Ecowise Environmental

FINAL REPORT

"Biological and Water Quality Monitoring of Five Core Sites in Spring 2005"

Contract No. EP/WQM/E1/05

for

City of Ryde

December 2005

The management of water resources is an integral part of environmental management and an essential requirement for supporting the economic, social and environmental objectives of our society

December 2005

Contact for further Information:

Grant Leslie

NSW Manager
Sydney Office
Telephone: +61 2 4721 3477
Facsimile: +61 2 4721 5699
Email: gleslie@ecowise.com.au

Ecowise Environmental ABN 68 074 205 780

Brisbane Office
Unit 2/49 Butterfield St
Herston QLD 4006
PO Box 673
Spring Hill QLD 4004
Telephone: +61 7 3854 0233
Facsimile: +61 7 3854 0288

Canberra Office
16A Lithgow St
PO Box 1834
Fyshwick ACT 2609
Telephone: +61 2 6270 7650
Facsimile: +61 2 6270 7631

Sydney Office
24 Lemko Place
Penrith NSW 2750
Telephone: +61 2 4721 3477
Facsimile: +61 2 4721 5699

Perth Office
Unit 2 / 4 Milson Place
O'Connor WA 6163
Telephone: +61 8 9337 4166
Facsimile: +61 8 9337 4577

Authors:

Kim Piercy
Nirvana Searle

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Executive Summary

Urban streams (such as those affected by runoff and discharges from urban areas) are an important subset of Australia's waterways. Most are degraded biologically, physically and chemically and therefore require specialised methods for health assessment and management. It is within this context that the City of Ryde has initiated a 7 year Biological/Chemical Monitoring Strategy which focuses on biological and water quality monitoring of 5 key urban creek systems within its area of operations.

Ecowise Environmental was commissioned by the City of Ryde to conduct the first two years of sampling as part of a 7 year Biological/Chemical Monitoring Strategy, and this report covers the third sampling event conducted in Spring 2005. Core sampling sites were selected by Council and included sites on Terrys Ck, Shrimptons Ck, Porters Ck, Buffalo Ck and Archer Ck.

Autumn sampling was conducted in September (6th & 7th), October (11th & 12th) and November (2nd). Sampling protocols defined in the "NSW Australian River Assessment System (AusRivAS) Sampling and Processing Manual, NSW EPA, July 2001" (Turak and Waddell, 2001) were adopted including physical and in-stream habitat descriptions. During each sampling event, water samples were collected and analysed for Total Dissolved solids, Total Phosphorus, Total Nitrogen, Ammonium, Total Alkalinity and Faecal Coliforms. In addition, an assessment of *in-situ* water quality was undertaken which included pH, Dissolved Oxygen, Electrical Conductivity, turbidity and water temperature.

A review of the water quality data indicated that dissolved oxygen concentrations regularly fell below the recommended ANZECC and ARMCANZ guideline value of 85% saturation across all sites for at least one sampling event in Spring 2005. Conductivity in Porters Ck (Site 3) was recorded above the ANZECC and ARMCANZ (2000), and nutrient levels (nitrogen and ammonium) and faecal coliforms were also recorded above the recommended trigger values at most sites during at least one sampling event.

A total of 38 aquatic macroinvertebrate families were recorded over the three Spring sampling events, with insects the most dominant (22 taxa) followed by gastropods (4 taxa), and crustaceans (3 taxa).

Following the identification and enumeration of the macroinvertebrates samples, the data were analysed using a number of univariate and multivariate techniques, including AusRivAS modelling. Both types of techniques provide differing levels of information. Univariate indices concentrate mainly on assessing the condition or "health" of the sites, whilst multivariate analysis routines allow patterns (if any) between sites/samples to be identified (Classification and Ordination), the key taxa from each sample which may be contributing to these differences (SIMPER), and the isolation of environmental variables that could be responsible for observed patterns (BVSTEP).

All sites within the City of Ryde study are indicative of urban creeks, with severe to extreme impairment of ecological health. The main influences on these sites, and the creeks on which they are located, include poor water quality (exceeding recommended ANZECC and ARMCANZ, 2000 guidelines), and poor habitat diversity. Biodiversity and ecosystem health results from the Spring 2005 sampling program are similar to those obtained in earlier monitoring programs, including the previous sampling programs in Spring 2004 and Autumn 2005. However, a

comparison of results from Spring 2002 to 2005 (Robyn Tuft and Associates and Ecowise) for Terrys Ck, Buffalo Ck and Porters Ck indicated a marginal improvement in the ecological health of these creeks in 2005.

The Spring 2005 sampling program has demonstrated that the design and methodology adopted for this project are appropriate to achieve the objectives of the City of Ryde program.

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1 INTRODUCTION

Urban streams are an important subset of Australia's waterways. Most are degraded biologically, physically and chemically and therefore require specialised methods for health assessment and management. The Urban Research and Development Program of the National River Health Program defines health in urban waterways as "the ability to support and maintain a balanced, integrative, adaptive community of organisms having a species composition, diversity and functional organisation as comparable as practicable to that of natural habitats of the region".

The increasing urbanisation of catchments results in four broad inter-related forms of disturbance or degradation that can affect stream ecology:

- Disturbance of hydrological and hydraulic patterns
- Disturbance to stream geomorphology
- Degradation of water quality, and
- Habitat degradation or simplification

We now recognise that the benefits we derive from our cities have come at a considerable environmental cost. Urbanisation and associated human activity has profoundly affected rivers and streams around the world and the importance of the links between stream health and human health is increasingly being recognised both internationally and nationally. Streams in urban areas have received relatively little scientific attention when compared with systems in natural (minimally disturbed) or rural areas.

1.1 Background

The City of Ryde approved a Biological/Chemical Water Quality Monitoring Strategy targeting 5 main creek systems within its area of operations. The program commenced in September 2004 and will be delivered over a 7 year period.

Shrimptons, Archer, Porters, Buffalo and Terrys Creeks have been targeted in this Strategy and it is proposed that one core monitoring site near the exit point of each of these creek systems be monitored within the terms of the Strategy.

The Strategy (COR Quotation No.: EP/WQM/E1/04) will enable the City of Ryde to:

- Evaluate chemical and biological water quality monitoring both for short and long term interpretation of creek health,
- Detail where, when and how often samples should be taken from creeks within the Ryde Local Government Area based on existing site data, catchment position and accessibility,
- Prescribe how to sample macroinvertebrates at each site, building on the standard protocols designed by AusRivAS,
- Provide for a series of options for identification of key indicator taxa to family and/or Morphospecies,
- Identify a standard suite of analyses to determine status and trends in water quality including calculation of the AusRivAS index,
- Provide the basis for an appraisal of the capacity of a standard monitoring program, eg. Streamwatch, and

- Provide the foundation to augment the Streamwatch capacity within the City of Ryde, including options for improved education awareness of water quality issues within schools and community groups.

Ecowise Environmental was commissioned by City of Ryde to conduct the bi-annual sampling program beginning in Spring 2004. This report covers the third sampling program for the Biological/Chemical Water Quality Monitoring Strategy in Spring 2005.

1.2 Scope of Works

The scope of works for the Spring 2005 sampling program, as specified in the project brief (Quotation No: EP/WQM/E1/05), included:

1. Measure aquatic macroinvertebrates and water chemistry at the 5 core sites selected by City of Ryde,
2. Sample in Spring 2005 (September, October and November). Each site, as a minimum should be sampled once per month and sampling shall be undertaken strictly in accordance with NSW AusRivAS protocols,
3. Collect macroinvertebrates and chemical data at each core site,
4. Characterise each core site according to AusRivAS protocols for physico-chemical properties and sample the recommended chemical data,
5. Sample macroinvertebrates from the same 5 edge habitats at each core site (modified from previous studies which sampled riffle habitats where applicable),
6. Identify samples of macroinvertebrates to family level, and
7. Preserve specimens from selected families to allow for morphospecies identification, when required by council.
8. Include relevant rainfall data in the interpretation of ecological data.

1.3 Historical sampling programs

Apart from the previous 2 sampling events conducted by Ecowise Environmental during Spring 2004 (Ecowise, 2004) and Autumn 2005 (Ecowise, 2005), a number of macroinvertebrate studies have previously been undertaken on the 5 core sites.

<u>Shrimptons and Archer Creeks</u>

- BioTrack (Dec, 2001) “Biological Water Quality Monitoring of Shrimptons and Archer Creeks, Ryde”. Progress Report prepared for Ryde City Council.
- BioTrack (July, 2002) “Biological Water Quality Monitoring of Shrimptons and Archer Creeks, Ryde”. Prepared for Ryde City Council.
- BioTrack (June, 2004) “Post restoration macroinvertebrate sampling of Archer Creek, Ryde”. Prepared for Ryde City Council.

The BioTrack (2001; 2002) programs were designed to provide baseline biological water quality monitoring data to assist Ryde City Council in assessing the effectiveness of remediation works. Three sites were assessed, with two sites on Shrimptons Ck (one upstream and one downstream of the proposed remediation works) and one site on Archer Ck to be used as a benchmark. Samples were collected monthly between June 01 and May 02, using NSW AusRivAS protocols. The program results indicated both

systems were typical of an urban creek environment, with abundant pollution tolerant taxa, and overall poor ecosystem health. This result was further enhanced by the post-restorative monitoring program conducted on Archer Ck at Maze Park by BioTrack (2004), with a dramatic reduction in taxa diversity when compared to the 2001 results. Several suggestions were thought to have caused this reduction including a reduced effort (only 3 sampling events), sampling was conducted over summer (conditions were unfavourable in Spring), and there was a reduced flow in the creek (no riffles were present).

Terrys, Porters and Buffalo Creeks

- Robyn Tuft & Associates (2002) "Macroinvertebrate Sampling Program Lane Cove River Catchments – Autumn 2002". Prepared for Lane Cove River Catchment Councils.
- Robyn Tuft & Associates (2003a) "Macroinvertebrate Sampling Program Lane Cove River Catchments – Autumn 2003". Prepared for Lane Cove River Catchment Councils.
- Robyn Tuft & Associates (2003b) "Macroinvertebrate Sampling Program Lane Cove River Catchments – Spring 2003". Prepared for Lane Cove River Catchment Councils.
- Robyn Tuft & Associates (2004) "Macroinvertebrate Sampling Program Lane Cove River Catchments – Autumn 2004". Prepared for Lane Cove River Catchment Councils.

These programs were aimed at providing information on stream ecology, habitat, and hydrological impacts as well as providing an integrated index of water quality for key stream sites in the catchment area of Lane Cove. Single sampling events were conducted twice yearly from Autumn 2002 to Autumn 2004, using the NSW AusRivAS methodology. Results were assessed using AusRivAS models, SIGNAL2 Indices and the Riparian Channel-Environmental Inventory (RCE) field observations. The three sites of interest (Porters Ck, Terrys Ck, and Buffalo Ck) were reported in moderate to poor ecological health with impacts from stormwater runoff and scouring flows during high storm events.

2 STUDY AREA

2.1 Site Locations

Core sample sites were pre-selected by City of Ryde and are included in Table 1.

Table 1: Site location codes and descriptions for each site sampled as part of the biological monitoring program for City of Ryde, Spring 2005.

Site Code	Site Location Description
Site 1	Terrys Ck near the M2 motorway at the end of Somerset Rd, North Epping
Site 2	Shrimptons Ck at Wilga Park
Site 3*	Porters Ck, accessed through the Ryde Council Depot, *after* the creek is piped under the Depot
Site 4^	Buffalo Ck, accessed through private property (52 Higginbotham Rd)
Site 5	Archer Ck at Maze Park

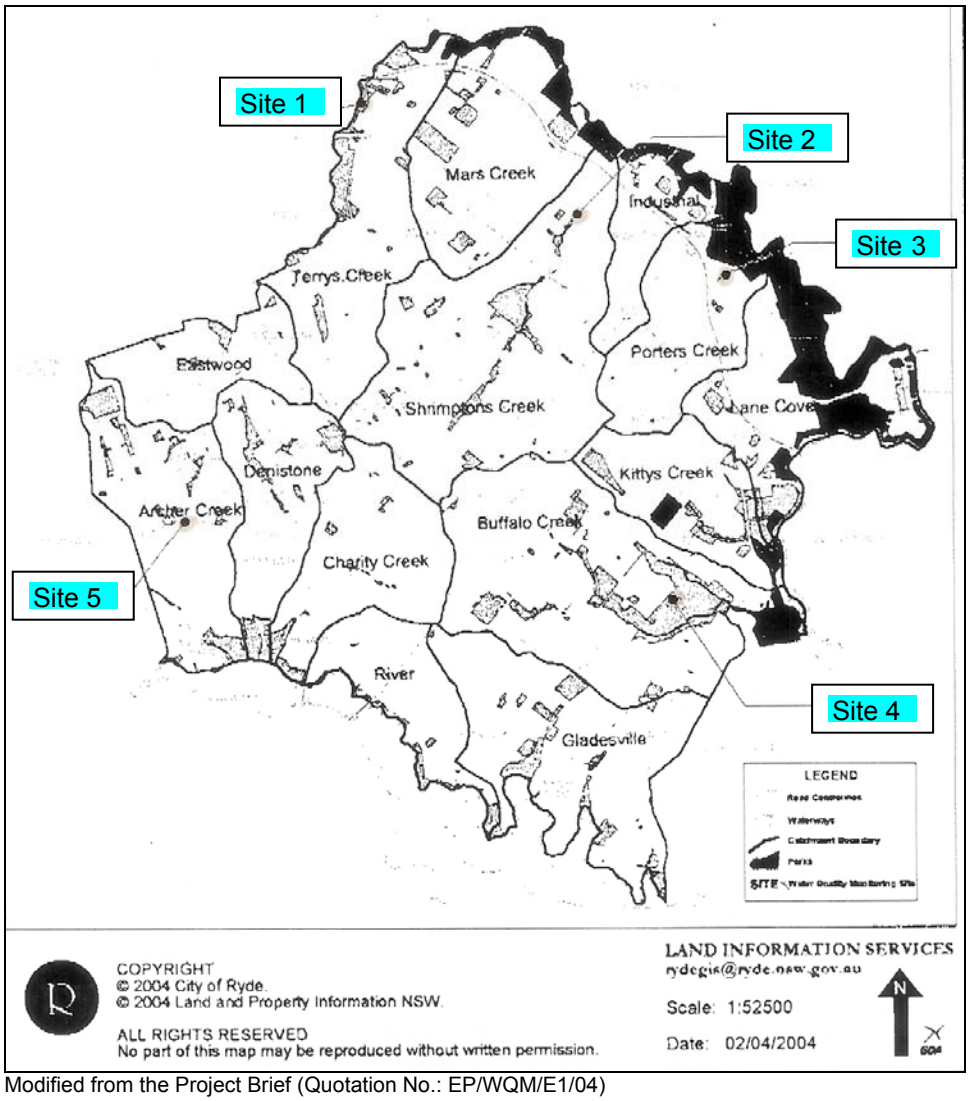
Note: * - previously labelled Site 6 in Ecowise (2004 & 2005) reports
^ - previously labelled Site 7 in Ecowise (2004 & 2005) reports

The locality of water quality monitoring sites, within their respective stormwater catchment areas, is presented in Figure 1 (City of Ryde Quotation No: EP/WQM/E1/04).

2.2 Spring 2005 Sampling Events

A total of three sampling events were conducted during the Spring 2005 monitoring program, with all sampling events in separate months as required by the City of Ryde project brief (Quotation No: EP/WQM/E1/05):

- Event 1 – 6th and 7th September,
- Event 2 – 11th and 12th October, and
- Event 3 – 2nd November.



Modified from the Project Brief (Quotation No.: EP/WQM/E1/04)

Figure 1: Site locations for the Macroinvertebrate and Water Quality Monitoring Strategy for the City of Ryde, Spring 2005.

3 METHODS

3.1 Physical Habitat Description

Physical and in-stream habitat descriptions were conducted in accordance with the River Bioassessment Manual and NSW AusRivAS protocols (MRHI, 1994; Turak *et al.*, 2004). Descriptions include using visual estimates of streambed composition (percentage of total for each substrate category), amount of in-stream organic material, and area of aquatic habitats. The mode width, mean depth and channel widths were also determined.

3.2 Water Quality Assessment

At each site, *in situ* dissolved oxygen, pH, electrical conductivity, and water temperature were measured using a Hydrolab DS5 multi-parameter water quality meter coupled to a Surveyor 5 digital display. This meter was fully calibrated in the laboratory, in accordance with Ecowise Quality System requirements, prior to deployment in the field. Turbidity was measured using a Hach 2100P Turbidimeter.

Water samples were collected and analysed for Total Dissolved Solids, Total Phosphorus, Total Alkalinity, and Faecal Coliforms, as specified by the City of Ryde project brief. Additional water samples were also collected for Total Nitrogen, Total Oxidised Nitrogen and Ammonium.

Water quality data was evaluated using default trigger values for Aquatic Ecosystems of south-east Australian lowland rivers, and the Recreational Waters and Aesthetics for Primary and Secondary Uses as outlined in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC and ARMCANZ, 2000) (Table 2). Trigger values are defined in the ANZECC and ARMCANZ (2000) guidelines as "the concentrations (or loads) of the key performance indicators measured for the ecosystem, below which there exists a low risk that adverse biological (ecological) effects will occur". Therefore, an action would be 'triggered' should these guidelines be exceeded, such as further specific ecosystem investigations, or implementation of management/remedial actions (ANZECC and ARMCANZ, 2000). However, these trigger values are not mandatory standards, and should be used to provide a framework for protecting water quality at a local scale.

Table 2: Parameters and relevant water quality guidelines and criteria (ANZECC and ARMCANZ, 2000).

Indicator	Units	ANZECC and ARMCANZ Guidelines (2000)		
		Aquatic Ecosystems	Recreational Waters	
			Primary Contact	Secondary Contact
Conductivity	µS/cm	125 - 2,200	*N/G*	*N/G*
pH	pH units	6.5 - 8.0	5.0 – 9.0	*N/G*
Dissolved Oxygen	% sat	85 - 110	*N/G*	*N/G*
Turbidity	NTU	6 - 50	*N/G*	*N/G*
Total Phosphorus	µg/L	50	*N/G*	*N/G*
Total Nitrogen	µg/L	500	*N/G*	*N/G*
NOx	µg/L	40	*N/G*	*N/G*
Ammonium	µg/L	20	*N/G*	*N/G*
Water Temperature	°C	*N/G*	15 - 35	*N/G*
Faecal Coliforms*	orgs/100ml	*N/G*	150	1000

N/G – No guideline

* – median values: (assessment should be based on 5 samples collected at regular intervals not exceeding one month, with four out of the five samples containing less than 600 orgs/100ml for primary contact or 4000 orgs/100ml for secondary contact).

3.3 Macroinvertebrate Sampling

3.3.1 Spring 2005 Program

Sampling was undertaken by Ecowise in strict accordance with the protocols defined in the 'NSW Australian River Assessment System (AusRivAS) Sampling and Processing Manual, NSW EPA, July 2004' (Turak *et al.,* 2004). All procedures were diligently followed.

All sampling was undertaken with ISO DIS/7828 250 μm mesh nets (ISO, 1983). Nets were washed thoroughly in creek water between sampling events to remove any invertebrates retained on them.

One 10 metre sample was collected from the edge habitat at each site. The littoral or edge habitat was defined as an area along the creek bank with little or no current. This habitat was sampled by sweeping the sample net along the edge of the stream. The net was swept around overhanging vegetation, against snags if present, in backwaters, and through beds of macrophytes. This process was continued, working upstream, over approximately 10 metres of edge.

3.3.2 Previous Sampling Methods

The sampling methods employed by Robyn Tuft and Associates outlined in Section 1.3 have several differences when compared to the standard NSW AusRivAS protocols (Turak and Waddell, 2001; Turak *et al.,* 2004) employed by Ecowise.

Programs managed by Robyn Tuft and Associates state that "samples were collected at each site for a period of 10 minutes and the complete sample was assessed at each site" (Robyn Tuft and Ass, 2002; 2003a; 2003b; 2004). In comparison, Turak *et al.,* (2004) require a total length of 10 metres to be sampled of each habitat and the use of a live-picking method on each sample to capture the widest diversity of taxa. Robyn Tuft and Associates (2002; 2003a; 2003b; 2004) did not reference the NSW AusRivAS manual (Turak *et al.,* 2004).

3.3.3 Sample Processing

For each sample, the collected material was placed into a sorting tray and macroinvertebrates picked for a minimum of 40 minutes by professionally qualified and experienced aquatic biologists using forceps and pipettes. If new taxa were collected between 30 and 40 minutes, sorting continued for a further 10 minutes. If no new taxa (not previously detected in sample) were found after the 10 minutes, then processing ceased. If new taxa were found, the 10-minute processing cycles were continued up to a maximum total sorting time of 1 hour. There is no set minimum or maximum number of animals collected using the NSW protocols (Turak *et al.,* 2004).

Samples were preserved in 80% ethanol and clearly labelled with information including site, habitat, sampling method, date and sampler. Samples were returned to the laboratory for identification using a dissecting microscope.

Most macroinvertebrate identification was to family level with some exceptions. Chironomidae (Diptera), were identified to sub-family, (Orthocladiinae, Tanypodinae, Chironominae etc.), Collembola, Nematoda and Oligochaeta were identified to class or order level in accordance with accepted convention (MRHI, 1994; Turak *et al.,* 2004) as were the microcrustacea, Ostracoda, Copepoda and Cladocera.

Samples were then preserved in an ethanol/water/glycerol mix for long term archiving and for future morphospecies identification if required.

3.3.4 Data Analysis

After the identification and enumeration of the macroinvertebrates samples, the data was analysed using a number of univariate and multivariate techniques. Both types of techniques provide differing levels of information, with univariate indices concentrating mainly on assessing the condition or "health" of the sites, whilst multivariate analyses allows comparisons between the sites based upon the community structure to determine if relationships exist between relevant environmental variables and macroinvertebrate communities.

Rapid bioassessment sampling (such as the NSW AusRivAS methods) does not provide a quantitative estimate of the abundance of each taxon in a sample and all macroinvertebrate data was converted to binary form (ie. presence/absence data) prior to analysis.

Univariate Analyses

Richness

Richness refers to the number of different taxa contained in the sample. Unlike some biological indices, a higher number does not always indicate better in-stream conditions. Higher values of this value may indicate favourable conditions in terms of availability of food and/or the quality of habitat. However, in some cases, high richness values can also occur when altered conditions provide habitats that may not occur naturally (e.g. riffle habitats due to altered flow conditions). Each richness value must be assessed individually with a final assessment based upon changes from natural or reference/control condition.

AusRivAS

AusRivAS (Australian River Assessment System) is a prediction system that uses macroinvertebrates to assess the biological health of Australian rivers. AusRivAS uses site-specific predictions of the macroinvertebrate fauna expected to be present in the absence of environmental stress. The expected fauna from sites with similar sets of predictor variables such as physical and chemical characteristics which can not be influenced due to human activities (e.g. altitude), are then compared to the observed fauna. The ratio derived from this comparison is used to indicate the extent of any impact.

Several AusRivAS models currently exist for NSW edge habitats, including:

- Single-Season models:
  - Spring Edge, and
- Combined-Season models:
  - Eastern Edge and Western Edge.

The Combined-Seasons model involves combining the biological results from Autumn and Spring sampling events for an overall health assessment of sites. However, using a Combined-Seasons model does not allow changes in condition to be detected between seasonal sampling events. As the City of Ryde strategy aims to utilise chemical and biological water quality monitoring both for short and long-term assessment of creek

health, it was not deemed appropriate to use the Combined-Seasons model on City of Ryde data.

To run the models, a number of variables are required from each site, depending upon the habitats present. The variables necessary to run the NSW Spring Edge model are presented in Table 3 below.

Table 3: Variables required from each site to run the NSW Spring Edge AusRivAS model.

Edge Habitat	Description
ALKALINITY	Total Carbonates (mg/L)
ALTITUDE	Height above sea level (m)
BEDROCK	Percent bedrock in habitat (%)
BOULDER	Percent boulder in habitat (%)
COBBLE	Percent cobble in habitat (%)
LATITUDE	Latitude of site (decimal degrees to 4dp)
LOGDFSM	Log 10 (x) Distance from source
LOGMODEWIDTH	Log 10 (x) average of Mode stream width at site
LOGSLOPE1KUS	Log 10 (x) Slope: Elevation difference in metres between the middle of the site and a point 1km upstream.
LONGITUDE	Longitude of site (decimal degrees to 4dp)
RAINFALL	Mean annual rainfall (mm)

Taxa Probability

The AusRivAS output also allows the ability to identify any *'indicator taxa'* collected or missing from the sample by measuring a taxa's probability of occurrence. The AusRivAS output includes:

- Taxa expected to be in the sample, that ***is*** collected; and
- Taxa expected to be in the sample, that is ***not*** collected.

Any taxa with a greater than 50% probability of occurrence, as indicated by the AusRivAS model, is expected to be collected if the site is in a healthy reference condition.

Indicator taxa are defined by Ecowise in this report as taxa within the PET (Plecoptera - stoneflies, Ephemeroptera - mayflies, and Trichoptera - caddisflies) orders, and/or with a SIGNAL2 score of equal to or greater than 6, having a moderate to high level of sensitivity to pollution. PET taxa have been found in many biomonitoring programs to be the orders most sensitive to environmental disturbance, and usually taxa belonging to these orders are the first to disappear following disturbance (EHMP, 2004).

This information, along with the taxa's SIGNAL2 score, will allow an assessment to be made of potential 'indicator taxa' present or absent from samples, which may be influencing the assessment of river health.

Observed / Expected Ratios

The Observed / Expected (O/E) ratio can range from zero, when none of the expected taxa are found at a site, to around one, when all the expected taxa are present. The value can also be greater than one when more families are found at the site than expected by the model. The O/E scores derived from the model can be placed in bands delineated by the Monitoring River Health Initiative (Table 4), which allows assessment of the level of environmental health at a site.

Table 4: Key to AusRivAS OE family scores and bands for NSW Spring Edge habitat.

Band Label	OE50 scores	Band Name	Comments
Band X	Infinity	More biologically diverse than reference sites.	More taxa found than expected. Potential biodiversity hot-spot. Possible mild organic enrichment.
Band A	1.16	Reference condition.	Most/all of the expected families found. Water quality and/or habitat condition roughly equivalent to reference sites. Impact on water quality and habitat condition does not result in a loss of macroinvertebrate diversity.
Band B	0.83	Significantly impaired.	Fewer families than expected. Potential impact either on water quality or habitat quality or both resulting in loss of taxa.
Band C	0.51	Severely impaired.	Many fewer families than expected. Loss of macroinvertebrate biodiversity due to substantial impacts on water and/or habitat quality.
Band D	0.19	Extremely impaired.	Few of the expected families remain. Extremely poor water and/or habitat quality. Highly degraded.

SIGNAL2

SIGNAL2 (Stream Invertebrate Grade Number Average Level - Version 2) (Chessman, 2003) is a simple scoring system for macroinvertebrates of Australian rivers and is derived from known responses of macroinvertebrate taxa to water pollution. Each taxon is assigned a number from 1 (tolerant) to 10 (sensitive). The site index has been calculated in the past by summing the sensitivity scores for all families present and then dividing by the number of families present (average of scores for all families in a sample).

The interpretation of the more recent SIGNAL2 data follows that suggested by Chessman (2003) and Coysh *et al*. (2000). In order to overcome natural variation, Chessman (2003) suggests using the observed / expected (OE) SIGNAL2 scores predicted using AusRivAS. The observed (O) SIGNAL2 score is the sum of the grades of taxa collected, divided by the number of families collected. The expected (E) SIGNAL2 score is obtained by multiplying the grade of each taxon by its probability of collection, summing the products, and dividing by the sum of the probabilities.

The example below (Table 5) used by Chessman (2003) best explains this equation.

Table 5: Simplified hypothetical example of the suggested use of AusRivAS computer outputs to calculate a predicted SIGNAL2 score (Chessman, 2003)

Taxon	SIGNAL2 grade	Probability of collection	Grade x Probability	Taxon Collected?
Family A	5	1	5	yes
Family B	3	0.8	2.4	no
Family C	10	0.6	6	no
Family D	7	0.6	4.2	yes
Family E	8	0.5	4	yes
Family F	4	0.3	1.2	yes
Family G	7	0.1	0.7	no
Family H	9	0.1	0.9	no
Family I	5	0	0	no
Family J	1	0	0	yes
Sum		**4**	**24.4**	

Observed Score = (5 + 7 + 8 + 4 + 1) / 5 = 5.0
Expected Score = 24.4 / 4.0 = 6.1

O/E50SIGNAL2 = 5.0 / 6.1 = 0.82

Currently, no bandings have been developed for this analysis (Coysh *et al.,* 2000; Chessman *pers comm*); however, an O/E50 SIGNAL2 score of around 1 would suggest the observed SIGNAL2 score was similar to what was expected at the site.

Multivariate Analyses

The use of multivariate analysis techniques allows exploration into the patterns of the macroinvertebrate communities of which univariate techniques cannot. The routines used in this study allow patterns (if any) between sites/samples to be identified (Classification and Ordination), the key taxa from each sample which may be contributing to these differences (SIMPER), and the isolation of environmental variables that could be responsible for observed patterns (BVSTEP).

Community multivariate analyses can be significantly altered due to the presence of rare or uncommon taxa. In this study, rare taxa were excluded prior to analysis primarily due to their occurrence being more a matter of chance rather than being properly represented in the community. Rare taxa do not contribute information to the patterns existing within the data, rather they can create 'noise' which has the effect of masking patterns (Clarke and Warwick, 2001). A common cut-off level used in presence/absence data is greater than 5% occurrence in samples (Clarke and Warwick, 2001) and this level was applied for this study. All multivariate analyses were performed using the statistical package PRIMER Version 5.2.9 (PRIMER-E: Plymouth Marine Laboratory, UK).

Classification

Classification (also called *cluster analysis*) is a mathematical method of grouping entities according to the relative similarity of their attributes. In an ecological setting these techniques can be used to group sites according to the similarity of the organisms found within them.

The initial step in this process was to calculate a similarity matrix for all pairs of samples based on the Bray-Curtis similarity coefficient (Bray & Curtis, 1957; Clifford & Stephenson, 1975). From this matrix, hierarchical agglomerative clustering was obtained. This classification formed the basis for the construction of a dendrogram, which presents the sites as groups based on a pattern of branching points, each defined by a level of similarity.

Ordination

Like classification, ordination provides a representation of the relative similarity of entities (i.e. site samples) based on their attributes (i.e. macroinvertebrate community composition) within a reduced dimensional space. The more similar sites are to each other, the closer they are located within the ordination space. This procedure is useful to display the samples' interrelations on a continuous scale and allows a check to see how "real" the groups identified in the classification technique are.

A Non-metric Multi-Dimensional Scaling (NMDS) ordination was performed on the similarity matrix for all pairs of samples based on the Bray-Curtis similarity coefficient. The number of axes used in the ordinations was based on resultant stress levels. The stress level is a measure of the distortion produced by compressing multi-dimensional data into a reduced set of dimensions and will increase as the number of axes (i.e. dimensions) is reduced. All ordinations were initially calculated for two axes; however, if the resultant stress level exceeded 0.30, the ordination was recalculated for three axes (i.e. 3 dimensions). A stress level of <0.2 is considered a useful ordination.

SIMPER

The SIMPER (SIMilarity PERcentages) routine was used to identify taxa that contributed most to the average dissimilarity between site groups identified from the classification (cluster analysis). SIMPER computes the average dissimilarity (Bray-Curtis) between all pairs of inter-group samples (every sample in group 1 with every sample in group 2 etc.) and then breaks this average down into the separate contributions from each taxon. In addition to calculating the average dissimilarity between groups, SIMPER also calculates the average similarity within a group.

BVSTEP

The proportion of macroinvertebrate variation explained by measured environmental variables (e.g. water depth, substrate composition etc) was calculated using the BVSTEP routine. BVSTEP is a procedure that calculates agreement between the macroinvertebrate similarity matrix (Bray-Curtis) and multiple Euclidean distance matrices derived from environmental variables (Clarke and Gorley, 2001). It is important to quantify the factors that may be contributing to the differences between sites, as it is a means of directly associating the changes related to an environmental factor and eliminates the "guess work" in identifying the possible causes in changing community composition.

4 RESULTS

4.1 Rainfall Data

Daily rainfall data collected from a weather station in Marsfield over the past 6 months is presented in Figure 2. All events were found to have minimal rainfall in the week preceding sampling (<15mm in 7 days), with the exception of the November sampling event which recorded 28.6mm within the 7 days prior to sampling.

There was also minimal rainfall between sampling events, including 36.4mm between the September and October events, and 51.1mm between the October and November sampling events.

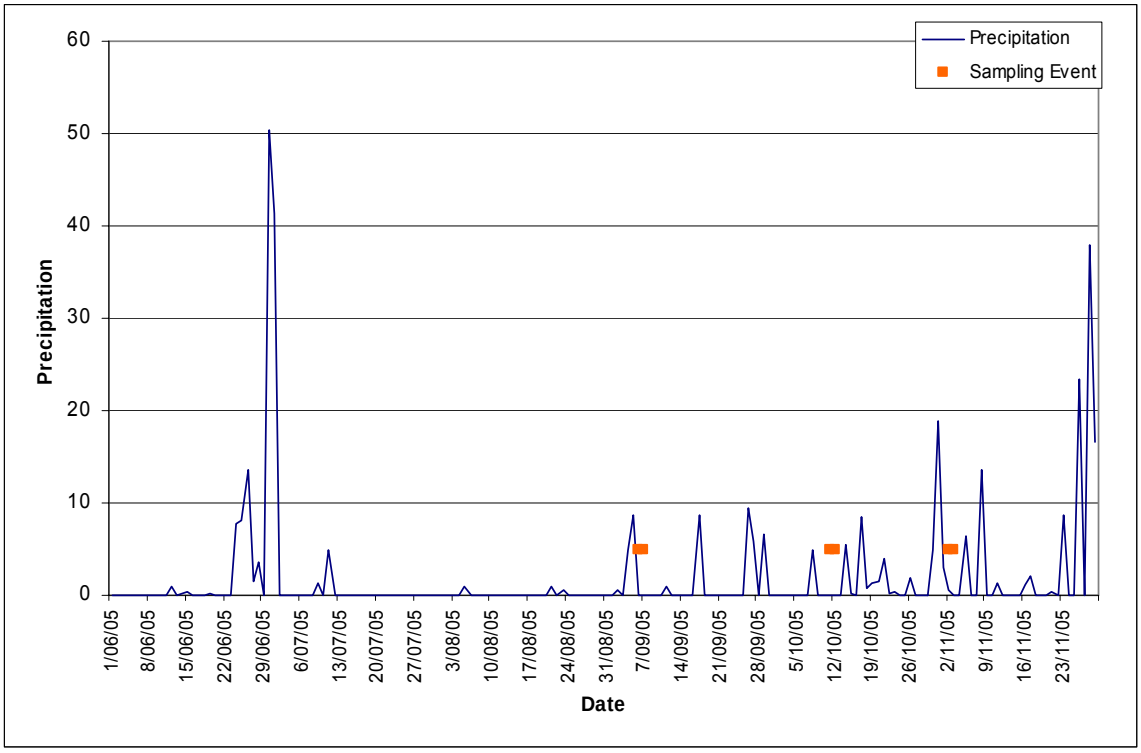


Figure 2: Daily rainfall data (mm) from Marsfield (Bureau Of Meteorology Station #.: 066156) between June 2005 to November 2005. The sampling events during Spring 2005 are also indicated.

4.2 Water Quality

4.2.1 *In situ* results

The results for *in situ* water quality parameters measured at each of the macroinvertebrate sites over the course of the program are presented in Table 6.

Table 6: In situ water quality results from the five sites within the City of Ryde, Spring 2005. Results outside the ANZECC and ARMCANZ (2000) guidelines have been highlighted in red.

Site	Sampling Event	Time sampled	Water Temp. (°C)	Conductivity (µS/cm)	pH	DO (mg/L)	DO (%sat.)	Turbidity (NTU)
***Aquatic Ecosystems**			**N/A**	**125 - 2200**	**6.5 – 8.0**	**N/A**	**85 - 110**	**50**
^Primary Contact			**15-35**	**N/A**	**5.0 – 9.0**	**N/A**	**N/A**	**N/A**
1	September	11:25	11.12	187.6	6.66	8.10	72.4	6.5
	October	11:00	13.64	244.5	7.14	4.49	43.0	2.2
	November	15:10	20.82	158.9	6.48	5.40	60.6	1.0
2	September	10:00	12.93	164.4	6.72	4.31	41.1	7.0
	October	9:30	15.74	246.4	7.15	3.26	32.6	3.9
	November	14:00	22.25	225.6	6.55	5.24	59.8	6.1
3	September	9:15	12.78	6141	6.97	8.75	84.9	3.0
	October	12:10	17.94	3965	7.63	8.67	93.7	4.5
	November	12:25	23.41	5633	7.14	7.89	95.3	6.4
4	September	11:15	13.16	620.9	6.98	6.19	59.5	5.5
	October	9:55	16.07	472	7.62	9.16	93.7	29.0
	November	10:20	21.02	299.3	7.01	5.65	63.8	4.1
5	September	13:00	14.70	244.9	6.84	5.56	54.4	10.0
	October	15:15	20.60	206.5	7.25	4.56	51.1	5.1
	November	16:35	25.09	350.4	6.89	5.58	69.6	12.6

* - ANZECC and ARMCANZ (2000) guidelines for Aquatic Ecosystems – lowland rivers of south eastern Australia
^ - ANZECC and ARMCANZ (2000) guidelines for Recreational Water Quality and Aesthetics (Primary eg swimming; Secondary eg. Boating).

A review of the water quality data showed that dissolved oxygen concentrations regularly fell below the recommended ANZECC and ARMCANZ guideline value (85% saturation) at all sites in at least one sampling event in Spring 2005.

Conductivity in Porters Ck (Site 3) was also recorded well above the ANZECC and ARMCANZ (2000) guidelines for Aquatic Ecosystems in all three sampling events.

4.2.2 Laboratory Water Quality Results

Results for the laboratory analyses of water samples at each of the macroinvertebrate sites over the course of the program are presented in Table 7.

Table 7: Laboratory analysed water quality results from the five sites within the City of Ryde, Spring 2005. Results outside ANZECC and ARMCANZ (2000) guidelines have been highlighted in red.

Site	Sampling Event	Time sampled	TDS (mg/L)	TP (µg/L)	TN (µg/L)	NOx (µg/L)	TKN (µg/L)	NH_4^+ (µg/L)	Faecal Coliforms (orgs/100ml)	Total Alk. ($CaCO_3$)
*Aquatic Ecosystems			N/A	50	500	40	N/A	20	N/A	N/A
^Primary Contact			N/A	N/A	N/A	N/A	N/A	N/A	150	N/A
^Secondary Contact			N/A	N/A	N/A	N/A	N/A	N/A	1000	N/A
1	September	12:50	140	10	140	48	90	59	300	43
	October	11:45	180	10	85	33	52	10	2000	47
	November	9:20	110	4	39	2	37	<1	380	37
2	September	13:10	140	4	65	37	28	5	90	42
	October	12:00	150	10	90	36	54	16	32000	43
	November	9:55	150	6	64	19	45	6	500	50
3	September	9:15	4000	2	300	58	240	110	500	37
	October	12:15	2600	5	180	51	130	54	16000	31
	November	9:45	3500	<1	250	42	210	83	260	30
4	September	11:10	380	8	77	50	27	10	16	79
	October	10:00	210	20	130	63	70	26	6500	44
	November	10:00	200	5	63	28	35	5	2000	60
5	September	12:30	160	11	82	26	56	17	2000	56
	October	11:20	100	10	100	54	50	6	3800	30
	November	9:00	210	4	74	18	56	6	640	79

* : ANZECC and ARMCANZ (2000) guidelines for Aquatic Ecosystems – lowland rivers of south eastern Australia
^ : ANZECC and ARMCANZ (2000) guidelines for Recreational Water Quality and Aesthetics (Primary eg swimming; Secondary eg. Boating).

Nutrient levels were only marginally above the ANZECC and ARMCANZ (2000) guidelines at some sites during the Spring 2005 program. High levels of Nitrogen and Ammonium were recorded during some events at several sites, with Porters Ck (Site 3) recording the highest results across all three events. Porters Ck recorded over 5 times the recommended Ammonium trigger level set by ANZECC and ARMCANZ (2000) during the September sampling program.

Faecal coliform results exceeded the primary contact guideline at all sites during all sampling events, with the exception of the September event at Shrimptons Ck (Site 2) and Buffalo Ck (Site 4). Also, all sites recorded faecal coliform values above the secondary contact guidelines at some point during the Spring 2005 sampling program. These results should be interpreted with caution however, as the ANZECC and ARMCANZ (2000) guidelines outline a minimum of five samples to be collected at regular intervals over a single month, and the results above are based on the sampling program of one sample per month over three months.

4.3 Macroinvertebrate Results

4.3.1 General Characteristics of Aquatic Macroinvertebrates

A total of 38 different families were recorded over three Spring sampling events, with insects the most dominant taxa (22 taxa) followed by gastropods (4 taxa), and crustaceans (3 taxa). A full macroinvertebrate taxa list is presented in **Appendix A**.

4.3.2 Univariate Analyses

Macroinvertebrate Taxa Richness

Taxa richness for each of the macroinvertebrate sites over the three events is presented in Table 8.

Terry's Ck (Site 1) recorded the highest taxa diversity during the October and November sampling events and also the highest combined sample diversity of all sites, with Porters Ck (Site 3) recording the highest taxa diversity during September and the second highest combined sample diversity. The lowest diversity for all three events was recorded at Shrimptons Ck (Site 2), which also recorded the lowest combined sample diversity for Spring 2005.

Table 8: Macroinvertebrate taxa richness from five sites within the City of Ryde, Spring 2005.

Site	Sampling Event			Combined sample diversity
	September	October	November	
1	17	22	23	32
2	15	10	12	18
3	23	14	15	27
4	18	17	15	24
5	16	10	14	22

SIGNAL2

SIGNAL2 scores for each site over the three events are presented in Figure 3. Most sites revealed low variation in the SIGNAL2 scores between sampling events (0.7 to 0.9 O/E50 Signal), the exception being Shrimptons Ck (Site 2) which exhibited a difference of greater than 0.3 between the October event and the September and November events.

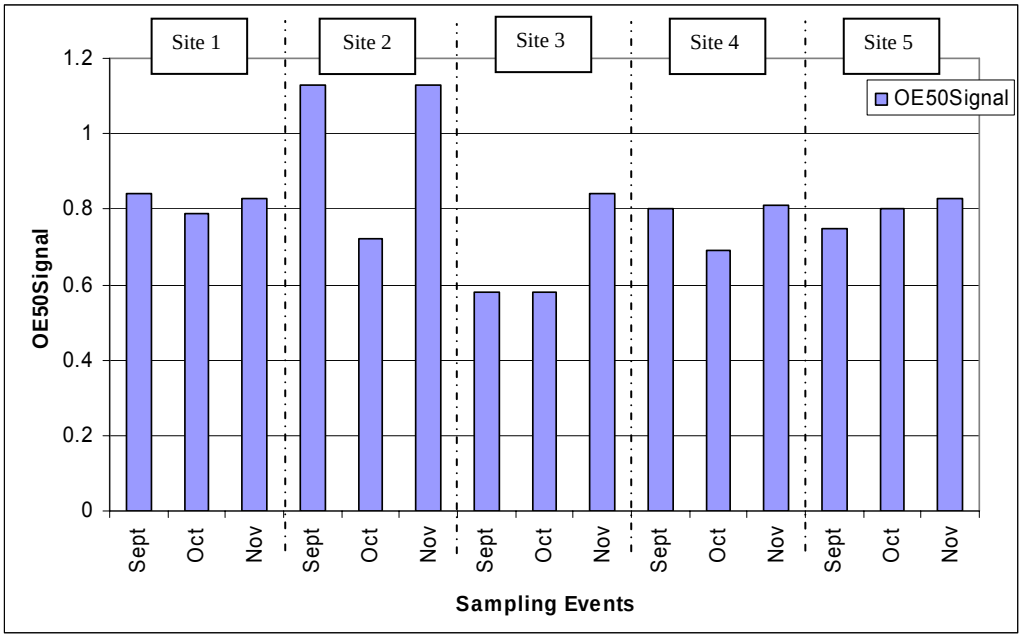


Figure 3: O/E50 SIGNAL scores from the five sites within the City of Ryde, Spring 2005.

AusRivAS

Observed / Expected Ratios

AusRivAS results for each site over the three events are presented in Figure 4. Most results were recorded in Band C, with 10 out of 15 results above 0.2 but below 0.51. Two results were recorded in the Band B from Terry's Ck (Site 1), while the remaining 3 samples were recorded in Band D. Shrimptons Ck (Site 2) recorded the lowest AusRivAS result of all samples with one result in Band D and two results only marginally higher in Band C.

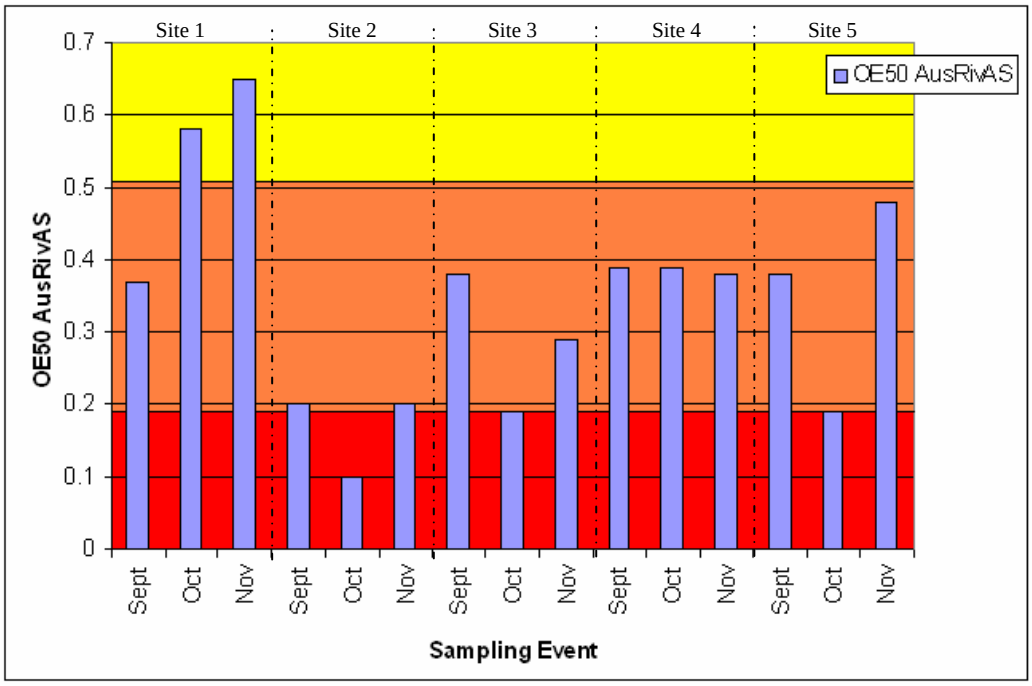


Figure 4: AusRivAS results from the five sites within the City of Ryde, Spring 2005. The AusRivAS bandings are also presented; D – Red, C – Orange, B – Yellow.

Taxa Probabilities

The AusRivAS taxa probability results for the Spring 2005 program are presented in **Appendices B** and **C**. A total of 16 taxa were predicted at the five sites but missing from the samples, with three of those missing within the PET taxa orders.

The PET taxa which had a >50% expectation at each site included:

- Leptophlebiidae (8) – Ephemeroptera (mayflies);
- Leptoceridae (8) - Trichoptera (caddisflies); and
- Baetidae (5) - Ephemeroptera (mayflies).

Leptophlebiidae (8) and Leptoceridae (8) were not collected in any of the samples yet was considered to have an 82-100% probability of occurrence in all samples. In contrast, Baetidae (5) was also not collected in any samples yet was only expected at 50-53% in two samples at Terry's Ck (Site 1).

Other indicator taxa expected in the samples included:

- Acarina (6) – mites
- Scirtidae (6) – beetles, and
- Synlestidae (7) – damselflies.

While a number of samples contained Acarina (10 out of 15 samples), this taxa was >50% expected in all samples. Scirtidae was also >50% expected in all samples but was not collected in any samples, and Synlestidae was expected in 10 out of the 15 samples collected, yet was only collected in one sample from Terry's Ck (Site 1).

The remaining 10 taxa >50% expected but not observed in the samples were all considered to be pollution tolerant taxa.

The taxa collected during all three events during Spring 2005 at each site, and dominating the samples, are presented in Table 9. The dominant taxa across all sites included Chironominae (3) (biting midges), Oligochaeta (2) (worms) and Physidae (1) (snails).

Table 9: Taxa collected in all samples during all three events at each site, Spring 2005 City of Ryde.

Site 1	Site 2	Site 3	Site 4	Site 5
Acarina	Chironominae	Chironominae	Acarina	Chironominae
Chironominae	Oligochaeta	Oligochaeta	Oligochaeta	Oligochaeta
Oligochaeta	Corbiculidae	Dytiscidae	Corbiculidae	Physidae
Corbiculidae	Copepoda	Hydrobiidae	Copepoda	Coenagrionidae
Tanypodinae	Physidae	Physidae	Ostracoda	Libellulidae
Physidae	Planorbidae	Corixidae	Chironominae	
Notonectidae	Glossiphoniidae	Erpobdellidae	Hydrobiidae	
Isostictidae	Dugesiidae	Glossiphoniidae	Physidae	
Megapodagrionidae		Isostictidae	Notonectidae	
Dugesiidae		Libellulidae	Oniscidae	
			Libellulidae	
			Dugesiidae	

Taxa Comparison with Spring 2004

A comparison of macroinvertebrate taxa observed in samples from all sites in Spring 2004 and Spring 2005 is presented in Table 10.

The most dominant taxa present in all samples across both sampling programs were Oligochaeta (worms), Physidae (snails), and Chironominae (biting midges). Other very common taxa present in most samples from both programs included:

- Acarina (6) – water mites,
- Coenagrionidae (2) and Megapodagrionidae (5) – Odonata: damselflies,
- Hemicordulidae (5) and Libellulidae (4) – Odonata: dragonflies,
- Corbiculidae/Sphaeriidae (4/5) – Bivalvia: freshwater muscles,
- Dugesidae (2) – Turbellaria: flatworms,
- Hydrobiidae (4) and Planorbidae (2) – Gastropoda: snails, and
- Stratiomyidae (4) – Diptera: soldier flies

Table 10: Comparison of macroinvertebrate taxa observed in City of Ryde samples from all sites in Spring 2004 and Spring 2005 (■ taxa present in three samples, ● taxa present in two samples, ▼ taxa present in one sample). Signal grades for each taxa are presented in brackets.

Taxa	Site 1		Site 2		Site 3		Site 4		Site 5	
	2004	2005	2004	2005	2004*	2005	2004*	2005	2004	2005
Acarina (6)		■	●	●		▼		■	■	▼
Aeshnidae (4)		▼				▼		▼	●	●
Ancylidae (4)	▼		■							
Atyidae (3)	▼					▼			▼	
Baetidae (5)									▼	
Belostomatidae (1)	▼									
Ceinidae (2)		●				●		●		▼
Ceratopogonidae (4)		▼	▼							
Chironominae (3)	■	■	■	■		■		■	■	■
Cladocera		●								
Coenagrionidae (2)	■	▼	●	▼		●			■	■
Copepoda	●	●	■	■		●		■	●	●
Corbiculidae/ Sphaeriidae (4/5)	■	■	■	■				■	●	●
Corixidae (2)		▼	●	▼		■		▼		▼
Culicidae (1)		▼				▼		▼		●
Dugesiidae (2)	■	■	■	■		▼		■	■	●
Dytiscidae (2)		▼				■		▼	▼	●
Elmidae (7)	●	▼								
Erpobdellidae (1)						■				
Gelastocoridae (5)				●						
Gerridae (4)	▼	●								▼
Glossiphoniidae (1)		●		■		■			●	
Gomphidae (5)	▼		▼			▼				
Hemicorduliidae (5)	■	▼	■			▼		▼	■	▼
Hydrobiidae (4)	■	●	▼	▼		■		■	■	
Hydroptilidae (4)	▼		●						●	
Isostictidae (3)	▼	■				■		▼		
Leptoceridae (6)			▼						▼	
Lestidae (1)			▼						▼	
Libellulidae (4)		●	▼	●		■		■	■	■
Lymnaeidae (1)	▼	●		▼						▼
Megapodagrionidae (5)	■	■	▼			●		●	▼	●
Naucoridae (2)	▼									
Nematoda (3)			▼						●	
Nepidae ()						▼				
Notonectidae (1)	▼	■				▼		■	▼	
Oligochaeta (2)	■	■	■	■		■		■	■	■
Oniscidae (2)		▼		▼		▼		■		●
Orthocladiinae (4)	●								●	
Ostracoda	▼		■	▼		▼		■	■	
Physidae (1)	■	■	■	■		■		■	■	■
Planorbidae (2)	●	●	■	■		●		▼		
Psychodidae (3)										
Scirtidae (6)	▼									
Simuliidae (4)		●						▼		
Stratiomyidae (4)	▼	▼	▼	▼		▼		▼	●	▼
Synlestidae (7)		▼								
Tanypodinae (4)	●	■						▼	■	▼
Telephlebiidae (5)										
Tipulidae (4)									●	
Veliidae (1)		▼							●	▼

Note: * - Site 3 and 4 incorrectly located during Spring 2004 program, therefore are not directly comparable to sites sampled as part of the Spring 2005 program.

Most taxa observed during a single season program only were only present in a small number of samples collected for that season, suggesting those taxa to be rare. A total of 21 taxa from the 50 taxa observed were isolated to one program, and only five of those taxa were collected in more than three samples. They were:

- Ancylidae (1) (limpet) – 4 samples, isolated to 2004 only,
- Ceinidae (2) (isopod) – 8 samples, isolated to 2005 only,
- Orthocladiinae (4) (biting midge) – 4 samples, isolated to 2004 only,
- Culicidae (1) (mosquito larvae) – 5 samples, isolated to 2005 only, and
- Hydroptilidae (4) (cased caddisfly) - 5 samples, isolated to 2004 only.

A total of 11 taxa were isolated to the 2004 program only, with 4 of the 11 taxa present classified as indicator taxa (Leptoceridae and Hydroptilidae - Trichoptera, Baetidae - Ephemeroptera, 1 x Scirtidae (6)). There were 10 taxa isolated to the 2005 program only, with no animals classified as indicator taxa.

4.3.3 Multivariate Analyses

Classification and Ordination

The classification analysis revealed 5 main groupings of samples at the 62% similarity level (Figure 5). Only the samples collected at Shrimptons Ck (Site 2) grouped out together on the same tree indicating there is little within-site variation at this site. All the samples from Terry's Ck (Sites 1) and Buffalo Ck (Site 4) grouped out together suggesting they are more similar in macroinvertebrate community composition than the remaining samples from other sites. Archer Ck (Site 5) is presented as having the highest within-site variation as all three samples grouped out individually.

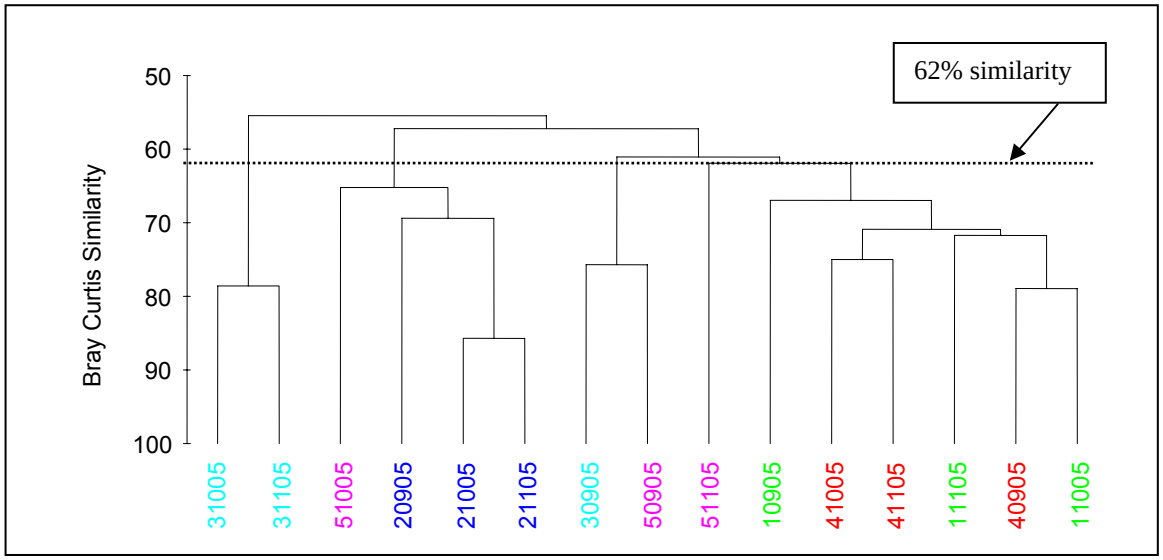


Figure 5: Classification of macroinvertebrate samples collected from five sites during the Spring 2005 monitoring program, City of Ryde. Samples are labelled with site code (eg. 1 – Terrys Ck) and sampling month (eg. 09 – September). 62% similarity is indicated.

The groupings presented in Figure 5 are further enhanced in the NMDS plot (Figure 6).

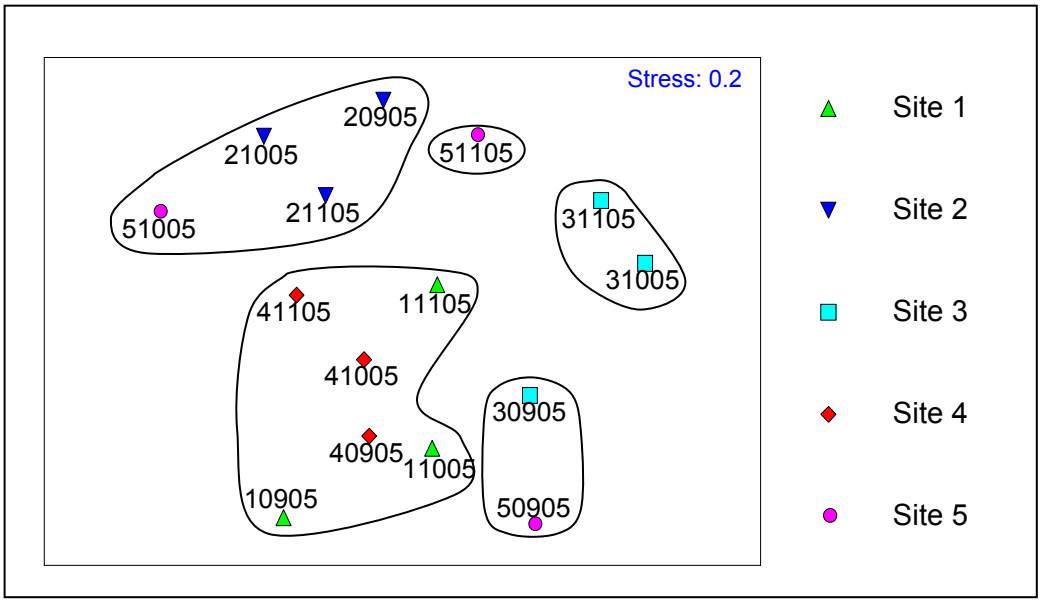


Figure 6: Non-metric Multi-dimensional Scaling (NMDS) ordination of macroinvertebrate samples collected from five sites during the Spring 2005 monitoring program, City of Ryde. Superimposed groupings refer to the 62% similarity level from the classification. (stress was calculated at 2 dimensions).

SIMPER

The SIMPER average dissimilarity results based on community composition between the five sites are presented in Table 11. The raw data is presented in **Appendix E.**

Table 11: Average dissimilarity (%) results for community composition data from samples collected at five sites during the Spring 2005 monitoring program, City of Ryde.

Site	1	2	3	4	5
1					
2	41.11				
3	41.22	44.04			
4	30.97	37.13	40.70		
5	43.65	44.23	46.68	40.76	

As has been found in the past, the highest dissimilarity between sites was between Porters Ck (Site 3) and Archer Ck (Site 5) (46.68%). Both sites contained taxa only present in one of the two sites. Porters Ck recorded Hydrobiidae (snails), Isostictidae (damselflies), Planorbidae (snails), and Erpobdellidae and Glossiphoniidae (leeches) in all or most samples during Spring while there were not collected in any samples at Archer Ck. Conversely, Archer Ck recorded Corbiculidae (bivalves) in most samples which were not collected in any samples from Porters Ck.

The most similar of all sites, and also highlighted in the classification and ordination plots (Figure 5 and Figure 6), was between Terry's Ck (Site 1) and Buffalo Ck (Site 4) (30.97%). Of the eighteen taxa contributing to the dissimilarity between the sites, only four taxa were present in some samples from a single site only. Ostracoda (crustacean) was collected in Buffalo Ck only, while Lymnaeidae (gastropoda), Glossiphoniidae (leeches), and Gerridae (water striders) were collected in some samples at Terry's Ck only.

BVSTEP

The output from the BVSTEP routine for the results from the five sites is presented in **Appendix F**.

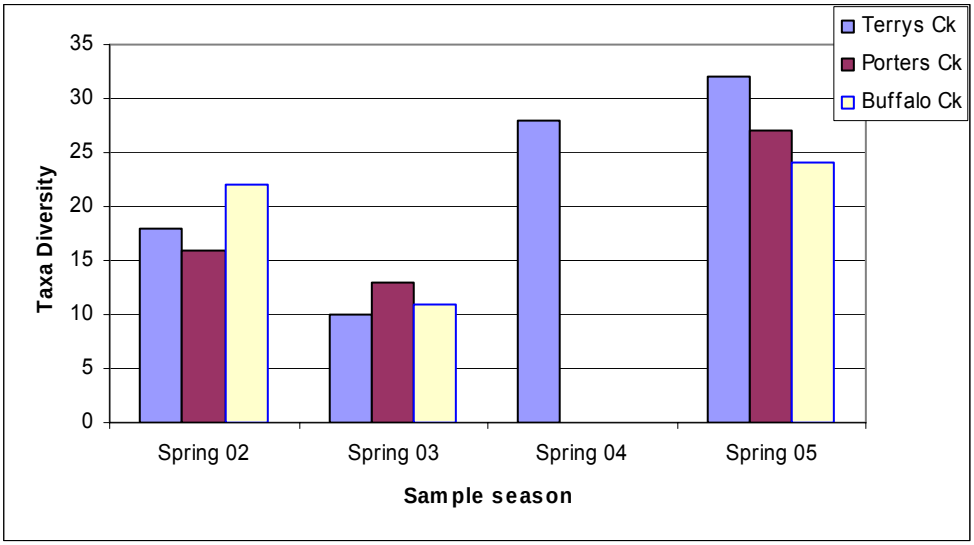
BVSTEP found a number of variables which could be contributing to the difference between sites, however the correlation was very weak at 0.209 (4.3%). The main variables highlighted included:

- Conductivity,
- Total Dissolved Solids, and
- Faecal Coliforms.

Historical Data Comparison

Limited information in each of the previous monitoring reports restricted the level of comparison with the current Spring 2005 data set. Historical taxa diversity and AusRivAS OE50 scores could be compared between those sites undertaken by Robyn Tuft and Associates (Site 1 – Terry's Ck, Site 3 – Porters Ck, and Site 4 – Buffalo Ck), but with some limitations (Figure 7 and Table 12). The Robyn Tuft and Associates programs collected single samples during each season, compared with three events over the Spring months during the Ecowise Spring 2005 programs. For comparative purposes, the Spring 2005 data was combined for diversity and averaged for the AusRivAS OE50 scores. The Ecowise Spring 2004 data from Porters Ck (Site 3) and Buffalo Ck (Site 4) was not included in the analysis as the sites were incorrectly located in 2004 and therefore not directly comparable with historical site locations.

After the initial decline in taxa diversity from 2002 to 2003, the results presented in Figure 7 show an increasing trend from 2003 for all sites. Terrys Ck showed the most improvement from 18 taxa recorded in 2003 to 32 taxa recorded in 2005.



Historical data sourced from Robyn Tuft and Associates (2004) report.

Figure 7: Taxa diversity for three of the core sites measured by Robyn Tuft and Associates Spring 2002 and 2003, and Ecowise Spring 2004 and 2005, City of Ryde.

In contrast to the improved trend in taxa diversity, Porters Ck and Buffalo Ck either remained with the same OE50 score or declined within the same AusRivAS banding. Terrys Ck was the only site which showed some improvements in comparison to historical trends.

Table 12: Comparison of AusRivAS O/E50 scores (and bandings) for the core creeks sampled by Robyn Tuft and Associates Spring 2002, and Ecowise Spring 2004 and 2005, City of Ryde.

Sampling event	Site		
	Terrys Ck	Porters Ck	Buffalo Ck
Spring 02	0.38 (C)	0.29 (C)	0.49 (C)
Spring 03	N/A	N/A	N/A
Spring 04	0.28 (C)	N/C	N/C
Spring 05	0.53 (B)	0.29 (C)	0.39 (C)

Historical data sourced from Robyn Tuft and Associates (2004) report.
Note: N/A – data not run through the AusRivAS model
N/C – sample not collected.

5 DISCUSSION

5.1 General Discussion

The results of the Spring 2005 sampling program indicate that the five City of Ryde sites are typical of urban creeks with moderate to poor ecological health, dominated by pollution tolerant taxa and poor water quality, including low dissolved oxygen, high nutrient levels and high faecal coliforms. These results are comparable with past sampling events conducted by Robyn Tuft and Associates (2002; 2003a&b; 2004), BioTrack (2001; 2002; 2004), and Ecowise (2004, 2005).

Low concentrations of dissolved oxygen (DO) can adversely affect many aquatic organisms that depend upon oxygen for their survival (ANZECC and ARMCANZ, 2000) as they can have a direct (eg. toxic) and indirect effect (eg. changing the redox potential of soils and releasing Phosphorus into the water column) on biota (ANZECC and ARMCANZ, 2000). DO regularly fell below the recommended ANZECC and ARMCANZ trigger value of 85% saturation at all sites for at least one sampling event during the Spring 2005 program. Levels at Porters Ck recorded DO marginally below the guideline during September only. The higher DO generally observed in Porters Ck (Site 3) in comparison to the other creeks may be explained by the many turbulent areas along Porters Ck where the water is aerated through the system, including cascades within the reach at Wicks Rd, the diffuser and piped section at the depot, and through the piped section just before the sample site (Figure 8).

Figure 8: Cascade at end of piped section immediately upstream of site on Porters Ck below the depot, Spring 2005.

The ANZECC and ARMCANZ (2000) guidelines recommend that even in highly modified ecosystems, dissolved oxygen concentrations, determined over at least one diurnal cycle, should not fall below 60% saturation. However, it must be recognised that under natural conditions dissolved oxygen concentrations can vary considerably over a daily period, and can also be influenced by other water quality variables such as water temperature, salinity, microbial activity and photosynthetic activity. Meaningful interpretation of dissolved oxygen values should be based on data incorporating the full daily range of values, and if possible, the diurnal (daily) range over a few days (ANZECC and ARMCANZ, 2000). The measurements taken during this study provide a 'snapshot'

of dissolved oxygen values within each creek and are only indicative of conditions prevailing at the time of assessment.

During the Spring 2005 program, the nutrient level guidelines were exceeded on several occasions at some sites for oxidised nitrogen and ammonium, including all sampling events at Porters Ck (Site 3). Urban catchments are known to deposit high volumes of nutrients into creeks from stormwater runoff, artificial fertilisers and sediment. Nutrients present in a river system can either be directly toxic to biota (eg. ammonium), or indirectly toxic through a direct effect on other stressors of biota (eg. nutrients which can result in excessive algal growth) (ANZECC and ARMCANZ, 2000).

High levels of Faecal Coliforms were recorded at all sites during at least one sampling event in the Spring 2005 program, with Shrimptons Ck (Site 2) and Porters Ck (Site 3) recording 32000 and 16000 orgs/100ml, respectively, during the October event. There is no obvious point source for these high readings and faecal coliform levels reduced significantly during the following November program; however, they still remained above the primary contact guidelines of 150orgs/100ml. Caution should be taken when interpreting these faecal coliform results as the ANZECC and ARMCANZ (2000) guidelines require a minimum of five samples to be collected at regular intervals over a single month and the current program results are based on the collection of one sample per month over three months. It may be warranted to expand the water quality sampling program to investigate faecal coliform levels based around the ANZECC and ARMCANZ (2000) suggested sampling regime during the Autumn 2006 program, should the bacterial levels exceed the median guidelines at any stage.

As has been found in past surveys, all sites were dominated by pollution tolerant taxa, including Oligochaeta – worms (2), Physidae – snails (1) and Chironominae – biting midges (3). The sites lacked many of the sensitive taxa present in high quality reference condition freshwaters, resulting in AusRivAS bandings of 'B' or lower. This suggested the sites were severely impaired with fewer taxa observed than expected. Urban creek catchments are generally impacted by poor/no riparian zones, channelisation, stormwater runoff and human impacts (illegal dumping of weeds, rubbish, contaminants etc), which could all contribute to poor species diversity. Many Chironomidae species are tolerant to heavy metals and the dominance of Chironominae and Oligochaeta in a sample could also suggest organic enrichment (Yandora, 1998). Physidae is an introduced taxa indicative of poor water quality and nutrient enrichment (Gooderham and Tsyrlin, 2003).

Many expected taxa highlighted in the AusRivAS output were found to be missing from the five sites, which suggested the creeks are in a degraded state. The absence of these animals indicates poor water quality and poor in-stream habitat diversity. Ten of the sixteen expected (but missing) taxa occurred from families with a low sensitivity to pollution (SIGNAL2 scores <5); however, the presence of several families of Odonata (dragonflies and damsel flies) such as Libellulidae (4) (all sites), Megapodagrionidae (5) (all sites but Shrimptons Ck), Isostictidae (3) (Terry's Ck, Porters Ck and Buffalo Ck), and Coenagrionidae (2) (all sites but Buffalo Ck) in most samples at all sites suggests the creeks do have a limited capacity to support some larger predatory animals.

The multivariate analyses highlighted within-site and between-site variation amongst the five sites, with Shrimptons Ck indicated as having the least within-site variation and a high level of between-site variation during the Spring 2005 program. A total of eight taxa out of 18 were collected in all three Shrimptons Ck samples Archer Ck was highlighted as having the highest within-site variation, with one sample grouping with Shrimptons Ck samples, another with a Porters Ck sample and the last with the group of Terry's Ck and Buffalo Ck samples. Archer Ck samples only contained five of the same taxa out of a

total of 22 taxa collected across the Spring 2005 program. The variation in samples highlights the necessity to collect multiple samples from a site to achieve a more thorough ecological assessment.

5.2 Individual Site Summaries

5.2.1 Site 1: Terrys Ck

Figure 9: Site 1 (Terrys Ck) facing downstream in September 2005.

The Terrys Ck site contained a moderate diversity of macroinvertebrate fauna, with 32 different taxa collected from the edge habitat over the 3 Spring sampling events. There are a number of microhabitats within the reach including shallow and deep slow-flowing sections, undercut banks, trailing bank vegetation, and shading from riparian vegetation, all of which provide quality habitat for macroinvertebrates.

The AusRivAS results showed a gradual improvement over the Spring 2005 sampling program from a classification of severely impaired (Band 'C') in September to significantly (Band 'B') impaired in October and November. This gradual improvement was also observed over time, with an improvement in taxa diversity and AusRivAS heath ratings from Spring 2003 to Spring 2005. Taxa differences between Spring 2004 and Spring 2005 included the presence of Acarina (6), Aeshnidae (4), Ceratopogonidae (4), Libellulidae (4), Simuliidae (4) and Synlestidae (7) plus other pollution tolerant taxa (8 taxa) only in the Spring 2005 results, compared to Ancylidae (4), Gomphidae (5), Hydroptilidae (4), Orthocladiinae (4), Scirtidae (6) and other pollution tolerant taxa (3 taxa) only in Spring 2004 results.

Six taxa had a >50% probability of occurrence, but were not collected in any samples from the creek during the Spring 2005 event. These included the indicator taxa Leptophlebiidae (8), Leptoceridae (6), and Scirtidae (6). Several indicator taxa including Acarina (6) and Synlestidae (7) were collected in some/all samples suggesting the creek has the capacity to sustain pollution sensitive taxa.

Of interest was a pipe that was found to be leaking along the walking track within the valley at Terrys Ck (Figure 10). It is unknown whether this pipe is from a sewer line or mains water, and although the faecal coliform results were lower than other sites within

Terrys Ck, this leak could be affecting the water quality at the site. Further investigation is warranted.

Figure 10:Leaking pipe along walking track to Terrys Ck site.

Impacts which may be affecting the presence of more pollution sensitive taxa include low dissolved oxygen levels, poor water quality (stormwater, sewage overflows, illegal discharges etc.) and scouring flows through the system. There is evidence of high flows through this site with scouring along the banks and the presence of rubbish and debris in surrounding riparian vegetation.

5.2.2 Site 2: Shrimptons Ck

Figure 11 Site 2 (Shrimptons Ck) facing upstream in November 2005.

Shrimptons Ck recorded the lowest taxa diversity of the five sites, totalling 18 different taxa during the Spring 2005 sampling events, and received the lowest O/E50 scores of

all samples. Shrimptons Ck also recorded the lowest dissolved oxygen of all sites and the highest faecal coliform results during the Spring 2005 sampling program.

Only 8 taxa were collected during all sampling events in Spring, and all are considered pollution tolerant taxa (<4 Signal score). There was also an abundance of missing taxa that were expected to be at the site (11 taxa in all samples) including 4 of the indicator taxa (Acarina, Scirtidae, Leptophlebiidae and Leptoceridae).

Possible impacts causing the overall poor ecological health for Shrimptons Ck include poor water quality (low dissolved oxygen, high nutrients), and potential toxicants in stormwater discharges. The site is highly infested with weed species in the riparian zone, and has limited good quality habitat for macroinvertebrates.

5.2.3 Site 3: Porters Ck

Porters Ck catchment is a highly modified system, with the majority of the creek piped underground. The site is located downstream of the Ryde Council Depot, within the National Park, where the creek returns to the surface as a natural channel.

Several water quality parameters at Porters Ck exceeded the ANZECC and ARMCANZ (2000) guidelines in the Spring 2005 sampling program including Conductivity, Faecal Coliforms, and Ammonium. Conductivity levels are well above the guideline levels, and have been recorded at high levels during previous programs in Spring 2004 and Autumn 2005 (Ecowise 2004, 2005), and should continue to be investigated.

Although Porters Ck resulted in the collection of the second highest taxa diversity (27 taxa) of all five sites, all animals collected were pollution tolerant taxa. No indicator taxa were present except Acarina (6) which was collected in one sample only during November. This resulted in a low OE50 score of Band 'C' and 'D', suggesting the site to be in a severely to extremely impaired condition. AusRivAS also listed 9 taxa which were expected but not collected from all samples (Appendix D) including four indicator taxa of which Leptophlebiidae (8) was 100% expected.

Figure 12:Site 3 (Porters Ck) upstream in October 2005.

Poor water quality, an abundance of pollution tolerant taxa and catchment impacts (stormwater inflows, unknown discharges, and illegal dumpings observed in previous programs) all influence the ecological health at this site.

5.2.4 Sites 4: Buffalo Ck

Buffalo Ck borders many residential properties and is highly infested with weed species along the riparian zone, although rehabilitation works are ongoing upstream. A large industrial drain flows into the site immediately upstream of the sampling location (see inset Figure 13).

Figure 13:Site 4 (Buffalo Ck) upstream with location of industrial drain inflow indicated.

A moderate number of taxa were collected over the course of the Spring program, including the indicator taxa Acarina (6) which was collected across all three sampling events. This site contained the most consistent number of animals, with 12 taxa collected in all three samples. All samples were comparable in regards to the AusRivAS results, with all samples recording similar OE50 scores (0.38-0.39) in the Band 'C' rating. However, in relation to the historical data, this site has declined slightly in ecological health compared with the Spring 2002 program.

Site 4 recorded the most similarities in macroinvertebrate community composition to Site 1 (the most ecologically healthy of the five sites) as presented in the classification, ordination and SIMPER results. These results suggest Buffalo Ck has similar microhabitats Terrys Ck and the potential to sustain a similar macroinvertebrate community.

The results indicate Buffalo Ck to be in moderate ecological health with generally poor water quality (low dissolved oxygen and high nutrients). The major impacts on this creek include residential runoff, current clearing and poisoning of privet upstream, scouring flows, and point source discharges from the industrial drain.

5.2.5 Site 5: Archer Ck

Archer Ck has had restoration works completed on the upstream end of Maze Park, with reconstructed banks using sandstone blocks for stabilisation and native plant revegetation. Vegetation growth has been steady at this site; however, weeds are still quite dense within the in-stream zones, and on-going maintenance may be necessary to prevent weeds spreading. A number of microhabitats were present at this site including macrophyte beds, trailing bank vegetation and a partially enclosed canopy for half of the

reach creating shade, however, ongoing siltation and log jams throughout the reach are reducing available habitat areas.

Figure 14:Site 5 (Archer Ck) upstream in October 2005.

Archer Ck recorded a combined diversity of 22 taxa, with only 5 taxa recorded consistently throughout the Spring 2005 program, in comparison to 28 taxa collected in Spring 2004, with 11 taxa collected in all three samples. The creek is slowly being encroached with aquatic and weed species in the channel decreasing the amount of available open water habitat, which may influence the taxa diversity at this site. This may also be the reason for the high level of dissimilarity between samples from this site.

AusRivAS O/E50 scores have also marginally reduced with Band 'B' and 'C' recorded in Spring 2004 to Band 'C' and 'D' in Spring 2005. Differences in taxa which would have influenced this result include the presence of indicator taxa Leptoceridae and Hydroptilidae (Trichoptera) and Baetidae (Ephemeroptera) in 2004 which were not collected in any samples during the 2005 program.

5.3 Conclusion

All sites within the City of Ryde study are indicative of urban creeks, with severe to extreme impairment of ecological health. The main influences on these sites, and the creeks on which they are located, include poor water quality (exceeding recommended ANZECC and ARMCANZ, 2000 guidelines), and poor habitat diversity.

Biodiversity and ecosystem health results from the Spring 2005 sampling program are similar to those obtained in earlier monitoring programs, including the previous sampling programs in Spring 2004 and Autumn 2005. However, a comparison of results from Spring 2002 to 2005 (Robyn Tuft and Associates and Ecowise) for Terrys Ck, Buffalo Ck and Porters Ck indicated a slight improvement in the ecological health of these creeks in 2005.

6 RECOMMENDATIONS

This program is the third of the City of Ryde's Biological/Chemical Water Quality Monitoring Strategy targeting five main creek systems and is to be continued twice yearly over a 7 year period. Following the completion of the Spring 2005 sampling event it is recommended that :

- A water quality monitoring program (including event based sampling) be considered to complement the bi-annual biological program conducted as part of this study to target potential contaminants at the core sites (including additional faecal coliform sampling). A comprehensive water quality dataset would also assist with the interpretation of the biological data,

- An additional faecal coliform sampling program based upon the ANZECC and ARMCANZ (2000) suggested regime of a minimum of five samples collected at regular intervals not exceeding one month. This program should be implemented if faecal coliform levels exceed the median guideline levels (or a more conservative level suggested by City of Ryde) at any stage throughout the biological monitoring program during Autumn 2006.

- The high conductivity concentrations are still occurring in Porters Ck. Further investigation may be warranted into the discharges into Porters Ck from a pipe located on the right bank at the junction of Epping Rd and Wicks Rd, Epping,

- Investigate the leaking pipe along the walkway into Terrys Ck to determine the potential impacts on water quality at this site, and

- Consider compiling all historical raw data (where comparable) for assessment with current study data to provide a temporal evaluation of ecological health of the targeted creeks.

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8 APPENDICES

Appendix A: Macroinvertebrate Results during the Spring 2005 Sampling Program

	Sample date	6th - 7th September 2005						11th - 12th October 2005						2nd November 2005				
	Site Name	Terrys Ck	Shrimptons Ck	Porters Ck	Buffalo Ck	Archer Ck		Terrys Ck	Shrimptons Ck	Porters Ck	Buffalo Ck	Archer Ck		Terrys Ck	Shrimptons Ck	Porters Ck	Buffalo Ck	Archer Ck
	Site Code	1	2	3	4	5		1	2	3	4	5		1	2	3	4	5
	Habitat	Edge	Edge	Edge	Edge	Edge		Edge	Edge	Edge	Edge	Edge		Edge	Edge	Edge	Edge	Edge
Order	Family																	
Acarina		*	*		*			*			*			*	*	*	*	*
Amphipoda	Ceinidae	*		*	*	*		*		*	*							
Bivalvia	Corbiculidae	*	*		*			*	*		*	*		*	*		*	*
Coleoptera	Dytiscidae			*		*		*		*	*					*		*
	Elmidae													*				
Crustacea	Cladocera							*						*				
	Copepoda		*	*	*	*		*	*	*	*	*		*	*		*	
	Ostracoda				*						*				*	*	*	
Decapoda	Atyidae									*								
Diptera	Ceratopogonidae							*										
	Culicidae			*		*		*			*	*						
	s-f Chironominae	*	*	*	*	*		*	*	*	*	*		*	*	*	*	*
	s-f Tanypodinae	*			*	*		*						*				
	Simuliidae	*									*			*				
	Stratiomyidae		*	*	*	*		*										

	Sample date	6th - 7th September 2005						11th - 12th October 2005						2nd November 2005				
	Site Name	Terrys Ck	Shrimptons Ck	Porters Ck	Buffalo Ck	Archer Ck		Terrys Ck	Shrimptons Ck	Porters Ck	Buffalo Ck	Archer Ck		Terrys Ck	Shrimptons Ck	Porters Ck	Buffalo Ck	Archer Ck
	Site Code	1	2	3	4	5		1	2	3	4	5		1	2	3	4	5
	Habitat	Edge	Edge	Edge	Edge	Edge		Edge	Edge	Edge	Edge	Edge		Edge	Edge	Edge	Edge	Edge
Order	Family																	
Gastropoda	Hydrobiidae			*	*			*		*	*			*	*	*	*	
	Lymnaeidae	*	*			*		*										
	Physidae	*	*	*	*	*		*	*	*	*	*		*	*	*	*	*
	Planorbidae	*	*						*	*				*	*	*	*	
Hemiptera	Corixidae		*	*						*	*			*		*		*
	Gelastocoridae		*						*									
	Gerridae							*						*				*
	Nepidae			*														
	Notonectidae	*		*	*			*			*			*			*	
	Veliidae													*				*
Hirudinea	Erpobdellidae			*						*						*		
	Glossiphoniidae		*	*				*	*	*				*	*	*		
Isopoda	Oniscidae	*	*	*	*	*					*						*	*
Odonata	Aeshnidae			*		*						*		*			*	
	Coenagrionidae		*	*		*						*		*		*		*
	Gomphidae			*														
	Hemicorduliidae	*		*	*	*												
	Isostictidae	*		*	*			*		*				*		*		

	Sample date	6th - 7th September 2005						11th - 12th October 2005						2nd November 2005				
	Site Name	Terrys Ck	Shrimptons Ck	Porters Ck	Buffalo Ck	Archer Ck		Terrys Ck	Shrimptons Ck	Porters Ck	Buffalo Ck	Archer Ck		Terrys Ck	Shrimptons Ck	Porters Ck	Buffalo Ck	Archer Ck
	Site Code	1	2	3	4	5		1	2	3	4	5		1	2	3	4	5
	Habitat	Edge	Edge	Edge	Edge	Edge		Edge	Edge	Edge	Edge	Edge		Edge	Edge	Edge	Edge	Edge
Order	**Family**																	
Odonata	**Libellulidae**			*	*	*		*	*	*	*	*		*	*	*	*	*
	Megapodagrionidae	*		*	*	*		*						*		*	*	*
	Synlestidae	*																
Oligochaeta		*	*	*	*	*		*	*	*	*	*		*	*	*	*	*
Turbellaria	**Dugesiidae**	*	*	*	*			*	*		*	*		*	*		*	*

Appendix B: QA Report

QA Report

For: City of Ryde Autumn Sampling Program 2005
Project No.: QE000037

Site	Buffalo Ck at 52 Higginbotham Rd		Porters Ck at Wicks Rd	
Site Code	Site 4		Site 3	
Event	September, 2005		October, 2005	
ID	**Original**	**QA**	**Original**	**QA**
Acarina	6	5		
Ceinidae		2		1
Talitridae	2		1	
Corbiculidae	5	5		
Dytiscidae			1	1
Copepoda	2	2	4	4
Ostracoda	1	1		
Atyidae			2	2
Chironominae	26	26	132	132
Tanypodinae	2	2		
Stratiomyidae	1	1		
Tipulidae		1		
Hydrobiidae	11	11	13	14
Physidae	7	7	8	6
Planorbidae			2	1
Corixidae			2	
Notonectidae	4	4		2
Erpobdellidae			2	2
Glossiphoniidae			4	4
Oniscidae	3	3		
Hemicorduliidae	7	9		3
Isostictidae	1	1	5	5
Libellulidae	2		5	2
Megapodagrionidae	20	20		
Oligochaeta	32	20	5	4
Dugesiidae	3	3		

identification error counting error

Bray Curtis dissimilarity	8.52		4.06
Pass or Fail	**Pass**	(<10%)	

Appendix C: AusRivAS output – Taxa >50% expected and observed

Taxa observed and >50% expected to be in the edge samples of the five sites within the City of Ryde, Autumn 2005. Taxa in bold are indicator taxa.

Site	Taxon Name	**Acarina**	Dytiscidae	Tanypodinae	Chironominae	Veliidae	Gerridae	Notonectidae	Aeshnidae
	Signal Score	**6**	2	4	3	3	4	1	4
Site	**Sampling Event**								
1	September	»0.92		»0.82	»0.65			»0.67	
	October	»0.91	»0.67	»0.83	»0.68		»0.62	»0.64	
	November	»0.92		»0.81	»0.64	»0.86	»0.61	»0.69	»0.55
2	September	»0.91			»0.70				
	October				»0.65				
	November	»0.91			»0.70				
3	September		»0.60		»0.60			»0.73	»0.60
	October		»0.60		»0.60				
	November	»0.93	»0.60		»0.60				
4	September	»0.93		»0.81	»0.62			»0.71	
	October	»0.93	»0.63		»0.63			»0.70	
	November	»0.93			»0.61			»0.72	»0.58
5	September		»0.60	»0.80	»0.60				»0.60
	October				»0.60				»0.60
	November	»0.93	»0.60		»0.60	»0.87	»0.60		

Appendix D: AusRivAS Output – Taxa >50% expected but *not* observed

Taxa NOT observed but >50% expected to be in the edge samples of the five sites within the City of Ryde, Spring 2005. Taxa in bold are indicator taxa.

Site	Taxon Name	**Acarina**	Atyidae	Dytiscidae	Gyrinidae	Hydrophilidae	**Scirtidae**	Culicidae	Tanypodinae	**Baetidae**	**Leptophlebiidae**	Veliidae	Gerridae	Notonectidae	**Synlestidae**	Aeshnidae	**Leptoceridae**
	Signal Score	**6**	3	2	4	2	**6**	1	4	**5**	**8**	3	4	1	**7**	4	**6**
Site	**Sampling event**																
1	September		0.55	0.65	0.84	0.83	0.54			0.5	0.98	0.85	0.61			0.52	0.88
	October		0.61		0.81	0.81	0.53			0.53	0.97	0.84					0.9
	November		0.53	0.64	0.87	0.84	0.54				0.99				0.5		0.88
2	September		0.55	0.72	0.69	0.85	0.61	0.53	0.83		0.94	0.87	0.59	0.61			0.84
	October	0.92	0.51	0.65	0.82	0.86	0.57		0.81		0.97	0.87	0.6	0.68		0.53	0.86
	November		0.55	0.72	0.69	0.85	0.61	0.53	0.83		0.94	0.87	0.59	0.61			0.84
3	September	0.93			0.93	0.87	0.53		0.8		1	0.87	0.6		0.53		0.87
	October	0.93			0.93	0.87	0.53		0.8		1	0.87	0.6	0.73	0.53	0.6	0.87
	November				0.93	0.87	0.53		0.8		1	0.87	0.6	0.73	0.53	0.6	0.87
4	September			0.63	0.88	0.86	0.55				0.99	0.87	0.6		0.51	0.57	0.86
	October				0.86	0.86	0.56		0.81		0.98	0.87	0.6		0.5	0.56	0.86
	November			0.61	0.91	0.86	0.54		0.8		0.99	0.87	0.6		0.52		0.86
5	September	0.93			0.93	0.87	0.53				1	0.87	0.6	0.73	0.53		0.87
	October	0.93		0.6	0.93	0.87	0.53		0.8		1	0.87	0.6	0.73	0.53		0.87
	November				0.93	0.87	0.53		0.8		1			0.73	0.53	0.6	0.87

Appendix E: SIMPER output – all sites

Parameters

Standardise data: No
Transform: None
Cut off for low contributions: 90.00%
Factor name: site

Factor groups
1
2
3
4
5

Group 1
Average similarity: 69.44

Group 2
Average similarity: 74.84

Group 3
Average similarity: 71.94

Group 4
Average similarity: 76.02

Group 5
Average similarity: 59.19

Groups 1 & 2

Average dissimilarity = 41.11

Species	Group 1 Av.Abund	Group 2 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Isostictidae	1.00	0.00	3.33	9.80	8.09	8.09
Megapodagrionidae	1.00	0.00	3.33	9.80	8.09	16.18
Tanypodinae	1.00	0.00	3.33	9.80	8.09	24.27
Notonectidae	1.00	0.00	3.33	9.80	8.09	32.36
Simuliidae	0.67	0.00	2.27	1.31	5.52	37.88
Ceinidae	0.67	0.00	2.27	1.31	5.52	43.40
Gerridae	0.67	0.00	2.11	1.32	5.14	48.54
Lymnaeidae	0.67	0.33	1.90	1.04	4.62	53.16
Hydrobiidae	0.67	0.33	1.82	1.05	4.42	57.58
Oniscidae	0.33	0.33	1.49	0.83	3.64	61.22
Libellulidae	0.67	0.67	1.49	0.83	3.64	64.85
Stratiomyidae	0.33	0.33	1.43	0.84	3.47	68.33
Corixidae	0.33	0.33	1.43	0.84	3.47	71.80
Coenagrionidae	0.33	0.33	1.43	0.84	3.47	75.27
Glossiphoniidae	0.67	1.00	1.21	0.66	2.95	78.22
Copepoda	0.67	1.00	1.21	0.66	2.95	81.17
Hemicorduliidae	0.33	0.00	1.21	0.66	2.95	84.11
Acarina	1.00	0.67	1.21	0.66	2.95	87.06
Ostracoda	0.00	0.33	1.09	0.66	2.65	89.71
Planorbidae	0.67	1.00	1.06	0.66	2.57	92.29

Groups 1 & 3

Average dissimilarity = 41.22

Species	Group 1 Av.Abund	Group 3 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Corbiculidae	1.00	0.00	2.89	8.59	7.02	7.02
Erpobdellidae	0.00	1.00	2.89	8.59	7.02	14.03
Tanypodinae	1.00	0.00	2.89	8.59	7.02	21.05
Dugesiidae	1.00	0.33	2.05	1.32	4.97	26.02

Notonectidae	1.00	0.33	2.05	1.32	4.97	30.99
Simuliidae	0.67	0.00	1.97	1.31	4.77	35.76
Lymnaeidae	0.67	0.00	1.97	1.31	4.77	40.54
Dytiscidae	0.33	1.00	1.97	1.31	4.77	45.31
Corixidae	0.33	1.00	1.97	1.31	4.77	50.08
Acarina	1.00	0.33	1.90	1.30	4.61	54.68
Gerridae	0.67	0.00	1.85	1.32	4.49	59.17
Coenagrionidae	0.33	0.67	1.58	1.04	3.84	63.02
Copepoda	0.67	0.67	1.32	0.84	3.20	66.21
Ceinidae	0.67	0.67	1.28	0.84	3.11	69.33
Oniscidae	0.33	0.33	1.28	0.82	3.11	72.44
Hemicorduliidae	0.33	0.33	1.28	0.82	3.11	75.55
Planorbidae	0.67	0.67	1.23	0.84	2.97	78.53
Culicidae	0.33	0.33	1.23	0.84	2.97	81.50
Stratiomyidae	0.33	0.33	1.23	0.84	2.97	84.47
Aeshnidae	0.33	0.33	1.23	0.84	2.97	87.45
Megapodagrionidae	1.00	0.67	1.06	0.66	2.56	90.01

Groups 2 & 3

Average dissimilarity = 44.04

Species	Group 2 Av.Abund	Group 3 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Isostictidae	0.00	1.00	3.64	6.72	8.27	8.27
Corbiculidae	1.00	0.00	3.64	6.72	8.27	16.54
Erpobdellidae	0.00	1.00	3.64	6.72	8.27	24.82
Dytiscidae	0.00	1.00	3.64	6.72	8.27	33.09
Dugesiidae	1.00	0.33	2.62	1.32	5.95	39.03
Corixidae	0.33	1.00	2.53	1.30	5.75	44.78
Hydrobiidae	0.33	1.00	2.45	1.29	5.56	50.34
Ceinidae	0.00	0.67	2.39	1.28	5.42	55.76
Megapodagrionidae	0.00	0.67	2.28	1.30	5.18	60.94
Coenagrionidae	0.33	0.67	1.99	1.04	4.53	65.47
Acarina	0.67	0.33	1.97	1.03	4.48	69.95
Ostracoda	0.33	0.33	1.63	0.83	3.69	73.64
Oniscidae	0.33	0.33	1.50	0.84	3.41	77.05
Stratiomyidae	0.33	0.33	1.50	0.84	3.41	80.46
Copepoda	1.00	0.67	1.26	0.66	2.86	83.32
Libellulidae	0.67	1.00	1.11	0.66	2.53	85.84
Lymnaeidae	0.33	0.00	1.11	0.66	2.53	88.37
Planorbidae	1.00	0.67	1.02	0.66	2.33	90.69

Groups 1 & 4

Average dissimilarity = 30.97

Species	Group 1 Av.Abund	Group 4 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Ostracoda	0.00	1.00	2.84	14.20	9.18	9.18
Lymnaeidae	0.67	0.00	1.93	1.32	6.24	15.41
Isostictidae	1.00	0.33	1.93	1.33	6.23	21.65
Tanypodinae	1.00	0.33	1.93	1.33	6.23	27.88
Glossiphoniidae	0.67	0.00	1.82	1.33	5.88	33.76
Oniscidae	0.33	1.00	1.82	1.33	5.88	39.63
Gerridae	0.67	0.00	1.82	1.33	5.88	45.51
Simuliidae	0.67	0.33	1.60	1.05	5.15	50.66
Planorbidae	0.67	0.33	1.57	1.05	5.08	55.74
Hemicorduliidae	0.33	0.33	1.28	0.84	4.13	59.88
Aeshnidae	0.33	0.33	1.27	0.84	4.10	63.97
Ceinidae	0.67	0.67	1.27	0.84	4.10	68.07
Culicidae	0.33	0.33	1.25	0.84	4.03	72.09
Dytiscidae	0.33	0.33	1.25	0.84	4.03	76.12
Corixidae	0.33	0.33	1.25	0.84	4.03	80.14
Stratiomyidae	0.33	0.33	1.24	0.84	3.99	84.14
Hydrobiidae	0.67	1.00	1.02	0.67	3.30	87.44
Copepoda	0.67	1.00	1.02	0.67	3.30	90.74

Groups 2 & 4

Average dissimilarity = 37.13

Species	Group 2 Av.Abund	Group 4 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Glossiphoniidae	1.00	0.00	3.56	10.79	9.58	9.58
Notonectidae	0.00	1.00	3.56	10.79	9.58	19.15
Oniscidae	0.33	1.00	2.47	1.32	6.64	25.80
Hydrobiidae	0.33	1.00	2.39	1.31	6.44	32.24
Ostracoda	0.33	1.00	2.39	1.31	6.44	38.68
Megapodagrionidae	0.00	0.67	2.39	1.32	6.43	45.11
Planorbidae	1.00	0.33	2.30	1.32	6.19	51.30
Ceinidae	0.00	0.67	2.30	1.32	6.19	57.49
Corixidae	0.33	0.33	1.54	0.84	4.15	61.64
Stratiomyidae	0.33	0.33	1.52	0.84	4.10	65.74
Acarina	0.67	1.00	1.30	0.67	3.51	69.25
Aeshnidae	0.00	0.33	1.26	0.66	3.39	72.63
Simuliidae	0.00	0.33	1.17	0.66	3.15	75.78
Culicidae	0.00	0.33	1.17	0.66	3.15	78.93
Dytiscidae	0.00	0.33	1.17	0.66	3.15	82.08
Isostictidae	0.00	0.33	1.13	0.66	3.04	85.12
Hemicorduliidae	0.00	0.33	1.13	0.66	3.04	88.16
Tanypodinae	0.00	0.33	1.13	0.66	3.04	91.20

Groups 3 & 4

Average dissimilarity = 40.70

Species	Group 3 Av.Abund	Group 4 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Glossiphoniidae	1.00	0.00	3.07	8.89	7.53	7.53
Corbiculidae	0.00	1.00	3.07	8.89	7.53	15.07
Erpobdellidae	1.00	0.00	3.07	8.89	7.53	22.60
Oniscidae	0.33	1.00	2.18	1.33	5.36	27.96
Dugesiidae	0.33	1.00	2.18	1.33	5.36	33.31
Notonectidae	0.33	1.00	2.18	1.33	5.36	38.67
Isostictidae	1.00	0.33	2.09	1.31	5.13	43.80
Dytiscidae	1.00	0.33	2.06	1.31	5.05	48.85
Corixidae	1.00	0.33	2.06	1.31	5.05	53.90
Acarina	0.33	1.00	2.01	1.30	4.94	58.84
Ostracoda	0.33	1.00	2.01	1.30	4.94	63.78
Coenagrionidae	0.67	0.00	1.94	1.32	4.77	68.55
Planorbidae	0.67	0.33	1.72	1.05	4.23	72.78
Megapodagrionidae	0.67	0.67	1.39	0.83	3.43	76.21
Ceinidae	0.67	0.67	1.39	0.84	3.41	79.62
Aeshnidae	0.33	0.33	1.34	0.83	3.30	82.93
Culicidae	0.33	0.33	1.31	0.84	3.22	86.15
Hemicorduliidae	0.33	0.33	1.30	0.84	3.18	89.33
Stratiomyidae	0.33	0.33	1.30	0.84	3.18	92.52

Groups 1 & 5

Average dissimilarity = 43.65

Species	Group 1 Av.Abund	Group 5 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Isostictidae	1.00	0.00	3.19	9.34	7.31	7.31
Notonectidae	1.00	0.00	3.19	9.34	7.31	14.61
Tanypodinae	1.00	0.33	2.22	1.32	5.10	19.71
Planorbidae	0.67	0.00	2.17	1.31	4.98	24.69
Simuliidae	0.67	0.00	2.17	1.31	4.98	29.67
Coenagrionidae	0.33	1.00	2.17	1.31	4.98	34.65
Acarina	1.00	0.33	2.13	1.31	4.89	39.53
Glossiphoniidae	0.67	0.00	2.03	1.32	4.65	44.19
Hydrobiidae	0.67	0.00	2.03	1.32	4.65	48.84
Lymnaeidae	0.67	0.33	1.83	1.04	4.18	53.02
Ceinidae	0.67	0.33	1.83	1.04	4.18	57.21
Culicidae	0.33	0.67	1.79	1.04	4.10	61.31
Aeshnidae	0.33	0.67	1.79	1.04	4.10	65.41

Dytiscidae	0.33	0.67	1.75	1.05	4.00	69.41
Gerridae	0.67	0.33	1.74	1.04	3.99	73.40
Oniscidae	0.33	0.67	1.72	1.04	3.94	77.34
Copepoda	0.67	0.67	1.45	0.84	3.32	80.65
Hemicorduliidae	0.33	0.33	1.43	0.83	3.27	83.93
Corixidae	0.33	0.33	1.40	0.84	3.20	87.13
Stratiomyidae	0.33	0.33	1.36	0.84	3.12	90.25

Groups 2 & 5

Average dissimilarity = 44.23

Species	Group 2 Av.Abund	Group 5 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Planorbidae	1.00	0.00	4.13	6.98	9.33	9.33
Glossiphoniidae	1.00	0.00	4.13	6.98	9.33	18.65
Coenagrionidae	0.33	1.00	2.88	1.30	6.51	25.17
Culicidae	0.00	0.67	2.76	1.29	6.25	31.42
Aeshnidae	0.00	0.67	2.76	1.29	6.25	37.67
Megapodagrionidae	0.00	0.67	2.57	1.31	5.82	43.48
Dytiscidae	0.00	0.67	2.57	1.31	5.82	49.30
Oniscidae	0.33	0.67	2.25	1.05	5.10	54.39
Acarina	0.67	0.33	2.24	1.04	5.06	59.46
Corixidae	0.33	0.33	1.78	0.83	4.03	63.49
Lymnaeidae	0.33	0.33	1.72	0.84	3.88	67.37
Stratiomyidae	0.33	0.33	1.72	0.84	3.88	71.25
Copepoda	1.00	0.67	1.36	0.66	3.08	74.32
Gerridae	0.00	0.33	1.36	0.66	3.08	77.40
Hydrobiidae	0.33	0.00	1.35	0.66	3.04	80.45
Ostracoda	0.33	0.00	1.35	0.66	3.04	83.49
Libellulidae	0.67	1.00	1.24	0.66	2.81	86.30
Corbiculidae	1.00	0.67	1.21	0.66	2.74	89.04
Dugesiidae	1.00	0.67	1.21	0.66	2.74	91.78

Groups 3 & 5

Average dissimilarity = 46.68

Species	Group 3 Av.Abund	Group 5 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Isostictidae	1.00	0.00	3.48	6.65	7.45	7.45
Glossiphoniidae	1.00	0.00	3.48	6.65	7.45	14.91
Hydrobiidae	1.00	0.00	3.48	6.65	7.45	22.36
Erpobdellidae	1.00	0.00	3.48	6.65	7.45	29.81
Planorbidae	0.67	0.00	2.49	1.31	5.34	35.15
Corbiculidae	0.00	0.67	2.44	1.30	5.22	40.38
Corixidae	1.00	0.33	2.33	1.29	4.99	45.36
Dugesiidae	0.33	0.67	2.05	1.03	4.40	49.76
Culicidae	0.33	0.67	2.00	1.03	4.28	54.03
Aeshnidae	0.33	0.67	2.00	1.03	4.28	58.31
Ceinidae	0.67	0.33	1.95	1.03	4.19	62.50
Oniscidae	0.33	0.67	1.92	1.05	4.12	66.62
Megapodagrionidae	0.67	0.67	1.61	0.84	3.46	70.08
Acarina	0.33	0.33	1.56	0.83	3.34	73.41
Copepoda	0.67	0.67	1.56	0.83	3.34	76.75
Hemicorduliidae	0.33	0.33	1.43	0.84	3.06	79.80
Stratiomyidae	0.33	0.33	1.43	0.84	3.06	82.86
Coenagrionidae	0.67	1.00	1.29	0.66	2.77	85.63
Dytiscidae	1.00	0.67	1.29	0.66	2.76	88.39
Ostracoda	0.33	0.00	1.20	0.66	2.57	90.96

Groups 4 & 5

Average dissimilarity = 40.76

Species	Group 4 Av.Abund	Group 5 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Hydrobiidae	1.00	0.00	3.40	10.01	8.34	8.34
Ostracoda	1.00	0.00	3.40	10.01	8.34	16.68

Notonectidae	1.00	0.00	3.40	10.01	8.34	25.03
Coenagrionidae	0.00	1.00	3.40	10.01	8.34	33.37
Acarina	1.00	0.33	2.27	1.31	5.58	38.95
Culicidae	0.33	0.67	1.90	1.04	4.65	43.60
Ceinidae	0.67	0.33	1.90	1.05	4.65	48.25
Aeshnidae	0.33	0.67	1.87	1.04	4.58	52.84
Dytiscidae	0.33	0.67	1.85	1.05	4.54	57.38
Megapodagrionidae	0.67	0.67	1.55	0.84	3.80	61.18
Corixidae	0.33	0.33	1.50	0.84	3.69	64.87
Hemicorduliidae	0.33	0.33	1.45	0.84	3.56	68.42
Tanypodinae	0.33	0.33	1.45	0.84	3.56	71.98
Stratiomyidae	0.33	0.33	1.45	0.84	3.56	75.54
Oniscidae	1.00	0.67	1.25	0.67	3.07	78.61
Planorbidae	0.33	0.00	1.20	0.66	2.94	81.56
Copepoda	1.00	0.67	1.13	0.67	2.76	84.32
Gerridae	0.00	0.33	1.13	0.67	2.76	87.08
Simuliidae	0.33	0.00	1.12	0.66	2.74	89.82
Isostictidae	0.33	0.00	1.08	0.66	2.65	92.48

Appendix F: BVSTEP output – all sites

BVSTEP
Biota and/or Environment matching

Similarity Matrix

File: T:\Projects\QE000037 City of Ryde BMP\2005 Spring\results\sim matrix Spring05.sid
Data type: Similarities
Sample selection: All

Parameters

Rank correlation method: Spearman
Termination criteria:
rho > 0.95
delta rho < 0.001
Use random selection for starting variables
Number of restarts: 5
Percentage of starting variables: 50

Similarity Matrix Parameters for sample data worksheet:
Analyse between: Samples
Similarity measure: Euclidean distance
Standardise: No
Transform: None

Variables

1 Water Temp	**14 sticks**
2 Conductivity	15 branches
3 pH	16 logs
4 DO (%sat.)	**17 algae**
5 Turbidity	18 macrophytes
6 Bedrock	**19 TDS (mg/L)**
7 Boulder	20 TP (µg/L)
8 Cobble	21 TN (µg/L)
9 Pebble	**22 NOx (µg/L)**
10 Gravel	23 TKN (µg/L)
11 Sand	24 Ammonia (µg/L)
12 Silt/clay	**25 Faecal Coliforms**
13 detritus	**26 Total Alk. (CaCO3)**

Best results

No. Vars	Corr.	Selections
10	**0.209**	**2,6,8,11,14,17,19,22,25,26**
7	0.209	2,8,11,13,17,19,25
7	0.209	2,6,7,14,17,19,25
6	0.208	2,14,17,19,22,25
3	0.208	2,19,25