukiefferiella	●		●	
Diptera	Orthocladiinae	Nanocladius			●	
Diptera	Orthocladiinae	Parakiefferiella	●			
Diptera	Orthocladiinae	Paralimnophyes			●	
Diptera	Orthocladiinae	Orthocladiinae	●	●		
Diptera	Orthocladiinae	Thienemanniella	●	●	●	
Diptera	Podonomidae	Podonomopsis	●	●	●	
Diptera	Simuliidae	Austrosimulium	●	●	●	
Diptera	Simuliidae	Simuliidae	●	●		
Diptera	Simuliidae	Simulium	●	●	●	●
Diptera	Stratiomyidae	Stratiomyidae			●	
Diptera	Tanypodinae	Ablabesmyia	●	●	●	●
Diptera	Tanypodinae	Coelopynia	●		●	●
Diptera	Tanypodinae	Tanypodinae	●			●
Diptera	Tanypodinae	Larsia			●	●
Diptera	Tanypodinae	Procladius	●		●	●
Diptera	Tanypodinae	Thienamannimyia				●
Diptera	Tipulidae	Tipulidae	●		●	

Order	Family	Genus	QBYN 1	QBYN 2	QBYN 1	QBYN 2
			Riffle	***Riffle***	***Edge***	***Edge***
Ephemeroptera	Baetidae	Baetidae	●	●	●	
Ephemeroptera	Baetidae	Centroptilum			●	●
Ephemeroptera	Caenidae	Caenidae	●	●	●	●
Ephemeroptera	Caenidae	Tasmanocoenis	●	●	●	●
Ephemeroptera	Coloburiscidae	Coloburiscoides				
Ephemeroptera	Leptophlebiidae	Atalophlebia	●		●	●
Ephemeroptera	Leptophlebiidae	Leptophlebiidae	●		●	●
Ephemeroptera	Leptophlebiidae	Jappa	●		●	●
Gastropoda	Ancylidae	Ferrissia	●		●	
Gastropoda	Lymnaeidae	Austropeplea			●	
Gastropoda	Lymnaeidae	Pseudosuccinea			●	
Gastropoda	Lymnaeidae	Lymnaeidae	●			
Gastropoda	Physidae	Physa	●		●	●
Gastropoda	Planorbidae	Glyptophysa	●		●	
Gastropoda	Planorbidae/physidae	Planorbidae/physidae	●	●	●	●
Hemiptera	Corixidae	Micronecta			●	●
Hemiptera	Corixidae	Sigara				●
Hemiptera	Notonectidae	Anisops				●
Hemiptera	Notonectidae	Enithares				●
Hemiptera	Veliidae	Microvelia			●	
Hirudinea	Glossiphoniidae	Glossiphoniidae	●			
Hydracarina	Hydracarina	Hydracarina	●		●	
Hydracarina	Oribatida	Oribatida	●			●
Lepidoptera	Pyralidae	Pyralidae				●
Megaloptera	Corydalidae	Archichauliodes	●			
Megaloptera	Corydalidae	Corydalidae	●			
Odonata	Coenagrionidae	Coenagrionidae				●
Odonata	Coenagrionidae	Ischnura				●
Odonata	Epiproctophora	Epiproctophora			●	●
Odonata	Gomphidae	Austrogomphus		●		
Odonata	Gomphidae	Gomphidae	●			
Odonata	Libellulidae	Libellulidae				●
Odonata	Zygoptera	Zygoptera			●	●
Oligochaeta	Lumbriculidae	Lumbriculidae	●		●	
Oligochaeta	Naididae	Dero				●
Oligochaeta	Naididae	Naidinae	●		●	●
Oligochaeta	Naididae	Pristina				●
Oligochaeta	Naididae	Naididae	●			
Oligochaeta	Naididae	Tubificinae	●			
Oligochaeta	Oligochaeta	Oligochaeta	●	●	●	●
Ostracoda	Ostracoda	Ostracoda	●		●	
Plecoptera	Gripopterygidae	Dinotoperla			●	
Plecoptera	Gripopterygidae	Gripopterygidae	●		●	
Trichoptera	Calamatoceridae	Anisocentropus				●
Trichoptera	Ecnomidae	Ecnomus	●		●	●
Trichoptera	Hydrobiosidae	Ulmerochorema	●	●		
Trichoptera	Hydropsychidae	Cheumatopsyche	●	●	●	●
Trichoptera	Hydropsychidae	Diplectrona		●		
Trichoptera	Hydropsychidae	Hydropsychidae	●		●	

Order	Family	Genus	QBYN 1	QBYN 2	QBYN 1	QBYN 2
			Riffle	*Riffle*	*Edge*	*Edge*
Trichoptera	Hydroptilidae	Hellyethira	●		●	●
Trichoptera	Hydroptilidae	Hydroptila			●	
Trichoptera	Hydroptilidae	Hydroptilidae	●		●	
Trichoptera	Hydroptilidae	Oxyethira	●	●	●	
Trichoptera	Leptoceridae	Leptoceridae	●			●
Trichoptera	Leptoceridae	Notalina	●	●	●	●
Trichoptera	Leptoceridae	Oecetis	●	●		●
Trichoptera	Leptoceridae	Triplectides			●	●

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.

Edge

Site	Taxa	Planorbidae	Elmidae	Leptophlebiidae	Synlestidae	Hydroptilidae	Ecnomidae	Gripopterygidae	Hydrobiidae	Conoesucidae	Total number of missing taxa
	Signal score	2	7	8	7	4	4	8	4	7	
Qbyn 1		●			●					●	3
Qbyn 1		●		●	●					●	4
Qbyn 1			●		●					●	3
Qbyn 2		●	●		●	●		●		●	6
Qbyn 2		●	●	●	●		●	●		●	7
Qbyn 2		●	●		●		●	●		●	6

Riffle

Site	Taxa	Hydrophilidae	Elmidae	Scirtidae	Podonominae	Leptophlebiidae	Caenidae	Gripopterygidae	Hydroptilidae	Conoesucidae	Psephenidae	Hydrobiosidae	Ancylidae	Glossosomatidae	Philopotamidae	Corydalidae	Ecnomidae	Total number of missing taxa
	Signal score	2	7	6	6	8	4	8	4	7	6	8	4	9	8	7	4	
Qbyn 1					●					●	●	●		●		●		6
Qbyn 1					●					●	●	●		●		●		6
Qbyn 1					●	●		●		●	●	●		●	●			8
Qbyn 1						●		●	●	●		●	●	●				7
Qbyn 1						●				●	●	●	●	●				6
Qbyn 1						●				●	●							3
Qbyn 2		●	●			●	●	●		●	●	●	●	●	●	●	●	13
Qbyn 2		●	●	●		●	●	●		●	●	●	●	●	●	●	●	14