ENVIRONMENTAL HEALTH OF STREAMS IN THE MARIBYRNONG RIVER CATCHMENT

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ABSTRACT

The health of urban and rural waterways depends on the geography of the surrounding area, and the type and degree of disturbance in their catchments. Catchments with extensive urban and industrial development – such as the Maribyrnong River system – are particularly prone to reduction in aquatic values.

Land use in the catchment may affect water quality. Leaching of nutrients, the input of livestock waste and agricultural chemicals, erosion, runoff, leakage of faulty septic tanks and discharge from sewage treatment plants may lead to increases in nutrient levels. There may also be accidental spillage of pollutants or discharge of industrial effluent. Lack of suitable habitat and clearing of the riparian zone can also reduce biotic diversity in rivers.

As part of the Commonwealth Government's Monitoring River Health Initiative (MRHI), EPA conducted a biological monitoring program at 17 sites in the Maribyrnong River catchment. The aims of this project were:

- to assess the ecological health of the Maribyrnong River and its major tributaries using macroinvertebrates and physico-chemical parameters
- to highlight areas that need management for the improvement of river health.

Analysis of the family-level macroinvertebrate data, collected by rapid bioassessment methods in the Maribyrnong River system, supports the geographical division of the system into two major sections – the Non-urban and the Urban – and the further separation of these two sections into Forest and Rural, and Urban Mainstream and Urban Tributaries, respectively.

The site on Barringo Creek at Barringo, the sole Forest Segment representative, clearly had the best water quality, although nutrient levels were elevated. The sites in the Rural, Urban Mainstream and Urban Tributaries Segments were in poorer health, generally due to a combination of several interacting factors:

- poor streamside vegetation
- erosion and siltation
- nutrient enrichment
- introduction of toxic materials.

Two of the Urban Mainstream sites were in better condition than the other sites, which are further into the urban area. The Urban Tributaries were in the poorest condition, as reflected by the depauperate communities of macroinvertebrates found at the sites, and by poor water quality. Restoration of the riparian zone, along with the reduction of sediment, nutrient and pollutant inputs**,** should be addressed to improve the health of the Maribyrnong system.

An additional aim of this project was to assess the State Environment Protection Policy (Waters of Victoria) Schedule F7 – Waters of the Yarra Catchment (Government of Victoria 1999) objectives for their general applicability to the Maribyrnong River system. Few sites met the objectives. Further investigation is needed to set specific objectives of environmental quality and ecological diversity for the Maribyrnong catchment.

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1. INTRODUCTION

The health of urban and rural waterways depends on the geography of the surrounding area and the type and degree of disturbance in their catchments. Catchments with extensive urban and industrial development – such as the Maribyrnong River system – are particularly prone to reduction in aquatic values.

The Maribyrnong River system drains a catchment area of approximately 1480 km^2, north-west of Melbourne (figure 1). Upstream, the river drains mainly agricultural and forested areas. Downstream, the river is a natural focus for the western suburbs of Melbourne and outlying regions, contributing areas of significant natural value and providing drainage of both urban stormwater runoff and waste-water from industries.

The Monitoring River Health Initiative (MRHI) was instigated in 1993 by the Commonwealth Government with the express intent of developing a nationally consistent approach to monitoring the condition of inland waters. The program aims to develop a standard methodology for monitoring the ecological health of freshwater systems using the Rapid Biological Assessment (RBA) technique described by Davies (1994) (EPA 1998). In Victoria, a Statewide biological monitoring program has been in place since 1990**,** with the EPA as the lead agency, developing and coordinating the program. The EPA has continued this role in the MRHI program.

It is widely recognised that the measurement and characterisation of aquatic biological communities is critical to assessment of water quality and is complementary to chemical monitoring of waterways (Wright *et al.* 1994; Norris and Norris 1995). Chemical monitoring alone is insufficient to adequately determine environmental impacts of pollution, since it is limited to an instantaneous measure of water quality. Measurement and characterisation of macroinvertebrate communities can allow a more complete picture of water and habitat quality. Aquatic organisms show an integrated response to the environmental factors that affect them over a period of time (Cullen 1990; Rosenberg and Resh 1993); they respond to intermittent stresses as well as ambient conditions. There is considerable information available on the response of macroinvertebrate communities to various forms of pollution and to changes in catchment use – such as agriculture, forestry and urbanisation. Moreover, pollution is essentially a biological phenomenon (Wright *et al.* 1994; Cullen 1990), hence measurement of biological parameters is crucial to an understanding and assessment of the effects of anthropogenic impacts on aquatic communities.

Each land use in a catchment has the potential to affect water quality. Agriculture may accelerate the leaching of nutrients, or the input of livestock waste and agricultural chemicals to the streams. Erosion may be increased by direct access of stock to streams, and by clearing of streamside vegetation. Residential development may also contribute to erosion, through clearing, road construction and other building activities. Runoff, leakage of faulty septic tanks, discharge from sewage treatment plants, and illegal or ineffective connections to the sewerage system may all lead to increases in nutrient levels. Industrial land use may lead to similar problems, with the additional possibility of accidental spillage of pollutants or discharge of industrial effluent, which may contain heavy metals and/or organic compounds, as well as other contaminants.

Sites with water quality which has been affected by pollution or gross nutrient-enrichment generally have reduced faunas, compared with less disturbed sites (Hellawell 1986). The exception is when only mild enrichment occurs, as this may cause a localised increase in community diversity. Sensitive taxa tend to be lost from the community as conditions deteriorate, resulting in a less diverse fauna. Some taxa, however, are pollution-tolerant, and these form the macroinvertebrate communities of degraded sites.

Lack of suitable habitat can also be a factor reducing community diversity in rivers. Even with good water quality, a healthy aquatic ecosystem cannot be supported if suitable habitat is not present. For example, increased sediment inputs can reduce the availability of microhabitats (Metzeling *et al.* 1995), as can removal of riparian vegetation. The riparian zone provides a buffer for the river, filtering sediment and nutrient runoff, and provides habitat and food resources for macroinvertebrates.

The Maribyrnong River catchment has been the focus of several water quality studies (EPA 1981a; EPA 1990). Published reports (Brown and Davies 1989; EPA 1990) have emphasised the use of aquatic biota to assess the health of the aquatic environment in the Maribyrnong catchment. In an earlier study by EPA (1990) four sites were sampled twice each year over three years, concentrating on a single aquatic habitat. This report is more comprehensive, assessing water quality by sampling macroinvertebrates from two aquatic habitats over two seasons, using rapid bioassessment techniques at a total of 17 sites in the catchment, in both urban and non-urban environments.

The project's aims are to assess the ecological health of the Maribyrnong River and its major tributaries using macroinvertebrates and physico-chemical parameters and, using this information, to highlight areas that need management for the improvement of river health.

The *State Environment Protection Policy (Waters of Victoria) Schedule F7 – Waters of the Yarra Catchment* (Government of Victoria 1999) classifies sections of the Yarra catchment according to characteristics based on the *General Surface Waters and Estuarine Segments of the Waters of Victoria Policy* (Government of Victoria 1988). Environmental and ecological objectives have been set in the SEPP for the proposed segments. As the Maribyrnong and Yarra river systems drain a significant portion of metropolitan Melbourne and outlying areas, the project will also assess Yarra SEPP objectives for their general applicability to the Maribyrnong River system.

2. CATCHMENT DESCRIPTION

The Maribyrnong River originates in the Great Dividing Range and flows for approximately 180 km to Melbourne, where it drains into the Yarra River estuary at the northern end of Port Phillip Bay (figure 1). At times, tidal influence and estuarine conditions extend 12 km upstream to the Canning Street Ford, in Avondale Heights. The upper portion of the catchment comprises three main tributaries, extending around the towns of Gisborne, Sunbury, Lancefield, Macedon, Riddells Creek, Darraweit Guim and Bulla.

The topography of the catchment can be classified into three major areas. From the mouth of the river to the suburb of Maribyrnong, the catchment is typified by low-lying floodplains. Further upstream, the river flows through basaltic plains, which cover more than half the basin. In this area, the river has incised deep valleys into the plains. The elevation increases rapidly in the northern and north-western sections of the catchment, rising from the plains to the hills and ridges of the Great Dividing Range. Prominent features of this region are the Macedon, Cobaw and Mount William Ranges. Runoff from the Macedon Ranges forms the headwaters of the three major tributaries of the Maribyrnong River: Deep Creek, Jacksons Creek and Emu Creek.

The largest stream arising in the Macedon Ranges is Deep Creek, which becomes the Maribyrnong River in its lower reaches. This creek drains more than half of the catchment. Its major tributaries are Boyd Creek, Konagaderra Creek and Emu Creek. Riddells Creek – a tributary of Jacksons Creek – drains the southern slopes of the Macedon Ranges. In the metropolitan section Arundel Creek, Taylors Creek, Steele Creek and Stony Creek join the main stream.

The catchment has a marine coastal to humid subtropical/continental climate with warm dry summers and cool winters. Rainfall peaks slightly in spring, with the average annual rainfall in the lower reaches of the catchment varying from 500–600 mm between Footscray and Sunbury. The seasonal flow pattern – based on average monthly flows – shows high winter/spring flows and low summer/autumn flows. Local rainfall events may cause short-term peak flows.

The main land use activities in the non-urban areas of the catchment are agriculture, quarrying and forestry operations. There are some forestry operations in the upper reaches of the catchment, and basalt and clay quarries operate along Emu Creek and along the Maribyrnong River, below the junction of Deep and Jacksons Creeks. Near Keilor, the catchment is subject to various activities – such as cropping, grazing and extensive market gardening. Areas south of Keilor – once used for horticulture – are now part of Brimbank Park, a recreational reserve. The Organ Pipes National Park and the Wombat State Forest are also in the Maribyrnong catchment. Residential, commercial and industrial land uses are primarily confined to the suburbs of Melbourne – Footscray, Sunshine, Essendon and Keilor – with further urban development in the outer Melbourne suburbs of Sunbury, Bulla and Diggers Rest.

3. SITE SELECTION

Seventeen sites were selected in the Maribyrnong catchment – four in the mainstream and 13 in tributaries of the river. The sampling program was intended to assess general water quality conditions of the catchment, rather than to investigate point-source problems. Sites were selected which represented a variety of impacts – from a little-disturbed, forested upland site in a closed catchment (Barringo Creek), to heavily developed and urbanised lowland sites. Specific site descriptions are contained in appendix 1. All sites comprise part of the Statewide biological monitoring network and have been allocated two-letter alpha codes which are used throughout the report.

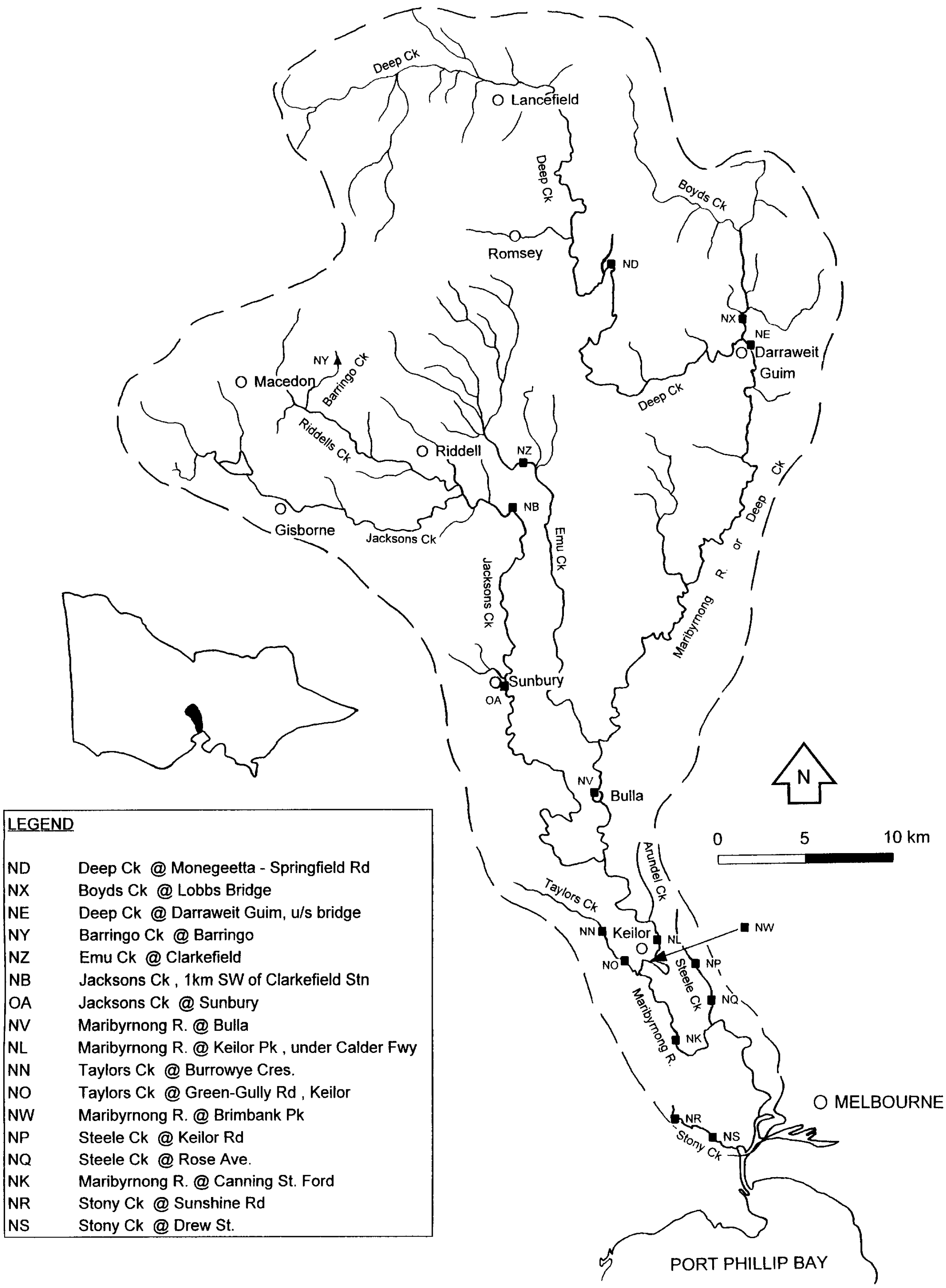

Figure 1: Map of the Maribyrnong catchment showing site locations

4. METHODS

4.1 SAMPLING FREQUENCY

Macroinvertebrate and physico-chemical sampling was conducted in spring 1994 and autumn 1995, to incorporate any seasonal variation in community structure. Data from a further two seasons (spring 1995 and autumn 1996) were collected for non-urban sites only.

4.2 BIOLOGICAL METHODS

A Rapid Biological Assessment (RBA) method, based on that of Davies (1994), was used to collect benthic macroinvertebrates from two distinct aquatic habitats at each site (EPA 1998). RBA is the standard macroinvertebrate sampling method developed for the Monitoring River Health Initiative (MRHI). This approach allows a faster evaluation of assemblages of benthic macroinvertebrates and is less expensive than traditional intensive quantitative techniques (Resh and Jackson 1993).

Where possible, two habitats – stream edges (including macrophyte beds) and riffles – were sampled at each site.

Riffles are areas of shallow, fast-flowing, turbulent water, usually running over rocks. Some sites lack this habitat. Kick-samples were taken from riffle habitats. This involves kicking and disturbing the streambed in riffles with a 250 µm-mesh kick-net positioned directly downstream to allow the water current to flush dislodged macroinvertebrates into the mouth of the net. Kick-sampling proceeded upstream for a 10 m length of riffle.

Sweep sampling of stream edges entails vigorous sweeping with a 250 µm-mesh net through macrophyte beds and along edges and backwaters with little or no water flow. A composite sample covering 10 m of bank was collected in this manner.

Samples were live-sorted in the field. The contents of the net were spread out in shallow trays and a subsample was picked out over 30 minutes, attempting to ensure that numbers of taxa and individuals picked were representative of their abundance in the whole sample. As broad a range of taxa as possible was collected. Riffle and edge samples were preserved separately in 80% ethanol and transported to the laboratory for further processing. Where possible, identifications were made to species-level for the non-urban sites, and to family-level for the urban sites, using standard published keys and extensive voucher collections maintained at EPA and Water EcoScience (WES) laboratories. Exceptions to these levels of identification were the Oligochaeta, Acarina, and Hirudinea which, for reasons of taxonomic difficulty, could not be resolved beyond class. In addition, Chironomidae were identified to subfamily. For the sake of simplicity, the term ‘family’ will be used to describe identifications to these other taxonomic levels. Sampling and macroinvertebrate identifications were coordinated between EPA and WES – urban sites were sampled by EPA, while non-urban sites were sampled by WES. Quality assurance systems were followed to ensure comparability of sampling effort and identifications between the two organisations. Macroinvertebrate identifications and counts were recorded on an extensive database. Macroinvertebrate data were analysed using univariate statistical and multivariate pattern analysis techniques.

4.3 PHYSICO-CHEMICAL AND ENVIRONMENTAL METHODS

Physico-chemical parameters measured *in situ* using field meters were dissolved oxygen (DO), pH, temperature and electrical conductivity (EC). Water samples were collected on each sampling occasion for determination of nitrates and nitrites (NOx), total Kjeldahl nitrogen (TKN), total phosphorus (Total P), turbidity and alkalinity. Detailed observations of a large number of habitat variables were recorded at the time of sampling, to allow more descriptive assessments of stream quality.

4.4 MACROINVERTEBRATE DATA ANALYSIS

Before analysis, all macroinvertebrate data were transformed to binary (presence/absence) data. The sample collection techniques were not sufficiently quantitative to include abundance data in the analysis. However, it has been demonstrated that binary data can be equally as effective as abundance data in analyses to determine ecological trends in water quality (Wright *et al.* 1995). Although rare taxa are often excluded from analyses because they may cause noise and potentially obscure ecological patterns (Gauch 1982), these taxa were retained in this study because of the small size of some of the data sets and the low level of taxonomic resolution. In addition, since non-urban zone sites were sampled over four seasons (whereas urban zone sites were sampled over only two seasons), data sets for whole-catchment analysis comprise only the sampling runs for spring 1994 and autumn 1995. If the entire data set for the non-urban sector were used in the combined analyses, additional families collected during the spring 1995 and autumn 1996 sampling runs would bias the results toward greater diversity at the non-urban sites. For this reason, the extra sampling runs were excluded from combined analyses. They were, however, retained for analyses limited to the non-urban sector.

All multivariate analyses were performed using the PATN program (Belbin 1993).

Univariate statistical tests were performed using SYSTAT statistical software program (Wilkinson *et al.* 1992).

Biotic indices were calculated using the SIGNAL index procedure developed by Chessman (1995) and the Key Families and RBA Families methods from the WoV Schedule F7 (Government of Victoria 1999).

Scores for AUSRIVAS observed/expected (O/E) families were calculated using the predictive modelling program developed at the Co-operative Research Centre for Freshwater Ecology in Canberra (Simpson *et al.* 1997) for the MRHI.

4.4.1 Univariate statistics

After tests for assumption of normality, untransformed data on numbers of families were subjected to one-way analysis of variance (ANOVA) (Zar 1974) to compare community richness between urban and non-urban zones, and between groupings identified by multivariate methods. Tukey’s HSD tests – comparing the means between treatments – were performed on significant ANOVA results to determine which groups were significantly different (Zar 1974). For this study, numbers of taxa were calculated from both riffle and edge samples combined, to give a ‘total number of families’ for each site. For sites without riffles, the total number of families was the number of families found in the edge sample.

4.4.2 Multivariate analysis

Multivariate analysis methods are powerful mathematical tools that present complex ecological data as relatively simple graphical displays. They are not statistical tools – they do not provide probability values or tests for significant differences but are designed to allow the examination of multiple variables simultaneously, for ease of interpretation of community data. Community data is multivariate – each site is represented by the presence of numerous taxa and these taxa are influenced by numerous environmental variables.

An association matrix is calculated on the basis of similarities or dissimilarities between samples, summarising biotic relationships into a coefficient measuring distances between sites, based on community composition. In this study, association matrices were calculated using the Bray-Curtis dissimilarity measure, which is widely used in ecology and is considered to be robust and reliable (Clarke 1993). This association matrix is then subjected to further analysis for graphical display as dendrograms (clustering) and ordinations (multidimensional scaling).

i. Classification using cluster analysis

Classification methods assign entities – such as species or sites – to distinct groups, with the members of each group being more similar to each other than to members of other groups (Gauch 1982). Numerous clustering techniques have been developed for this purpose. In this study, unweighted pair-groups with arithmetic averaging (UPGMA) was used to determine site groupings based on the presence or absence of taxa. UPGMA is the most frequently used clustering technique and is recommended where there is no specific reason for using another technique (Sneath and Sokal 1973). This is an hierarchical agglomerative clustering technique that classifies sites, using information on all the taxa, grouping the two most similar entities into a cluster, then the next most similar, and so on, until all entities are classified. The resulting classification is presented as a dendrogram.

ii. Multidimensional scaling

Ordination methods present multidimensional data in a reduced number of dimensions, for ease of interpretation. In effect, multidimensional scaling (MDS) is an ordination technique which presents biotic relationships as a ‘map’, with the distances between sites in the map representing biotic dissimilarity between sites (Clarke 1993). A semi-strong ‘hybrid’ ordination model (HMDS) (Belbin 1993) was used to calculate axis scores. Two-dimensional ordinations were used for ease of interpretation, since calculated stress values – indicating ‘goodness-of-fit’ – were acceptable. In HMDS ordinations, each axis is unweighted and equivalent, thus information is equally represented by axes 1 and 2; the HMDS configuration can be arbitrarily rotated or expanded, but the relative position of samples within the ordination is not arbitrary (Clarke 1993).

4.4.3 Biotic indices

Biotic indices attempt to combine data on taxonomic structure of a community and ecological tolerances of the taxa into a single, easily interpreted number. Though occasionally criticised for their lack of wider application, biotic indices can be useful tools for the assessment of the ecological health of waterways because of their simplicity and ease of interpretation (Washington 1984). They are particularly useful in association with other analytical techniques such as classification and ordination (Gerritsen 1995). It is helpful to use a number of indices to assess the health of the catchment, since different indices can vary in their sensitivity to the type and severity of impacts (Washington 1984). Several indices (see below), used in conjunction, can improve the robustness and reliability of any conclusions.

i. SIGNAL Index

The SIGNAL Index (Stream Invertebrate Grade Number – Average Level) (Chessman 1995) was developed in south-eastern Australia and thus has local application. SIGNAL scores represent a mean value calculated for each site, based on the presence of families of aquatic invertebrates. While SIGNAL is particularly good for assessing salinisation and organic pollution, its usefulness for other toxic impacts and types of disturbance is uncertain (EPA 1995a).

For the calculation of the index, each family found at a site is allocated a score (1–10) relating to its pollution sensitivity, with a low score indicating pollution-tolerant taxa and a high score indicating pollution-sensitive taxa. These values are summed and the total is divided by the number of families at that site, giving a SIGNAL score which can be used to infer water quality (table 1). In this study, SIGNAL scores have been calculated for family lists from combined riffle and edge samples. The SIGNAL score for Oligochaeta, although not identified beyond class in this study, was taken to be 1, as oligochaetes are generally very pollution-tolerant. This allocation is in line with calculations used in the preparation of WoV Schedule F7 objectives (EPA 1995a). In addition, for Hirudinea (also not identified to family-level), an average score of all families in that taxon was calculated. This combined average score was then used in the SIGNAL calculation in place of Chessman’s (1995) recommended individual family scores.

Table 1: Key to SIGNAL scores (Chessman 1995)

SIGNAL score	Water Quality
>6	Clean water
5–6	Doubtful quality, possible pollution
4–5	Probable moderate pollution
<4	Probable severe pollution

ii. Key Families Index

In the WoV Schedule F7 (Government of Victoria 1999), a number of macroinvertebrate families were identified as being important indicators of stream water quality (table 2). Criteria for the presence of a defined subset of these families were set out for selected segments of the Yarra River system. Three separate lists are necessary to account for the differences in the macroinvertebrate communities which would be expected in differing sections of the catchment. For instance, for a site in the Aquatic Reserves Segment of the Yarra River catchment to satisfy WoV Schedule F7 objectives, at least 19 of the total of 24 listed families must be present (Government of Victoria 1999).

Table 2: Lists of key families expected in selected segments of the Yarra River system (WoV Schedule F7 (Government of Victoria 1999)

Common Name	**List 1** **Aquatic Reserves Segment & Parks and Forest Segment**	**List 2** **Rural Western Waterways Segment**	**List 3** **Urban Waterways Segment**
Stoneflies	Gripopterygidae	Gripopterygidae	Gripopterygidae
	Austroperlidae	Austroperlidae	
	Eustheniidae		
	Notonemouridae		
Mayflies	Leptophlebiidae	Leptophlebiidae	Leptophlebiidae
	Baetidae	Baetidae	Baetidae
	Coloburiscidae	Coloburiscidae	
		Caenidae	Caenidae
Dragonflies	Aeshnidae	Aeshnidae	Aeshnidae
		Lestidae/Synlestidae/ Corduliidae	Lestidae/Synlestidae/ Corduliidae
			Megapodagrionidae
			Any other family of Odonata
True flies	Athericidae	Athericidae	
	Blephariceridae		
Caddis flies	Leptoceridae	Leptoceridae	Leptoceridae
	Hydrobiosidae	Hydrobiosidae	Hydrobiosidae
	Hydropsychidae	Hydropsychidae	Hydropsychidae
	Philorheithridae	Philorheithridae	
	Calocidae	Calocidae	
	Conoesucidae	Conoesucidae	
	Helicophidae		
	Philapotamidae		
	Helicopsychidae		
	Glossosomatidae	Glossosomatidae	
		Calamoceratidae	Calamoceratidae
		Ecnomidae	Ecnomidae
		Atriplectididae	
Beetles	Elmidae	Elmidae	Elmidae
	Ptilodactilidae	Ptilodactylidae	
	Scirtidae	Hydrophilidae	Hydrophilidae
		Hydrochidae	Psephenidae
Amphipods	Eusiridae	Ceinidae/Eusiridae	Ceinidae/Eusiridae
Shrimps		Atyidae	Atyidae
Snails/bivalves		Hydrobiidae/Corbiculidae	Hydrobiidae/Corbiculidae
TOTAL	24	26	19

iii. RBA Families Index

The number of macroinvertebrate families collected by the Rapid Bioassessment (RBA Families) method was counted and compared with the WoV Schedule F7 objectives (Government of Victoria 1999). The number of macroinvertebrate families found can give a reasonable indication of stream health, but is too much of a simplification to be used alone. Lack of suitable habitat and/or poor water quality may act to reduce the number of families. The use of the RBA Families index complements SIGNAL, which may underestimate the effect of toxicants.

iv. AUSRIVAS Observed/Expected Families Index

One of the main aims of the National River Health Program was the development of predictive models which could be used for the assessment of river health. The Australian Rivers Assessment System (AUSRIVAS) computer program consists of mathematical models developed for use with data from different aquatic habitats and collected during different seasons (Simpson *et al.* 1997). The program compares a test site with a group of reference sites which have similar physical and chemical characteristics to those which one would expect to find at the test site in the absence of any environmental impact – such as pollution or habitat modification. One of the products of this program is a list of the probabilities of occurrence of aquatic macroinvertebrate families which would be expected to occur at the test site if there were no impacts. By comparing the list of predicted taxa with the list of taxa actually found, a ratio can be calculated for each site – the observed number of families divided by expected number of families (or O/E Families). This ratio can range from 0 (none of the expected families found at the site) to about 1 (all of the expected families found). It is possible to derive a score of greater than 1 if more families were found at the site than were predicted by the model. Such a site may be unexpectedly diverse, or the score may indicate mild nutrient enrichment by organic pollution, which could allow additional macroinvertebrate families to colonise. The O/E scores derived from the particular model used can be placed in bands recommended under the MRHI (table 3), allowing some characterisation of the reach which was sampled, and an assessment of the level of impact on the site. Although AUSRIVAS is sensitive to multiple impacts, it appears that it may be more responsive to habitat quality than the SIGNAL index (Metzeling[1], pers. comm.).

Table 3: AUSRIVAS O/E family scores and bands for combined seasons, edge habitat model (Simpson *et al.* 1997)

Band Label	O/E score	Band Name	Comments
X	>1.14	Richer than reference	• More families found than expected • Potential biodiversity 'hot spot' • Possible mild organic enrichment
A	0.85–1.14	Reference	• Index value within range of the central 80% of reference sites
B	0.55–0.84	Below reference	• Fewer families than expected • Potential mild impact on water quality, habitat or both
C	0.25–0.54	Well below reference	• Many fewer families than expected • Moderate to severe impact on water and/or habitat quality
D	<0.25	Impoverished	• Very few families collected • Highly degraded • Very poor water and/or habitat quality

[1] L. Metzeling (Freshwater Sciences, EPA, Melbourne)

4.5 PHYSICO-CHEMICAL DATA ANALYSIS

To identify whether patterns in macroinvertebrate communities, as shown in the MDS ordinations, were correlated with environmental information, the environmental data were related to the ordinations using the Principal Axis Correlation (PCC) routine in PATN. This routine calculates a vector of maximum linear correlation for each variable and plots its direction in ordination space to show an environmental trend. The purpose is to determine whether the biological data is responding to the environmental attributes in any systematic way (Belbin 1993). Parameters that did not satisfy normality were transformed, to account for Type I errors. Correlations were tested for significance at p< (0.05 divided by the number of variables) and only significant correlations were presented in the results.

To assess the levels of pollution at the sites, the physico-chemical measurements were compared to water quality objectives taken from *Preliminary Nutrient Guidelines for Victorian Inland Streams* (EPA 1995b), *SEPP (Waters of Victoria)* (Government of Victoria 1988), *Australian Water Quality Guidelines for Fresh and Marine Waters* (ANZECC 1992) and the WoV Schedule F7 (Government of Victoria 1999).

5. RESULTS OF BIOLOGICAL ANALYSES

5.1 FAMILY-LEVEL ANALYSIS OF COMBINED URBAN AND NON-URBAN MACROINVERTEBRATE COMMUNITIES

Seventy families (including four sub-families of Chironomidae), as well as the classes Oligochaeta and Hirudinea and the order Acarina were collected. For the most part, family richness was similar in both non-urban and urban zones (table 4). However, two orders – the Trichoptera (caddisflies) and the Odonata (dragonflies and damselflies) – had considerably fewer representatives in the urban areas of the catchment than at the non-urban sites.

Table 4: The number of macroinvertebrate families from each taxon collected from non-urban and urban zones of the Maribyrnong catchment

Taxon	Number of Families	
	Non-urban	*Urban*
Turbellaria	1	1
Mollusca	5	5
Amphipoda	3	2
Isopoda	1	1
Decapoda	1	2
Coleoptera	8	6
Diptera	10	10
Ephemeroptera	3	3
Hemiptera	5	3
Lepidoptera	1	1
Odonata	9	4
Plecoptera	3	1
Trichoptera	15	6
Total	65	45

Table 5 lists the families found at each site in the sampling runs of spring 1994 and autumn 1995. Oligochaeta, Acarina and Hirudinea were not identified beyond class level, and Chironomidae were identified to subfamily. Many taxa are cosmopolitan, being present at all or most sites. Such taxa include the Oligochaeta (worms), Dytiscidae (diving beetles), Orthocladiinae and Chironominae (both midges), Coenagrionidae (damselflies), Aeshnidae (dragonflies) and Hydropsychidae (net-spinning caddisflies). These taxa, being so prevalent, are not as useful as indicators of water quality as some of the less widespread taxa. Dugesiidae (flatworms) and Tipulidae (craneflies) were found most commonly in urban sites, with few representatives in non-urban sites. These may be good indicators of anthropogenic disturbance. There are also numerous taxa found at non-urban sites but not commonly collected from urban sites; Gyrinidae (whirly-gig beetles), Baetidae and Leptophlebiidae (both mayfly families), most of the Odonata families (dragonflies and damselflies) and Trichoptera families (caddisflies) were all more prevalent in the non-urban zone.

A particularly notable site was Barringo Creek at Barringo (site NY). This site had a very diverse fauna, many taxa of which were not found at any other site. This was most evident with the Trichoptera – five families of which were not found at any other site. Interestingly, the Hemiptera (true bugs) were not represented, perhaps because the water was flowing faster in the backwaters at this site than at other sites.

Table 5: Families of macroinvertebrates found at each site from both edge and riffle habitats (* denotes no riffle sample taken)

	NON-URBAN								URBAN								
	NY	*NX*	*NZ**	*ND*	*NE**	*NB*	*OA*	*NV*	*NL*	*NW*	*NK*	*NN*	*NO*	*NP*	*NQ*	*NR**	*NS*
Turbellaria																	
Dugesiidae				•		•	•		•		•	•		•	•	•	
Mollusca																	
Hydrobiidae	•	•		•	•	•	•	•	•	•	•	•	•	•	•		
Lymnaeidae									•					•			
Ancylidae		•		•	•	•	•				•	•		•			
Planorbidae			•	•	•	•			•								
Corbiculidae		•	•	•	•	•	•	•	•	•	•	•					
Sphaeriidae	•	•		•	•		•	•									
Hirudinea																	
Hirudinea		•			•	•		•	•			•	•	•	•	•	•
Oligochaeta																	
Oligochaeta	•	•		•		•	•	•	•			•	•	•	•	•	•
Acarina																	
Acarina	•		•	•	•	•		•	•	•				•	•	•	
Amphipoda																	
Ceinidae	•	•	•	•	•	•	•	•	•		•	•	•				
Eusiridae	•																
Paracalliopidae							•		•		•						
Isopoda																	
Sphaeromatidae											•						
Janiridae								•									
Decapoda																	
Atyidae	•	•	•	•	•	•	•	•	•	•	•	•	•				
Hymenosomatidae									•								
Coleoptera																	
Haliplidae		•															
Dytiscidae		•	•	•	•	•	•	•	•	•		•	•	•	•	•	•
Gyrinidae	•	•	•			•		•	•								
Hydrophilidae			•	•		•	•				•	•	•	•	•	•	•
Scirtidae	•				•		•						•				
Elmidae	•	•	•	•	•	•	•	•	•	•	•	•	•				
Psephenidae	•		•	•	•	•	•	•	•				•		•		
Ptilodactylidae	•																
Diptera																	
Tipulidae	•						•		•			•	•		•		
Chaoboridae																	•
Culicidae															•	•	•
Ceratopogonidae	•	•			•										•		
Simuliidae	•	•		•		•	•	•	•	•	•	•		•			
Psychodidae														•			
Stratiomyidae				•													
Empididae			•				•						•				
Dolichopodidae	•																
Podonominae	•																
Tanypodinae	•	•	•	•	•	•	•	•	•	•		•	•				
Orthocladiinae	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•

	NON-URBAN								URBAN								
	NY	***NX***	***NZ****	***ND***	***NE****	***NB***	***OA***	***NV***	***NL***	***NW***	***NK***	***NN***	***NO***	***NP***	***NQ***	***NR****	***NS***
Chironominae	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	
Ephemeroptera																	
Baetidae		•	•	•	•	•	•	•	•	•	•				•		
Leptophlebiidae	•			•	•	•	•				•						•
Caenidae		•	•		•		•		•	•							
Hemiptera																	
Hydrometridae																	
Veliidae		•		•	•		•	•	•	•	•	•	•	•	•	•	
Gerridae		•					•	•									
Corixidae		•	•	•	•	•	•	•	•	•	•	•			•	•	
Notonectidae		•	•	•	•	•	•	•	•			•	•	•	•		
Pleidae				•													
Lepidoptera																	
Pyralidae		•	•	•	•	•		•									
Odonata																	
Corydalidae		•				•	•	•									
Coenagrionidae		•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Isostictidae										•							
Lestidae		•	•	•		•											
Megapodagrionidae		•															
Synlestidae			•		•	•	•										
Amphipterygidae		•		•	•												
Aeshnidae	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Gomphidae		•	•			•	•										
Cordulidae	•	•		•								•	•		•	•	•
Plecoptera																	
Austroperlidae	•																
Gripopterygidae	•					•	•					•	•				
Notonemouridae	•			•													
Trichoptera																	
Hydrobiosidae	•					•	•		•		•	•					
Hydroptilidae	•	•	•	•	•	•	•	•	•	•	•						
Philopotamidae	•					•	•										
Hydropsychidae	•	•		•		•	•	•	•	•	•	•		•	•		
Ecnomidae						•		•	•		•						
Limnephilidae	•																
Conoesucidae	•					•											
Helicopsychidae	•																
Calocidae	•																
Helicophidae	•																
Philorheithridae	•																
Odontoceridae			•	•		•											
Atriplectidae					•												
Calamoceratidae				•	•	•	•	•	•								
Leptoceridae	•	•	•	•	•	•	•	•	•	•	•	•	•		•		
Total No. of Families	*37*	*35*	*27*	*37*	*32*	*40*	*39*	*31*	*34*	*20*	*24*	*26*	*22*	*18*	*22*	*14*	*11*

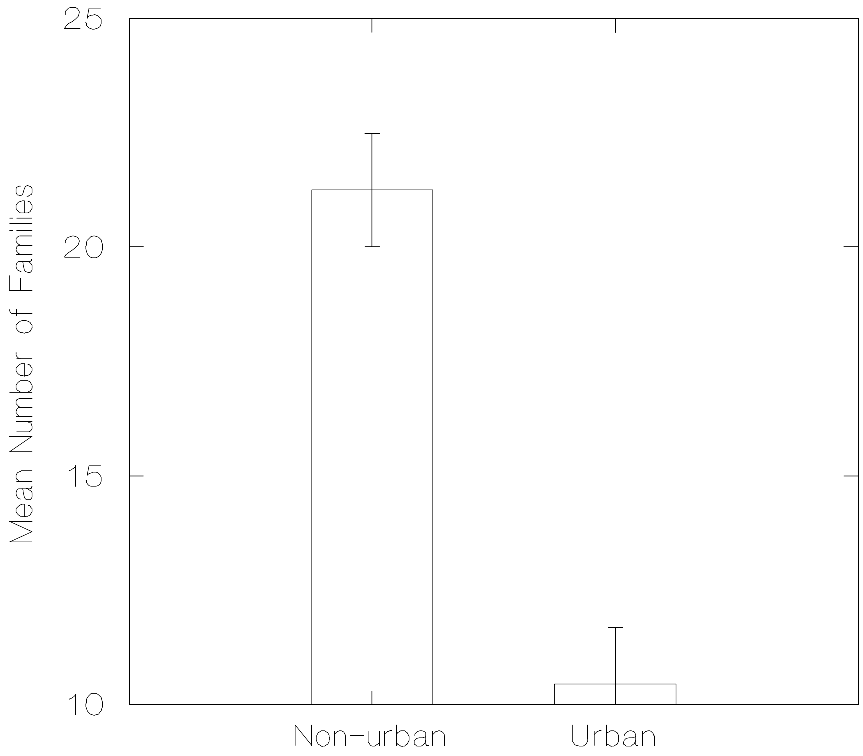

Figure 2: Mean number of macroinvertebrates (± standard error) found in non-urban and urban zones in the Maribyrnong catchment from combined riffle and edge samples (n=17)

Preliminary multivariate analyses of the non-urban macroinvertebrate data sets revealed that little difference between clustering and ordination results using the same analysis on data at different taxonomic resolution – that is, family-level, genus-level or species-level comparisons. Therefore, for the sake of consistency with urban data, non-urban data has been analysed at the coarser taxonomic level of family. Other studies have shown that family-level identifications are sufficient to identify and delineate impacts in aquatic environments (Wright *et al.* 1994). The preliminary multivariate analyses also demonstrate that in this study, comparison of sites at the family-level is valid and comparable to species-level resolution. Therefore, the greater effort involved in species-level analysis of this study of the Maribyrnong River catchment was not justified. Furthermore, other preliminary analyses of non-urban only and urban only data sets did not reveal any additional information to the combined analyses, so only the combined analyses are presented here.

Four groups can be distinguished in the edge samples (figure 3). In the cluster analysis using the 'two seasons, edge' data-set, Barringo Creek at Barringo (NY – Group 1), is clearly separated from all other sites and site groups. The rest of the non-urban tributary sites form a large group (Group 2), with three urban mainstream Maribyrnong River sites – the Maribyrnong River at Bulla (NV), the Maribyrnong River at Keilor Park (under the Calder Freeway) (NL) and the Maribyrnong River downstream of the Brimbank Sewage Treatment Plant (NW). Group 3 is formed by the remaining urban mainstream site – Maribyrnong River at Canning Street Ford (NK) – plus the two sites on Taylors Creek (NN and NO). Group 4 is formed by the remaining urban tributary sites.

The two-dimensional HMDS ordination of the edge data reveals similar site groupings to those resulting from the cluster analysis (figure 4 and figure 3 respectively). Barringo Creek (NY) is clearly different (Group 1) and separates from all other sites along axis 1. The remaining sites fall into groups along axis 2. The least species-rich sites – those on Stony (NR and NS) and Steele Creeks (NP and NQ) – form an 'urban tributaries' group (Group 4). The non-urban sites form a cluster (Group 2) which includes the non-urban mainstream Maribyrnong site at Bulla (NV), and two urban mainstream sites, at Keilor Park (NL) and downstream of Brimbank sewage treatment plant (NW). The two Taylors Creek sites (NN and NO) and the most downstream mainstream site at Canning Street Ford (NK), form Group 3.

Fewer sites are included in the classification of the riffle data, since riffles were not present at sites on Emu Creek at Clarkefield (NZ), Deep Creek at Darraweit Guim (NE) and Stony Creek at Sunshine Road (NR). The riffle data for the combined data-set (figure 5) distinguishes somewhat similar groups to the edge data (figure 3), but five groups are formed, with several sites changing group membership. All of the non-urban sites – two mainstream Maribyrnong sites (Canning Street Ford (NK) and Keilor Park (NL)) and Taylors Creek at Burrowye Crescent (NN) – form one large group (Group 2). Barringo Creek (NY) falls in the centre of the dendrogram (Group 1), but it is still distinct from any other group. Sites on the Maribyrnong River, downstream of Brimbank Park (NW – Group 3), and on Taylors Creek at Green Gully Road (NO – Group 4) also fall as individuals in this ordination. The three urban tributary sites – Steele Creek at Keilor Road (NP) and at Rose Avenue (NQ) and Stony Creek at Drew Street (NS) – are, for convenience, placed together as Group 5, although there appears to be some separation between Stony Creek and the two Steele Creek sites.

The ordination of riffle data (figure 6) clearly reflects the grouping defined in the UPGMA dendrogram. Barringo Creek (NY – Group 1), Maribyrnong River downstream of Brimbank Park (NW – Group 3) and Taylors Creek at Green Gully Road (NO – Group 4) are separated off as individual sites. The non-urban tributaries, two mainstream Maribyrnong River sites (NK and NL) and Taylors Creek at Burrowye Crescent (NN) from one large group (Group 2). Steele Creek (NP and NQ) and Stony Creek (NS) form an urban tributaries group (Group 5), although, as in the UPGMA dendrogram, Stony Creek is somewhat separated from the other two urban tributary sites.

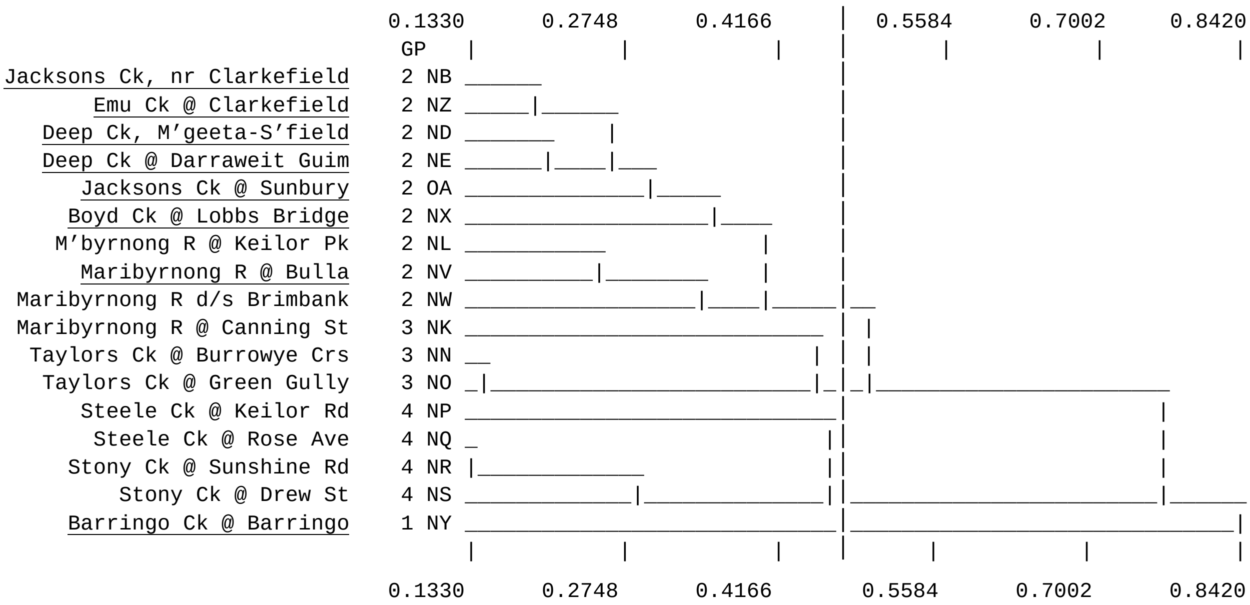

Figure 3: UPGMA dendrogram of urban and non-urban edge data (spring 1994, autumn 1995). Non-urban sites are underlined; GP = group

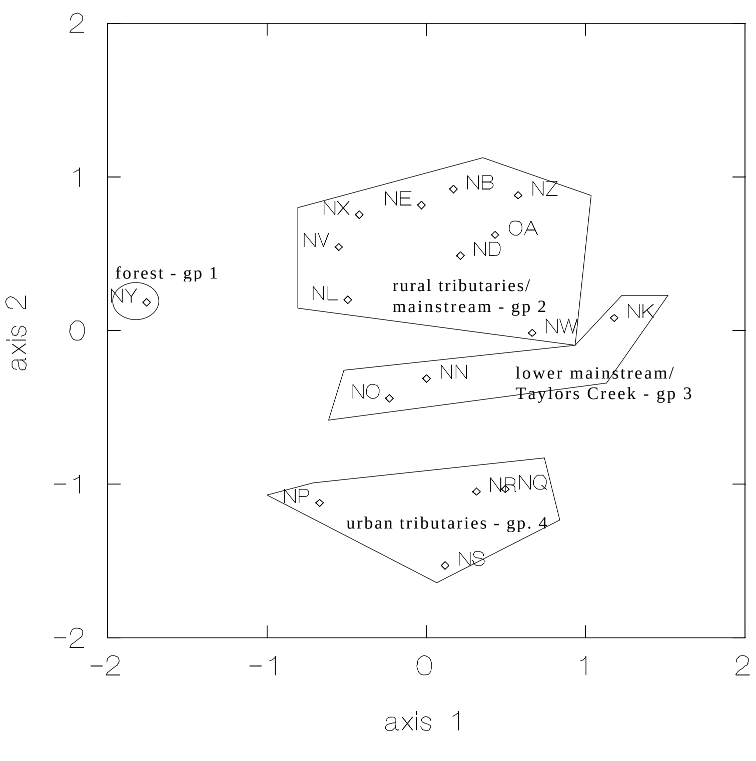

Figure 4: HMDS ordination of urban and non-urban edge data (spring 1994, autumn 1995) Stress=0.210. Site groupings are derived from the UPGMA classification

```
                                 0.2540      0.3644      0.4748      0.5852      0.6956      0.8060
                              GP    |           |           |    |        |           |           |
Jacksons Ck, nr Clarkefield   2  NB  _                           |
      Jacksons Ck @ Sunbury   2  OA |___________                 |
      Maribyrnong R @ Bulla   2  NV __          |                |
     Boyd Ck @ Lobbs Bridge   2  NX _|_________|_________        |
Deep Ck, M'geeta-S'field Rd   2  ND ___________________ |         |
 Maribyrnong R @ Canning St   2  NK ______________   | |         |
Maribyrnong R @ Keilor Park   2  NL ______        |    | |         |
  Taylors Ck, Burrowye Cres   2  NN _____|_______|____|_|________|____
     Barringo Ck @ Barringo   1  NY _____________________________|___|__________
Maribyrnong d/s Brimbank Pk   3  NW _____________________________|____________|_________
Taylors Ck @ Green Gully Rd   4  NO _____________________________|______________________|_________
      Steele Ck @ Keilor Rd   5  NP _                                       |                     |
       Steele Ck @ Rose Ave   5  NQ |_______________________________________ |                     |
         Stony Ck @ Drew St   5  NS _______________________________________|_|_____________________|
                                    |           |           |           |  |        |           |
                                  0.2540      0.3644      0.4748      0.5852 |   0.6956      0.8060
```

Non-urban (underlined) sites: Jacksons Ck, nr Clarkefield; Jacksons Ck @ Sunbury; Maribyrnong R @ Bulla; Boyd Ck @ Lobbs Bridge; Deep Ck, M'geeta-S'field Rd; Barringo Ck @ Barringo.

Figure 5: UPGMA dendrogram of urban and non-urban riffle data (spring 1994, autumn 1995). Non-urban sites are underlined; GP = group

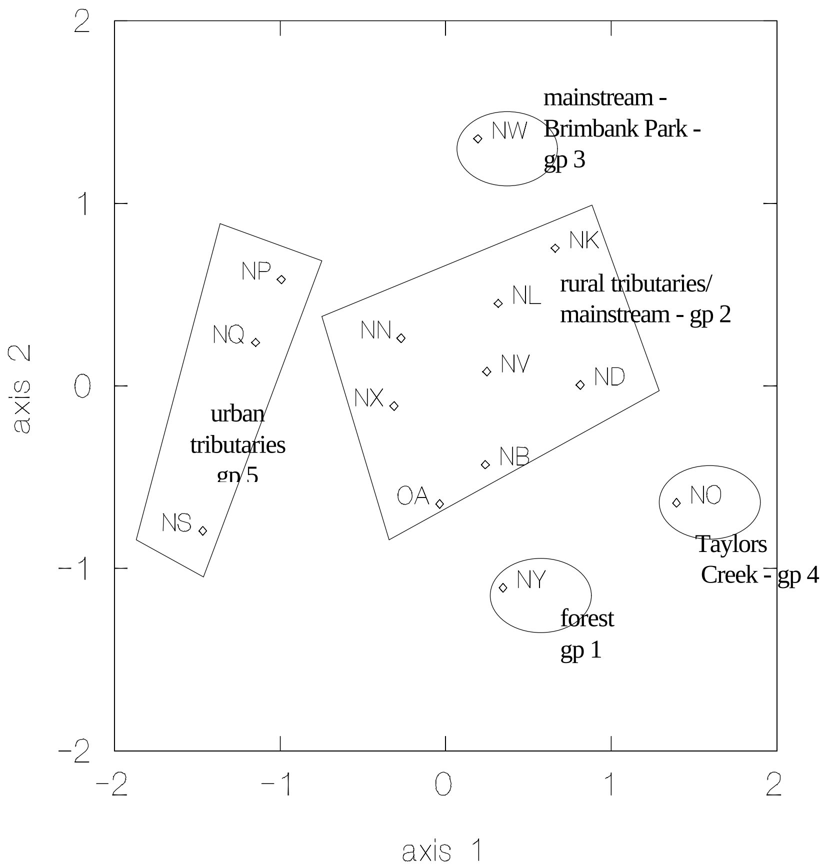

Figure 6: HMDS ordination of urban and non-urban riffle data (spring 1994, autumn 1995). Stress=0.238. Site grouping are derived from the UPGMA classification

If the location of the sites in the catchment is superimposed on the ordination of data taken from the edge samples (that is, the habitat sampled at all of the sites), it is possible to allocate the sites to groups, or segments, based on similarities in both community composition and geographical position within the catchment (figure 7). Although the groupings do not match the ordination and classification groups exactly, they can be seen as an alternative interpretation of distances between the sites in ordination space. As a result of their location in the catchment, the segments have been designated Forest, Rural, Urban Mainstream and Urban Tributaries (table 6).

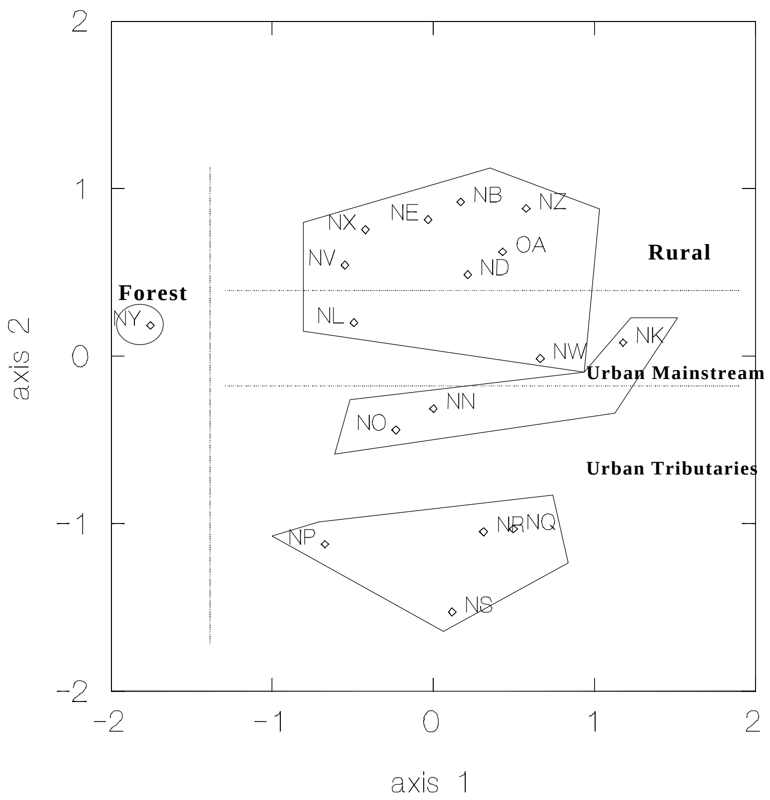

Figure 7: Geographic location within the Maribyrnong catchment superimposed on the HMDS ordination of urban and non-urban edge data

A single site – Barringo Creek at Barringo (NY), the only site in a closed catchment – is assigned to the Forest Segment in both the riffle and edge analyses. Sites on the non-urban tributaries, and Maribyrnong River at Bulla (NV), one of the mainstream sites, also consistently group together. These have been allocated to the Rural Segment. Maribyrnong River at Keilor Park (NL) also groups with the non-urban sites in the analyses, although it is surrounded by urban development. In some ways, this site is transitional between urban and non-urban. The sites on the inner urban tributaries – Steele and Stony Creeks (NP, NQ, NR, NS) – are uniformly allocated to the Urban Tributaries Segment. The two remaining mainstream Maribyrnong sites (NW, NK) and the two Taylors Creek sites (NN, NO) are inconsistent in their placement in the classification and ordination analyses. All four are undoubtedly urban, and for convenience the Maribyrnong River sites are placed in the Urban Mainstream Segment, and the Taylors Creek sites in the Urban Tributaries Segment.

Table 6: Segments of the Maribyrnong River and its tributaries identified from combined geographical location and cluster and ordination analyses

Segment Site	Site Code
Forest	NY
Barringo Ck @ Barringo	
Rural	
Boyds Ck @ Lobbs Bridge	NX
Emu Ck @ Clarkefield	NZ
Deep Ck @ Monegeeta-Springfield Rd	ND
Deep Ck @ Darraweit Guim	NE
Jacksons Ck, 1 km SW Clarkefield Stn	NB
Jacksons Ck @ Sunbury	OA
Maribyrnong R @ Bulla	NV
Urban Mainstream	
Maribyrnong R @ Keilor Park	NL
Maribyrnong R @ Brimbank Park d/s STP	NW
Maribyrnong R @ Canning St Ford	NK
Urban Tributaries	
Taylors Ck @ Burrowye Cres	NN
Taylors Ck @ Green Gully Rd	NO
Steele Ck @ Keilor Rd	NP
Steele Ck @ Rose Ave	NQ
Stony Ck @ Sunshine Rd	NR
Stony Ck @ Drew St	NS

There is a clear and significant difference ($p<0.001$, appendix 2) between the number of families in the non-urban part of the catchment (the Forest and Rural Segments) and the urban section (the Urban Mainstream Maribyrnong and Urban Tributaries Segments). There is no significant difference between segments within either the non-urban portion of the catchment or the urban portion (figure 8).

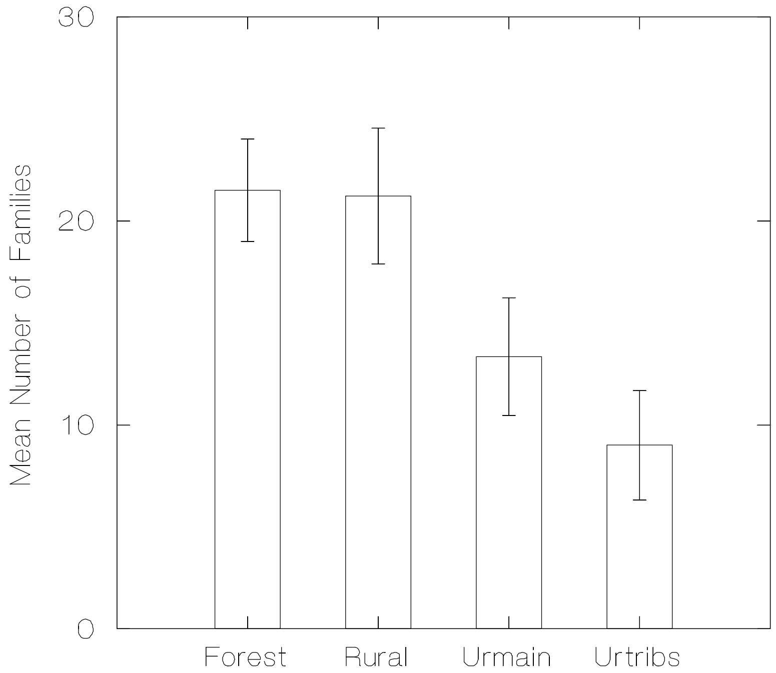

Figure 8: Histogram of mean number of families (± standard error) over spring and autumn from segments identified by cluster and ordination analysis. Forest=Forest Segment, Rural=Rural Maribyrnong and Tributaries, Urmain=Urban Mainstream Maribyrnong, Urtribs=Urban Tributaries

5.2 COMPARISON WITH THE DESIGNATED RIVER SYSTEM SEGMENTS OF THE WATERS OF VICTORIA SCHEDULE F7. WATERS OF THE YARRA CATCHMENT

In the WoV Schedule F7 (Government of Victoria 1999), the Yarra catchment is divided into a number of segments. These segments were based largely on surrounding land use, but physical characteristics of the area and environmental quality were also taken into account. Beneficial uses requiring protection, and environmental quality and ecological objectives were determined for each segment.

To assess the applicability of dividing a catchment into segments, each with suggested environmental and biological objectives, groups of Maribyrnong catchment sites were allocated objectives from the Yarra segment groups, based on the similarity of the Maribyrnong sites to the Yarra waterways. The segment names are based on descriptors similar to those of the Yarra segments. Segment names and the justification for their inclusion in each segment are as follows.

Forest Segment

From the Yarra *Aquatic Reserves Segment*, includes undisturbed forested catchments upstream of water supply off-takes in the upper Yarra catchment. In the Maribyrnong system, this would include the Barringo Creek site at Barringo, which is in the closed catchment.

Rural Waterways Segment

From the Yarra *Rural Western Waterways Segment*, includes rural stretches of tributaries of the Yarra River which run through agricultural land to the north and west of Melbourne. These waterways are most similar in land use and form to the Maribyrnong non-urban waterways sampled in this study. These have higher electrical conductivity than streams in the east of the Yarra catchment.

Urban Waterways Segment

From the Yarra *Urban Waterways Segment*, includes all surface waters running through urban areas of Melbourne. This segment has lower ecological objectives for the tributaries of the Yarra River than it does for mainstream Yarra. In the Maribyrnong catchment, the two related segments are:

- *Urban Mainstream Segment* which would include sites in the main channel of the Maribyrnong River, from Keilor downstream
- *Urban Tributaries Segment* which would include sites on Steele, Stony and Taylors Creeks and any other tributaries that drain directly into the Maribyrnong River in built-up urban areas.

5.3 BIOTIC INDICES

In the WoV Schedule F7 (Government of Victoria 1999), ecological objectives use three indices – the SIGNAL index, Key Families index and RBA Families index – as a means of assessing river health (table 7).These indices have been calculated for each site in the Maribyrnong catchment, using presence or absence of macroinvertebrate families in the samples collected (table 8). The indices calculated for the Maribyrnong system have been compared with the objectives proposed for the similar segments in the Yarra catchment. In this way, it is possible to assess whether the sampling sites compare with the ecological objectives established for corresponding segments in the Yarra.

Table 7: Macroinvertebrate community objectives used in the WoV Schedule F7 (Government of Victoria 1999)

Yarra Segments	SIGNAL score objective	Key Families objective	Minimum no. of families RBA
Aquatic Reserves	≥7.0	≥19 of 24 listed families	30
Rural Western	≥5.5	≥10 of 26 listed families	20
Urban Waterways (mainstream)	≥6.0	≥16 of 19 listed families	26
Urban Waterways (tributaries)	≥5.5	≥12 of 19 listed families	20

Table 8: Biotic indices for sites in each segment of the Maribyrnong River and its tributaries

Segment (corresponding to Yarra segment) Site	**Site code**	**SIGNAL score**	**Key Family no.**	**RBA Family no.**	**O/E Families combined seasons – edge score band^**	
Forest (Aquatic Reserves)						
Barringo Ck @ Barringo	NY	6.8	18	32	1.13	A
Rural (Rural Western)						
Boyd Ck @ Lobbs Bridge	NX	5.5	10	32	1.17	X
Emu Ck @ Clarkefield	NZ*	5.6	10	24	1.13	A
Deep Ck @ Monegeeta-Springfield Rd	ND	5.6	12	32	0.91	A
Deep Ck @ Darraweit Guim	NE*	6.0	12	29	1.09	A
Jacksons Ck, 1 km SW Clarkefield Stn	NB	5.6	16	36	0.99	A
Jacksons Ck @ Sunbury	OA	5.6	15	35	1.25	X
Maribyrnong R @ Bulla	NV	5.0	10	27	0.90	A
Urban Mainstream (Urban waterways – mainstream)						
Maribyrnong R @ Keilor Park	NL	4.9	12	28	0.96	A
Maribyrnong R @ Brimbank Park d/s STP	NW	5.5	8	17	0.85	A
Maribyrnong R, Canning St Ford	NK	5.5	13	21	0.63	B
Urban Tributaries (Urban waterways – tributaries)						
Taylors Ck @ Burrowye Cres	NN	5.1	12	23	0.70	B
Taylors Ck @ Green Gully Rd	NO	5.1	11	19	0.69	B
Steele Ck @ Keilor Rd	NP	4.1	5	15	0.27	C
Steele Ck @ Rose Ave	NQ	4.6	9	19	0.34	C
Stony Ck @ Sunshine Rd	NR*	4.1	4	11	0.34	C
Stony Ck @ Drew St	NS	5.1	5	8	0.20	D

^ *for band definitions, see table 3*

* *sites where riffle samples were unavailable*

Sites above dotted line are reference sites, those below are test sites

5.3.1 SIGNAL

Barringo Creek at Barringo (NY), allocated to the Forest Segment, received a score of 6.8 (table 8). This exceeds the score used as the cut-off for ‘clean’ water (table 1), but is below that specified for Yarra Aquatic Reserves (table 7).

All sites in the Rural Segment and the majority of sites in both the Urban Mainstream and Urban Tributary segments, fall within the range (5–6) indicating water of ‘doubtful quality, possible pollution’. Maribyrnong River at Keilor Park (NL), Steele Creek at Rose Avenue (NQ) and at Keilor Road (NP) and Stony Creek at Sunshine Road (NR) fall into the SIGNAL range denoting probable moderate pollution (4–5). The Maribyrnong River at Bulla (NV) is on the borderline between possible and probable moderate pollution.

All sites in the Rural Segment, with the exception of Maribyrnong River at Bulla (NV), reached the SIGNAL objective established in the WoV Schedule F7 (Government of Victoria 1999). The SIGNAL scores for all sites in the Urban Mainstream and Urban Tributaries segments of the catchment were below the specified SIGNAL objectives for the corresponding Yarra segments (table 7).

A histogram of the mean SIGNAL score for each of the Maribyrnong catchment segments is shown in figure 9. There is an obvious trend towards poorer water quality at downstream sites, with the mean SIGNAL score decreasing from the Forest Segment to the Urban Tributaries Segment. This general trend can also be seen from the map in figure 10.

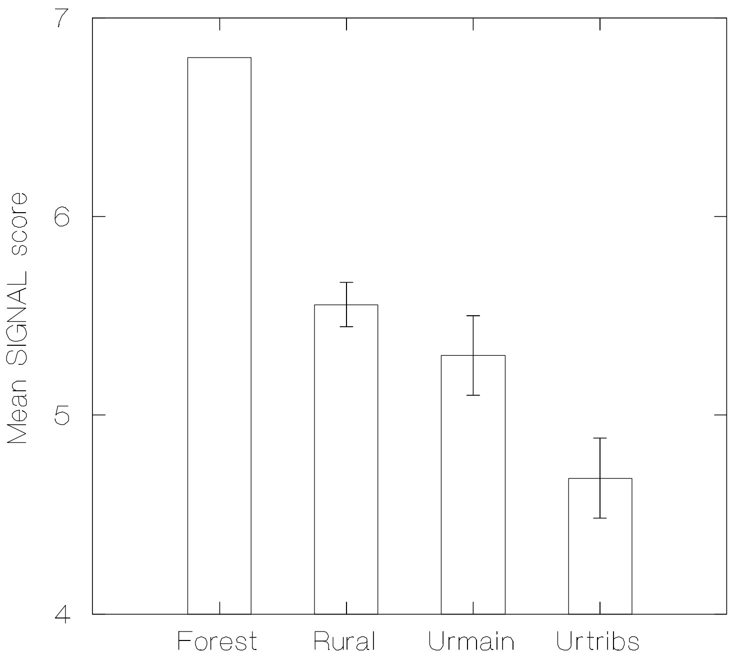

Figure 9: Histogram of mean SIGNAL score per segment (± standard error) as identified using WoV Schedule F7 guidelines; total for both seasons. Forest=Forest Segment, Rural=Rural Maribyrnong and Tributaries, Urmain=Urban Mainstream Maribyrnong, Urtribs=Urban Tributaries

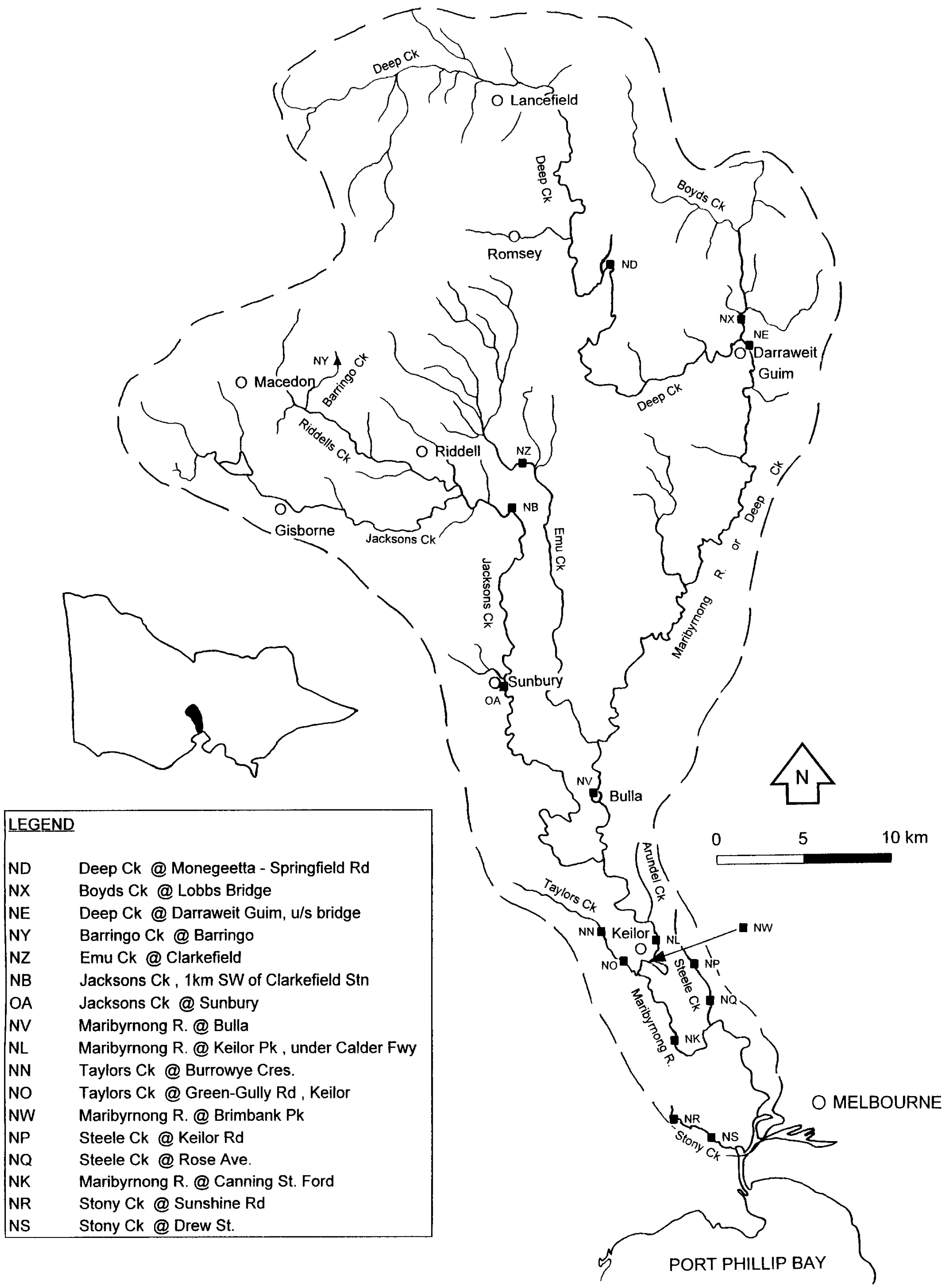

Figure 10: SIGNAL scores for 17 sites in the Maribyrnong catchment

5.3.2 Key Families

The highest number of Key Families (18 families, table 8) was found at Barringo Creek (NY). The two sites on Jacksons Creek (NB and OA) yielded 15 and 16 families respectively. Both of these sites were in the Rural Segment of the catchment. The remainder of the Rural Segment sites, the majority of the Urban Segment sites and both of the Taylors Creek sites (within the Urban Tributaries Segment) had between 10 and 15 families. The remaining Urban Tributary sites had fewer than nine families in the combined riffle and edge samples.

Barringo Creek, the only site in the Forest Segment, did not reach the objective set for Key Families for the corresponding Aquatic Reserves Segment in the Yarra SEPP (table 7). The sites in the Rural Segment did meet the objective for the corresponding Yarra segment. None of the Urban Mainstream sites and only one of the Urban Tributaries (Taylors Creek at Burrowye Crescent – NN) reached the required number of Key Families.

5.3.3 RBA Families

Two sites – both in the Rural Segment of the Maribyrnong system – had more than 30 families. The majority of Rural Segment sites, the Forest Segment site (Barringo Creek – NY) and one Urban Mainstream Segment site (Maribyrnong River at Keilor Park, under Calder Freeway – NL) had between 25 and 30 families. The remaining Urban Mainstream Segment sites had between 20 and 25 families per site, while all the Urban Tributaries Segment sites had fewer than 20 families.

Barringo Creek met the minimum number of RBA families required by the WoV Schedule F7 objectives (table 7) for the Aquatic Reserves Segment. All Rural Segment sites reached the objectives, but only one site in the Urban Waterways (mainstream) group (Maribyrnong River at Keilor Park – NL) and one in the Urban Mainstream (tributaries) segment (Taylors Creek at Burrowye Crescent – NN) reached the objectives set for their respective corresponding segments.

5.3.4 AUSRIVAS observed/expected families

The AUSRIVAS O/E families score calculated for Barringo Creek at Barringo (NY – 1.13) placed the site within the ‘reference’ band (band A, table 3). This suggests that there has been little impact upon water quality or habitat at this site.

Boyd Creek (NX) and Jacksons Creek at Sunbury (OA) had O/E scores above the ‘reference’ level. According to the suggested interpretation of these scores (table 3), this indicates either particularly diverse sites or some nutrient enrichment, with the stream able to support the recruitment of more families than would normally be expected.

Two mainstream Maribyrnong River sites – at Bulla (NV) and at Keilor Park (NL) – had scores of greater than or equal to 0.9, and the site on the Maribyrnong River at Brimbank Park (NW) had a score of 0.85, placing them all in the ‘reference’ band. In contrast, Maribyrnong River at Canning Street Ford (NK) scored 0.63. This latter score indicates mild deterioration in water or habitat quality, or both.

Both sites on Taylors Creek – at Burrowye Crescent (NN) and Green Gully Road (NO) – had O/E scores of around 0.7, pointing to mild disturbance of the habitat or mild pollution.

Steele Creek (NP and NQ) and Stony Creek at Sunshine Road (NR) had O/E families scores which fall into the ‘impoverished’ category. Few of the families which were expected to be at the sites were found, suggesting a severe impact on the habitat, water quality or both.

Stony Creek at Drew Street (NS) registered an O/E family score of 0.20, indicating a highly degraded site, with very poor water quality, severe habitat disturbance or both.

A map of the Maribyrnong catchment, indicating AUSRIVAS scores (figure 10) for the edge habitat, shows that there are relatively diverse macroinvertebrate communities at the upper sites in the catchment with a general trend towards less diverse communities in the lower reaches, particularly in the urban tributaries.

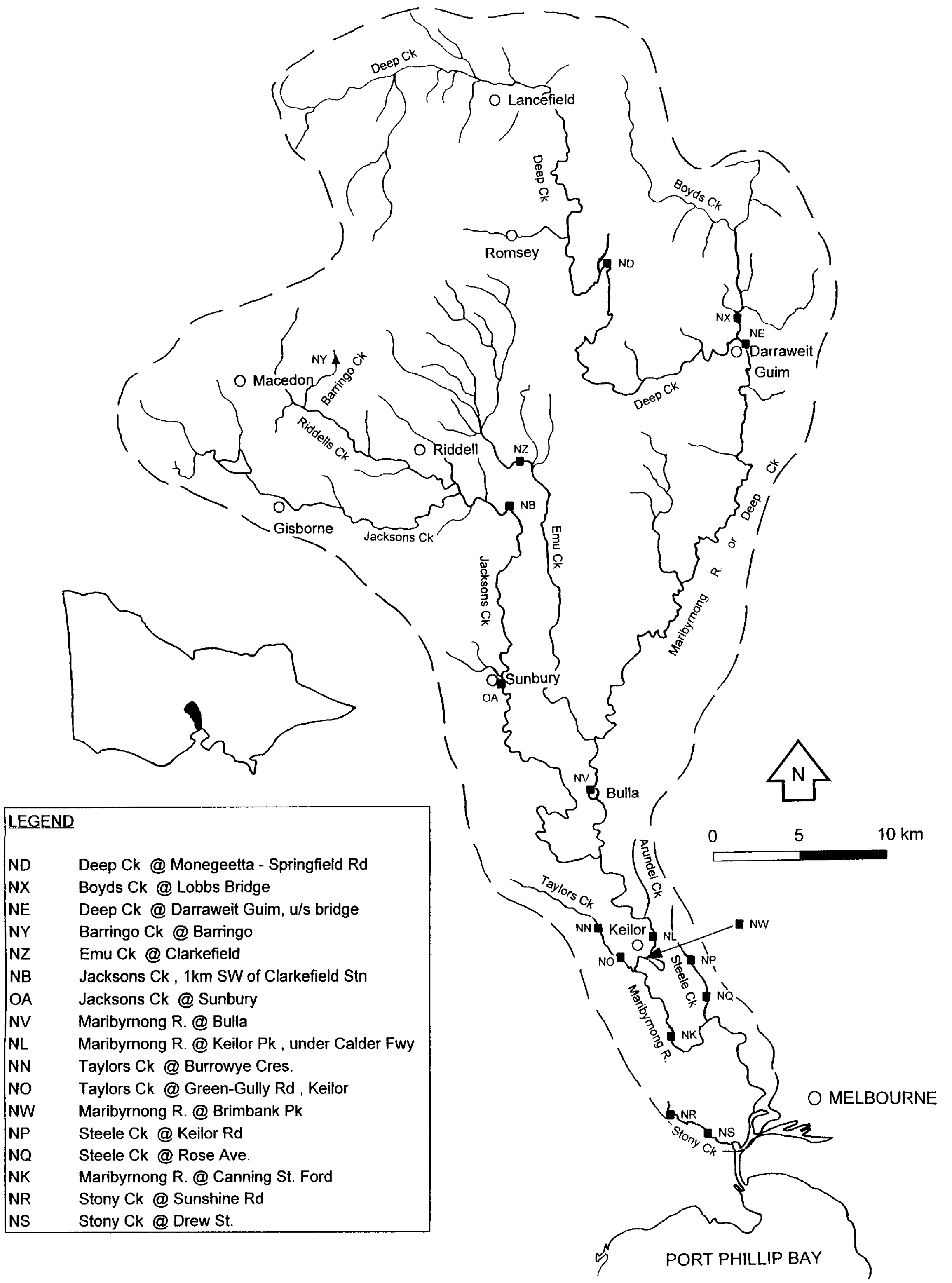

Figure 11: AUSRIVAS O/E Family scores for edge habitat (combined seasons) at 17 sites in the Maribyrnong catchment

Table 9 presents a summary of the extent of attainment of the Maribyrnong catchment sites with objectives set for macroinvertebrate community indices for comparable segments in the WoV Schedule F7 (Government of Victoria 1999).

Table 9: Compliance with macroinvertebrate community objectives used in the WoV Schedule F7 (Government of Victoria 1999)

Segment site	Site code	SIGNAL objective	Key Families objective	RBA Families objective
Forest				
Barringo Ck @ Barringo	NY	X	X	✓
Rural				
Boyd Ck @ Lobbs Bridge	NX	✓	✓	✓
Emu Ck @ Clarkefield	NZ*	✓	✓	✓
Deep Ck @ Monegeeta-Springfield Rd	ND	✓	✓	✓
Deep Ck @ Darraweit Guim	NE*	✓	✓	✓
Jacksons Ck, 1 km SW Clarkefield Stn	NB	✓	✓	✓
Jacksons Ck @ Sunbury	OA	✓	✓	✓
Maribyrnong R @ Bulla	NV	X	✓	✓
Urban Mainstream				
Maribyrnong R @ Keilor Park	NL	X	X	✓
Maribyrnong R @ Brimbank Park d/s STP	NW	X	X	X
Maribyrnong R @ Canning St Ford	NK	X	X	X
Urban Tributaries				
Taylors Ck @ Burrowye Cres	NN	X	✓	✓
Taylors Ck @ Green Gully Rd	NO	X	X	X
Steele Ck @ Keilor Rd	NP	X	X	X
Steele Ck @ Rose Ave	NQ	X	X	X
Stony Ck @ Sunshine Rd	NR*	X	X	X
Stony Ck @ Drew St	NS	X	X	X

X *does not meet objective in WoV Schedule F7*

✓ *meets objective in WoV Schedule F7*

* *denotes sites where riffle samples were unavailable*

6. RESULTS OF PHYSICO-CHEMICAL DATA ANALYSES

Some physical parameters and catchment features of the sites are shown in table 10. Results of water quality, measured *in situ* or from water samples analysed in the laboratory, are presented in tables 11 (spring 1994) and 12 (autumn 1995).

To assess the levels of pollution at the sites, the physico-chemical measurements were compared to water quality objectives taken from *Preliminary Nutrient Guidelines for Victorian Inland Streams* (EPA 1995b), the *SEPP (Waters of Victoria)* (Government of Victoria 1988), *Australian Water Quality Guidelines for Fresh and Marine Waters* (ANZECC 1992) and the WoV Schedule F7 (Government of Victoria 1999). These objectives are given in table 13.

Most noticeable in the data are the high conductivity levels in Deep (ND), Boyd (NX) and Emu Creeks (NZ), and in the mainstream Maribyrnong River downstream of the sewage treatment plant at Brimbank Park (NW). These conductivities often exceed recommended levels (table 13) – the levels beyond which the aquatic biota may be adversely affected. Deep Creek was formerly known as Saltwater Creek (Metzeling, 1993) and creeks in this area largely flow over Ordovician marine sediments. This may explain the increased conductivity in waters from this portion of the catchment. Since these increased salinities are historical, it would be expected that the macroinvertebrate communities found at these sites would be tolerant of these levels.

Preliminary Nutrient Guidelines for Victorian Inland Streams (EPA 1995b) provides preliminary nutrient guidelines for total phosphorus and total nitrogen for streams under base-flow conditions. The majority of the Maribyrnong catchment falls within the Southern Lowland and Urban River Ecoregion, as defined by *Preliminary Nutrient Guidelines for Victorian Inland Streams*. However, the higher altitude and more forested conditions at the site on Barringo Creek, at Barringo (NY), suggest that it is more probable that this site falls into the Southern and Isolated Foothills River Ecoregion. The total nitrogen measured at many of the sites exceeded recommended levels (table 13). This would be expected where the effects of agriculture increase the nutrients in waters draining the catchment. It is not until the more industrialised and urbanised sections of the catchment are reached, and in particular the urban tributaries, that total phosphorus levels exceed long term recommended levels, although some sites do meet interim objectives. Water samples taken in spring appear to be closer to the recommendations, perhaps due to increased flow following winter and spring rains. Comparisons with long term data taken from four sites in the catchment (table 14) however, show that most nitrogen and phosphorus measured during the current program fall within the range experienced over the last ten years.

SEPP objectives (Government of Victoria 1988) and national guidelines (ANZECC 1992) for dissolved oxygen and pH (table 13) are not exceeded and also fall within the historical range (table 14).

To identify whether patterns in macroinvertebrate communities, as shown in the MDS ordination, were correlated with environmental information, a number of the recorded environmental variables were related to the ordinations using the Principal Axis Correlation (PCC) routine in PATN. Chemical data was unavailable for one site – Deep Creek at Darraweit Guim (NE) – which was excluded from the ordination. Many more environmental variables were available for analysis, but only those with the highest levels of correlation are presented. A clear drop in correlation values was taken as the cut-off point.

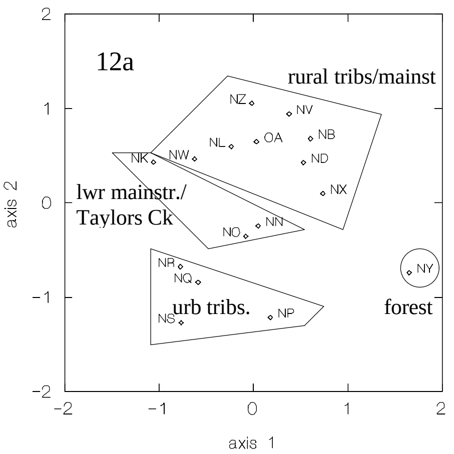

Figure 12a: 2-dimensional HMDS ordination of urban and non-urban sweep data

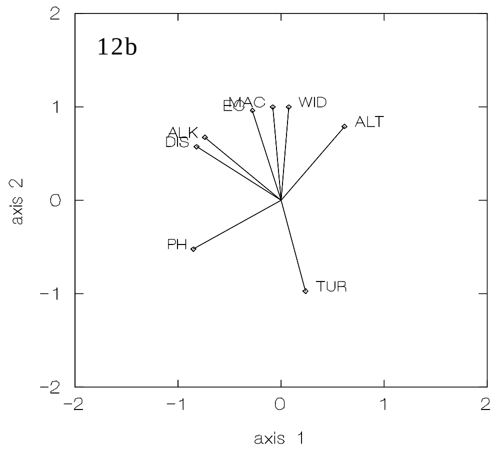

Figure 12b: 2-dimensional PCC for environmental variables

ALT=altitude, WID=stream width, MAC=number of macrophyte taxa, EC=conductivity, ALK=alkalinity, DIS=distance from source, PH=pH, TUR=turbidity

The HMDS ordination of urban and non-urban data, and the derivation of groups of sites has been discussed previously. The ordination plot in figure 12a differs from that in figure 4 because of the removal of site NE. When this ordination (figure 12a) is compared with the 2-dimensional PCC of the environmental data (figure 12b), there appears to be a relationship between some of the groupings and the environmental variable vectors for turbidity, distance from source and alkalinity. Turbidity generally increases towards the lower reaches of the catchment, and appears to be an important variable in the separation of the urban tributaries. Alkalinity and distance from source show a negative association with the Forest Segment site at Barringo Creek (NY). Alkalinity measurements were low in both spring and autumn (tables 11 and 12).

Table 10: Physical characteristics of the sites in the Maribyrnong catchment

Segment (based on cluster and ordination analysis)	Segment (based on WoV Schedule F7 segments)	Site name	Distance from source (km)	Slope (m/km)	Altitude (m)	Latitude (decimal)	Longitude (decimal)	Discharge area upstream of site (km^2)	Number of macro-phyte taxa	Mean width (m)
Forest	Aquatic Reserves	Barringo Creek @ Barringo	5	53.3	520	37.42	144.62	5.5	3	1.2
Rural	Rural Western	Jacksons Creek, 1 km SW Clarkefield Stn	38	12	240	37.49	144.74	290	6	15
		Emu Creek @ Clarkefield	18.5	2.5	310	37.46	144.74	93.1	8	5
		Deep Creek @ Monegeeta-Springfield Road	43	3.6	380	37.36	144.80	320	6	15
		Deep Creek @ Darraweit Guim	68	5.7	270	37.4	144.89	350	2	7
		Jacksons Creek @ Sunbury	55.5	1.6	190	37.58	144.74	337	3	8
		Boyd Creek @ Lobbs Bridge	15	15	250	37.39	144.89	135	8	3
		Maribyrnong River @ Bulla	120.5	5	80	37.64	144.80	865	5	12
Urban Mainstream	Urban Waterways (Mainstream)	Maribyrnong R, Canning St. Ford	24.5	0.8	15	37.77	144.85	1682	3	20
		Maribyrnong R, Keilor Park	12.8	1.7	20	37.72	144.84	1663	2	7
		Maribyrnong River @ Brimbank Park d/s STP	17.4	0.7	20	37.72	144.84	1303	4	15
Urban Tributaries	Urban Waterways (Tributaries)	Taylors Ck, Burrowye Cres	5.5	8	60	37.71	144.81	14.7	1	1
		Taylors Ck, Green Gully Rd	8.1	10	20	37.72	144.82	20.6	2	1.5
		Steele Ck, Rose Ave	7.1	20	20	37.74	144.87	18.9	2	3
		Stony Ck, Sunshine Rd	10.7	4	25	37.79	144.84	0.6	1	1.5
		Stony Ck, Drew St	15.3	4	15	37.81	144.87	10.0	1	2
		Steele Ck, Keilor Rd	4.9	5	40	37.73	144.87	13.6	1	9.8

Table 11: Physico-chemical measurements taken at the sites in the Maribyrnong catchment in spring 1994

Segment (based on cluster and ordination analysis)	Segment (based on WoV Schedule F7 segments)	Site name	DO (mg/L)	EC (µS/cm)	Total Alkalinity (mg/L)	pH	Turbidity (NTU)	NO_2 + NO_3 (mg/L)	TKN (mg/L)	Total N (mg/L)	Total P (mg/L)
Forest	Aquatic Reserves	Barringo Creek @ Barringo	11.2	86.5	14	6.6	3.9	0.048	0.6	0.65	0.016
Rural	Rural Western	Jacksons Creek, 1km SW Clarkefield Stn	8.74	431	46	7.2	4	0.012	0.6	0.61	0.028
		Emu Creek @ Clarkefield	10.1	1896	200	8.2	6.6	0.051	0.6	0.65	0.018
		Deep Creek @ Monegeeta-Springfield Road	6.88	1519	200	7.6	3	<0.003	0.5	0.5	0.016
		Deep Creek @ Darraweit Guim	6.6	1317	230	7.4	9.4	NA	NA	NA	NA
		Jacksons Creek @ Sunbury	7.6	548	86	8.2	5	0.019	0.7	0.72	0.032
		Boyd Creek @ Lobbs Bridge	10.2	2800	210	7.8	3.7	0.019	0.7	0.72	0.031
		Maribyrnong River @ Bulla	7	2090	340	8.6	6	<0.003	0.9	0.9	0.032
Urban Mainstream	Urban Waterways (Mainstream)	Maribyrnong R, Canning St. Ford	7.5	1400	160	8.1	9.5	1.6	0.6	2.2	0.8
		Maribyrnong R, Keilor Park	12.6	1400	170	8.8	2.7	0.31	0.6	0.91	0.031
		Maribyrnong River @ Brimbank Park d/s STP	8.2	1013	170	8.4	4	<0.003	0.7	0.7	0.025
Urban Tributaries	Urban Waterways (Tributaries)	Taylors Ck, Burrowye Cres	6.1	200	68	7.6	77	0.026	0.4	0.42	0.08
		Taylors Ck, Green Gully Rd	9	2200	160	8.3	10	0.091	0.7	0.71	0.051
		Steele Ck, Rose Ave	10	800	120	8.9	3	0.19	0.8	0.99	0.12
		Stony Ck, Sunshine Rd	8.5	170	58	7.4	8.9	0.16	0.3	0.46	0.097
		Stony Ck, Drew St	8.75	170	57	7.7	17	0.25	0.6	0.85	0.1
		Steele Ck, Keilor Rd	6.5	400	84	8.9	44	0.18	0.5	0.68	0.38

NA – data not available

Table 12: Physico-chemical measurements taken at the sites in the Maribyrnong catchment in autumn 1995

Segment (based on cluster and ordination analysis)	Segment (based on WoV Schedule F7 segments)	Site name	DO (mg/L)	EC (µS/cm)	Total Alkalinity (mg/L)	PH	Turbidity (NTU)	NO_2 + NO_3 (mg/L)	TKN (mg/L)	Total N (mg/L)	Total P (mg/L)
Forest	Aquatic Reserves	Barringo Creek @ Barringo	11.8	87	15	6.9	2.4	0.02	0.6	0.62	0.03
Rural	Rural Western	Jacksons Creek, I km SW Clarkefield Stn	9.5	545	63	7.5	2.8	0.022	0.8	0.82	0.08
		Emu Creek @ Clarkefield	10.1	2060	140	7.6	8.2	0.009	0.6	0.61	0.02
		Deep Creek @ Monegeeta-Springfield Rd	8.7	1889	210	8	3.4	<0.003	0.8	0.8	0.02
		Deep Creek @ Darraweit Guim	9.4	1435	240	7.7	4.5	NA	NA	NA	NA
		Jacksons Creek @ Sunbury	10.1	708	94	7.3	36	0.087	0.8	0.89	0.04
		Boyd Creek @ Lobbs Bridge	8	2830	200	8.2	3	<0.003	0.8	0.8	0.03
		Maribyrnong River @ Bulla	9.7	2340	290	8.2	5.1	0.008	1	1	0.03
Urban Mainstream	Urban Waterways (Mainstream)	Maribyrnong R, Canning St. Ford	8.2	1700	170	8.1	9.5	1.2	2.3	3.5	0.92
		Maribyrnong R, Keilor Park	8.4	1900	200	8.6	15	0.19	1.4	1.6	0.13
		Maribyrnong River @ Brimbank Park d/s STP	4.73	1306	160	7.9	8.25	0.17	0.9	1.07	0.04
Urban Tributaries	Urban Waterways (Tributaries)	Taylors Ck, Burrowye Cres	4.8	200	28	7.4	56	0.54	1	1.54	0.13
		Taylors Ck, Green Gully Rd	5.2	1500	11	7.9	150	0.27	0.6	0.87	0.62
		Steele Ck, Rose Ave	11	1000	9.5	8.9	160	0.31	0.6	0.37	0.07
		Stony Ck, Sunshine Rd	6.2	300	6.3	7.8	110	0.27	0.5	0.82	0.11
		Stony Ck, Drew St	10.1	130	3.4	8.3	68	0.29	0.4	0.69	0.54
		Steele Ck, Keilor Rd	8.7	350	8.8	9.8	80	0.37	0.5	0.13	0.13

NA – data not available

Table 13: Recommended water quality objectives taken from *Preliminary Nutrient Guidelines for Victorian Inland Streams* (EPA 1995b), *SEPP (Waters of Victoria)* (Government of Victoria 1988), ANZECC (1992) and the WoV Schedule F7 (Government of Victoria 1999)

Source of Recommendation	Segment	Time frame	Total P mg/L	Total N mg/L	DO mg/L	DO % sat.	pH	Salinity µS/cm
Nutrient Guidelines								
Southern Lowlands and urban Rivers region	rural rivers and streams		0.05	0.6				
	urban rivers	interim	0.08	0.9				
		long term	0.05	0.6				
	urban tributaries	interim	0.1	1.0				
		long term	0.03	0.2				
Southern and isolated foothills region			0.03	0.2				
Waters of Victoria								
parks and forests					6	60	6.5–8.5	
general surface waters					5	50	6.0–9.0	
ANZECC					>6	>80-90%	6.5–9	1500
WoV Schedule F7								
aquatic reserves			N	N	N	N	N	
rural western waterways			0.05	0.6	>6	>60	6.5–8.5	
urban waterways	mainstream		0.08	0.9	>6	>60	6.5–8.5	
	tributaries		0.1	1.0	>6	>60	6.5–8.5	

N – natural background level

Table 14: Summary statistics taken from EPA's Inland Water Quality Monitoring Network, Maribyrnong catchment, 1984–95

Network Monitoring Site	Percentile	DO (mg/L)	EC (µS/cm)	pH	Turbidity (NTU)	NO_2 + NO_3 (mg/L)	TKN (mg/L)	Total N (mg/L)	Total P (mg/L)
Jacksons Ck, Sunbury	10th %	7.4	290	6.9	2.4	0.17	0.35	0.52	0.02
	50th %	9.4	495	7.5	10	0.765	0.6	1.36	0.043
	90th %	11.4	800	8.1	95.5	0.0586	1.1	1.16	0.16
Deep Ck, Bulla Weir	10th %	7.9	34	7.2	1.1	<0.011	0.4	0.4	0.012
	50th %	9.9	1291	8	3.8	0.073	0.6	0.67	0.024
	90th %	12	2462	8.5	52	0.61	1.3	1.91	0.093
Maribyrnong River, upstream of Brimbank Park	10th %	6.9	310	7	2.2	0.046	0.55	0.60	0.03
	50th %	9.5	920	7.6	10	0.47	0.8	1.27	0.07
	90th %	11.6	1470	8.2	63	0.91	1.3	2.11	0.2
Maribyrnong R, Canning St	10th %	6.8	341	7	4.5	0.225	0.605	0.63	0.068
	50th %	9.2	935	7.7	17	0.665	1	1.67	.255
	90th %	11.6	1538	8.2	69	1.42	1.45	2.87	0.84

7. DISCUSSION

The 17 sites selected for sampling in this study exhibited a wide range of impacts – from a near pristine closed-catchment site at Barringo, to highly degraded and extremely depauperate sites at the lower end of the catchment in urban Melbourne. The four segments delineated using multivariate procedures in conjunction with site location within the catchment displayed a general trend towards poorer macroinvertebrate community structure as a result of deterioration in habitat, water quality or both, from the upper to lower reaches of the catchment.

The Forest Segment, consisting of the single Barringo Creek site, had the highest SIGNAL score in the catchment (table 8). A relatively large number of families was recorded at this site (table 5), with many of them noted for their preference for cleaner waters. For example, larval Ptilodactylidae (beetles) and the caddisfly families Helicophidae, Limnephilidae, Helicopsychidae, Calocidae and Philorheithridae were found only at this site and are typical of unimpacted sites (Williams 1980; Chessman 1995). In general, caddisflies and stoneflies are more likely to be found in cleaner waters, and more families of these two major groups were found at Barringo Creek than at any other site in the catchment. It is the only sampled site which met Chessman's (1995) SIGNAL criterion for clean water, with a score exceeding 6.0. Despite this, it does not satisfy the WoV Schedule F7 SIGNAL score objective of 7.0 for Aquatic Reserves (table 7). It also fails to meet the minimum number of macroinvertebrate Key Families, but it does meet the WoV Schedule F7 objective for RBA families.

Failure to reach these objectives may be due to poor water quality, lack of physical habitat or both. Though Barringo Creek is a small watercourse (1–1.5 m wide) at the sampling site, the riparian vegetation was extensive and undisturbed, and a diversity of instream habitats was noted. The AUSRIVAS O/E score for this site lies within the 'reference' band. AUSRIVAS predictive models appear to be more sensitive to physical habitat quality than the SIGNAL index, which is more sensitive to nutrient enrichment (Metzeling[2], pers. comm.). It is possible that, despite its location in a closed, forested catchment, some nutrient enrichment has affected macroinvertebrate community development, though the source of nutrients is as yet undetermined. If this site is considered to be part of the Southern and Isolated Foothills Ecoregion, as described in Preliminary Nutrient Guidelines for Victorian Inland Streams (EPA 1995b), then nitrogen levels do not meet the nutrient guidelines, exceeding recommended levels by about 0.4 mg/L. As this was the only minimally impacted site sampled in the catchment, it would be worth examining water quality and biota at more sites in near pristine condition to determine if this elevated nitrogen level is common in the Maribyrnong catchment.

The Rural Segment had the next highest mean SIGNAL score (figure 9). Most sites were above mid-range for the next SIGNAL water quality category ('doubtful quality, possible pollution'; table 1) with one site – Deep Creek at Darraweit Guim (NE) – approaching the clean water category. With the exception of Maribyrnong River at Bulla (NV), all of the Rural waterways sites satisfied WoV Schedule F7 objectives for SIGNAL scores for the corresponding Yarra segment (table 7). All of the sites also achieve RBA Families and Key Families objectives for their corresponding Yarra segment. Several caddisfly families were present at sites in this segment, along with representatives of a number of damselfly and dragonfly families. Gyrinidae (beetles), Baetidae and Leptophlebiidae (mayflies) were also more commonly found in Rural sites (table 5). These families all show a preference for less disturbed conditions (Chessman 1995). This suggests that overall water quality and available habitat is sufficient to maintain diverse macroinvertebrate communities. The O/E scores for all of these sites were in the 'above reference' or 'reference' categories (table 8), with the number of families found at each site at or above the anticipated level.

[2] L. Metzeling (Freshwater Sciences, EPA, Melbourne)

Some developed sections of the catchment are still unsewered and the adjacent waterways may be influenced by septic leachate, contributing nitrogen. Jacksons Creek at Sunbury (OA) is just downstream of the urban centre and the Sunbury sewage treatment plant. The high O/E score at this site suggests that town runoff and STP effluent is having little effect on the stream ecosystem, other than by nutrient enrichment. Substantial filamentous algal growth, suggestive of increased nutrient levels, was found at all sites in the Rural Segment except Deep Creek at Monegeeta-Springfield Road (ND). This was also the only site which met the nutrient guideline level for nitrogen. Nutrient levels are also likely to be elevated as a result of runoff from agricultural land – especially in areas where grazing pasture is prevalent. Over-grazing on steep slopes can lead to erosion, which increases the deposition of sediments into streams. When nutrients attached to soil particles are carried into streams, they can be released into the water column through the re-suspension of fine sediments, or through the release (by bacteria) of phosphorous from sediment – especially under anoxic conditions (Wetzel 1983). Animal manure and fertiliser application can also lead to elevated nitrogen and phosphorous levels in pasture runoff (Rosich and Cullen 1982) and potential inputs from these non-point-sources should be examined to ensure minimal nutrient input into streams.

Although there is some streamside vegetation at all of the non-urban sites, the quality and extent of the riparian zones vary markedly, with a high representation of weedy species at some sites. Bank erosion is evident at many of the sites, often as a result of direct stock access to streams and at times, silt covers the creek beds at many sites. Large quantities of silt can reduce the number and quality of microhabitats available for macroinvertebrate colonisation (Metzeling *et al.* 1995), and thereby reduce community diversity at affected sites. Boyd Creek, Emu Creek and Deep Creek are in agricultural areas and are highly prone to such impacts. Streamside vegetation stabilises banks and stream-beds, can prevent stock from obtaining access to streams, acts as a filter to reduce surface runoff, and, through leaf-litter and woody debris-fall, provides the food source and habitat for a wide range of aquatic macroinvertebrates (Cummins 1986). In addition, riparian vegetation often provides terrestrial refugia for adult forms of aquatic larvae (Cummins 1986). Protecting and restoring streamside vegetation in the upper reaches of a waterway improves local water quality and leads to improved water quality for downstream receiving-waters.

The Urban Mainstream waterways segment, covering three sites along the Maribyrnong River, exhibited relatively poor water quality, with SIGNAL scores suggesting probable moderate pollution (table 8). None of these sites satisfied either WoV Schedule F7 objectives for SIGNAL scores or Key Families – no stoneflies and low numbers of caddisfly, dragonfly and damselfly families were present (table 5). Maribyrnong River at Keilor Park (NL) did meet the RBA Families objective, with substantially more families recorded than at the other two sites in this segment. It appears that this site is in some ways a 'transitional' site between Rural and Urban Segments. The sites at Keilor Park and Brimbank Park had O/E scores within the 'reference' band. Both are in parkland, surrounded by urban areas, with large eucalypts in the riparian zone and macrophyte beds fringing the river, providing good habitat for macroinvertebrates. In contrast, the Maribyrnong River site at Canning Street Ford (NK) had an O/E score below 'reference'. At the time of sampling, the water was turbid, with large amounts of filamentous algal growth. Both total phosphorus and total nitrogen levels were extremely high. Contaminants in stormwater runoff and other sources of pollutants common in urban areas may have contributed to the low O/E score at this site. In most cases, these sites do not meet the nutrient guidelines, although in spring, and at Brimbank Park (NP) downstream of the STP discharge in autumn, some of the measurements do meet the recommendations – perhaps due to increased flow creating a dilution effect.

Within the Urban Tributaries Segment, both sites on Taylors Creek were in better condition than the other four sites. Taylors Creek at Burrowye Crescent (NN) met the Key Families and RBA Families objectives, although it did not meet the SIGNAL score requirements for the Urban Tributaries Segment (table 8). Taylors Creek at Green Gully Road (NO) fell just short of the Key Families and RBA Families requirements. The O/E scores for both sites were in the 'below reference' category, with fewer families present at the sites than would be expected, suggesting mild disturbance of the habitat or mild pollution.

The families present tended to be those more tolerant of poorer water quality. Again, nitrogen levels were higher than recommended. Both of these sites are in parkland, with recent plantings and some older riparian vegetation. Filamentous algae was present at both sites, suggesting nutrient enrichment. Although the habitat is in reasonable condition, the sites are in urban areas, with the problems of urban runoff and highly variable flows. These inputs should be addressed. As the recent plantings establish, it is likely that instream habitat will improve and, provided that water quality does not deteriorate further, this will have a beneficial effect on macroinvertebrate communities.

The Steele and Stony Creeks sites are more heavily impacted than the sites on Taylors Creek. Their SIGNAL scores put three of the four sites in the ‘probable moderate pollution’ category, and Stony Creek at Drew Street (NS) had a SIGNAL score at the low end of the ‘doubtful quality, possible pollution’ range (table 8). Key Families values were low and the RBA Families were below those required by the WoV Schedule F7. The AUSRIVAS O/E scores put three of these sites in the ‘well below reference’ band, with considerably fewer families collected than expected, suggesting a moderate to severe impact on either the habitat, water quality or both. Stony Creek at Drew Street had an O/E score in the ‘impoverished’ category (D), indicating a severe impact on the aquatic environment. This site does appear to separate out from the other urban sites in some of the classification and ordination procedures. None of these sites met the nitrogen or phosphorus guidelines.

Urbanisation can have a number of deleterious effects on stormwater runoff into streams: runoff volumes are increased as a result of an increase in impermeable surfaces – such as roads and carparks – runoff reaches streams more quickly because of efficient drainage systems and large amounts of pollution (such as fuel leakage, fine particles from worn tyres, atmospheric fallout, litter and animal droppings) are washed into the waterways (Weeks 1982). Urban streams may also be affected by old or poor sewerage connections, adding to the nutrient loads in the water column. The interaction of these factors can lead to the severely impacted and depauperate macroinvertebrate communities typical of urban streams. In addition, both Stony Creek and Drew Creek flow through heavily industrialised areas and are often affected by spills entering from the surrounding areas. Stony Creek sustains a high level of impact, with spills occurring at a frequency of up to one per week (Vasel[3], pers. comm.). These spills have included hydrocarbons, edible oils, paper-waste sludge, dyes, ammonia, and sewage. Spills into Steele Creek are less frequent, but include dyes (often copper-based), sewage, methylene chloride and heavily organically-enriched wash-out waters (from animal-pen cleaning and factory cleaning). These would adversely affect macroinvertebrate communities. The stream channels are also modified, with many sections of these streams little more than concrete drains, offering little or no habitat for invertebrates and increasing hydraulic shear stresses during peak flows. The smaller the tributary, the greater the potential impact of inputs on the macroinvertebrate community. Larger watercourses – such as the mainstream Maribyrnong – have more and better quality water (by virtue of less-disturbed upstream sources) that can act as a diluent for pollutants.

Maps of the Maribyrnong catchment showing the SIGNAL scores and O/E scores for each sampling site are presented in figures 9 and 10. It was not possible to infer the condition of all the streams or of the entire length of the Maribyrnong River from the data collected in this study. The length of the ‘colour-bar’ describing the stream condition, depends on the density of sampling sites and on consideration of other information – such as land use and physico-chemical data. Although the two indices did not give the same indication of stream health at each site, there were many similarities and a general pattern can be seen. Barringo Creek at Barringo (NY) and Deep Creek at Darraweit Guim (NE) appear to be clean-water sites with diverse communities. The other sites in the non-urban section of the catchment are slightly degraded, with nutrient enrichment from surrounding agricultural land or residential development, as well as sediment input resulting from bank erosion and lack of the sediment trapping action of riparian zones. Lower in the catchment, the effects of industrial and dense urban development are evidenced by indications of more severe pollution levels in the water and by impoverished macroinvertebrate communities. The reduced number of Trichoptera in the samples

[3] P. Vasel (EPA, Melbourne)

taken in the Urban section of the catchment is also characteristic of streams with organic enrichment (Wright *et al.* 1995).

The physico-chemical data do not show the downstream trend in deterioration of water quality as clearly as the biotic data, although they do show a general trend of increasing nutrient levels in the urban-industrialised section of the catchment. According to the principal component correlation (PCA), the only environmental parameters which may have some correlation with the macroinvertebrate communities are turbidity, distance from source and alkalinity (figures 12a, b). Turbidity, which was positively correlated with the Urban Tributaries group, appears to increase from low levels in the upper catchment to high levels downstream, particularly in the urban tributaries. This is likely to be a result of increased particulate runoff and erosion in agricultural areas, exacerbated in the urban areas by stormwater runoff in the city of Melbourne. Distance from source and alkalinity are both negatively correlated with the Forest site on Barringo Creek (NY); both environmental parameters are low at this site. Arising in the Macedon Ranges at 520 m altitude, Barringo Creek is in an upland section of the Maribyrnong catchment with historically much lower salinity than the rest of the catchment (Tiller[4], pers. comm.). The physico-chemical results in this study are inconclusive. This may reflect the low number of sampling periods (2) for parameters which can vary as widely as nutrient levels.

The different biotic indices used – SIGNAL, Key Families, RBA Families and the AUSRIVAS bands – have been shown to give slightly varying results at several sites. This demonstrates the importance of using a range of indices to describe the ecological health of streams as indices may vary in their sensitivity to different aspects of river health. The indices used in this study have been shown to be complementary to the multivariate methods employed in analysis and, in this case, more effective than traditional physico-chemical methods.

Future investigations of the health of streams in the Maribyrnong catchment using rapid bioassessment methods may need to further explore the level of taxonomic resolution required. This study found family-level analysis was little different to genus- or species-level multivariate analyses. However, a concurrent study on the health of streams in the Western Port catchment (EPA 1998) demonstrated that species-level analysis provided a more complete picture of the biological condition of sites, although it was concluded that this may not always be necessary for management decisions. Determination of the taxonomic resolution required for a sampling program must be made with regard to the type of disturbance, the scale of the study and the intention of the sampling program (Marchant *et al.* 1995; Marchant 1990).

The segments of the Maribyrnong system, based on cluster and ordination analysis, have been tentatively associated with segments taken from the WoV Schedule F7, based on similarities in physical characteristics and land use. When the WoV Schedule F7 ecological objectives (based on SIGNAL index, Key Families and RBA Families) are applied to the Maribyrnong River system segments, only a few sites meet the objectives. The assessment of the ecological health of the Yarra River (EPA, in press) has found that sites in the Yarra catchment often fail to meet these objectives. Given that these objectives were designed to encourage improvement, rather than reflect current conditions (EPA 1995a), the poor 'match' may be appropriate and act as a standard to strive towards. Aspects of the Maribyrnong catchment may also differ from conditions prevailing in the Yarra system (for example, the historically higher salinity levels in parts of the Maribyrnong catchment), therefore the WoV Schedule F7 guidelines may not be directly applicable to the Maribyrnong catchment. Though comparisons with the WoV Schedule F7 have been instructive, objectives specifically set for the Maribyrnong catchment are necessary to reflect these geographical and catchment differences. More extensive investigations of aspects of water quality and aquatic biota in the Maribyrnong catchment are needed to set specific ecological objectives for this catchment.

[4] D. Tiller (Freshwater Sciences, EPA, Melbourne)

8. CONCLUSIONS

- Analysis of the family-level data collected by rapid bioassessment methods in 17 sites in the Maribyrnong River system supports the geographical division of the system into two major sections – the Non-urban and the Urban – and the further separation of these two sections into Forest and Rural, and Urban Mainstream and Urban Tributaries. In general, there were significantly more pollution-intolerant macroinvertebrate families collected from non-urban sites than from urban sites.
- Barringo Creek at Barringo, the sole Forest Segment representative, clearly has the best water quality. It is in a closed catchment, and consequently has little site disturbance or water quality degradation, though nutrient levels are elevated. The sites in the Rural, Urban Mainstream and Urban Tributaries Segments are in poorer health, generally due to a combination of several interacting factors: poor streamside vegetation, erosion and siltation, nutrient enrichment and introduction of toxic materials. Two of the Urban Mainstream sites are in better condition than the other site, which is further into the urban area. The Urban Tributaries were in the poorest condition, reflected by the depauperate communities of macroinvertebrates found at the sites and poor water quality.
- Large amounts of filamentous algae at some sites – particularly Boyd Creek, Jacksons Creek, Steele Creek and Stony Creek – indicate nutrient enrichment of the water, most likely from non-point-sources such as agricultural and urban runoff. Nutrient input from sewage may also be a problem in some areas, particularly where there are old sewerage systems – such as in the inner urban suburbs – or where septic systems may be inadequate.
- There is some revegetation occurring at sites in the Urban Mainstream and Urban Tributaries Segments; river environs are being beautified and developed as urban parks (for example, at the sites on the Maribyrnong River). If this development continues, including restoration of native riparian vegetation on river banks, there is little doubt that the river habitat in urban regions will improve. Restoration of riparian zones is also necessary in non-urban areas to reduce bank erosion, siltation and runoff from pastures and unsealed roads, as well as to provide habitats for aquatic invertebrates.

9. RECOMMENDATIONS

Many sites in the Maribyrnong catchment are in poor condition and require action to improve water quality and instream habitats. It is suggested that the following aspects should be addressed in order to improve the ecological health of the Maribyrnong River system.

Riparian zone improvement

Replanting and restoration of the fringing vegetation along watercourses will improve instream macroinvertebrate habitat, reduce sediment and nutrient inputs and provide refugia for adult stages of aquatic invertebrates. In non-urban areas, riparian vegetation will serve to exclude stock from direct access to streams and reduce erosion of stream banks. In urban areas, revegetation will significantly add to the natural value of recreational areas and increase public enjoyment of parklands.

Reduction of sediment and nutrient inputs

Riparian zone improvement will address this to some degree but land management practices in non-urban areas need to be improved to reduce nutrient and sediment loads in streams.

Reduction in the frequency of toxic spills and pollution incidents

This would minimise the impact of toxicants on aquatic communities in the urban tributaries.

Investigation of septic and sewerage systems

There is a need to determine whether these are contributing significantly to nutrient loads in the Maribyrnong River system.

In addition, environmental quality and ecological indicator objectives should be developed specifically for the Maribyrnong River system, as has been done for the Yarra system in the WoV Schedule F7. To achieve this, more extensive coverage of the catchment is needed. Additional sites should be investigated on tributaries and in reaches of the Maribyrnong River which were not sampled in this study. It is also recommended that monitoring of a few selected sites that have been sampled in this study be continued in order to track changes in water quality and habitat over time.

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APPENDIX 1 SITE DESCRIPTIONS

NON-URBAN SITES

Barringo Creek at Barringo (Site NY)

This site is at a Rural Water Corporation gauging station in a closed catchment that provides the town water supply for Gisborne. At this point the creek is surrounded by undisturbed eucalypt forest with a mixed shrub understorey of acacias, *Pomaderris, Prostanthera*, and a ground cover of *Gahnia*, grasses, herbs and *Blechnum* ferns. The creek is 1–1.5 m wide and very shallow (10–20 cm), with a substrate composed of gravel, pebbles and some cobbles, all with a slight covering of silt. No filamentous algae was observed at the site. Aquatic mosses and liverworts grow on the stones in the stream and a few sedges grow along the creek banks.

Deep Creek at Monegeeta-Springfield Road (Joyce Crossing) (Site ND)

The creek at this site is about 3–5 m across, up to 1 m in depth and runs through grazing pasture set among gently undulating hills. The riparian zone is well established in parts and consists of eucalypts, acacias and willows. Macrophyte beds are extensive and consist of a mixture of *Myriophyllum*, *Elodea* and the emergent reed *Phragmites.* The stream bed is mainly composed of pebbles with some larger cobbles present. Over this lies a fine layer of sediment. There was very little filamentous algae observed when the site was sampled. The banks of the creek are steep and deeply cut away in stretches. Some erosion is evident.

Deep Creek at Darraweit Guim (Site NE)

Deep Creek at Darraweit Guim is surrounded by cattle grazing pasture. The riparian zone is well vegetated and consists of acacias, eucalypts, bottle-brushes and some willows. There are numerous macrophyte species, including *Alisma plantago-aquatica*, *Triglochin procera*, *Elodea*, *Polygonum*, *Juncus*, *Phragmites* and *Eleocharis*. The creek bed comprises mainly cobbles and pebbles, with an overlay of fine sediments. The banks are relatively stable but in some patches erosion is occurring.

Boyd Creek at Lobbs Bridge (Site NX)

At this site, Boyd Creek is 2–8 m wide, 25–50 cm deep and surrounded by sheep and cattle pasture. The riparian zone is narrow and only sparsely vegetated with acacias and willows. The macrophytes *Elodea*, *Phragmites* and *Juncus* are present in the stream and there are very large amounts of filamentous algae in the pools. The creek banks are very high, steep and unstable. They are heavily eroded in parts and fine sediment covers the mainly-bedrock substrate.

Deep Creek (Maribyrnong River) at Bulla (Site NV)

The Maribyrnong River is wide at this point and set among undulating steep hills. The surrounding land is agricultural and residential. There is a quarry upstream and a recreational barbecue area next to the river. The site is used by local people for swimming. The riparian vegetation along the steep banks is composed of willows, eucalypts, acacias and many weeds: grasses, fennel and thistles. The macrophytes at the site include *Eleocharis*, *Potamogeton*, *Triglochin*, *Phragmites* and *Elodea*. The substrate is primarily bedrock and is covered in sediment and filamentous algae. The water was slightly turbid at the time of sampling.

Emu Creek at Clarkefield (Site NZ)

This site is in a broad valley at a Rural Water Commission gauging site. Erosion is evident in some areas, with parts of the banks cut away. The riparian vegetation is reduced and includes a few exotic trees – such as willows and pines. Sorrel and grasses form the understorey. Very little vegetation overhangs the creek and the area is subject to grazing. The macrophytes include *Phragmites*, *Potamogeton*, *Juncus* and *Typha*, and there is some filamentous algae present. The substrate is cobble, with silt overlying the substrate in slower-flowing areas.

Jacksons Creek 1 km SE Clarkefield Railway Station (Site NB)

This site is located in a broad valley; the river winds through pastoral grazing land. The riparian vegetation forms a fairly narrow band and consists mainly of blackberries, acacias and gorse, with some small willows, fennel and Patterson's Curse. Macrophytes include *Elodea*, *Polygonum*, *Typha*, *Juncus, Crassula* and *Potamogeton.* There is heavy growth of filamentous algae, and a large amount of sediment and silt.

Jacksons Creek at Sunbury (Site OA)

This site is in a broad valley, situated next to the main Sunbury-Melbourne Road. It is located in parkland with walking and cycling tracks and a playground, adjacent to a vineyard. The riparian vegetation includes very few natives and is primarily elms, willows and peppercorn trees, with some eucalypts. The understorey is comprised mainly of blackberries and grasses. The macrophytes are *Juncus*, *Triglochin*, *Typha* and *Polygonum.* The substrate is bedrock, boulders and cobbles. The depth is greater than 1m in spots, with the riffle 10–30 cm deep and the creek 3–8 m wide. Filamentous algal mats are well developed in the slow sections, with all stony substrates covered with a silt/algae matrix. The water was slightly turbid at the time of sampling.

URBAN SITES

Taylors Creek at Green Gully Road (Site NO)

At this site, Taylors Creek runs through a wide grassy urban park in a broad valley that has extensive residential development on the upper slopes. Recent plantings of native trees and shrubs and older more established trees are scattered throughout the park, especially on the slopes of the valley. The creek itself is heavily vegetated, with the main channel obscured by large stands of *Phragmites*. A few eucalypts, acacias and willows line the stream banks. The substrate consists of mainly boulders with a covering layer of fine sediments and detritus. There is some filamentous algae growing in clumps in the main channel.

Taylors Creek at Burrowye Crescent (Site NN)

At the Burrowye Crescent site, Taylors Creek runs through a reserve among relatively new housing. Some of the original river red gums (*E. camaldulensis*) still exist and seedlings from these trees are re-establishing. Revegetation with native grasses and shrubs is also occurring. The creek bed comprises boulders and cobbles, with a thick covering of sediment. The macrophytes *Carex* and *Phragmites* grow in small stands in the stream and patches of the floating fern *Azolla* are in sheltered, still reaches.

Stony Creek at Sunshine Road (Site NR)

This upstream section of Stony Creek is 1–1.5 m wide, shallow (10–40 cm) and located among light to heavy industrial development. The stream channel at the site has been modified and is straight, with very steep banks. The immediate surroundings are grassy, with a row of poplars and willows lining the banks. Macrophytes growing in the stream include extensive beds of *Potamogeton crispus*, some *Callitriche*, *Polygonum* and *Alisma plantago* (water plantain). The substrate is rocky with a deep covering of sediment and fine detritus. At the time of sampling there was a lot of filamentous algae present and the water was turbid and slightly milky with an organic chemical odour.

Stony Creek at Drew Street (Site NS)

At this site, Stony Creek runs through urban parklands, including bike trails and a playground, with residential housing surrounding the park. The creek is 1–2 m wide and 20–50 cm deep, with both riffle and pool habitats present. Riparian vegetation is quite sparse with, for the most part, mown grasses on the stream verges. A few large willows and planted native trees and shrubs are scattered along the creek edges and throughout the park. Macrophytes growing in the creek include *Phragmites*, some *Potamogeton crispus* and the sedges *Juncus* and *Carex*. There was also a considerable amount of filamentous green algae blanketing the rocks. The substrate is mainly rocky, with a thick covering of black anaerobic-smelling mud and detritus.

Steele Creek at Rose Avenue (Site NQ)

Steele Creek at Rose Ave is 1–3 m wide, 10–50 cm deep, and runs through parkland in a broad valley surrounded by residential developments. On the left bank, (facing downstream) further building is about to commence. The parkland is grassy, with recent plantings of eucalypts and acacias. A few mature willows line the stream banks. The stream edges are artificial; bluestone boulders form the creek banks. The stream bed is composed of embedded pebbles and gravel, with an easily disturbed overlay of fine sediment. The substrate is covered in parts by a thick and extensive growth of filamentous green algae. *Polygonum*, aquatic grasses and *Potamogeton pectinatus* form the macrophyte beds in the stream.

Steele Creek at Keilor (Site NP)

This site, on Steele Creek, is located near the Calder Freeway, in the Green Gully Reserve parklands. The stream here is narrow (1–2 m) and shallow (10–30 cm depth). Adjacent land use is recreational, with barbecues, playgrounds and cycling trails located throughout the park. The stream banks are modified with large boulders to stabilise the steep banks. The rocky substrate is mainly composed of cobbles with an overlay of fine brown sediments and detritus. Riparian vegetation is sparse, with only a few eucalypts, acacias, and exotic ornamental trees planted in the park. A few willows, plum and poplar trees shade the stream. Several macrophyte species grow in the creek, including *Ranunculus*, *Juncus* and the sedges *Carex* and *Cyperus*.

Maribyrnong River at Keilor under Calder Freeway (Site NL)

This site is immediately under the Calder Freeway, near a ford. The river is approximately 8 m wide at this point and flows through a steep valley, with large willows lining the banks. The surrounding hills are cleared, with a few eucalypts and acacias near the river. Grasses and blackberries cover large areas of the bank and trail in the water, although there are unvegetated areas which may be subject to erosion. Substantial patches of *Juncus* line parts of the channel. The river bed is primarily pebble, with some cobbles, gravel and sand.

Maribyrnong River d/s Sewage Treatment Plant at Brimbank Park (Site NW)

This site is in Brimbank Park, a large urban parkland located immediately downstream of a sewage treatment plant. The river runs through a broad valley, with quite steep banks. The surrounding hills have been cleared, but scattered trees dot the grassed areas. There are large river red gums and acacias, and grasses down to the river edge. The macrophyte vegetation is well-developed, and includes *Triglochin*, *Juncus* and *Phragmites*. The floating fern *Azolla* grows in the large pool area. The substrate is mainly cobble, with some boulders and pebbles.

Maribyrnong River at Canning Street Ford (Site NK)

At this site, the Maribyrnong River is wide and deep and runs through a broad deep valley developed as a large urban park. The park is mainly grassland with some large stands of native trees and shrubs. Recreational activities in the park include cycling, walking, horse riding and fishing. Extensive private residential developments lie adjacent to the park boundaries. The banks of the river are heavily vegetated in parts, with a well-developed riparian zone. Other stretches of river bank are devoid of overstorey vegetation. The river bed is composed of a heterogeneous mix of boulders, cobbles, smaller pebbles and gravel. The ford itself is a series of large boulders that are used as stepping stones to cross the river. Some of the instream rocks are heavily covered with filamentous algae.

APPENDIX 2 DETAILED ANOVA TABLES

Results of a one-factor ANOVA comparing mean number of macroinvertebrate families found in urban and non-urban zones in the Maribyrnong catchment from both riffle and edge habitats. (n=17)

Source	**df**	**MS**	**F-ratio**	**p**
No. of families, urban vs non-urban	1	544.0	92.727	<0.001
Error	15	5.867		

Since the F-ratio is much larger than predicted ($F_{.001[1,15]} = 16.59$), the mean number of families in the urban zone differs significantly from the mean number of families in the non-urban zone.

Results of a one-factor ANOVA comparing mean number of macroinvertebrate families found in segments in the Maribyrnong catchment from both riffle and edge habitats. (n=17)

Source	**df**	**MS**	**F-ratio**	**p**
No. of families per segment	3	185.881	32.498	<0.001
Error	13	5.720		

Since the F-ratio is much larger than predicted ($F_{.001[3,13]} = 10.21$), the mean number of families in the each of the segments differs significantly from the mean number of families in each other segment.