Aquatic macroinvertebrate survey

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Appendix Q

Aquatic macroinvertebrate survey

PHOENIX

ENVIRONMENTAL SCIENCES

Aquatic Macroinvertebrate Survey of Beeliar Wetlands for the Roe Highway Extension Project

Final Report

October 2010

Beeliar Regional Park Aquatic Macroinvertebrate Survey for the Roe Highway Extension Project

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Final Report

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EXECUTIVE SUMMARY

Phoenix Environmental Sciences Pty Ltd (Phoenix) was commissioned by South Metro Connect (SMC) to undertake a macroinvertebrate survey of some wetlands in the northern part of Beeliar Wetland chain for the Roe Highway Extension Project ('the proposed project'). The Government of Western Australia is planning to extend Roe Highway, located between Farrington Road near the Kwinana Freeway Jandakot to Stock Road, Coolbellup in the City of Cockburn, Perth Western Australia (the 'project area').

The scope of the survey encompassed Bibra Lake, North Lake, South Lake, Horse Paddock Swamp, Roe Swamp, Lower Swamp and Melaleuca Swamp ('the study area'); Roe Swamp and Horse Paddock Swamp were however dry at the time of sampling (and remained so through 2010) and therefore were not surveyed. Sampling was undertaken in October 2009 (spring) and December 2009 (summer). Seasonal differences in water level and water quality altered the habitat types and the number sites available for sampling between the two seasons. Consequently 14 sites were sampled across the five wetlands in October 2009 and eight sites were sampled in December 2009.

The five wetlands sampled in the survey are important aquatic ecosystems that have environmental, cultural, aesthetic and scientific values; most notably Bibra Lake and to a lesser degree, North Lake. Aquatic macroinvertebrate assemblages of the wetlands are integral to some of these values. In particular, aquatic macroinvertebrates play a critical role in ecological processes. They are an essential food resource for higher-order fauna, particularly wetland birds, frogs and the Long-necked Turtle (*Chelodina oblonga*). They also play an important role for nutrient decomposition and cycling; as well as water quality maintenance.

The sampled wetlands were characterised by five broad macroinvertebrate habitat types: open water, riparian, *Typha orientalis*, *Baumea articulata* and *Melaleuca preissiana* 'closed forest'. North Lake, Bibra Lake and South Lake were the most complex of the wetlands in terms of habitat diversity.

The assemblages at each wetland were dominated by insects (59 species), crustaceans (ostracods, 13 sp. and copepods (7 sp.), arachnids (9 sp.) and Clitellata or worms and leeches (8 sp.). All wetlands recorded a decline in species, genus and family richness from the spring to summer sampling rounds. Such seasonal declines are typical of wetlands on the Swan Coastal Plain.

The most diverse macroinvertebrate assemblage was recorded at Bibra Lake (64 species), followed by South Lake (51 sp.) and North Lake (46 sp.). Species richness at Bibra Lake declined from 50 species in October to 32 species in December. North Lake and South Lake experienced less pronounced seasonal declines in species richness. Melaleuca Swamp recorded the lowest species richness overall (25 sp.) and in each season (20 sp. in October and 6 sp. in December).

The results of the survey largely agree with earlier surveys (Horwitz et al (2009); Giles and Davis (2005) in terms of species richness and overall macroinvertebrate diversity. However, in contrast to Horwitz et al (2009) who found macroinvertebrate assemblages to be largely homogenous across 66 Swan Coastal Plain wetlands, this survey found the five sampled wetlands to be markedly different at the species level. The seasonally inundated sumplands Lower Swamp and Melaleuca Swamp, were found to support the most distinct assemblages.

The relative similarity of assemblages was largely dictated by only a few species. For example, the similarity of Bibra Lake and South Lake is due to the presence of three species (*Physa acuta*, *Austrochiltonia subtenius* and *Sarscypridopsis aculeate*) found across all habitat types in both lakes. Conversely these three species also made a significant contribution to the dissimilarity of Bibra Lake and South Lake with the other three wetlands investigated. These species are therefore candidates as indicators of health within these two wetlands. In contrast, the freshwater crayfish, the Gilgie (*Cherax quinquecarinatus*), which was recorded in Lower Swamp, would be the most likely candidate as an indicator species in this wetland.

All sampled wetlands recorded at least one indicator species known to respond positively to eutrophication on the Swan Coastal Plain (as per Davis et al (1993). Bibra Lake recorded five such species. Bibra, North and South lakes also recorded negative eutrophic indicator species. The mixed results suggest that although these wetlands have been modified to some extent, they still retain elements of the original macroinvertebrate assemblage. The results from Bibra Lake indicate there has been a continuing improvement in macroinvertebrate diversity, as previously reported by Giles and Davis (2005).

Impacts to wetlands and aquatic macroinvertebrates

The proposed project is not expected to directly impact the aquatic macroinvertebrate assemblages of any of the five wetlands sampled, during either the construction or operational stages. However, the proposed project does carry a number of secondary or indirect impact risks which may need to be managed.

The most important secondary impact is the potential for the proposed project to restrict or alter groundwater flows through the downward pressure (load) exerted by the road (at grade) and the footings (where bridges and arches are used) on the underlying sediment. Sufficient loading may act to reduce the underlying sediment pore size resulting in a decline in groundwater quantity flow-through may occur.

In the absence of a complete groundwater data set, it is postulated that North Lake is at most risk of suffering reduced groundwater inputs. Construction techniques should therefore aim to minimise the load bearing within the section of the project area immediately between North Lake (southern shores) and Bibra Lake (northern shores). Construction should not proceed until the full groundwater data set is available. In the event that the data suggests that the load bearing will be sufficient to detrimentally restrict groundwater movement between the wetlands, mitigation measures in the form of sub-surface flow structures should be considered.

Shading of the Bibra Lake and Row Swamp riparian zone and over-storey, respectively, is the other major secondary potential impact. In the case of Roe Swamp shading effects may be minimal as the Roe Swamp water body and associated riparian vegetation (that forms the habitat for aquatic macroinvertebrates) is already heavily shaded by the closed Melaleuca ‘ forest’ that forms the over-storey of this wetland. Thus the system already operates on a lower-energy budget that than of Bibra Lake and North Lake for example.

With respect to Bibra Lake (at the Progress Drive – Hope Road intersection) any significant shading of the northern shore may result in a decline in riparian vegetation cover and density (habitat structure), potentially resulting in an associated decline in aquatic macroinvertebrate diversity and abundance. All of these impacts would therefore also have impacts on water birds nesting and feed in that northern area.

The following recommendations are given with respect to maintaining or improving water quality conditions:

- Construct nutrient stripping water retention basins (artificial wetlands) in order to treat all water draining off the proposed project. All wetlands appear to be suffering from elevated nutrient loads. The proposed project must not contribute further to this loading;
- Ensure that the construction phase and the final structures do not impact upon groundwater flows; and
- Installation of artificial aeration devices.

The following recommendations are given with respect to ensuring maintenance of or improvement in, macroinvertebrate diversity and overall wetland condition:

- Bi-annual monitoring of macroinvertebrate assemblages and water quality parameters in each of the five wetlands for a period of five years during and after construction (Roe Swamp and Horse Paddock Swamp should also be sampled in the event of inundation;
- Investigation into the remediation of Lower Swamp and Horse Paddock Swamp.
    - Prevent or limit damage or removal of any riparian or terrestrial vegetation (upstream of surface flows) during the construction phase. Particularly at the intersection of Progress Drive and Hope Road and, where surface flow inputs would otherwise be intersected by native vegetation, e.g. Frog Brook.
- Develop a strategy for the removal of introduced fish species such as *Gambusia holbrooki* at Bibra Lake. Removal of *G.holbrooki* etc would ideally be followed up with the reintroduction of genetically suitable native fish species.

1.0 INTRODUCTION

In October 2010, Phoenix Environmental Sciences Pty Ltd (Phoenix) was commissioned by South Metro Connect (SMC) to undertake a macroinvertebrate survey of some wetlands in the northern part of Beeliar Wetland chain for the Roe Highway Extension Project ('the proposed project'). The Government of Western Australia is planning to extend Roe Highway from the Kwinana Freeway in Jandakot to Stock Road, Coolbellup in the City of Cockburn, Perth Western Australia (the 'project area') (Figure 1-1**)**. This report documents the results of the survey, which was undertaken in October (spring) and December (summer) 2009.

1.1 Background

The proposed alignment for the Roe Highway Extension between the Kwinana Freeway and North Lake Road is through the Beeliar Wetlands between Bibra Lake and North Lake (Figure 1-1). The project area is considered to be of high environmental value and as such, extensive biological surveys are required.

Most of the sampled wetlands fall within Beeliar Regional Park, which is located in southern metropolitan Perth. The northernmost area of the Park (Blue Gum Lake) is located approximately 10 kilometres (km) from Perth's Central Business District (CBD) while the southernmost area (The Spectacles) is approximately 33km from the CBD. The park comprises 19 lakes and many other associated wetlands in two main chains located parallel to the coast. The western chain is approximately two kilometres from the coast and the eastern chain is between five and six kilometres from the coast. The wetlands sampled in the survey form part of the eastern chain.

1.2 Scope of Work and Survey Objectives

Macroinvertebrate assemblage surveys are not usually required for environmental impact assessment (EIA), except where a project has the potential to directly impact upon aquatic ecosystems. A desktop review identified a need for aquatic macroinvertebrate sampling of wetlands within and adjacent to the project area, primarily due to a lack of recent survey work. The survey was also intended to provide a baseline for a before and after (BACI) study, in the event that such a study was deemed necessary. The subsequent scope of works was to undertake a bi-seasonal survey (autumn and spring 2009) of the aquatic macroinvertebrate assemblages within the following wetlands ('the study area'):

- North Lake;
- Bibra Lake;
- South Lake;
- Horse Paddock Swamp;
- Lower Swamp;
- Melaleuca Swamp; and
- Roe Swamp;

Specific objectives for these wetlands included:

- Sampling of the seasonal macroinvertebrate assemblages (autumn and spring 2009);
- Water quality analysis (where surface water was available for sampling);
- Comparison of between (habitats) and within (season) wetland macroinvertebrate assemblages;
- Comparison of results with existing and historic biological and water quality data; and
- Identification of macroinvertebrate indicator species e.g. eutrophication and heavy metal contamination, that could be used to monitor the wetlands in the future.

Roe Swamp and Horse Paddock Swamp were dry at the time of sampling and therefore were not surveyed.

Figure 1-1
Location of the Roe Highway Extension Project

Legend

Project boundary

0 1 2 3

Kilometres

Datum: GDA94 Projection: MGA z50

Date Modified: 23/09/2010

Author: CBB J:\Client_Data\Main_Roads\60100953_Roe_Extension\Workspaces\2010_09_23__Phoenix_Maps__Current_Versions\Invertebrate_Technical_Report_Figures\Figure 1-1 - Location of the Roe Highway Extension Project.mxd

1.3 Survey Significance

Wetlands in Western Australia are protected and managed under various state and federal government policies and legislation and also under a number of international framework agreements. Further, the assessment of environmental impacts to wetlands through the EIA process is guided by a number of guidance and position statements published by the Environmental Protection Authority. The most relevant agreements, frameworks, legislation and policies are listed below.

State

- Wetlands Conservation Policy for Western Australia (Government of Australia 1997);
- State Water Quality Management Strategy (2001);
- State Water Strategy (2003);
- Bush Forever (2000);
- Western Australian Natural Resource Management Framework Policy (1999)
- EPA Position Statement No. 3: *Terrestrial Biological Surveys as an Element of Biodiversity Protection* (EPA 2002);
- Bilateral Agreement between the Commonwealth of Australia and the State of Western Australia to deliver the Natural Heritage Trust (2002);
- EPA Position Statement No. 4: Environmental Protection of Wetlands (EPA 2004);
- EPA Guidance Statement No. 33: Environmental Guidance for Planning and Development: (EPA 2008);
- EPA Guidance Statement No. 56: *Terrestrial Fauna Surveys for Environmental Impact Assessment in Western Australia* (EPA 2004);
- Department of Environment and Conservation Regional and Area Management plans under the Conservation and Land Management Act 1984; and
- Stormwater Management Manual for Western Australia (DEC 2004).

National

- Wetlands Policy of the Commonwealth Government of Australia (1997);
- Directory of Important Wetlands (Environment Australia 2001);
- National Framework for the Management and Monitoring of Australia's Native Vegetation (2001);
- National Local Government Biodiversity Strategy (1998);
- Natural Heritage Trust (established 1997); and
- State of the Environment Reports (1996, 2001).

International

- Convention on the Conservation of Migratory Species of Wild Animals (Bonn 1979);
- Asia–Pacific Migratory Waterbird Conservation Strategy: 2001-2005 (2001);
- Chinese-Australian Migratory Bird Agreement (CAMBA) (1986);
- Convention on Wetlands of International Importance, especially as Waterfowl Habitat (Ramsar 1971); and
- Japan–Australia Migratory Bird Agreement (JAMBA) (1974).

EPA Position Statement No. 4: Environmental Protection of Wetlands outlines the following broad principles for protecting wetlands:

- To protect the environmental values and functions of wetlands in Western Australia;
- To protect, sustain and, where possible, restore the biological diversity of wetland habitats in Western Australia;
- To protect the environmental quality of the wetland ecosystems in Western Australia through sound management in accordance with the concept of 'wise use', as described in the Ramsar Convention and ecologically sustainable development principles, regardless of land use or activity; and
- To have as an inspirational goal, no net loss of wetland values and functions.

Wetland classification is used to distinguish the types, characteristics, important traits and ecological values of wetlands in Australia. This information, along with the legislative frameworks and guidance, provides focus for wetland management and conservation.

There are several models for wetland classification in Australia, but the most commonly used is the geomorphic classification system of Semeniuk (1987). This system classifies different wetland types on the basis of geomorphic and vegetation traits and subsequently evaluates wetland uniqueness and importance in a regional context (Table 1-1).

Table 1-1 The geomorphic classification and evaluation of each wetland sampled in the project area (based on Semeniuk 1987).

Wetland Name	Classification[1]	Evaluation[1]
Bibra Lake (Lake Walliabup)	Lake	Resource Enhancement/ Multiple Use
Horse Paddock Swamp (Ibis Swamp)	Lake	Conservation
Roe Swamp and surrounding sumplands	Sumpland	Conservation
Lower Swamp (Frog Swamp) and Melaleuca Swamp	Sumpland	Conservation
North Lake (Lake Coolbellup)	Lake	Conservation
South Lake	Sumpland	Conservation

[1] based on the Semeniuk geomorphic wetland classification model (Semeniuk 1987).

2.0 EXISTING ENVIRONMENT

The wetlands of the Swan Coastal Plain (SCP) support a diverse range of terrestrial and aquatic flora and fauna. Agricultural, urban and industrial development over the past century has severely depleted the number of wetlands that once existed on the SCP, with estimates that less than 25% remain, although this figure is now likely to be even lower (Balla 1994). These ecosystems have been filled in to allow for construction, drained to facilitate market gardens and other uses, mined for peat or clay, or simply cleared of vegetation (Balla and Davis 1993; Balla 1994; Horwitz et al 2009).

Into the future, SCP wetlands will continue to face direct threats primarily from urban development, but also indirect threats through upland vegetation clearing and nutrient enrichment from grazing, contamination and unsustainable groundwater extraction regimes.

A number of wetland research projects initiated in the 1990's resulted in the publication of the "Wetlands of the Swan Coastal Plain" series (1993 to 1996) (Balla and Davis 1993; Davis et al 1993; Froend et al 1993; Storey et al 1993; Townley et al 1993; Balla 1994; Hill et al 1996a; b). The seven-volume series remains the most comprehensive synthesis of data and technical information on SCP wetlands. However a more recent review of wetland aquatic invertebrate richness and endemism has made a new major contribution to an enhanced understanding of the SCP wetlands by bringing together the data from 18 studies of 66 different wetlands (Horwitz et al 2009).

2.1 Climate

Climate conditions for the proposed project can be surmised from recordings at Jandakot Airport, approximately 3km to the east of the project area (BOM 2010). The mean daily maximum temperature of 31.3°C occurs in February, along with the highest minimum of 16.8°C. July is the coldest month on average, reaching a maximum temperature of 17.8°C. The lowest minimum is shared between July and August, both of which average 6.9°C. Rainfall occurs mainly during the cooler winter months between May and August, peaking in July with an average rainfall of 180.3mm. Annual rainfall is 837mm.

Climate affects annual water input into wetlands and therefore has an important influence on the hydrology, hydroperiod and nutrient cycles of wetlands.

2.2 Surface Water

Generally, the project area lies within the surface water catchment contributing to Bibra Lake, North Lake, Roe Swamp (consisting of independent sumplands - Lower Swamp (also known as Frog Swamp), Melaleuca Swamp and Roe Swamp), Horse Paddock Swamp (also known as Ibis Swamp) and other adjacent swamps and damplands.

Based on existing topographic features and anecdotal evidence, surface water flows through an artificial drain (Murdoch Drain or Frog Brook) in a north-westerly direction (Figure 2-1). This drain flows into North Lake via Lower Swamp. The section of swampland that lies north of Farrington Road (Melaleuca Swamp), near the intersection with Bibra Drive, has been disconnected from the drain due to the blockage of a culvert under Farrington Road. It is understood that the drain was blocked in several places in the mid nineteen-nineties to decrease nutrient flows from Murdoch University to North Lake (Philip Jennings pers. comm. 2009). Water that backs up in this low area is pumped north to Murdoch Swamp, which is located within the Murdoch University Campus. A gross pollutant trap (mesh screening that traps large debris) that filters stormwater before it enters Roe Swamp is located on the eastern side of Bibra Lake, slightly to the north of Parkway Road.

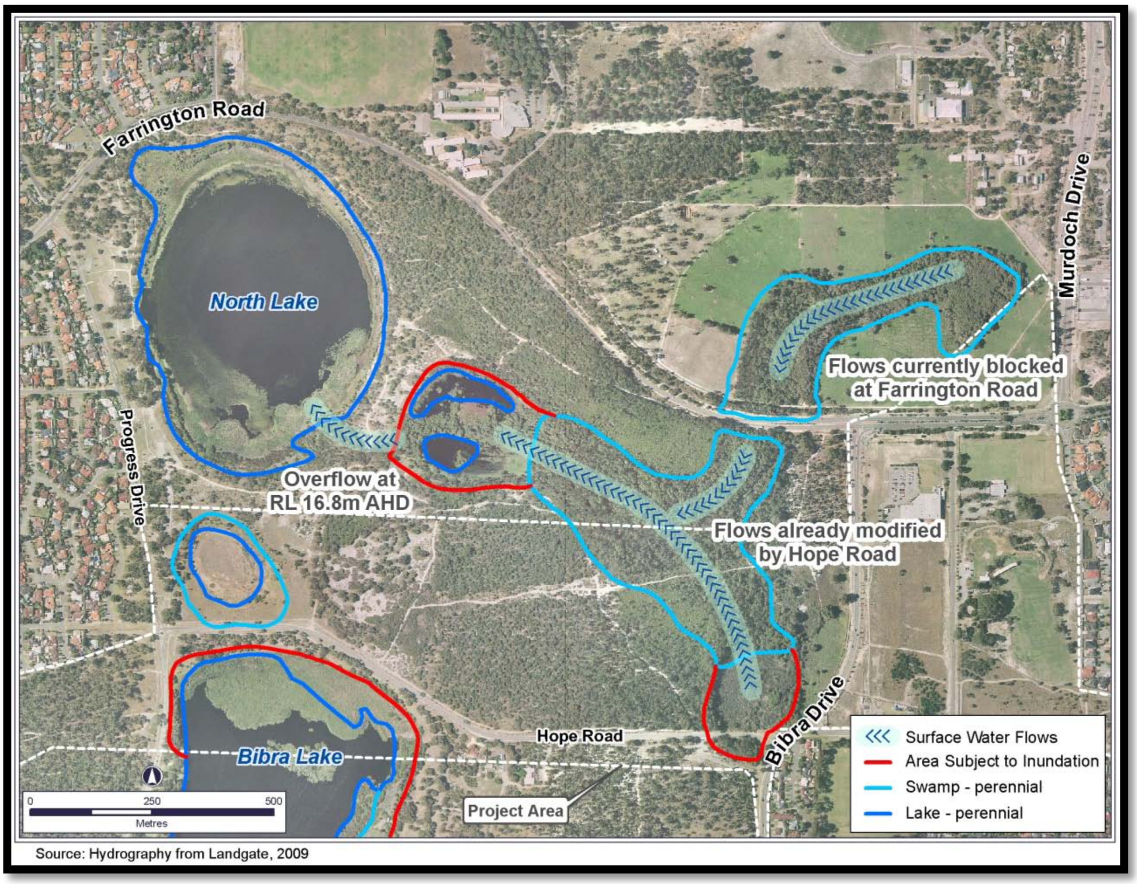
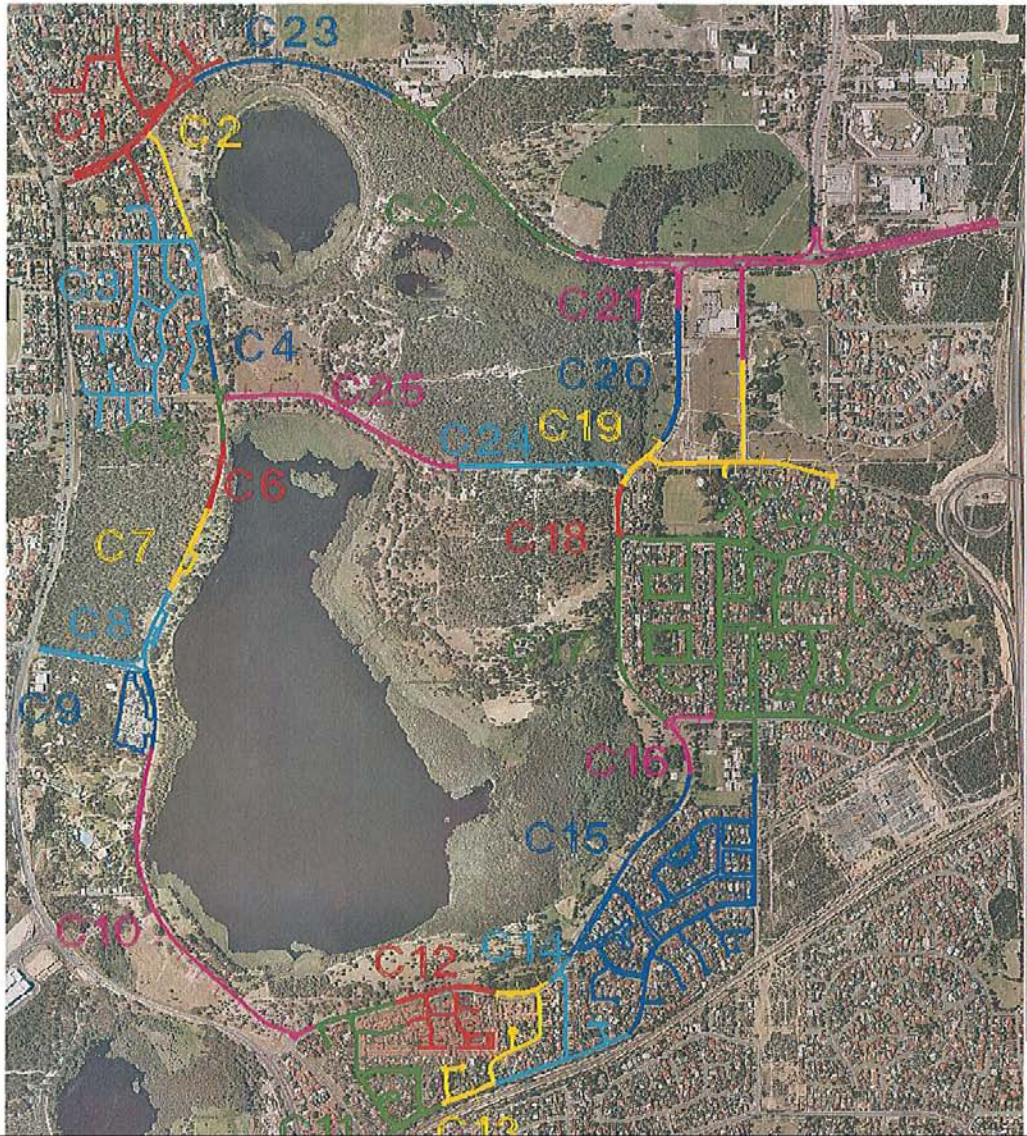


Figure 2-1 Surface Water Flows.

The construction of Hope and Farrington Roads modified the natural flow paths associated with the connections between Roe Swamp, Lower Swamp, Horse Paddock Swamp, and North and Bibra Lakes. Based on site inspections and City of Cockburn information, there do not appear to be any culvert crossings under Hope Road to allow water to flow (south to north) through these low lying areas. Information obtained from the City of Cockburn suggests that there are substantial surface water contributions to the project area from the existing drainage networks, either by direct discharge or by overflow from constructed basins.

The catchment area that either directly or indirectly contributes surface water to Bibra Lake or North Lake is estimated to be $120km^2$. This includes natural topographic and drainage network catchments as well as basin locations and direction of basin overflow. Specifically, the area of road drainage contributing to each wetland respectively is, 23.376 ha (Bibra Lake), 7.141 ha (Roe Swamp), 4.078 ha (North Lake) and 2.601 ha (Horse Paddock Swamp). The road catchment area was not calculated for Lower Swamp and Melaleuca Swamp, but would be expected to be similar to that of North Lake for Lower Swamp (Figure 2-2).



Catchment Name	Road Catchment (ha)	Comments	approx. distance u/s of main water body (m)
C1	2.104	residential roads with piped drainage discharging to council basin with piped outlet to North Lake foreshore	180
C2	0.342	road catchment direct runoff to North Lake foreshore reserve	90
C3	2.449	residential roads with piped drainage discharging to council basin with unknown overflow to Horsepaddock	120
C4	0.152	road catchment direct runoff to Horsepaddock Swamp	90
C5	0.219	road catchment direct runoff to Bibra Lake foreshore	20
C6	0.296	road catchment direct runoff to Bibra Lake foreshore	20
C7	0.589	road and carpark catchment direct runoff for Bibra Lake foreshore	50
C8	1.141	road and carpark catchment piped drainage discharging directly to Bibra Lake	40
C9	2.358	road and carpark catchment piped drainage discharging directly to Bibra Lake	70
C10	1.081	road catchment direct runoff to Bibra Lake foreshore	20
C11	1.432	residential roads with piped drainage discharging to Bibra lake foreshore	100
C12	1.170	residential roads with piped drainage discharging to Bibra lake foreshore	200
C13	0.970	residential roads with piped drainage discharging to Bibra lake foreshore	300
C14	0.956	residential roads with piped drainage discharging to Bibra lake foreshore	360
C15	4.047	residential roads with piped drainage discharging to Bibra lake foreshore	320
C16	0.367	road catchment direct runoff to Bibra Lake foreshore	590
C17	7.831	residential roads with piped drainage discharging to Bibra lake foreshore	500
C18	0.202	road catchment piped discharge to Roe Swamp	0
C19	1.510	road catchment and residential roads with piped drainage discharging to Roe Swamp	0
C20	0.639	road catchment discharging to Roe Swamp	100
C21	4.146	road catchment discharging to Frog Swamp	0
C22	0.952	road catchment discharging to North Lake foreshore	250
C23	0.680	road catchment piped discharge to North Lake foreshore	30
C24	0.644	road catchment discharging to Roe Swamp	0
C25	0.919	road catchment discharging to Bibra Lake	30

Summary	
Road Catchment to North Lake (ha)	4.078
Road Catchment to Horsepaddock Swamp (ha)	2.601
Road Catchment to Bibra Lake (ha)	23.376

Figure 2-2 Road Catchment schematics and contributions for the wetlands sampled in this study.

2.3 Groundwater

The Jandakot groundwater mound, used for water supply purposes, is located approximately 3km east of Bibra Lake. At the centre of the mound, the saturated thickness of the superficial formations is in the order of 4m, decreasing towards the coast.

Groundwater levels fluctuate seasonally by about 1m, being highest during September-October and lowest during April-May (Davidson 1983) (Figure 2-2). Groundwater contours indicate that groundwater flows in a generally westerly direction from the Jandakot Mound to discharge in the near-shore marine environment of Cockburn Sound.

North Lake, South Lake and Bibra Lakes are considered to be hydraulically connected with unconfined groundwater in the superficial formations. Annual water balances show that lake levels are maintained by groundwater inflow, direct precipitation and road-runoff from adjacent urban areas (Merigian 1982). The Beeliar wetlands to the west of the Jandakot mound (e.g. North and Bibra Lakes) are ‘through-flow’ lakes and expressions of the water table (CyMod 2009). Generally, groundwater discharges into the lakes at one section and the lakes recharge the groundwater in another section, creating a through flow of groundwater.

The depth to the unconfined groundwater is at or near the surface of the lakes and various associated wetlands. In areas where groundwater is near the surface, significant groundwater is lost by evapotranspiration from wetland vegetation. In other areas, the depth to groundwater is substantially deeper. Groundwater is in the order of 30 to 50 metres below ground level in the elevated areas to the west of Bibra Lake, near Coolbellup Drive.

It is apparent that the groundwater interactions on the Jandakot Groundwater Mound are complex, with each wetland displaying a different trend. For example, within the study area, Bibra Lake seems to be near the bottom of a drying trend (Figure 2-2a), while North Lake, which is downstream of Bibra Lake appears to be experiencing its driest period to date (Figure 2-2b). Beyond the study area, Thomsons Lake has recorded a gradual rise in water levels over the past 30 years (Figure 2-2c), while Lake Forestdale has consistently and with less variance recorded its lowest water levels over the past decade Figure 2-2d).

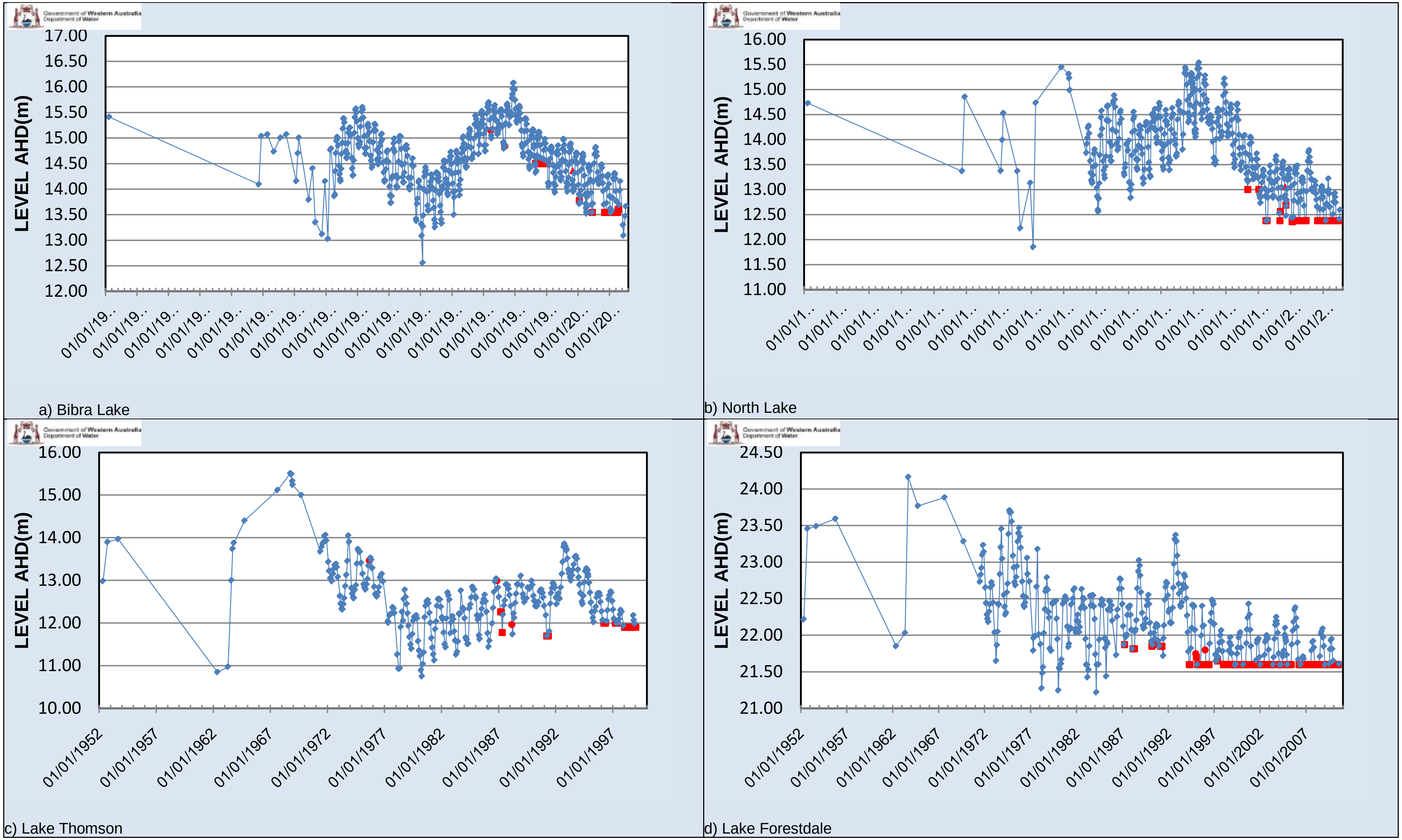


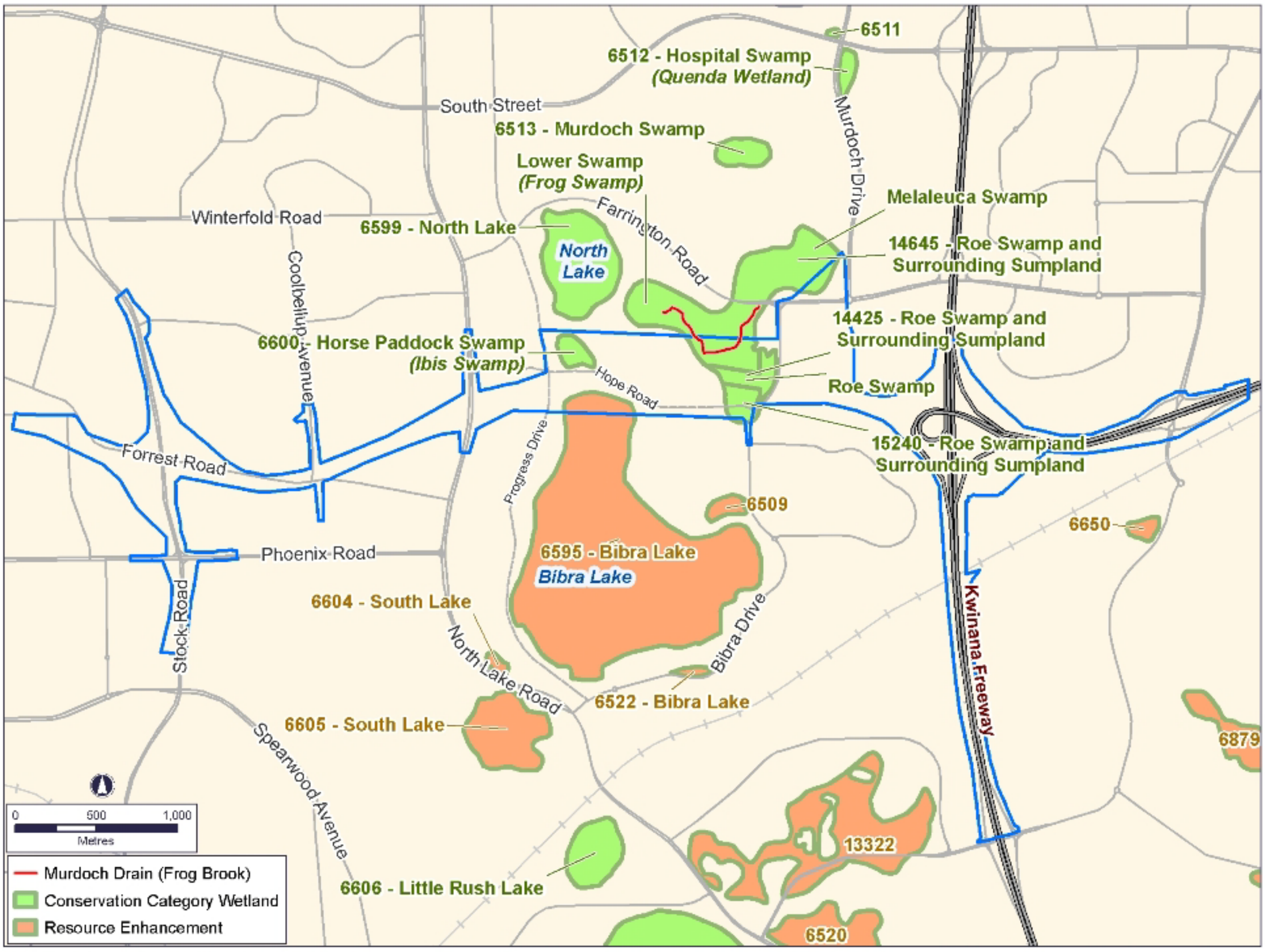
Figure 2-3 **Historical Beeliar Regional Park lake water levels for a) Bibra Lake, b) North Lake within the study area and c) Lake Thomson and Lake Forestdale south of the study area.**

2.4 Groundwater Dependent Ecosystems / Wetlands

There are two general classes of groundwater dependent ecosystems ('GDEs'). One relies on the surface expression of groundwater (e.g. swamps and wetlands) while the other relies on the availability of groundwater below the surface within the rooting zone of the vegetation (Eamus 2009).

Groundwater dependent wetlands are widely recognised as significant for their ecological, hydrological, social and economic values. They have characteristic vegetation, faunal assemblages and geomorphology that typically support a high level of biological productivity and diversity.

There are many groundwater dependent ecosystems within and adjacent to the project area, including North and Bibra Lakes and several smaller, ephemeral wetlands (EPA 2003) (Figure 2-3).



Source: Department of Environment, 1997

Figure 2-4 Location of all known GDE wetlands in the project area.

As part of the Jandakot Groundwater Scheme Stage II, the Minister for the Environment set statutory conditions for the Department of Water (DoW) regarding wetland monitoring for a number of wetlands (including North and Bibra Lakes), under Section 46 of the *Environmental Protection Act 1986*.

Environmental Water Provisions were also set, which include a preferred minimum water level and an absolute minimum level. These levels apply to several wetlands within the Beeliar Regional Park (including Bibra Lake) with the aim of maintaining historical water regimes and protecting wetland ecology (Strategen 2008).

2.4.1 GDE's / Wetlands within the Project Area

The DEC has created a Geomorphic Wetlands dataset which includes GDE's and provides both a wetland classification and an evaluation of values for each wetland (Table 2-1). Conservation Category wetlands

(CCWs) are the highest priority wetlands, as they support a high number of ecological attributes and functions. Resource Enhancement wetlands (REWs) are those which may have been partially modified, but still support substantial ecological attributes and functions. These are priority wetlands with the ultimate objective of management, restoration and protection towards improving their conservation status. Multiple Use wetlands are those with few important ecological attributes and functions remaining (WRC 2001).

Table 2-1 Summary of GDE wetlands in the project area.

UFI	Wetland Name	Classification	Evaluation	Location
6595	Bibra Lake (Lake Walliabup)	Lake	Resource Enhancement	Northern most portion of this wetland is within project area
6522	Bibra Lake (Lake Walliabup)	Lake	Resource Enhancement	Approximately 1.5km south of project area
6601	Bibra Lake (Lake Walliabup)	Lake	Multiple Use	Within project area
6598	Bibra Lake (Lake Walliabup)	Lake	Multiple Use	Approximately 340m South of project area
13320	Bibra Lake (Lake Walliabup)	Lake	Multiple Use	Approximately 760m south of project area
6600	Horse Paddock Swamp (Ibis Swamp)	Lake	Conservation	Within project area
15240	Roe Swamp and surrounding sumplands	Sumpland	Conservation	Within project area
14425	Roe Swamp and surrounding sumplands	Sumpland	Conservation	Within project area
14645	Lower Swamp (Frog Swamp) and Melaleuca Swamp	Sumpland	Conservation	Partially within project area
6599	North Lake (Lake Coolbellup)	Lake	Conservation	Approximately 80m north of project area
	South Lake	Lake	Conservation	Approximately 1.77km south of the project area

Source: Geomorphic Wetlands Dataset (DEC 2009d).

Note: For the purposes of this document wetlands (UFIs 15240, 14425 & 14645) are referred to as Roe Swamp and surrounding sumplands. UFI = Unique Feature Identifier.

North Lake (aka Lake Coolbellup)

The Geomorphic Wetlands dataset identifies North Lake (Unique Feature Identifier (UFI) 6599) as a CCW (DEC 2009). North Lake is a groundwater expression of the western Jandakot groundwater mound. Groundwater flow enters the lake through the sandy eastern shore (EPA and WAWA 1990). This CCW is protected under the Environmental Protection (Swan Coastal Plain Lakes) Policy 1992 (Lakes EPP). North Lake is part of Bush Forever Site 244.

Roe Swamp (i.e. Lower Swamp (aka Frog Swamp), Melaleuca Swamp, Roe Swamp and Surrounding Sumplands)

The Geomorphic Wetlands dataset identifies Roe Swamp as a sumpland with CCW status. A sumpland is described as a seasonally inundated basin which periodically experiences surface water. Roe Swamp, Lower Swamp, Melaleuca Swamp, and surrounding sumplands (hereafter referred to as Roe Swamp) (UFIs 15240, 14425 & 14645) are ephemeral wetlands, located to the east of North Lake. An artificial drain, known locally as Frog Brook, links the three wetland areas. Although the three wetlands are linked together and form one system, it is also possible that they function separately and contain different values. There is minimal available literature that describes these sumplands in detail.

Despite surrounding urban development, Roe Swamp has remained relatively unaltered in terms of its hydrological regime and vegetation cover (EPA 2003). During recent inspections (August 2009), it was observed that these sumplands are infested by various weed species, particularly the Arum Lily. Roe Swamp is composed of two channel-ways with deeper water pockets draining into North Lake (LeProvost et al 1984). Roe Swamp is considered unique, diverse and of high fauna habitat value, relative to other wetlands in the Perth region, despite the presence of an artificial drain. The high value of the swamp results largely from its morphological and physical (via drainage lines) relationships to the North Lake/Bibra Lake chain of wetlands (*DPUD* 1990).

The majority of Roe Swamp (with the exception of the eastern section) is located within Bush Forever Site 244, which describes the wetland vegetation as being equivalent to the Bassendean Complex in terms of the number of large Melaleucas present. The western portion of Roe Swamp (UFI 14645) is protected under the Lakes EPP.

Bibra Lake (aka Lake Walliabup)

Bibra Lake is one of the largest lakes in the Beeliar Wetland chain and consists of open water which is a reflection of groundwater on the western side of the Jandakot Mound. The Geomorphic Wetlands dataset identifies Bibra Lake (UFIs 6595 & 6522) as a sumpland with REW status. In comparison, other distinct parts of the lake (UFIs 6601, 6598 & 13320) are classified as Multiple Use sumplands. The REW (UFI 6595) and Multiple Use wetlands (6601, 6598 and parts of UFI 6510) are protected under the Lakes EPP (DEC 2009d). There are an additional three sumpland wetlands (UFIs 6508, 6510 & 6509) adjoining Bibra Lake, which are unnamed but classified as REW and Multiple Use.

Bibra Lake has relatively impermeable lake deposits, with sandy shores restricted to a small area to the west. As a consequence, groundwater inflow and outflow is restricted when the water level drops (EPA and WAWA 1990). Bibra Lake is part of Bush Forever Site 244.

Horse Paddock Swamp (aka Ibis Swamp)

The Geomorphic Wetlands dataset identifies Horse Paddock Swamp (UFI 6600) as a CCW. This swamp, which is located between North and Bibra Lakes, is also protected under the Lakes EPP. Although it has been colonized extensively by terrestrial vegetation such as thistle and grasses, its gently sloping shores and surrounds have been cleared with scattered trees remaining (EPA 2003). Horse Paddock Swamp is located within Bush Forever Site 244, which describes the wetland vegetation as being equivalent to the Herdsman Complex. It is also worth noting that Horse Paddock Swamp is by far the most heavily degraded and modified of the sampled wetlands in this study.

The project area lies outside of the Jandakot Underground Water Pollution Control Area boundaries. This area consists of three priority-protection levels utilised by the Department of Water (formerly the Water and

Rivers Commission), which have been established in order to restrict activities that may cause groundwater contamination (WAPC 2003).

2.4.2 GDEs/Wetlands Adjacent to the Project Area

According to the EPBC Act Protected Matters Report, the project area is located within the same catchment as the following wetlands of international significance (i.e. Ramsar sites): Forrestdale and Thomsons Lakes, Becher Point Wetlands, Peel-Yalgorup System and within ten kilometres of Forrestdale and Thomsons Lakes. Surface water run-off from the project area does not directly drain into these Ramsar sites (DEWHA 2009).

2.5 Water Quality

Surface water and groundwater resources are an integral component of the Beeliar wetland system. Water quality requires careful assessment, management and monitoring in order to identify potential risks to environmental values of the wetland complex.

The superficial aquifers have been contaminated by phosphorus and nitrates from nutrient loadings from septic tanks, intense horticultural activities and industrial waste in the catchment. On that basis, the Beeliar Lakes have been classified as hyper-eutrophic (Burkett 2005). Water quality is also affected by the ongoing processes of evaporation, evapotranspiration and groundwater recharge. Purpose-built stormwater treatment devices do not appear to exist for outlets draining to Bibra Lake. For inflows to North Lake, stormwater is treated by gross pollutant traps. Discussions with DoW, DEC and Main Roads have revealed that none of these organisations monitor the stormwater quality within the project area.

Stormwater and groundwater that is currently discharging to lake and swamp environments is likely to be acidic and contain contaminants including heavy metals and pesticide residues; nitrogen and phosphorus; minerals, organic material and microbes. Bibra Lake is the most studied of the five wetlands sampled in this survey.

2.5.1 North Lake

North Lake runoff gains overflow water from a wetland located to the south, as well as water from surrounding urban areas and Murdoch Drain. Previous research indicates that Murdoch Drain once provided approximately 73 percent of the phosphorus and 60 percent of the nitrogen in North Lake, with the balance entering from groundwater (Bayley et al 1989). This situation is likely to have changed since flows under Farrington Road were diverted to Murdoch Swamp.

Data collected previously from bores located upstream of North Lake show that groundwater has been a significant source of nutrients in the past, and in comparison to nearby lakes. Sediment samples taken in January 1988 from the deeper parts of the lake returned high concentrations of phosphorus. Monitoring data from 1970 to 1986 showed that ammonium, nitrate and chlorophyll-α levels were higher in North and Bibra Lakes in comparison with Thomsons Lake (Davis et al 1988).

2.5.2 Bibra Lake

Bibra Lake is considered to be a hyper-eutrophic wetland (Bayley et al 1989). Studies from 1988 - 2009 show that water quality has been significantly affected by a number of nutrients and pollutants:

- Phosphorus is limited by virtue of very high nitrogen to phosphorus ratio throughout the year. The main sources of Phosphorus include:
    - Sediment: Bibra Lake has a 400mm light floculated sediment layer over a detritus layer that can extend 1m to 2m deep. This sediment contributes an estimated 59% of the phosphorus load into the lake
    - Groundwater: the groundwater contributes approximately 27.3% of phosphorus in the water column
    - Landfill: the confirmed landfill site on the south east edge of the lake and possibly four other unconfirmed landfill sites contribute approximately 11.5% of phosphorus load

  - Stormwater: the storm water outlets that allow stormwater to run into the lake contributes approximately 1.4% of the phosphorus load (SKM 2002).

- Organic phosphate is at its highest concentration in autumn and summer, and lowest in winter and spring. This indicates that the phosphorus is assimilated in phytoplankton during the warm summer months. Chlorophyll levels peak during the same period.

- Ammonia concentrations are highest in autumn and winter but below concentrations that are toxic to aquatic organisms.

- Lake waters tend to be slightly alkaline due to groundwater inflows and bicarbonate shift caused by algal carbon fixation.

- The highest organic and total nitrogen levels are evident in autumn and winter, and lowest in summer.

- Electrical conductivity varies throughout the year, most likely as a result of fresh inflows from runoff and shallow groundwater during winter; and

- Concentrations of solutes increase through summer and autumn, which may be due to the hot and dry conditions and associated evaporation and transpiration.

The water quality of Bibra Lake has been considerably affected by the increase in development around the lake in recent decades. Factors that have been most influential include the now-decommissioned landfill sites, stormwater drainage from urban areas and clearing of native vegetation around the lake which have subsequently increased the nutrient loadings into the lake (Giles and Davis 2005). A study by Sinclair Knight Merz (SKM) in 2002 concluded that to reduce nutrient loads into Bibra Lake to a point where the lake is classed as ‘healthy’, phosphorus loads would need to be reduced by approximately 80%.

Bibra Lake exhibited improved water quality in the period 2000-2005, with lower phosphorus concentrations and less frequent algal blooms. This improvement has been attributed to a decrease in the average annual rainfall over the last decade, resulting in lower runoff volumes and therefore lower nutrient loads into the lake (Giles and Davis 2005). However, analysis of more recent water quality data shows a trend of increasing phosphorus levels, and increasing soluble phosphorus as a proportion of total phosphorus. Soluble phosphorus is the biologically active component that is able to be utilised by algae, potentially leading to algal blooms. Therefore, it is possible water quality will deteriorate in the future without the implementation of actions to reduce phosphorous loads entering the lake.

The nutrient enrichment of Bibra Lake is associated with a corresponding increase in midge numbers. There is a strong correlation between lake water phosphorus concentrations and midge larvae (chironomid) counts. Algal blooms caused by high phosphorous loads eventually die and sink, providing a nutrient rich food source for larval midges living in the sediment of the wetland. As midges have a short life cycle, they can take advantage of algal blooms and quickly build up to very large numbers. Natural predation on midges can be limited at this time due to decreased visibility from the algal blooms. Other factors such as low oxygen levels and reduced habitat diversity, associated with lack of aquatic vegetation, may also contribute to low predator numbers (Midge Research Group 2005b).

2.5.3 Existing Management

With the increase in urban development around the Beeliar Wetlands, various management measures have been put in place as a means of protecting the values of the wetlands and the adjacent Jandakot Mound. In particular, maximum and minimum water level criteria for North and Bibra Lakes have been established.

The DoW advised that the proposed project is subject to compliance with Ministerial Condition 688 (Minster for the Environment 2005), which relates to the Jandakot Mound with regards to North and Bibra Lakes (Table 2-2).

Table 2-2 Jandakot Mound compliance criteria (Ministerial Condition 688).

Wetland	SWRIS ID No.	Current Water Level Criterion (mAHD)		Other Criteria
		Preferred	Absolute	
North Lake	Staff Q6142521 Bore 424 G1410726	13.29	12.68	Water levels should not decline at rate greater than 0.1 m/year Monitor staff gauge
Bibra Lake	Staff Q6142520 Bore BM7C G61410177B	13.6 – 14.2 <15.0 peak	13.6	Not to dry more than 2 in 3 years, and preferably less than 1 in 3 years

mAHD = Australian Height Datum (metres)

2.6 Sources of Potential Contamination

Groundwater in the area between North Lake Road and Kwinana Freeway is highly vulnerable to contamination from agricultural, industrial and urban activities. Sand, peat and clay deposits in wetland areas with a shallow water table (less than 3m below ground surface) can act as carriers for contaminants in aquatic systems. These sediments may also be a source of contamination to groundwater (and soil) when disturbed and oxidised (Ahlf and Förstner 2001).

The historical land use along some edges of Bibra Lake provides evidence of contamination sources. These edges have been used previously as a sanitary landfill (EPA and WAWA 1990), commercial laundry, burial of animal bodies, a paper mill and piggeries (Hirschberg 1991) (Figure 2-4). An area with identified soil and groundwater contaminant impact is located south of the proposed project and west of Bibra Lake, and this area is now under management (Golder Associates 2004).

Generally speaking, many wetlands within metropolitan areas of the Swan Coastal Plain have suspected historical use as unauthorised dumps, with fringe areas subject to fly-tipping. Moreover, uncontrolled fill has been used in the past during earthworks to modify wetland edges for the purpose of building infrastructure such as roads. All of these identified sites and land uses are located outside of the project area, but some of these factors have ultimately contributed to the existing state of each wetland within the study area.

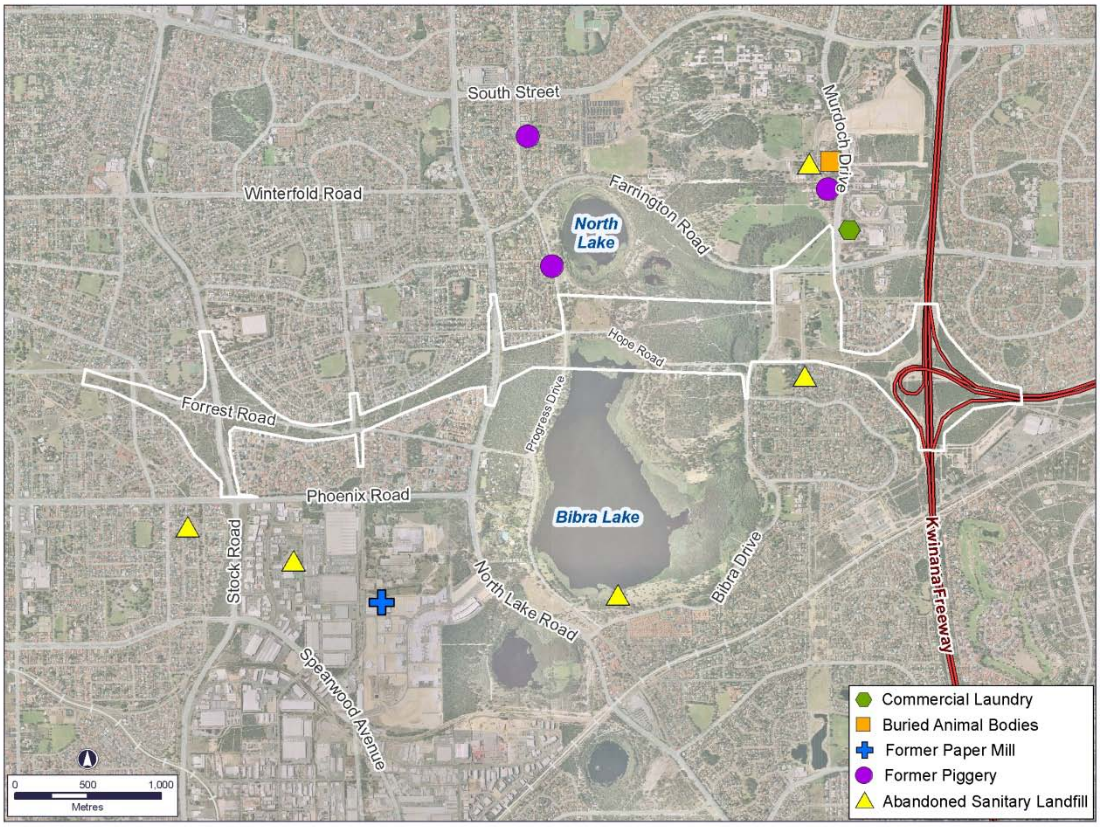


Figure 2-5 Sources of potential contaminants in lakes within and adjacent to the project area.

2.7 Biota

The wetlands of the study area support a relatively diverse aquatic macroinvertebrate faunal assemblage, of which Bibra Lake and North Lake are most studied. Horwitz et al (2009) conducted a review of the species richness and degree of endemism within 66 SCP wetlands. The review tested the hypothesis (among others) that SCP wetlands are relatively homogeneous in their aquatic assemblages because of their relatively recent formation. This was largely determined to be correct; however despite the apparent homogeneity, a rich aquatic faunal assemblage was reported on the whole. This is both surprising and important in the context of the degree of historic alteration and disturbance to these systems. Although taxonomically rich, local and regional endemism was found to be relatively low compared with other regional assessments.

Within the study area, Bibra Lake was found to harbour a somewhat ‘middle of the road’ species richness of 45 species (morpho-species) and 29 named species. The species were found to represent 42 genera and 31 families. In contrast, North Lake was found to harbour 98 morpho-species and 57 named species. These were found to represent 64 genera and 50 families (Horwitz et al 2009).

Horwitz et al (2009) also listed a number of wetlands and springs/seeps considered to be high-priority in terms of management based on their species richness, degree of endemism or rarity. None of the wetlands surveyed in this study were listed. The closest listed wetland to the study area is Thomsons Lake, approximately 7km to the south.

In contrast to Horwitz et al (2009), over a decade earlier Hill et al (1996a) found wetland macroinvertebrate assemblages to be heterogeneous, with between-wetland dissimilarity being greater than within-wetland (habitat) dissimilarity.

3.0 METHODS

3.1 Habitat Assessment and Site Selection

Habitats (sites) from seven wetlands (North Lake, Bibra Lake, South Lake, Horse Paddock Swamp, Lower Swamp, Melaleuca Swamp and Roe Swamp) were selected for inclusion in the water quality and macroinvertebrate survey in the spring and summer of 2009 (Figure 3-1). Six of the wetlands are located within or directly adjacent to the project area. One wetland, South Lake, is located south of the project area. Roe Swamp and Horse Paddock Swamp were dry at the time of sampling and therefore were not surveyed.

The habitat monitoring protocol designed for the survey was based on similar programs conducted elsewhere on the SCP (Gnangara Mound Macroinvertebrate Monitoring Program; Hill et al 1996a) and more widely (Kaminski and Murkin 1981; Friday 1987; Growns et al 1997; Humphries et al 1998). The protocol employed in the survey is considered to be the minimum requirement for documenting habitat-related macroinvertebrate communities at the sediment-water column interface as well as free-swimming taxa.

Habitat assessment largely followed Chessman's (1995) rapid assessment method which requires the establishment and sampling of fixed sites within the three dominant habitat types in each wetland. This approach aims to capture the diversity of habitats and biota therein.

Habitats were principally defined by their vegetation structure, specifically, the dominant vegetation species and diversity. Each habitat type was deemed to be a 'site'. Seasonal variation was an important influential factor in the sampling program. Seasonal differences in water level and quality altered both the habitat types and the number sites available for sampling. Fourteen sites were sampled in spring (October 2009) and eight sites were sampled in summer (December 2009).

In some lakes (North Lake, Bibra Lake and South Lake) all vegetated habitats were dry in summer and sampling was limited to open water sites. Preference was given to sites with beds of submerged macrophytes (such as *Ruppia*, *Chara* or *Villarsia*) which usually have higher invertebrate diversity and local representation than open water over bare sediment.

Habitat complexity was described in terms of;

- Percentage composition (as viewed from above) of bare substrate: submerged macrophytes, emergent macrophytes, algae and detritus; and
- Density of each vegetation component (estimated on a scale of 1 to 5).

Records were also made of other parameters, namely substrate type, weather conditions, time of sampling and presence of vertebrates.

Macrophyte samples were taken for identification as required. Site locations were described and mapped (Appendix 1 and 2).

3.2 Water Quality

A range of typical physico-chemical parameters were measured in-situ in each survey, including:

- Conductivity (µs/cm);
- pH (pH units);
- Temperature (ºC);
- Redox (reduction oxidation reactions) (mV);
- Dissolved oxygen concentration (mg/L and percent saturation) and;
- Depth of the water column (cm).

Chemical parameters were measured just below the water surface. They would normally also be measured at the sediment-water interface, but as water levels were generally very low (<30cm) during the surveys, only a single measurement was taken. Water chemistry parameters were measured using a Hack Multi-meter, where the calibration of each parameter was assured via certification prior to deployment. Depth of the water column was measured with a 1cm scale marked on the sweep net handle (2.0m).

3.3 Macroinvertebrates

Macroinvertebrate sampling involved a two-minute net sweep at all sites. A 250µm meshed D-framed net was used to sweep through the full depth of the water column, including any dense filamentous algae, silt or very fine organic matter encountered (such as at South Lake).

Samples were gently washed in the lake water while in the net and were then double-bagged and stored in a cool, dark esky, for a maximum of three hours after collection before being transported to Phoenix's laboratory.

All macroinvertebrates were live-picked. A maximum of 12 animals of any individual taxon was picked. More than ten individuals of very small taxa (e.g. mites, Ostracods, Copepods, Cladocera) were taken because these often contain more than one family.

The exact picking time depended on the amount of filamentous algae, silt or very fine organic matter in the sample. Generally, each sample was picked for a minimum of 30 minutes and then sorted in white trays using overhead lighting. In some cases, additional time was taken to ensure that as much diversity had been captured as possible. During field sorting, specimens were identified to family or genus level where possible, then immediately preserved in 100% ethanol after sorting. Samples were later identified to species level in the laboratory.

Aquatic macroinvertebrate spring and summer 2009 survey sites Figure 3-1

0 0.25 0.5 0.75 1
Kilometres
1:35,000 (A4)
Datum: GDA94 Projection: MGA z50

Aquatic macroinvertebrate spring and summer 2009 survey sites

Sites surveyed only in spring

Sites surveyed in spring and summer

Project area

Horse Paddock Swamp and Roe Swamp not sampled

Date Modified: 24/09/2010

Author: CBB J:\Client_Data\Main_Roads\60100953_Roe_Extension\Workspaces\2010_09_23__Phoenix_Maps__Current_Versions\Aquatic macroinvertebrates\Figure 3-1 - Aquatic macroinvertebrate spring and summer 2009 survey sites.mxd

3.4 Statistical Analysis

3.4.1 Hierarchical Cluster Analyses

Hierarchical Cluster Analyses aim to determine the degree of taxonomic relatedness of each site, habitat, or other factor, as defined. Such analyses have particular relevance to aquatic macroinvertebrate surveys as it enables identification of unique wetlands in a suite wetlands, or unique habitats within a wetland.

For this survey, Hierarchical Cluster Analysis was performed on a Resemblance Matrix (Bray-Curtis similarity) derived from the original presence/absence dataset. No data transformation was necessary. The "group average" cluster mode was selected. All taxa identified (species level) were included in the analysis.

3.4.2 SIMPER Analysis

The similarity (or dissimilarity) of the assemblages were further analysed using a SIMPER Analysis within the Plymouth Routines in Multivariate Ecological Research (PRIMER) 6.0 statistical package. SIMPER Analysis examines the contribution of each variable (species, in this case) to the average resemblances between sample groups (seasons, habitats and wetlands).

The strength of SIMPER Analysis is the identification of individual species which drive the differences in species composition and quantify each species' contribution to the observed differences.

In this study, the SIMPER Analysis was performed on a Resemblance Matrix (Bray-Curtis similarity) derived from the original presence/absence dataset. For Bray-Curtis similarities, SIMPER Analysis determines the contributions of each pair or group of samples to the average Bray-Curtis dissimilarity between them. It also determines the contributions to the average similarity within a group.

For Euclidean distances (environmental data), SIMPER Analysis breaks down the average distance between pairs of groups, and within each group. No data transformation was necessary for the dataset from this survey.

A one-way crossed analysis was performed with each of the respective factors chosen for each analysis (e.g. factor: 'season' or 'lake'). All taxa identified (species level) were included in the underlying similarity matrix.

Statistical analysis allowed the derivation of indicator species for each of the wetlands in this study.

3.5 Taxonomy and Nomenclature

Jarrad Clark undertook taxonomic determinations of all groups except the Cladocera, Copepoda and Ostracoda, which were undertaken by Bennelongia P/L (J. McCrae, S. Halse and M. Scanlon).

The following taxonomic literature is relevant to the Swan Coastal Plain aquatic macroinvertebrates and was used during species identification:

- Andersen, N. M & Weir, T. A. (2004). Australian Water Bugs. Their Biology and Identification (Hemiptera-Heteroptera, Gerromorpha & Neomorpha) Entomonograph Volume 14. Apollo Books/CSIRO Publishing (Andersen and Weir 2002).
- Davis, J. & Christidis, F. (1997). A guide to wetland invertebrates of southwestern Australia. Western Australian Museum. Perth Western Australia (Davis and Christidis 1997).
- Department of Health. (2004). Mosquito Management Manual: a general reference on mosquito management, and the official manual for the Mosquito Management Course held in Mandurah, 13-17 September 2004 (Department of Health 2004).
- Elson-Harris, M. M. (1990). Keys to the immature stages of some Australian Ceratopogonidae (Diptera). Journal of the Australian Entomological Society. 29: 267-275 (Elson-Harris 1990).
- Gooderham, J & Tsyrlin, E. (2002). The Water Book: a guide to the freshwater macroinvertebrates of temperate Australia. CSIRO Publishing, Collingwod, Australia (Gooderham and Tsyrlin 2002).

- Govedicj, F. R. (2001). A reference guide to the ecology and taxonomy of freshwater and terrestrial leeches (Euhirudinea) of Australasia and Oceania. Identification Guide No 35. cooperative Research Centre for Freshwater Ecology (Govedicj 2001).
- Hawking, J. H. (2001). An Introduction to the identification of Aquatic Caterpillars (Lepidoptera) found in Australian Inland Waters. Identification guide no 37. Cooperative Research Centre for Freshwater Ecology (Hawking 2001).
- St. Clair, R. M. (2000). Preliminary keys for the identification of Australian Caddisfly larvae of the family Leptoceridae. Identification Guide No. 27. Cooperative Research Centre for Freshwater Ecology (St. Clair 2000).
- Vondel, B. J. von. (1995). Revision of the Haliplidae (Coleoptera) of the Australian region and the Moluccas. Records of the South Australian Museum. 28 (1): 61-101 (Vondel 1995).
- Watts, C.H.S. (1978). A Revision of Australian Dytiscidae (Coleoptera). Australian Journal of Zoology. Supplementary series no. 57. 1-166 (Watts 1978).
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- Watts, C.H.S. (1998). Revision of Australian Enochrus Thomson (Coleoptera: Hydrophilidae). Records of the South Australian Museum 30 (2): 137-156 (Watts 1998).
- Watts, C.H.S. (2002). Checklists and Guides to the Identificatin, to Genus, of Adult & Larval Australian Water Beetles of the Families Dytiscidae, Noteridae, Hygrobiidae, Haliplidae, Gyrinidae, Hydraebidae and the Superfamily Hydrophiloidae (Insecta: Coleoptera). Identification & Ecology Guide No. 43. Cooperative Research Centre for Freshwater Ecology (Watts 2002).
- Zwick, P. (1977). Australian Hydraena (Coleoptera: Hydraenidae). Australian Journal of Zoology. 25 147-184 (Zwick 1977).

3.6 Survey Timing and Effort

Sampling was undertaken between 26 and 29 October 2009 (spring) and between 29 and 31 December 2009 (summer). A total of 14 sites were sampled in spring. Water levels dictated that only eight discrete sites could be sampled during the summer survey.

In the spring survey, sampling was undertaken from early morning until approximately 1.30pm. In the summer survey, all sampling was conducted in the morning and was completed by 9am.

3.7 Survey Personnel

Personnel involved in the macroinvertebrate field survey, laboratory and reporting components of the survey are listed in Table 3-1.

Table 3-1 Survey Personnel.

Person	Position	Qualifications
Mr. Jarrad Clark	Senior Invertebrate Zoologist, Project Manager	B.Sc. Env. Mgt.
Dr Simon Judd	Wetland Ecologist	Dr. Philosophy (Env. Mgt.)

4.0 RESULTS

4.1 Habitat

The sampled wetlands were characterised by five broad habitat types: open water, riparian, *Typha orientalis*, *Baumea articulata* and *Melaleuca preissiana* 'closed forest' (Table 4-1). Melaleuca Swamp and Roe Swamp are entirely comprised of *Melaleuca preissiana* 'closed forest' and therefore have reduced input. Lower Swamp is comprised of riparian habitat, predominantly immature *Melaleuca preissiana* regrowth over terrestrial grasses, with an 'island habitat' that adds to the structural complexity of the sumpland.

North Lake, Bibra Lake and South Lake were the most complex of the wetlands. North Lake is comprised predominantly of open water and *Typha orientalis* habitats, with the majority of native riparian habitats having been converted to 'parkland' shoreline (i.e. on the western fringe). Bibra Lake retains a considerable amount of native riparian vegetation, especially along its eastern margins, although *Typha orientalis* habitat is dominant on the northern and southern fringes. As with North Lake, the western fringes have been converted to recreational parkland, with little habitat value for macroinvertebrate assemblages.

South Lake retains the greatest degree of native riparian vegetation, with *Melaleuca preissiana* 'closed forest' present throughout the northern and western fringes of the lake. A mix of *Typha orientalis* and *Baumea articulata* habitats are found on the eastern margins. South Lake also contains a large area of open water habitat, particularly during summer, when water levels recede from the fringes.

Table 4-1 Macroinvertebrate habitats of the sampled wetlands.

Site	Open water	Riparian[1]	*Typha orientalis*	*Baumea articulata*	*Melaleuca preissiana* 'closed forest'
Melaleuca Swamp					✓
Lower Swamp		✓			
Roe Swamp[2]					✓
Horse Paddock Swamp[2]	✓[3]				
North Lake	✓		✓		
Bibra Lake	✓	✓	✓	✓	
South Lake	✓	✓	✓	✓	✓

1 - A mix of riparian plant species with none dominant.
2 – This wetland not sampled because it was dry throughout 2009.
3 - Dominated by terrestrial grasses due to long periods without inundation.

4.2 Macroinvertebrate Assemblages

A number of clear trends and interesting results emerged from the spring and summer (2009) aquatic macroinvertebrate assemblages recorded across the five wetlands sampled in the project area (Figure 4-1, Figure 4-2 and Table 4-2). Detailed species by site records are provided in Appendix 3.

Insects (59 species), ostracods (13 sp.), arachnids (9 sp.), Clitellata or worms and leeches (8 sp.) and copepods (7 sp.) were the most diverse groups recorded, consistently across all sites in the project area. As expected, all wetlands recorded a decline in species, genus and family richness from the spring to summer sampling rounds, associated with a decrease in water levels and quality (Figure 4-1 and Figure 4-2).

Arachnids, worms, insects and copepods were all most speciose at Bibra Lake. Ostracods were most speciose at North Lake, and most notably, the freshwater Gilgie (crayfish), *Cherax quinquecarinatus,* was only recorded at Lower Swamp.

Bibra Lake recorded the most diverse assemblage with a total of 64 species, followed by South Lake (51 sp.) and North Lake (46 sp.). North Lake and South Lake experienced a similar seasonal decline in species richness and these were less pronounced than at Bibra Lake.

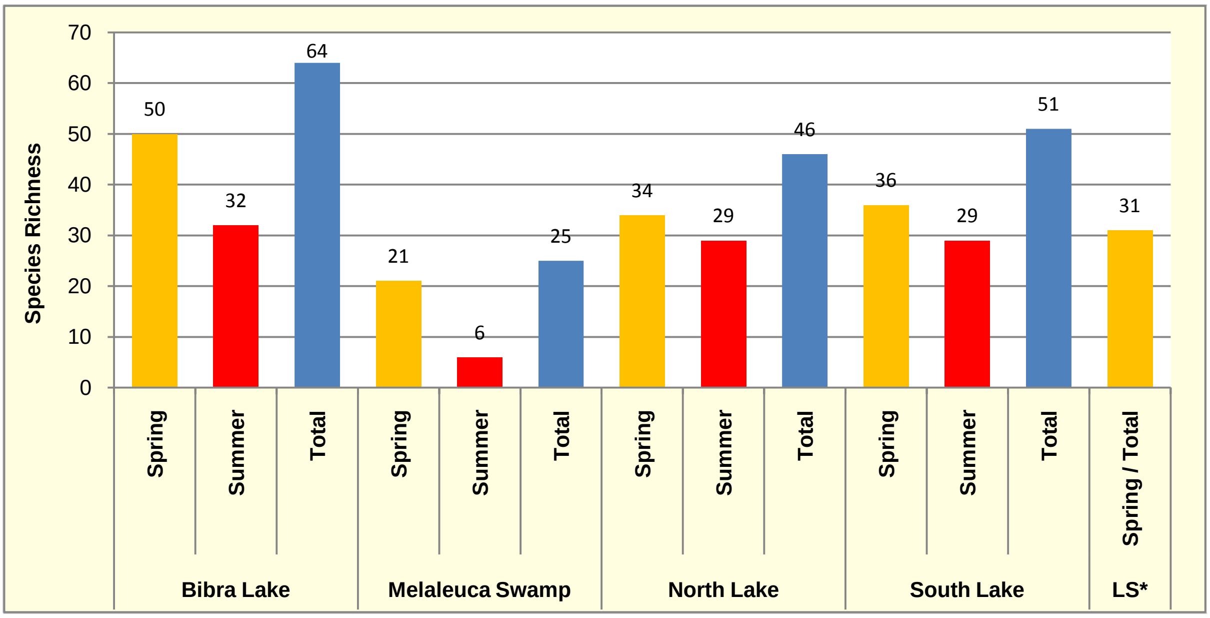


Figure 4-1 Total assemblage seasonal comparisons between the five wetlands sampled.

LS* Refers to Lower Swamp.

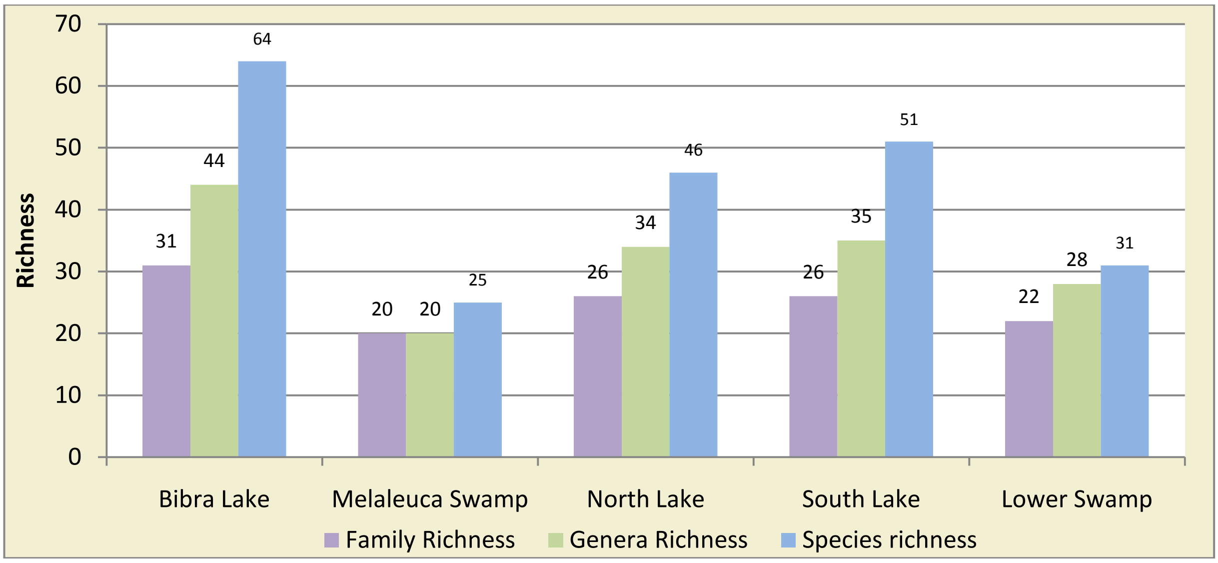


Figure 4-2 The family, genus and species richness of each wetland.

Table 4-2 Seasonal summary of the aquatic macroinvertebrate assemblages of five wetlands within and adjacent to the project area.

	Bibra Lake			Melaleuca Swamp			North Lake			South Lake			Lower Swamp	
Taxa	SP	SU	Total	SP	SU	Total	SP	SU	Total	SP	SU	Total	SP/Total	TOTAL
Arachnida (mites)	4	2	6	1	0	1	4	2	4	5	2	6	3	9
Clitellata (worms)	6	2	7	2	1	3	3	2	3	2	1	3	3	8
Crustacea	8	8	14	4	1	4	6	8	10	8	3	7	3	23
Branchiopoda (Cladocera: water fleas)	2	2	2	0	0	0	1	1	1	0	0	0	0	2
Copepoda	6	2	6	1	1	1	1	1	1	2	0	2	0	7
Decapoda (i.e. freshwater crayfish)	0	0	0	0	0	0	0	0	0	0	0	0		1
Ostracoda	6	4	6	3	0	3	4	6	8	6	3	6	3	13
Gastropoda (Snails and limpets)	2	2	2	2	0	2	2	2	2	1	1	1	3	5
Hydrazoa	0	0	0	0	0	0	0	1	1	0	0	0	0	1
Insecta	20	16	31	8	4	12	18	13	25	18	19	30	16	59
Coleoptera (beetles)	4	3	7	4	2	6	5	3	6	3	0	3	5	16
Diptera (flies)	4	4	6	0	1	1	2	0	2	4	6	9	1	11
Hemiptera (true bugs)	6	7	11	2	1	3	8	7	11	5	10	12	6	20
Odonata (dragon flies)	2	2	4	2	0	2	3	2	5	3	2	4	2	6
Tricoptera (caddis flies)	2	2	2	0	0	0	0	1	1	1	2	2	2	4
Malacostraca (Amphipods and Isopods)	2	1	2	4	0	4	1	1	1	2	2	2	2	5
Rotifera	2	2	2	0	0	0	0	0	0	0	0	0	0	2
TOTAL RICHNESS	50	32	64	20	6	25	34	29	46	36	29	51	31	113

According to the Cluster Analysis derived from the Bray-Curtis Similarity Matrix, the difference in the macroinvertebrate composition of each wetland indicates that the Roe Swamp wetlands (Melaleuca Swamp, and to a lesser degree Lower Swamp), contain the most distinctive macroinvertebrate assemblages (Figure 4-3). This distinctiveness is accounted for by the markedly different habitat type and influence of the gross pollutant trap.

The Cluster Analysis also suggests that the three larger wetlands (Bibra Lake, South Lake and North Lake), with their associated greater degree of habitat complexity (including open water habitats) were most similar to each other. In particular, the assemblages at Bibra Lake and South Lake appeared most similar.

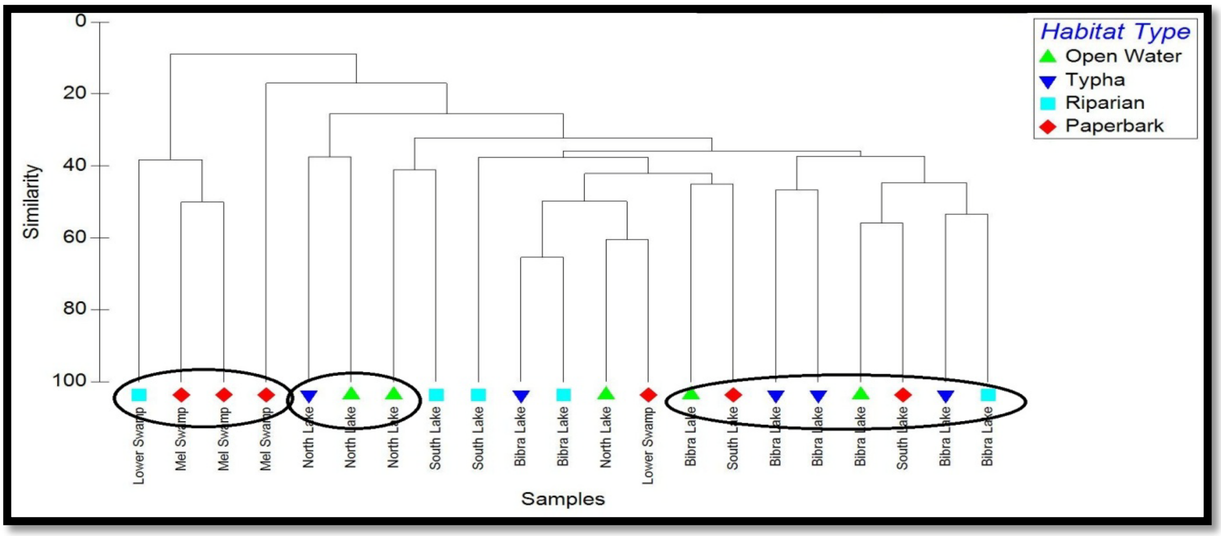


Figure 4-3 **Cluster analysis based on species composition.**

A multi-dimensional scaling (MDS) plot of the different sampling sites within each wetland illustrates similarity in assemblages between wetlands of the same geomorphic wetland classification (Figure 4-4). That is, the assemblages of wetlands classified as 'lakes' grouped together, while those classified as 'sumplands' were typically well separated from the lake assemblages. This is consistent with previous studies, such as Hill et al (1996a).

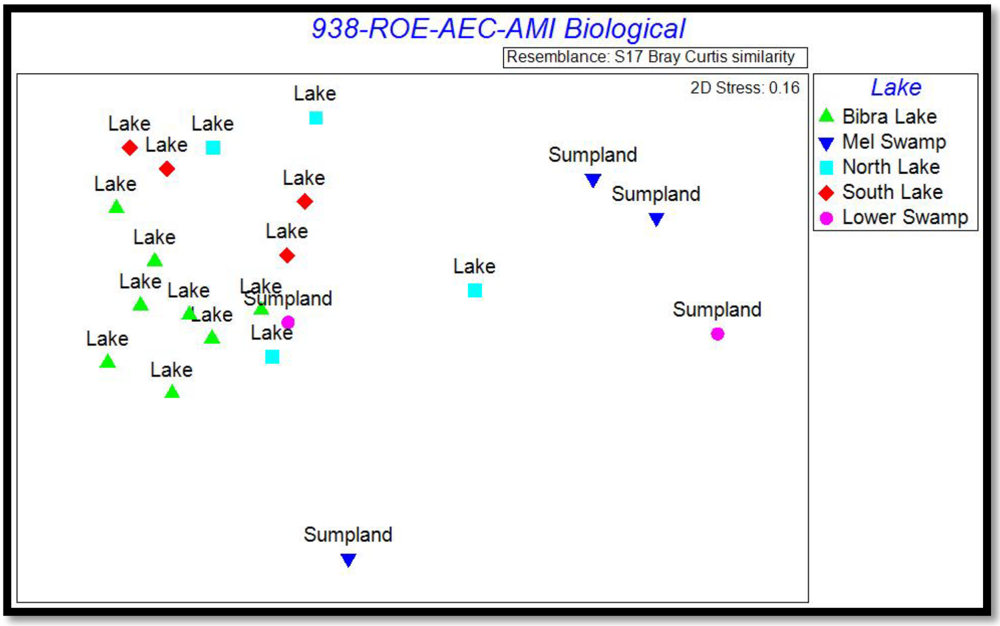


Figure 4-4 **Multi-dimensional scaling plot of the macroinvertebrate assemblage at each site with respect to Geomorphic wetland classification (as per Semeniuk 1988).**

Generally, the survey results suggested that there were distinct seasonal assemblages in each wetland as overall species richness declined from spring to summer and the decline was associated with a different set of species present in each season (Table 4-3; Table 4-4; Appendix 4 and Appendix 5). There was a strong species turnover from the spring peak maximum water levels to the summer peak minimum water levels.

At Melaleuca Swamp for example, a Dissimilarity figure of 94.74 was recorded between each seasonal assemblage, whereas at the larger lakes (Bibra Lake, South Lake and North Lake), the dissimilarity figures were lower (58.23, 64.26 and 61.84, respectively) (Table 4-4). This means that the three larger lakes recorded nearly 50% turnover in species composition between spring and summer, in addition to the significant decline between these seasons.

Table 4-3 SIMPER Dissimilarity summary matrix.

Wetland	Bibra Lake	Mel. Swamp	North Lake	South Lake	Lower Swamp
Bibra Lake	43.08*				
Mel. Swamp	88.46	20.18*			
North Lake	72.83	83.59	36.32*		
South Lake	**65.09**	87.66	71.49	37.05*	
Lower Swamp	77.85	79.98	75.22	78.48	17.65*

*Refers to 'similarity' analyses. Note the summarised data presented here is available in Appendix 4.

Table 4-4 SIMPER Biotic dissimilarity analyses, by habitat and season.

Wetland	Habitats	Season
Bibra Lake	57.80	58.23
Melaleuca Swamp*	-	94.74
North Lake	67.50	61.84
South Lake	64.10	64.26
Lower Swamp	82.35	DRY

*Only one habitat type present. Note the summarised data presented here is available in Appendix 5.

A closer review of the SIMPER analysis shows that the relative similarity of Bibra Lake and South Lake (compared to other lakes) is largely driven by the presence of three species; the Gastropod *Physa acuta*, the Amphipoda *Austrochiltonia subtenius,* and the Ostracod *Sarscypridopsis aculeata* (data not shown). These three species are found in all habitat types in both lakes and contribute nearly 50% of the between-habitat similarity in each wetland. Conversely, these three species also make a significant contribution to the dissimilarity of Bibra Lake and South Lake, with the other three wetlands investigated (data not shown).

Similarly to Bibra and South Lakes, the other three wetlands recorded just three to five species as contributing over 50% of the between-habitat similarity in the macroinvertebrate assemblage (data not shown). One of the most notable apparent exclusions from the SIMPER analysis is the Gilgie (*Cherax quinquecarinatus)* recorded only at Lower Swamp.

4.3 Summary by Wetland

4.3.1 Bibra Lake

Bibra Lake displayed the most diverse assemblage of all wetlands surveyed with a total of 64 species, declining from 50 species in spring to 32 species in summer. This decreasing seasonal trend was evident in most of the taxonomic groups recorded at Bibra Lake. Arachnids, worms, insects and copepods were all most speciose at Bibra Lake. This result was expected as Bibra Lake is by far the largest of the wetlands sampled and also contains the greatest degree of habitat diversity, with *Typha* habitats located at the northern and southern ends of the lake, open water throughout the centre and large areas of the western shoreline, and with various native riparian vegetation complexes dominating much of the eastern shoreline.

As with the macroinvertebrate assemblage, water quality conditions were variable between habitats and seasons. The pH was slightly basic in spring, as would be expected in a wetland abutting a limestone ridge; however in summer, the water column was slightly acidic. This summer acidity may be the factor driving the significant decline in species richness. As to what is in fact driving the pH below 7.0 in what should be a heavily buffered wetland is not clear at present, but is likely to be related to nutrient concentrations (which were not sampled as part of this study).

4.3.2 South Lake

South Lake was the second most species rich assemblage, with a total 51 species being recorded. The summer species richness (29 sp.) was lower than that of spring (36 sp.). The macroinvertebrate assemblage between South Lake and Bibra Lake was the most similar recorded in this study. South Lake is the second largest wetland sampled and contained the second greatest degree of habitat diversity, with open water habitat, dense riparian zones dominated by overhanging paperbark trees on the western shore (with small embayments and associated woody debris) and dense, inundated melaleuca shrubs dominating the eastern shoreline.

South Lake, similarly to Bibra Lake, is strongly buffered by the geology in which is resides, however the pH conditions measured are strongly basic (>9.0) and are above ANZECC guidelines (ANZECC 2002). These conditions may be partly correlated with known contamination from its previous use as a landfill site. Additionally, seasonal variation in the surface water quality can be partly attributed to ground water seasonal variation in flow (being stronger during winter/spring period) which would act to mobilise chemicals into the water column, in turn increasing the pH (more alkaline). Conversely, as the winter/spring groundwater peak flow ceases and the wetland starts to dry and the pH decreases, falling to a near-neutral level, before drying completely.

4.3.3 North Lake

North Lake recorded the third highest species richness (46 sp.) however this richness varied only slightly from spring to summer, in contrast to the other four wetlands (34 species in spring and 29 species in summer). These results are most strongly explained by the lower habitat diversity at North Lake, compared with Bibra Lake and South Lake, which are similar in size. Only two habitat types were present in both spring and summer, open water and *Typha*. Revegetation of the northern and western shores with native wetland and riparian species would no doubt increase the macroinvertebrate species richness to be comparable to the other two lakes.

The water quality also explains the reduced species richness at North Lake, which recorded the most acidic conditions of the three lakes and was comparable to the highly seasonal sumplands samples (Melaleuca Swamp, and Lower Swamp)

4.3.4 Melaleuca Swamp

Melaleuca Swamp, which is best defined as a closed '*Melaleuca* forest', displayed the lowest total species diversity (25 sp.) of the five wetlands sampled, and in each season (spring = 20, summer = 6). This wetland is comprised of a single 'habitat type' (despite relatively good structural complexity within the one habitat) and is regularly accessed by Murdoch University cattle and other farm research animals. Despite resulting nutrient run-off into Melaleuca Swamp recorded a unique and relatively diverse assemblage.

4.3.5 Lower Swamp

Lower Swamp recorded the most significant aquatic invertebrate of the five wetlands, the freshwater Gilgie (crayfish), *Cherax quinquecarinatus*. The results in relation to this species and the overall assemblage diversity, suggest that the presence of a gross pollutant trap located upstream of Frog Brook is effectively reducing nutrient and sediment inputs. Similarly to Melaleuca Swamp, Lower Swamp recorded a unique and diverse assemblage.

Lower Swamp appears to be facing 'terrestrialisation' as water level depth (m) and presumably inundation duration continue to decline. Terrestrial grasses today cover nearly 100% of the basin sediment. However this has been some recent recruitment of *Melaleuca preissiana*

4.4 Indicator Species

Terrestrial and aquatic invertebrates are commonly used as bio-indicators in ecosystem monitoring programs. A list of species considered to respond either positively or negatively to elevated nutrient levels in the wetlands on the SCP are provided in Davis et al (1993) (Table 4-5). Several of these species, including both positive-response and negative-response indicator species, were present within the five wetlands sampled.

Five and four species known to respond positively to eutrophication were recorded at Bibra Lake and South Lake, respectively. North Lake, Lower Swamp and Melaleuca Swamp recorded between one and two positive indicator species. The positive indicator species water boat-man, *Micronecta robusta*, was recorded at all five wetlands.

In contrast, the damselfly, *Austrolestes annulosus,* which is known to respond negatively to eutrophication, was recorded from Bibra Lake, North Lake and South Lake. These mixed results suggest that although these wetlands have been modified to some extent, they still retain elements of the original macroinvertebrate assemblage. The results from Bibra Lake display a continuing improvement in macroinvertebrate diversity, as previously reported by Giles and Davis (2005) (Appendix 6).

Table 4-5 Species known to respond to eutrophication on the Swan Coastal Plain.

Taxon	Bibra Lake	North Lake	South Lake	Melaleuca Swamp	Lower Swamp
Positive response to Eutrophication					
Daphnia carinata	✓				
Candonocypris novaezelandiae	✓	✓	✓		✓
Micronecta robusta	✓	✓	✓	✓	✓
Agraptocorixa hirtifrons		✡	✡		
Polypedilum nubifer	✓		✓		
Kiefferulus intertinctus	✓		✓		
Negative response to Eutrophication					
Calamoecia attenuata	✡				
Chydorids (cladocerans)					
Cloeon sp. (mayflies)					
Austrolestes annulosus	✓	✓	✓		
Sigara truncatipala	✓		✓		
Notalina fulva					
Acritoptila globosa					

Note: species derived from (Davis et al 1993). ✡ Members of the genus present.

4.5 Water Quality

The in-situ water quality parameters measured at each habitat within each wetland, in both seasons showed similarities with previously recorded data for these wetlands (Table 4-6 and Table 4-7). In the case of pH and dissolved oxygen (% saturation), there were many records that breached the ANZECC (2002) guidelines for south-western Australian freshwater wetlands and lakes, particularly in the summer sampling round when water levels were much lower.

The most notable breach of the ANZECC (2002) guidelines was dissolved oxygen (percent saturation), which breached the guidelines at all sites within all wetlands in both the spring and summer sampling rounds. North Lake and Melaleuca Swamp breached the lower bounds of ANZECC's suggested pH levels (acidity) in spring and summer, with the pH at North Lake falling below 6.0 in summer. Notably, South Lake was the only wetland to breach the upper limit of the ANZECC guidelines for pH. The breach occurred at both sites sampled in spring. However, the pH of this wetland fell within the guideline range in the summer sampling round. The results indicated some seasonal trends that are typical of SCP wetlands, such as the decline in pH of surface waters (becoming more acidic) in all wetlands between spring and summer (Figure 4-5).

Electrical conductivity followed a similar trend in all wetlands except North Lake, where electrical conductivity increased between seasons (Figure 4-5). An increase in salt concentration with decreasing summer water levels is typical of most SCP wetlands (and more broadly wetlands operating under a Mediterranean rainfall regime). In that context, the trend toward fresher water in the other three wetlands sampled in summer was considered unusual and may be related to the calibration of the salinity meter.

No clear seasonal trends were evident with respect to dissolved oxygen, measured as either mg/L or % saturation (Figure 4-5). Generally water temperature would be expected to increase markedly between spring and summer rounds because the minimum average air temperature in summer is greater than that of spring. Such a difference was not uniformly observed. This result is most likely due to the different time of sampling between spring and summer, with spring sampling occurring later into the day.

Total depth (cm) declined rapidly at each wetland from the spring to the summer round (Figure 4-5).

Table 4-6 Water quality parameters of sampled wetlands (spring 2009).

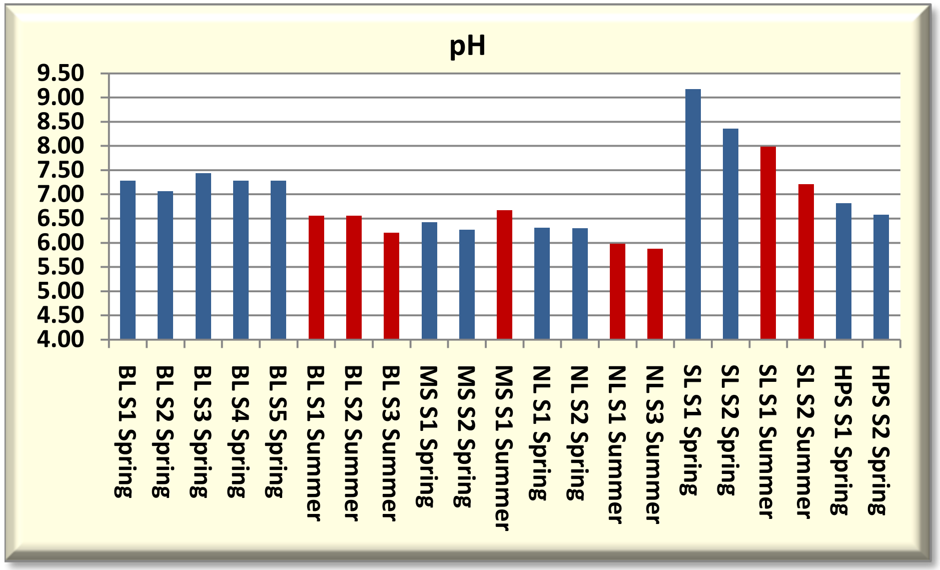
Wetland	pH	DO %	DO (mg/L)	Temp	Conductivity (ms/cm)	Depth (cm)
Melaleuca Swamp Site 1	6.43*	6.47*	0.64	17.60	1032	30
Melaleuca Swamp Site 2	6.67	12.00*	0.87	17.60	853	25
North Lake Site 1	6.31*	15.20*	1.42	19.80	1575	20
North Lake Site 2	6.30	60.60*	5.31	21.90	1625*	<40
Bibra Lake (Typha)	7.06	9.71*	0.89	19.70	1309	45
Bibra Lake Riparian	7.44	40.50*	3.57	21.40	1317	35
Bibra Lake (Baumea)	7.28	27.10*	2.37	22.00	1350	40
Bibra Lake (Open Water)	7.57	47.80*	4.16	22.00	1311	80
Bibra Lake (Typha)	7.28	57.00*	4.90	22.40	1301	40
Lower Swamp Site 1	6.81	44.00*	4.14	22.50	764	30
Lower Swamp Site 2	6.57	13.40*	1.25	18.40	722	40
South Lake Site 1	9.17*	170.00*	14.50	23.60	994	80
South Lake Site 2	8.35*	70.00*	6.10	22.30	1011	80
ANZECC (2002) Guidelines	6.5 - 8.0	90 - 120	-	-	300 - 1500	-
Mean	**7.17**	**44.14**	**3.86**	**20.86**	**1166.46**	**45.42**
Std.Dev.	**0.84**	**43.48**	**3.71**	**2.01**	**291.92**	**22.00**

*Breach of ANZECC guidelines.

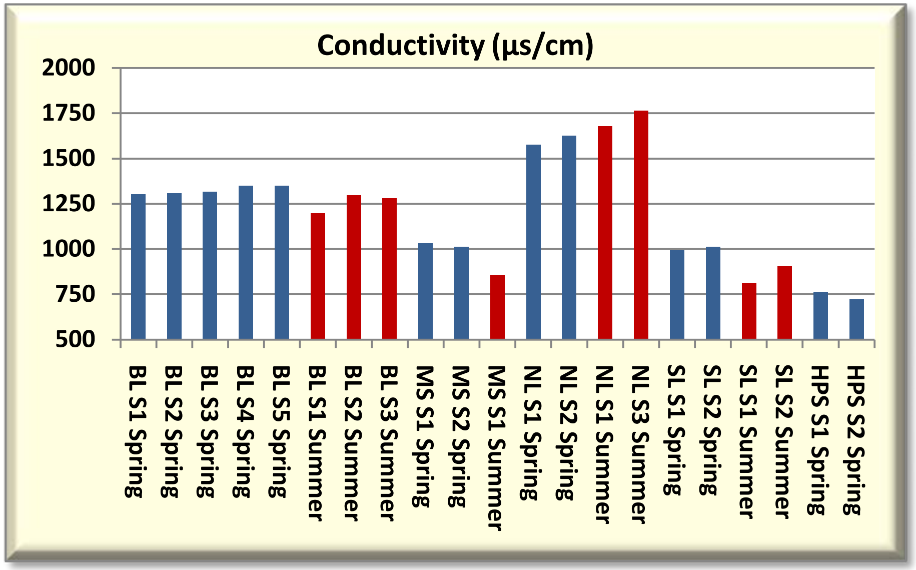
Table 4-7 Water quality parameters of sampled wetlands (summer 2009).

Wetland	pH	DO %	DO (mg/L)	Temperature (ºC)	Conductivity (µs/cm)	Depth (cm)
Melaleuca Swamp Site 1	-	-	-	-	-	0
Melaleuca Swamp Site 2	-	-	-	-	-	0
North Lake Site 1	5.98*	25.36*	2.25	20.00	1678*	10
North Lake Site 2	5.87*	71.25*	6.98	20.15	1765*	12
Bibra Lake (Typha)	6.56	9.71*	9.26	21.25	1298	25
Bibra Lake (Riparian)	6.21*	45.25*	3.95	22.22	1279	20
Bibra Lake (Baumea)	6.55	29.06*	2.65	22.50	1199	10
Bibra Lake Open Water	6.23*	52.00*	4.56	23.00	1205	11
Lower Swamp Site 1	-	-	-	-	-	0
Lower Swamp Site 2	-	-	-	-	-	0
South Lake	7.98	165.00*	15.94	25.23	809	8
South Lake	7.21	81.00*	7.98	24.98	905	8
ANZECC Guidelines	6.5 - 8.0	90 - 120	-	-	300 - 1500	-
Mean	**6.57**	**60.40**	**6.61**	**22.71**	**1260.78**	**9.91**
Std. Dev.	**0.7**	**45.53**	**4.22**	**2.05**	**310.31**	**7.50**

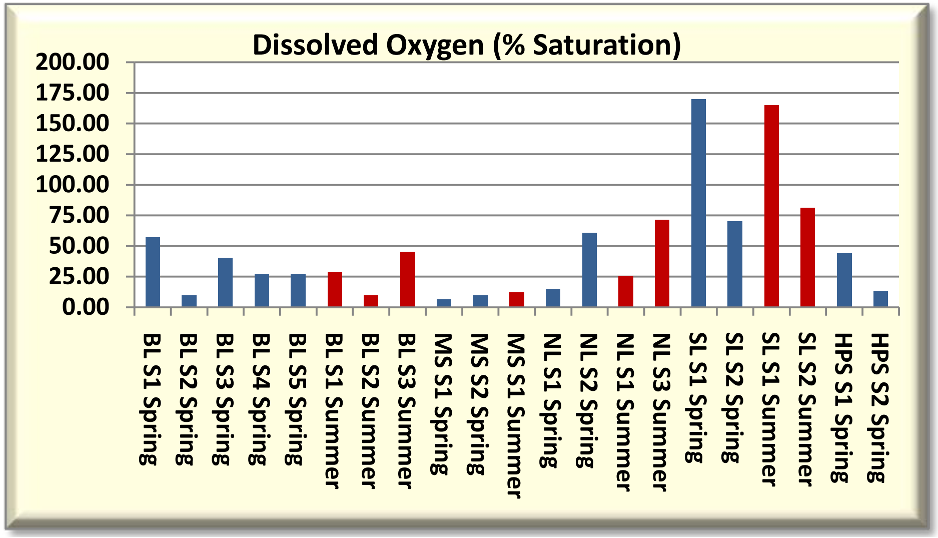
*Breach of ANZECC guidelines.


pH
9.50
9.00
8.50
8.00
7.50
7.00
6.50
6.00
5.50
5.00
4.50
4.00
BL S1 Spring
BL S2 Spring
BL S3 Spring
BL S4 Spring
BL S5 Spring
BL S1 Summer
BL S2 Summer
BL S3 Summer
MS S1 Spring
MS S2 Spring
MS S1 Summer
NL S1 Spring
NL S2 Spring
NL S1 Summer
NL S3 Summer
SL S1 Spring
SL S2 Spring
SL S1 Summer
SL S2 Summer
HPS S1 Spring
HPS S2 Spring

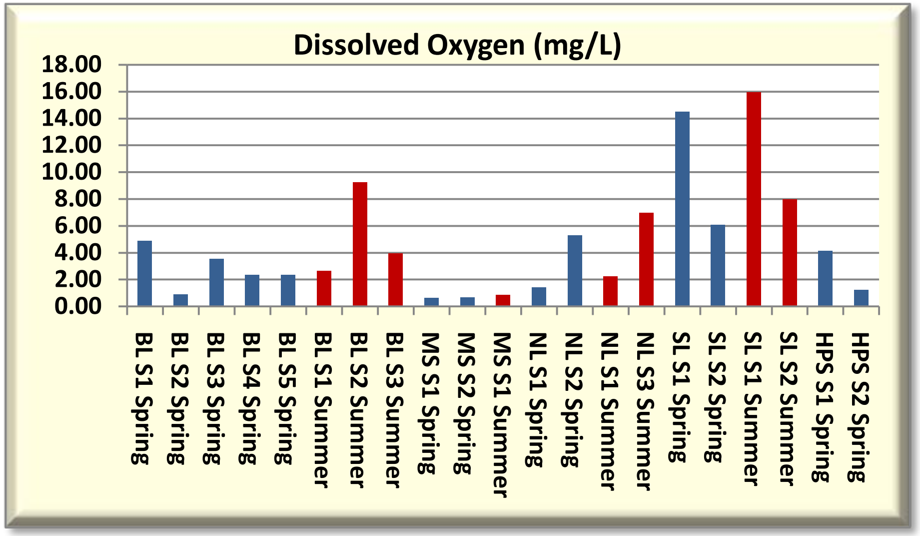
a)


Conductivity (µs/cm)
2000
1750
1500
1250
1000
750
500
BL S1 Spring
BL S2 Spring
BL S3 Spring
BL S4 Spring
BL S5 Spring
BL S1 Summer
BL S2 Summer
BL S3 Summer
MS S1 Spring
MS S2 Spring
MS S1 Summer
NL S1 Spring
NL S2 Spring
NL S1 Summer
NL S3 Summer
SL S1 Spring
SL S2 Spring
SL S1 Summer
SL S2 Summer
HPS S1 Spring
HPS S2 Spring

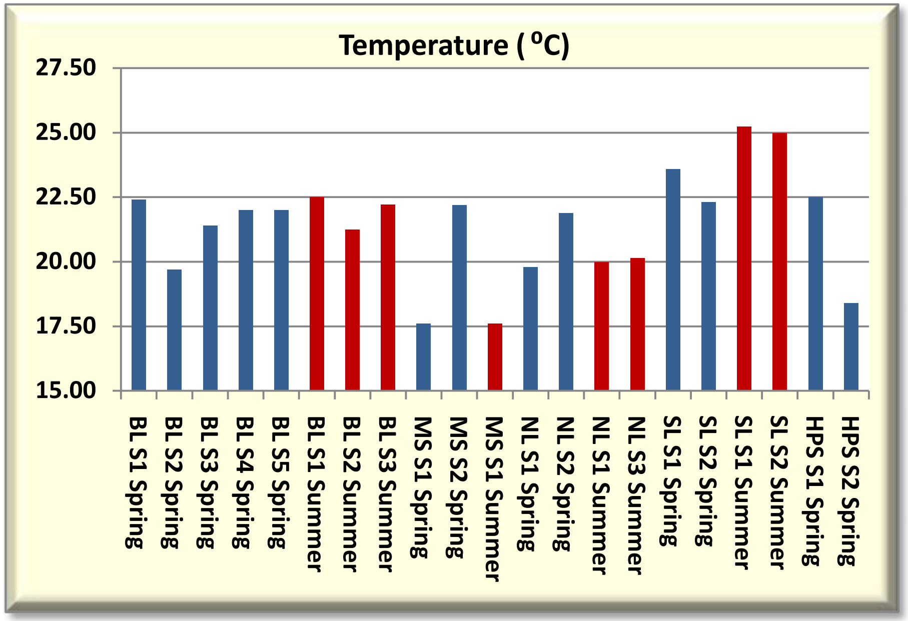
b)


Dissolved Oxygen (% Saturation)
200.00
175.00
150.00
125.00
100.00
75.00
50.00
25.00
0.00
BL S1 Spring
BL S2 Spring
BL S3 Spring
BL S4 Spring
BL S5 Spring
BL S1 Summer
BL S2 Summer
BL S3 Summer
MS S1 Spring
MS S2 Spring
MS S1 Summer
NL S1 Spring
NL S2 Spring
NL S1 Summer
NL S3 Summer
SL S1 Spring
SL S2 Spring
SL S1 Summer
SL S2 Summer
HPS S1 Spring
HPS S2 Spring

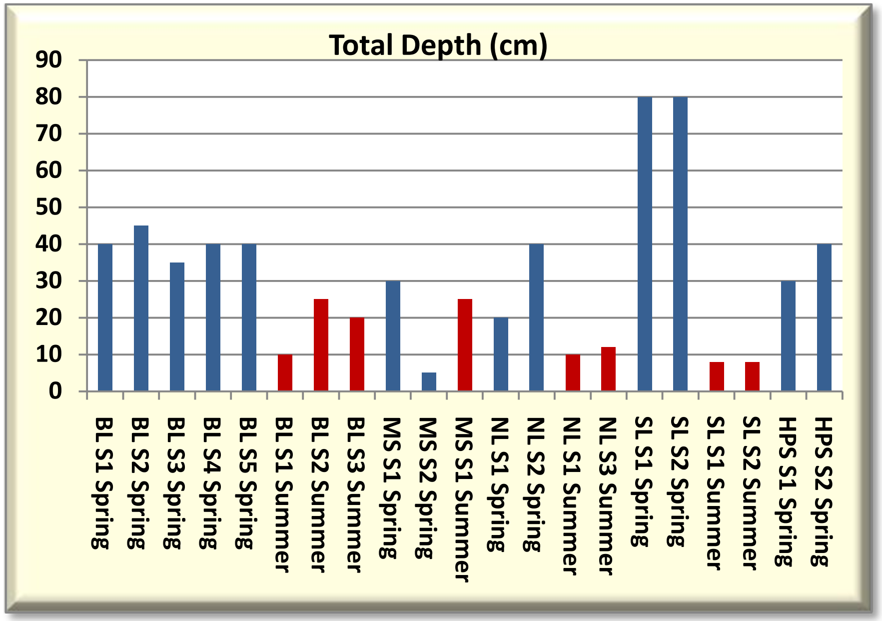
c)


Dissolved Oxygen (mg/L)
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
BL S1 Spring
BL S2 Spring
BL S3 Spring
BL S4 Spring
BL S5 Spring
BL S1 Summer
BL S2 Summer
BL S3 Summer
MS S1 Spring
MS S2 Spring
MS S1 Summer
NL S1 Spring
NL S2 Spring
NL S1 Summer
NL S3 Summer
SL S1 Spring
SL S2 Spring
SL S1 Summer
SL S2 Summer
HPS S1 Spring
HPS S2 Spring

d)



e)



f)

Figure 4-5 Water quality parameters for each wetland sampled

a) pH; b) Conductivity (µs/cm); c) Dissolved Oxygen (% saturation); d) Dissolved oxygen (mg/L); e) Temperature (ºC) and f) Total depth (cm). Spring data are in blue and summer data are in red for each wetland respectively. HPS=Horse Paddock Swamp; SL=South Lake; NL=North Lake; MS=Melaleuca Swamp; BL=Bibra Lake.

4.6 Limitations

Limitations of the survey are outlined in Table 4-8.

Table 4-8 Survey limitations.

Limitations	Limitation in this survey?	Comments
Competency/experience of the consultant carrying out the survey.	No	Jarrad Clark was manager of the Gnangara Mound Macroinvertebrate Monitoring Program for three years 2002 – 2005). He has extensive experience in conducting aquatic invertebrate sampling, sorting, identification and reporting on wetlands of the Swan Coastal Plain.
Scope (what faunal groups were sampled and were some sampling methods not able to be employed because of constraints such as weather conditions, e.g. pitfall trapping in waterlogged soils or inability to use pitfall traps.)	No	All methods were employed as intended. Water levels dropped quickly throughout the project area; therefore the summer samples were a good representation of each system just prior to drying.
Proportion of fauna identified, recorded and/or collected.	No	Comparison with Horwitz et al (2009) suggests that a very thorough survey has occurred, with a large proportion of the assemblage being recorded at each wetland.
Sources of information e.g. previously available information (whether historic or recent) as distinct from new data.	No	There is much historic data concerning the macroinvertebrate composition and water quality of Bibra Lake in particular.
Timing/weather/season/cycle.	Yes	The spring sample was probably taken after the spring peak water level. The summer sample occurred within days of the complete drying of the majority of the wetlands.
The proportion of the task achieved and further work which might be needed.	Yes	The program was implemented as planned for five of the seven target wetlands. Roe Swamp and Horse Paddock Swamp were dry at the time of sampling and therefore were not sampled. High rainfall years would be required to sample these wetlands, especially Horse Paddock Swamp which has been dry for several years.
Disturbances (e.g. fire, flood, accidental human intervention etc.) which affected results of survey.	No	The wetlands on the whole have suffered considerable historical disturbance, including clearing, feral animal usage (horses), landscaping, ground and surface water decline (quantity and quality). This disturbance does not affect the survey per se, but is relevant to the interpretation of data.
Intensity (in retrospect, was the intensity adequate?)	No	All major habitat types were sampled and both the highest and lowest water levels were sampled.
Completeness (was relevant area fully surveyed?)	Yes	Roe Swamp and Horse Paddock Swamp were dry at the time of sampling and therefore were not sampled. High rainfall years would be required to sample these wetlands, especially Horse Paddock Swamp which has been dry for several years.
Remoteness and/or access problems.	No	Not applicable
Availability of contextual (e.g. biogeographic) information on the region.	No	The wetlands of the SCP are well studied both biotically and abiotically. Thus contextual information was readily available.

5.0 DISCUSSION AND CONCLUSIONS

The five wetlands sampled in the survey are important aquatic ecosystems that have significant environmental, cultural, aesthetic and scientific values; most notably Bibra Lake and to a lesser degree, North Lake (Cornwell 2004; CALM 2006), in the context of the proposed development. The aquatic macroinvertebrate assemblages of each of these wetlands are integral to maintaining many of these values. In particular, aquatic macroinvertebrates play a critical role in ecological processes. They are an essential food resource for higher-order vertebrate fauna, particularly wetland birds, frogs and the Long-necked Turtle (*Chelodina oblonga*). They also play an important role in nutrient decomposition and cycling and water quality maintenance.

The two wetlands not sampled in the survey (Roe Swamp and Horse Paddock Swamp) are thought to be similarly important, and will make similar contributions to that of Lower Swamp, due to their intermittent nature. In order to document the current macroinvertebrate assemblage at these two wetlands, the collection of sediment to enable the hatching of eggs and cysts could be considered.

This survey represents the first published comprehensive, biannual survey of macroinvertebrate assemblage within the Bibra Lake/Beeliar wetlands area in the past five years (i.e. since Giles and Davis (2005)). The results largely agree with that of Horwitz et al (2009) and Giles and Davis (2005) in terms of species richness and overall macroinvertebrate diversity. Bibra Lake has recorded continued improvement in macroinvertebrate diversity, as noted by five years earlier by Giles and Davis (2005).

The dominant groups of the macroinvertebrate assemblages recorded (insects, crustaceans, arachnids, hemipterans and clitellata) are typical of what would be expected from SCP wetlands. Although detailed analysis was not undertaken, the functional diversity of the species present in the sampled wetlands suggests functional food webs are present, despite having been found to display somewhat modified macroinvertebrate assemblages (evidenced by the presence of a number of species that respond positively to eutrophication). The presence of negative eutrophic indicator species in Bibra Lake, North Lake and South Lake is a good indication that at least part of the original assemblage remains, despite nutrient enrichment of the wetlands.

The consistent decline in species, genus and family richness between the spring and summer sampling rounds was also expected. This seasonal decline was most marked at Bibra Lake and to a lesser extent at North Lake and South Lake. Such seasonal declines are typical of wetlands of the SCP and generally in wetlands governed by a Mediterranean climate regime. This decline is related to the loss of structural habitat diversity as water levels decline into summer, resulting in the drying of the riparian / fringing habitats (leaving only open water habitats). The similarity in macroinvertebrate assemblage between wetlands of the same Geomorphic Wetland classification was also expected and strongly agrees with the previous work of Semeniuk (1987) .

In contrast to Horwitz et al (2009) who found macroinvertebrate assemblages to be largely homogenous across 66 wetlands of SCP, statistical analysis of the data from this survey found that the five wetlands surveyed were markedly different at the species level within and between wetlands and, between seasons. The difference between this study and that of the review of Horwitz et al (2009) may lie in the level of identification achieved in this study, compared with the historically surveys incorporated in that review (i.e. family level vs. species level identification). Thus, this survey agrees with the earlier surveys of Hill et al (Hill et al 1996a) who surveyed 41 wetlands over three consecutive seasons.

The proposed project is not expected to directly impact the aquatic macroinvertebrate assemblages of any of the five wetlands sampled, during either the construction or operational stages. However, the proposed project does carry a number of secondary or indirect impact risks which may need to be managed.

The most important secondary impact is the potential for the proposed project to restrict or alter groundwater flows through the downward pressure (load) exerted by the road (at grade) and the footings (where bridges and arches are used) on the underlying sediment. If this loading is sufficient to reduce the underlying sediment pore size, a significant decline in groundwater quantity flow-through may occur. The information to better understand this situation (and risk) is still being collected by Syrinx Environmental through a series of recently installed shallow bores.

In the absence of a complete groundwater data set, it is postulated that North Lake is at most risk of suffering reduced groundwater inputs. Groundwater in the region generally moves in an east west direction. However, North Lake is known to receive groundwater that has already passed through Bibra Lake to the south. As the proposed road is to be constructed between these two wetlands, compaction of the sub-surface sediments between the two wetlands may potentially impact upon groundwater inputs to North Lake.

Construction techniques should therefore aim to minimise the load bearing within the section of the project area immediately between North Lake (southern shores) and Bibra Lake (northern shores). Construction should also not proceed until the full groundwater data set is available. In the event that the data suggests that the load bearing will be sufficient to detrimentally restrict groundwater movement between the wetlands, mitigation measures in the form of sub-surface flow structures should be considered to ensure that North Lake continues to receive seasonal groundwater inputs and thus continues to provide the various values and functions that make North Lake an important wetland in the South Metropolitan area.

The other major secondary impact is shading as a consequence of the structure itself, particularly on the northern shores of Bibra Lake and Roe Swamp. In the case of Roe Swamp the effects of shading may be minimal (even though the structure is higher at this point, compared to the Progress Drive – Hope Road intersection), as the Roe Swamp water body and associated riparian vegetation (that forms the habitat for aquatic macroinvertebrates) is already heavily shaded by the closed Melaleuca 'forest' that forms the over-storey of this wetland. Thus the system already operates on a lower-energy budget than that of Bibra Lake and North Lake, for example.

At the Progress Drive – Hope Road intersection any significant shading of the northern shore may result in a decline in riparian vegetation cover and density (habitat structure), potentially resulting in an associated decline in aquatic macroinvertebrate diversity and abundance. All of these impacts would therefore also have impacts on water birds nesting and feed in that northern area. That being said the northern shores of Bibra Lake are dominated by the introduced plant species *Typha orientalis*. Habitat provided by native riparian *Baumea* species would of course be preferable, however *T.orientalis* currently provides habitat for a number of water birds and thus a loss of this introduced weed species would still result in local impacts to aquatic macroinvertebrates and water birds in the short terms.

There are also a number of potential impacts which will be managed through Standard Operating Procedures and design. These include:

- Nutrient enrichment through road road-off;
- Introduction of pollutants, toxic and other harmful and bioaccumulating substances through vehicle accidents resulting in spillage into Bibra Lake;
- Increased fire risk due to littering of cigarette butts, for example and;
- Increased rubbish in the transport corridor and immediate area through littering of road users;

6.0 RECCOMENDATIONS

The following recommendations are given with respect to maintaining or improving water quality conditions:

- Construct nutrient stripping water retention basins (artificial wetlands) in order to treat all water draining off the proposed highway. All wetlands sampled appear to be suffering from elevated nutrient loads, as evidenced by members of the macroinvertebrate assemblages. The proposed project must not contribute further to this loading. Nutrient stripping basins with the capacity to process local catchment run-off have the potential to vastly improve water quality in Bibra Lake and North Lake.

- Ensure that the construction phase and the final structures (particularly at the Progress Drive - Hope Road intersection) do not impact upon groundwater flows. As Bibra Lake and North Lake are groundwater dependent wetlands, any limit to the quantity of groundwater through-flow will be detrimental to wetland health.

- Artificial aeration of the water columns of Bibra Lake and North Lake are recommended. These two wetlands appear to be suffering from hypo-oxygenation (<100%).

The following recommendations are given with respect to ensuring maintenance of, or improvement in, macroinvertebrate diversity and overall wetland condition:

- Bi-annual monitoring of macroinvertebrate assemblages and water quality parameters in each of the five wetlands for a period of five years during and post-construction. Roe Swamp and Horse Paddock should be sampled in the event that they are inundated in a given year.

- Investigation into the remediation of Lower Swamp and Horse Paddock Swamp. Critical components of which would be the annual inundation of the basins (artificial inundation would be necessary), removal of terrestrial grasses and increased riparian cover and diversity (principally *Melaleuca preissiana*);

- Prevent or limit damage or removal of any riparian or terrestrial vegetation (upstream of surface flows) during the construction phase;
    - Both at the intersection of Progress Drive and Hope Road and, where surface flow inputs would otherwise be intersected by native vegetation, i.e. Frog Brook.

- Develop a strategy for the removal of introduced fish species such as *Gambusia holbrooki* at Bibra Lake. Removal of *G.holbrooki* etc would ideally be followed up with the reintroduction of genetically suitable native fish species.

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APPENDIX 1: PROJECT SITE DESCRIPTIONS

Wetland	Habitat description	Fire Disturbance	Depth (cm)
Melaleuca Swamp	*Melaleuca preissiana* to 12m over sparse mixed shrubs, Bracken fern (*Pteridium aquilinum*) and tall thick *Baumea articulta* and other sedges. Very thick understory with broken bark and stick debris.	Recent fire scaring evident near the tops of trees.	30
Comments	Darkly stained water column, many mosquitoes, and deep organic matter accumulation with little open water to sample.		

Wetland	Habitat description	Fire Disturbance	Depth (cm)
Melaleuca Swamp	*Melaleuca preissiana* and over *Baumea articulta*, fine leafed sedge and broad leafed sedge. Very thick understorey with plentiful bark and stick debris.	None seen	25
Comments	Stained water, with high levels of detritus and coarse woody debris. As well as submerged and emerging macrophytes.		

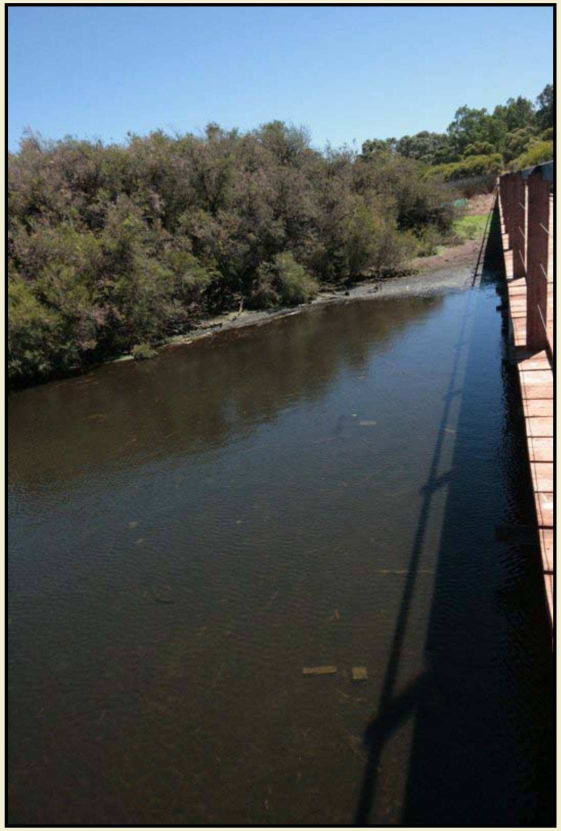

Wetland	Habitat description	Fire Disturbance	Depth (cm)
North Lake	Thicket of *Typha orientalis,* over floating algae and macrophytes.	None seen	20

Comments

Wetland	Habitat description	Fire Disturbance	Depth (cm)
North Lake	Edge of terrestrial grass area, some patches of floating macrophytes and some colonising *Melaleuca preissiana*. Submerged macrophytes and thick algae in water column.		<40
Comments	Greater degree of habitat structure than North Lake Site 1 (Typha)	None seen	

Wetland	Habitat description	Fire Disturbance	Depth (cm)
Bibra Lake	Dense thicket of *Typha orientalis.* Plentiful debris with organic matter accumulation developing under foot. Some floating macrophytes present.		40-50
Comments	Cloudy and turbid water column due to fine *Typha* debris	None seen	

Wetland	Habitat description	Fire Disturbance	Depth (cm)
Bibra Lake	Fringing bottle brush (M*elaleuca* sp.) over low mixed shrubs and terrestrial grasses. Plentiful coarse woody debris.		30-40
Comments	Coarse woody debris from *Melaleuca* sp. Floating macrophytes. Turbid water with very fine suspended particles.	None seen	



Wetland	Habitat description	Fire Disturbance	Depth (cm)
Bibra Lake	*Baumea articulata* amongst *melaleuca* shrubs. Floating macrophytes amongst fine particulates with areas of coarse woody debris.	None seen	

Comments

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Wetland	Habitat description	Fire Disturbance	Depth (cm)
Bibra Lake	Thicket of *Typha orientalis* amongst fringing M*elaleuca* sp. Floating and emergent macrophytes. Lots of algae and detritus in the water column.	None seen	40

Comments

Wetland	Habitat description	Fire Disturbance	Depth (cm)
Bibra Lake	"Open water" at lakes western edge, terrestrial grasses leading into water column, with small clumps of *Baumea articulta* and few floating macrophytes.	None seen	
Comments	Coarse woody debris and fine organic matter.		

Wetland	Habitat description	Fire Disturbance	Depth (cm)
Lower Swamp	Terrestrial grasses and open water island habitat with some *Melaleuca preissiana* (but not contributing to habitat structure)		30
Comments	Chocked with floating and suspended algae, some weedy terrestrial submerged macrophytes in heavily tannin stained water.	None seen	

Wetland	Habitat description	Fire Disturbance	Depth (cm)
Lower Swamp	Small artificial drainage line. *Baumea articulta* under *Melaleuca preissiana.* Terrestrial grasses at margin. Relatively good habitat structure. Well Shaded.		40
Comments	Tannin stained waters, emerged and submerged macrophytes. Algae relatively less dense. Lots of woody debris and some *Typha orientalis*. Mosquitoes breeding plentifully.	None seen	Comments
	NO PHOTOGRAPH AVAILABLE		
South Lake	Fringing 'forest' of *Melaleuca preissiana* and *Eucalyptus rudis*. Plentiful coarse woody debris. Very similar around western extent of lake. Floating and fine suspended algae in water column.	None seen	<80
Comments	High abundance of adult dragon flies.		

Wetland	Habitat description	Fire Disturbance	Depth (cm)
South Lake	Embayment of *Melaleuca preissiana over Baumea articulata.* Plentiful coarse woody debris and detritus, with submerged terrestrial vegetation, with floating and fine suspended algae (<250µm).	None seen	<80
Comments	Industrial block to the SW probably may be leaching nutrients into lake.		

APPENDIX 2: SAMPLE SITE GPS COORDINATES

Datum:	WGS-84 (50 K)			
Name	Easting (UTM)	Northing (UTM)	October 2010	December 2010
Melaleuca Swamp Site 1	390202	6450254	✓	DRY
Melaleuca Swamp Site 2	390162	6450252	✓	DRY
North Lake Site 1	389113	6450112	✓	✓
North Lake Site 2	388875	6450415	✓	✓
North Lake Site 3				
Lower Swamp Site 1	3389520	6450010	✓	DRY
Lower Swamp Site 2			✓	DRY
Bibra Lake Site 1 (Open Water)	388994	6449614	✓	✓
Bibra Lake Site 2 (*Typha*)	389219	6449217	✓	✓
Bibra Lake Site 3 (Riparian)	389336	6448925	✓	✓
Bibra Lake Site 4 (Open Water)	388937	6449328	✓	✓
Bibra Lake Site 5 (*Typha* – south)	389148	6447930	✓	DRY
South Lake 1	388495	6447274	✓	✓
South Lake 2	388510	6447670	✓	✓

APPENDIX 3: AQUATIC MACROINVERTERBATE ASSEMBLAGE DATA

CLASS	ORDER	FAMILY	*GENUS*	SPECIES	BL S1 R1	BL 2 R1	BL S3 R1	BL S4 R1	BLS5 R1	BL S1 R2	BL S2 R2	BL S3 R2	MS S1 R1	MS S2 R1	MS S1 R2	NL S1 R1	NL S2 R1	NLS2 R2	NLS3 R2	SL S1 R1	SL S2 R1	SL S1 R2	SL S2 R2	LS S1 R1	LS S2 R1
Arachnida	Acariformes	Arrenuridae	*Arrenurus*	sp.						1			1	1		1		1		1					
Arachnida	Acariformes	Eylaidae	*Eylais*	sp.																			1	1	
Arachnida	Acariformes	Hydrachnidae	*Hydrachna*	sp.						1									1	1		1			
Arachnida	Acariformes	Hydrodromidae	*Hydroma*	sp.																	1				
Arachnida	Acariformes	Limnesiidae	*Limnesia*	sp.	1												1			1	1			1	
Arachnida	Acariformes	Limnocharidae	*Limnochares*	*australica*	1																				
Arachnida	Acariformes	Pionidae	*Acercella*	*falcipes*													1								
Arachnida	Acariformes	Pionidae	*Piona*	sp.					1																
Arachnida	Acariformes	Pionidae	*Pionidae*	sp.		1	1		1							1				1				1	
Branchiopoda	Cladocera	Chydoridae	*Pleuroxus*	sp.	1	1					1					1	1	1							
Branchiopoda	Cladocera	Daphniidae	*Daphnia*	*carinata sl*			1		1	1	1														
Clitellata	Oligochaeta	sp.	*Oligochaeta*	sp.		1	1				1	1			1	1	1	1			1			1	
Clitellata	Rhychobdellida	Erpobdellidae	*Erpobdellidae*	sp.		1	1																		
Clitellata	Rhychobdellida	Glossiphoniidae	*Glossiphoniidae*	sp.						1		1											1		
Clitellata	Rhychobdellida	Hirudinidae	*Hirudinea*	sp.										1											
Clitellata	Rhynchobdellida	Glossiphoniidae	*Glossiphoniidae*	sp.				1	1											1				1	
Clitellata	Tubificida	Naididae	*Dero*	*nivea*		1	1										1	1						1	
Clitellata	Tubificida	Tubificidae	*Antipodrilus*	*davidus*									1			1									
Clitellata	Tubificida	Tubificidae	*Group A.*	Group A.		1																			
Copepoda	Calanoida	Centropagidae	*Boeckella*	*triarticulata*	1	1	1																		
Copepoda	Calanoida	Centropagidae	*Calamoecia*	sp.			1																		
Copepoda	Calanoida	Centropagidae	*Centropagidae*	sp.					1																
Copepoda	Cyclopoida	Cyclopidae	*Eucyclops*	*australiensis*			1					1													
Copepoda	Cyclopoida	Cyclopidae	*Mesocyclops*	*brooksi*			1									1					1				

CLASS	ORDER	FAMILY	*GENUS*	SPECIES	BL S1 R1	BL 2 R1	BL S3 R1	BL S4 R1	BLS5 R1	BL S1 R2	BL S2 R2	BL S3 R2	MS S1 R1	MS S2 R1	MS S1 R2	NL S1 R1	NL S2 R1	NLS2 R2	NLS3 R2	SL S1 R1	SL S2 R1	SL S1 R2	SL S2 R2	LS S1 R1	LS S2 R1
Copepoda	Cyclopoida	Cyclopidae	*Mesocyclops*	sp.	1	1	1														1				
Copepoda	Harpacticoida	Canthocamptidae	*Canthocamptus*	*australicus*									1		1										
Crustacea	Decapoda	Parastacidae	*Cherax*	*quinquecarinatus*																					1
Gastropoda		Ancylidae	*Ferrisia*	sp.										1											1
Gastropoda		Ferrisa	*Ferrisa*	sp.									1												
Gastropoda		Physidae	*Physa*	*acuta*	1	1	1	1	1	1	1	1				1	1	1	1	1	1	1	1	1	
Gastropoda		Physidae	*Physa*	sp.																					1
Gastropoda		Planorbidae	*Helisoma*	sp.	1		1	1	1	1		1					1		1						
Hemiptera	Notonectidae	Notonectidae	*Anisops*	sp.																			1		
Hirudinida	Arhynchobdellida	Erpobdellidae	*Vivabdella*	sp.			1																		
Hydrazoa	sp.	sp.	*Hydrazoa*	sp.															1						
Insecta	Coleoptera	Dytiscidae	*Allodessus*	*bistrigatus*										1											1
Insecta	Coleoptera	Dytiscidae	*Berosus*	sp.								1													
Insecta	Coleoptera	Dytiscidae	*Hyphydrus*	sp.		1	1	1											1						
Insecta	Coleoptera	Dytiscidae	*Liodessus*	*dispar*												1								1	1
Insecta	Coleoptera	Dytiscidae	*Liodessus*	*inornatus*										1											
Insecta	Coleoptera	Dytiscidae	*Onychohydrus*	*scutellaris*																1					
Insecta	Coleoptera	Dytiscidae	*Rhantus*	sp.				1																1	
Insecta	Coleoptera	Haliplidae	*Haliplus*	*gibbus*													1		1						
Insecta	Coleoptera	Hydraenidae	*Hydraena*	sp.										1											
Insecta	Coleoptera	Hydrophilidae	*Berosus*	*approximans*																1					
Insecta	Coleoptera	Hydrophilidae	*Berosus*	sp.		1	1		1		1						1							1	
Insecta	Coleoptera	Hydrophilidae	*Enochrus*	*eyriensis*						1															
Insecta	Coleoptera	Hydrophilidae	*Enochrus*	sp.												1									
Insecta	Coleoptera	Hydrophilidae	*Helochares*	*clypeatus*											1						1				
Insecta	Coleoptera	Hydrophilidae	*Helochares*	sp.											1	1			1						

CLASS	ORDER	FAMILY	*GENUS*	SPECIES	BL S1 R1	BL 2 R1	BL S3 R1	BL S4 R1	BLS5 R1	BL S1 R2	BL S2 R2	BL S3 R2	MS S1 R1	MS S2 R1	MS S1 R2	NL S1 R1	NL S2 R1	NLS2 R2	NLS3 R2	SL S1 R1	SL S2 R1	SL S1 R2	SL S2 R2	LS S1 R1	LS S2 R1
Insecta	Coleoptera	Hydrophilidae	*Helochares*	*tenuistriatus*						1		1													
Insecta	Coleoptera	Scirtidae	*Scirtidae*	sp.				1					1	1											1
Insecta	Diptera	Ceratopogonidae	*Nilobezzia*	sp.																			1		
Insecta	Diptera	Chironomidae	*Chironomidae*	sp.			1															1			
Insecta	Diptera	Chironomidae	*Chironomus*	*alternans*		1	1	1	1	1	1	1			1		1			1	1		1	1	
Insecta	Diptera	Chironomidae	*Discrotendipes*	*conjunctus*			1														1				
Insecta	Diptera	Chironomidae	*Kiefferulus*	*intertinctus*						1		1											1		
Insecta	Diptera	Chironomidae	*Polypedilum*	*nubifer*						1		1											1		
Insecta	Diptera	Chironomidae	*Procladius*	*villosimanus*																	1				
Insecta	Diptera	Culicidae	*Culex*	*annulirostris*												1									
Insecta	Diptera	Culicidae	*Culex*	*australicus*				1																	
Insecta	Diptera	Muscidae	*Muscidae*	sp.																1					
Insecta	Diptera	Stratiomyidae	*Stratiomyidae*	sp.						1													1		
Insecta	Hemiptera	Corixidae	*Agraptacorixa*	*eurynome*																1		1	1		
Insecta	Hemiptera	Corixidae	*Agraptacorixa*	sp.															1		1				
Insecta	Hemiptera	Corixidae	*Corixidae*	sp.							1														
Insecta	Hemiptera	Corixidae	*Corixidae*	sp.								1						1							
Insecta	Hemiptera	Corixidae	*Micronecta*	*robusta*	1	1		1	1	1	1	1			1	1	1		1			1		1	
Insecta	Hemiptera	Corixidae	*Micronecta*	sp.		1	1	1									1					1		1	
Insecta	Hemiptera	Corixidae	*Sigara*	sp.						1															
Insecta	Hemiptera	Corixidae	*Sigara*	*truncatipala*					1													1			
Insecta	Hemiptera	Nepidae	*Ranatra*	sp.																		1			
Insecta	Hemiptera	Notonectidae	*Anisops*	*baylii*												1									
Insecta	Hemiptera	Notonectidae	*Anisops*	*gratus*			1										1		1		1	1		1	
Insecta	Hemiptera	Notonectidae	*Anisops*	*occidentalis*					1																
Insecta	Hemiptera	Notonectidae	*Anisops*	*occipitalis*																			1		

CLASS	ORDER	FAMILY	*GENUS*	SPECIES	BL S1 R1	BL 2 R1	BL S3 R1	BL S4 R1	BLS5 R1	BL S1 R2	BL S2 R2	BL S3 R2	MS S1 R1	MS S2 R1	MS S1 R2	NL S1 R1	NL S2 R1	NLS2 R2	NLS3 R2	SL S1 R1	SL S2 R1	SL S1 R2	SL S2 R2	LS S1 R1	LS S2 R1
Insecta	Hemiptera	Notonectidae	*Anisops*	sp.	1		1	1		1	1						1	1	1		1	1	1		
Insecta	Hemiptera	Notonectidae	*Anisops*	sp.1					1																
Insecta	Hemiptera	Notonectidae	*Anisops*	sp.2					1																
Insecta	Hemiptera	Notonectidae	*Anisops*	*thienemanni*												1	1	1	1			1	1	1	
Insecta	Hemiptera	Notonectidae	*Notonectidae*	sp.																1					
Insecta	Hemiptera	Vellidae	*Mesovelia*	*hugerfordi*														1							
Insecta	Hemiptera	Vellidae	*Microvelia*	sp.									1	1		1									1
Insecta	Hemiptera	Vellidae	*Microvelia (Pacificovelia)*	*oceanica*									1	1		1								1	1
Insecta	Odonata	Megapodagrionidae	*Argiolestes*	*pusillis*										1											
Insecta	Odonata	Aeshnidae	*Hemianax*	*papuensis*	1	1											1			1	1			1	
Insecta	Odonata	Coenagrionidae	*Xanthagion*	*erythroneurum*						1								1	1			1	1		
Insecta	Odonata	Lestidae	*Austrolestes*	*analis*		1							1	1		1					1				1
Insecta	Odonata	Lestidae	*Austrolestes*	*annulosus*						1									1		1	1	1		
Insecta	Odonata	Lestidae	*Austrolestes*	*io*													1								
Insecta	Trichoptera	Ecnomidae	*Ecnomus*	*Pansus/turgidus*																		1			
Insecta	Trichoptera	Leptoceridae	*Lectrides*	sp AV1																					1
Insecta	Trichoptera	Leptoceridae	*Oecetis*	sp.			1																		
Insecta	Trichoptera	Leptoceridae	*Triplectides*	*australis*	1	1	1		1		1	1						1	1	1	1		1	1	
Malacostraca	Amphipoda	Amphisopidae	*Paramphisopus*	*subtenuis*																					1
Malacostraca	Amphipoda	Ceinidae	*Austrochiltonia*	*subtenuis*	1	1	1	1	1	1		1	1							1	1	1	1		
Malacostraca	Amphipoda	Perthidae	*Perthia*	*acutitleson*										1											
Malacostraca	Amphipoda	Perthidae	Perthia	sp.									1												
Malacostraca	Isopoda	Amphisopidae	*Paramphisopus*	*palustris*		1							1	1		1	1	1	1	1	1		1	1	
Ostracoda	Podeocopida	Cyprididae	*Alboa*	*worooa*									1	1							1				
Ostracoda	Podeocopida	Cyprididae	*Bennelongia*	*australis sp.*		1	1										1			1				1	1
Ostracoda	Podeocopida	Cyprididae	*Candonocypris*	*novaezelandiae*	1	1	1			1	1	1							1		1		1	1	

CLASS	ORDER	FAMILY	*GENUS*	SPECIES	BL S1 R1	BL 2 R1	BL S3 R1	BL S4 R1	BLS5 R1	BL S1 R2	BL S2 R2	BL S3 R2	MS S1 R1	MS S2 R1	MS S1 R2	NL S1 R1	NL S2 R1	NLS2 R2	NLS3 R2	SL S1 R1	SL S2 R1	SL S1 R2	SL S2 R2	LS S1 R1	LS S2 R1
Ostracoda	Podeocopida	Cyprididae	*Cypretta*	*aff globosa*															1						
Ostracoda	Podeocopida	Cyprididae	*Cypretta*	*baylyi*												1			1		1				
Ostracoda	Podeocopida	Cyprididae	*cypretta*	sp 1													1								
Ostracoda	Podeocopida	Cyprididae	*cypretta*	sp.		1	1				1	1		1						1		1			
Ostracoda	Podeocopida	Cyprididae	*Cypricercus*	*salina*			1																		
Ostracoda	Podeocopida	Cyprididae	*Ilodromus*	sp.																1		1			
Ostracoda	Podeocopida	Cyprididae	*Ilyodromus*	sp 413															1						
Ostracoda	Podeocopida	Cyprididae	*Ilyodromus*	*viridulus*													1	1							
Ostracoda	Podeocopida	Cyprididae	*Plesiocypridopsis*	sp.	1					1			1						1						
Ostracoda	Podeocopida	Cyprididae	*Sarscypridopsis*	*aculeata*	1	1	1	1	1	1	1	1								1	1	1	1	1	
Rotifera	Ploima	Brachionidae	*Brachionus*	*angularis*	1					1															
Rotifera	Ploima	Brachionidae	*Brachionus*	*calyciflorus*	1					1															

APPENDIX 4: SIMPER ANALYSIS OF WITHIN WETLAND SPECIES CONTRIBUTIONS

Group	**Bibra**	**Lake**				
Average	**Similarity:**	**43.08**				
Species		**Av.Abund**	**Av.Sim**	**Sim/SD**	**Contrib%**	**Cum.%**
Physa	*acuta*	1	5.43	5.47	12.61	12.61
Sarscypridopsis	*aculeata*	1	5.43	5.47	12.61	25.23
Micronecta	*robusta*	0.88	4.35	1.64	10.11	35.33
Chironomus	*alternans*	0.88	4.03	1.59	9.34	44.68
Austrochiltonia	*subtenuis*	0.88	3.88	1.62	9	53.68

Group	**Melaleuca**	**Swamp**				
Average	**Similarity:**	**20.18**				
Species		**Av.Abund**	**Av.Sim**	**Sim/SD**	**Contrib%**	**Cum.%**
Canthocamptus	*australicus*	0.67	3.51	0.58	17.39	17.39
Arrenurus	*sp.*	0.67	2.38	0.58	11.8	29.19
Scirtidae	*sp.*	0.67	2.38	0.58	11.8	40.99
Microvelia	*sp.*	0.67	2.38	0.58	11.8	52.8

Group	**North**	**Lake**				
Average	**Similarity:**	**36.32**				
Species		**Av.Abund**	**Av.Sim**	**Sim/SD**	**Contrib%**	**Cum.%**
Physa	*acuta*	1	5.46	8.88	15.04	15.04
Anisops	*thienemanni*	1	5.46	8.88	15.04	30.08
Paramphisopus	*palustris*	1	5.46	8.88	15.04	45.12
Pleuroxus	*sp.*	0.75	2.86	0.91	7.86	52.98

Group	**South**	**Lake**				
Average	**Similarity:**	**37.05**				
Species		**Av.Abund**	**Av.Sim**	**Sim/SD**	**Contrib%**	**Cum.%**
Physa	*acuta*	1	4.95	17.9	13.36	13.36
Austrochiltonia	*subtenuis*	1	4.95	17.9	13.36	26.73
Sarscypridopsis	*aculeata*	1	4.95	17.9	13.36	40.09
Agraptacorixa	*eurynome*	0.75	2.59	0.91	6.98	47.08
Anisops	*sp.*	0.75	2.47	0.91	6.65	53.73

Group	**Lower**	**Swamp**				
Average	**Similarity:**	**17.65**				
Species		**Av.Abund**	**Av.Sim**	**Sim/SD**	**Contrib%**	**Cum.%**
Liodessus	*dispar*	1	5.88		33.33	33.33
Microvelia	*(Pacificovelia) oceanica*	1	5.88		33.33	66.67
Bennelongia	*australis sp.*	1	5.88		33.33	100

APPENDIX 5: SIMPER ANALYSIS OF BETWEEN WETLAND COMMUNITY STRUCTURE

Groups	Bibra	Lake	&	Melaleuca	Swamp		
Average	Dissimilarity	=	**88.46**				
Species		Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Physa	acuta	1	0	3.46	4.31	3.91	3.91
Sarscypridopsis	*aculeata*	1	0	3.46	4.31	3.91	7.82
Helisoma	*sp.*	0.75	0	2.56	1.55	2.9	10.72
Triplectides	*australis*	0.75	0	2.56	1.55	2.9	13.61
Candonocypris	*novaezelandiae*	0.75	0	2.48	1.54	2.8	16.41
Canthocamptus	*australicus*	0	0.67	2.46	1.29	2.78	19.19
Anisops	*sp.*	0.63	0	2.19	1.17	2.47	21.67
Austrochiltonia	*subtenuis*	0.88	0.33	2.18	1.19	2.47	24.13
Microvelia	*sp.*	0	0.67	2.07	1.34	2.34	26.47
Microvelia	*(Pacificovelia) oceanica*	0	0.67	2.07	1.34	2.34	28.81
Alboa	*worooa*	0	0.67	2.07	1.34	2.34	31.15
Micronecta	*robusta*	0.88	0.33	2	1.24	2.26	33.41
Arrenurus	*sp.*	0.13	0.67	1.99	1.23	2.25	35.66
Austrolestes	*analis*	0.13	0.67	1.99	1.23	2.25	37.9
Paramphisopus	*palustris*	0.13	0.67	1.99	1.23	2.25	40.15
Chironomus	*alternans*	0.88	0.33	1.98	1.21	2.24	42.39
Scirtidae	*sp.*	0.13	0.67	1.98	1.19	2.24	44.63
Oligochaeta	*sp.*	0.5	0.33	1.72	0.92	1.95	46.58
Cypretta	*sp.*	0.5	0.33	1.7	0.93	1.92	48.5
Daphnia	*carinata*	0.5	0	1.66	0.92	1.88	50.37

Groups	Bibra	Lake	&	North	Lake		
Average	Dissimilarity	=	**72.83**				
Species		Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Anisops	*thienemanni*	*0*	*1*	*2.74*	*5.84*	*3.76*	*3.76*
Sarscypridopsis	*aculeata*	*1*	*0*	*2.74*	*5.84*	*3.76*	*7.53*
Paramphisopus	*palustris*	*0.13*	*1*	*2.44*	*2.35*	*3.35*	*10.87*
Austrochiltonia	*subtenuis*	*0.88*	*0*	*2.34*	*2.37*	*3.21*	*14.09*
Chironomus	*alternans*	*0.88*	*0.25*	*1.91*	*1.39*	*2.63*	*16.71*
Candonocypris	*novaezelandiae*	*0.75*	*0.25*	*1.7*	*1.23*	*2.33*	*19.04*
Pleuroxus	*sp.*	*0.38*	*0.75*	*1.54*	*1.08*	*2.11*	*21.15*
Arrenurus	*sp.*	*0.13*	*0.5*	*1.45*	*0.95*	*1.99*	*23.15*
Ilyodromus	*viridulus*	*0*	*0.5*	*1.44*	*0.95*	*1.97*	*25.12*
Xanthagion	*erythroneurum*	*0.13*	*0.5*	*1.42*	*0.95*	*1.95*	*27.07*
Helisoma	*sp.*	*0.75*	*0.5*	*1.42*	*0.96*	*1.95*	*29.02*
Dero	*nivea*	*0.25*	*0.5*	*1.41*	*0.95*	*1.94*	*30.96*
Oligochaeta	*sp.*	*0.5*	*0.75*	*1.4*	*0.96*	*1.92*	*32.88*
Berosus	*sp.*	*0.5*	*0.25*	*1.34*	*0.96*	*1.85*	*34.72*
Triplectides	*australis*	*0.75*	*0.5*	*1.34*	*0.96*	*1.84*	*36.56*
Daphnia	*carinata*	*0.5*	*0*	*1.32*	*0.95*	*1.82*	*38.38*
cypretta	*sp.*	*0.5*	*0*	*1.32*	*0.95*	*1.82*	*40.2*
Helochares	*sp.*	*0*	*0.5*	*1.3*	*0.97*	*1.79*	*41.99*
Cypretta	*baylyi*	*0*	*0.5*	*1.3*	*0.97*	*1.79*	*43.78*
Anisops	*gratus*	*0.13*	*0.5*	*1.28*	*0.97*	*1.76*	*45.55*
Haliplus	*gibbus*	*0*	*0.5*	*1.27*	*0.97*	*1.74*	*47.29*
Anisops	*sp.*	*0.63*	*0.75*	*1.19*	*0.85*	*1.63*	*48.92*
Hyphydrus	*sp.*	*0.38*	*0.25*	*1.15*	*0.85*	*1.58*	*50.51*

Groups	Melaleuca	Swamp	&	North	Lake		
Average	Dissimilarity	=	**83.59**				
Species		Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Physa	*acuta*	*0*	*1*	*3.47*	*4.83*	*4.15*	*4.15*
Anisops	*thienemanni*	*0*	*1*	*3.47*	*4.83*	*4.15*	*8.29*
Pleuroxus	*sp.*	*0*	*0.75*	*2.68*	*1.54*	*3.21*	*11.5*
Anisops	*sp.*	*0*	*0.75*	*2.63*	*1.53*	*3.14*	*14.64*
Canthocamptus	*australicus*	*0.67*	*0*	*2.46*	*1.28*	*2.94*	*17.59*
Scirtidae	*sp.*	*0.67*	*0*	*2.08*	*1.33*	*2.48*	*20.07*
Alboa	*worooa*	*0.67*	*0*	*2.08*	*1.33*	*2.48*	*22.55*
Oligochaeta	*sp.*	*0.33*	*0.75*	*1.91*	*1.11*	*2.28*	*24.84*
Microvelia	*sp.*	*0.67*	*0.25*	*1.9*	*1.1*	*2.28*	*27.12*
Microvelia	*(Pacificovelia) oceanica*	*0.67*	*0.25*	*1.9*	*1.1*	*2.28*	*29.4*
Austrolestes	*analis*	*0.67*	*0.25*	*1.9*	*1.1*	*2.28*	*31.67*
Micronecta	*robusta*	*0.33*	*0.75*	*1.9*	*1.05*	*2.27*	*33.94*
Dero	*nivea*	*0*	*0.5*	*1.84*	*0.91*	*2.2*	*36.15*
Xanthagion	*erythroneurum*	*0*	*0.5*	*1.84*	*0.91*	*2.2*	*38.35*
Triplectides	*australis*	*0*	*0.5*	*1.84*	*0.91*	*2.2*	*40.55*
Ilyodromus	*viridulus*	*0*	*0.5*	*1.84*	*0.91*	*2.2*	*42.76*
Helochares	*sp.*	*0.33*	*0.5*	*1.73*	*0.9*	*2.07*	*44.83*
Arrenurus	*sp.*	*0.67*	*0.5*	*1.73*	*0.9*	*2.06*	*46.89*
Cypretta	*baylyi*	*0*	*0.5*	*1.62*	*0.94*	*1.94*	*48.83*
Helisoma	*sp.*	*0*	*0.5*	*1.57*	*0.94*	*1.88*	*50.71*

Groups	Bibra	Lake	&	South	Lake		
Average	Dissimilarity	=	65.09				
Species		Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Agraptacorixa	*eurynome*	*0*	*0.75*	*1.99*	*1.65*	*3.06*	*3.06*
Helisoma	*sp.*	*0.75*	*0*	*1.93*	*1.65*	*2.96*	*6.03*
Austrolestes	*annulosus*	*0.13*	*0.75*	*1.8*	*1.42*	*2.77*	*8.79*
Micronecta	*robusta*	*0.88*	*0.25*	*1.79*	*1.43*	*2.74*	*11.54*
Paramphisopus	*palustris*	*0.13*	*0.75*	*1.77*	*1.42*	*2.72*	*14.26*
Anisops	*thienemanni*	*0*	*0.5*	*1.34*	*0.97*	*2.06*	*16.32*
Ilodromus	*sp.*	*0*	*0.5*	*1.34*	*0.97*	*2.06*	*18.37*
Xanthagion	*erythroneurum*	*0.13*	*0.5*	*1.33*	*0.97*	*2.05*	*20.42*
Hydrachna	*sp.*	*0.13*	*0.5*	*1.33*	*0.97*	*2.05*	*22.47*
Candonocypris	*novaezelandiae*	*0.75*	*0.5*	*1.32*	*0.97*	*2.02*	*24.49*
cypretta	*sp.*	*0.5*	*0.5*	*1.3*	*0.97*	*2*	*26.49*
Anisops	*gratus*	*0.13*	*0.5*	*1.29*	*0.97*	*1.99*	*28.47*
Hemianax	*papuensis*	*0.25*	*0.5*	*1.28*	*0.97*	*1.96*	*30.43*
Oligochaeta	*sp.*	*0.5*	*0.25*	*1.28*	*0.97*	*1.96*	*32.39*
Limnesia	*sp.*	*0.13*	*0.5*	*1.27*	*0.97*	*1.95*	*34.34*
Daphnia	*carinata*	*0.5*	*0*	*1.26*	*0.96*	*1.93*	*36.27*
Berosus	*sp.*	*0.5*	*0*	*1.26*	*0.96*	*1.93*	*38.2*
Anisops	*sp.*	*0.63*	*0.75*	*1.13*	*0.86*	*1.74*	*39.94*
Micronecta	*sp.*	*0.38*	*0.25*	*1.12*	*0.85*	*1.72*	*41.66*
Pionidae	*sp.*	*0.38*	*0.25*	*1.09*	*0.85*	*1.67*	*43.34*
Mesocyclops	*sp.*	*0.38*	*0.25*	*1.07*	*0.86*	*1.65*	*44.98*
Glossiphoniidae	*sp.*	*0.25*	*0.25*	*1.01*	*0.75*	*1.55*	*46.53*
Pleuroxus	*sp.*	*0.38*	*0*	*1*	*0.75*	*1.54*	*48.07*
Triplectides	*australis*	*0.75*	*0.75*	*1*	*0.75*	*1.54*	*49.61*
Glossiphoniidae	*sp.*	*0.25*	*0.25*	*0.96*	*0.75*	*1.48*	*51.09*

Groups	Melaleuca	Swamp	&	South	Lake		
Average	Dissimilarity	=	87.66				
Species		Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Physa	*acuta*	*0*	*1*	*3.23*	*6.59*	*3.68*	*3.68*
Sarscypridopsis	*aculeata*	*0*	*1*	*3.23*	*6.59*	*3.68*	*7.37*
Agraptacorixa	*eurynome*	*0*	*0.75*	*2.49*	*1.6*	*2.84*	*10.21*
Anisops	*sp.*	*0*	*0.75*	*2.42*	*1.59*	*2.76*	*12.97*
Austrolestes	*annulosus*	*0*	*0.75*	*2.42*	*1.59*	*2.76*	*15.73*
Triplectides	*australis*	*0*	*0.75*	*2.36*	*1.6*	*2.69*	*18.42*
Canthocamptus	*australicus*	*0.67*	*0*	*2.28*	*1.32*	*2.6*	*21.02*
Austrochiltonia	*subtenuis*	*0.33*	*1*	*2.22*	*1.3*	*2.54*	*23.56*
Scirtidae	*sp.*	*0.67*	*0*	*1.95*	*1.35*	*2.23*	*25.78*
Microvelia	*sp.*	*0.67*	*0*	*1.95*	*1.35*	*2.23*	*28.01*
Microvelia	*(Pacificovelia) oceanica*	*0.67*	*0*	*1.95*	*1.35*	*2.23*	*30.24*
Austrolestes	*analis*	*0.67*	*0.25*	*1.79*	*1.13*	*2.04*	*32.28*
Alboa	*worooa*	*0.67*	*0.25*	*1.79*	*1.13*	*2.04*	*34.33*
Arrenurus	*sp.*	*0.67*	*0.25*	*1.78*	*1.11*	*2.03*	*36.36*
Chironomus	*alternans*	*0.33*	*0.75*	*1.78*	*1.1*	*2.03*	*38.39*
Hydrachna	*sp.*	*0*	*0.5*	*1.68*	*0.94*	*1.92*	*40.31*
Anisops	*thienemanni*	*0*	*0.5*	*1.68*	*0.94*	*1.92*	*42.22*
Xanthagion	*erythroneurum*	*0*	*0.5*	*1.68*	*0.94*	*1.92*	*44.14*
Ilodromus	*sp.*	*0*	*0.5*	*1.68*	*0.94*	*1.92*	*46.05*
cypretta	*sp.*	*0.33*	*0.5*	*1.65*	*0.93*	*1.88*	*47.93*
Anisops	*gratus*	*0*	*0.5*	*1.61*	*0.93*	*1.83*	*49.77*
Candonocypris	*novaezelandiae*	*0*	*0.5*	*1.55*	*0.94*	*1.77*	*51.53*

Groups	North	Lake	&	South	Lake		
Average	Dissimilarity	=	71.49				
Species		Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Austrochiltonia	*subtenuis*	*0*	*1*	*2.61*	*9.32*	*3.65*	*3.65*
Sarscypridopsis	*aculeata*	*0*	*1*	*2.61*	*9.32*	*3.65*	*7.29*
Agraptacorixa	*eurynome*	*0*	*0.75*	*2*	*1.65*	*2.8*	*10.09*
Pleuroxus	*sp.*	*0.75*	*0*	*2*	*1.64*	*2.8*	*12.89*
Oligochaeta	*sp.*	*0.75*	*0.25*	*1.68*	*1.23*	*2.35*	*15.23*
Austrolestes	*annulosus*	*0.25*	*0.75*	*1.65*	*1.23*	*2.31*	*17.54*
Chironomus	*alternans*	*0.25*	*0.75*	*1.63*	*1.24*	*2.28*	*19.82*
Micronecta	*robusta*	*0.75*	*0.25*	*1.56*	*1.23*	*2.19*	*22.01*
Dero	*nivea*	*0.5*	*0*	*1.36*	*0.95*	*1.9*	*23.91*
Ilyodromus	*viridulus*	*0.5*	*0*	*1.36*	*0.95*	*1.9*	*25.82*
Arrenurus	*sp.*	*0.5*	*0.25*	*1.35*	*0.96*	*1.88*	*27.7*
cypretta	*sp.*	*0*	*0.5*	*1.35*	*0.96*	*1.88*	*29.58*
Ilodromus	*sp.*	*0*	*0.5*	*1.35*	*0.96*	*1.88*	*31.46*
Hydrachna	*sp.*	*0.25*	*0.5*	*1.33*	*0.96*	*1.86*	*33.32*
Anisops	*gratus*	*0.5*	*0.5*	*1.3*	*0.96*	*1.82*	*35.14*
Xanthagion	*erythroneurum*	*0.5*	*0.5*	*1.3*	*0.96*	*1.82*	*36.96*
Limnesia	*sp.*	*0.25*	*0.5*	*1.28*	*0.96*	*1.79*	*38.75*
Hemianax	*papuensis*	*0.25*	*0.5*	*1.28*	*0.96*	*1.79*	*40.54*
Candonocypris	*novaezelandiae*	*0.25*	*0.5*	*1.28*	*0.96*	*1.79*	*42.33*
Triplectides	*australis*	*0.5*	*0.75*	*1.28*	*0.96*	*1.79*	*44.12*
Cypretta	*baylyi*	*0.5*	*0.25*	*1.27*	*0.96*	*1.78*	*45.89*
Anisops	*thienemanni*	*1*	*0.5*	*1.26*	*0.96*	*1.76*	*47.66*
Helochares	*sp.*	*0.5*	*0*	*1.25*	*0.97*	*1.74*	*49.4*
Helisoma	*sp.*	*0.5*	*0*	*1.21*	*0.97*	*1.7*	*51.1*

Groups	Bibra	Lake	&	Lower	Swamp		
Average	Dissimilarity	=	77.85				
Species		Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Liodessus	*dispar*	*0*	*1*	*2.89*	*4.7*	*3.72*	*3.72*
Microvelia	*(Pacificovelia) oceanica*	*0*	*1*	*2.89*	*4.7*	*3.72*	*7.44*
Austrochiltonia	*subtenuis*	*0.88*	*0*	*2.47*	*2.23*	*3.17*	*10.6*
Bennelongia	*australis*	*0.25*	*1*	*2.3*	*1.57*	*2.96*	*13.56*
Helisoma	*sp.*	*0.75*	*0*	*2.15*	*1.56*	*2.76*	*16.32*
Anisops	*sp.*	*0.63*	*0*	*1.83*	*1.17*	*2.34*	*18.66*
Cherax	*quinquecarinatus*	*0*	*0.5*	*1.66*	*0.95*	*2.13*	*20.79*
Ferrisia	*sp.*	*0*	*0.5*	*1.66*	*0.95*	*2.13*	*22.92*
Physa	*acuta*	*1*	*0.5*	*1.66*	*0.95*	*2.13*	*25.05*
Physa	*sp.*	*0*	*0.5*	*1.66*	*0.95*	*2.13*	*27.17*
Allodessus	*bistrigatus*	*0*	*0.5*	*1.66*	*0.95*	*2.13*	*29.3*
Microvelia	*sp.*	*0*	*0.5*	*1.66*	*0.95*	*2.13*	*31.43*
Lectrides	*sp*	*0*	*0.5*	*1.66*	*0.95*	*2.13*	*33.55*
Paramphisopus	*subtenuis*	*0*	*0.5*	*1.66*	*0.95*	*2.13*	*35.68*
Sarscypridopsis	*aculeata*	*1*	*0.5*	*1.66*	*0.95*	*2.13*	*37.81*
Micronecta	*robusta*	*0.88*	*0.5*	*1.63*	*0.93*	*2.09*	*39.9*
Austrolestes	*analis*	*0.13*	*0.5*	*1.62*	*0.93*	*2.08*	*41.97*
Chironomus	*alternans*	*0.88*	*0.5*	*1.6*	*0.94*	*2.06*	*44.03*
Scirtidae	*sp.*	*0.13*	*0.5*	*1.58*	*0.95*	*2.04*	*46.07*
Triplectides	*australis*	*0.75*	*0.5*	*1.55*	*0.94*	*1.98*	*48.05*
Candonocypris	*novaezelandiae*	*0.75*	*0.5*	*1.53*	*0.94*	*1.96*	*50.01*

Groups	Melaleuca	Swamp	&	Lower	Swamp		
Average	Dissimilarity	=	79.98				
Species		Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Liodessus	*dispar*	*0*	*1*	*3.73*	*3.64*	*4.67*	*4.67*
Bennelongia	*australis*	*0*	*1*	*3.73*	*3.64*	*4.67*	*9.33*
Canthocamptus	*australicus*	*0.67*	*0*	*2.66*	*1.19*	*3.33*	*12.66*
Arrenurus	*sp.*	*0.67*	*0*	*2.21*	*1.24*	*2.76*	*15.43*
Alboa	*worooa*	*0.67*	*0*	*2.21*	*1.24*	*2.76*	*18.19*
Cherax	*quinquecarinatus*	*0*	*0.5*	*2.21*	*0.88*	*2.76*	*20.95*
Physa	*sp.*	*0*	*0.5*	*2.21*	*0.88*	*2.76*	*23.72*
Lectrides	*sp*	*0*	*0.5*	*2.21*	*0.88*	*2.76*	*26.48*
Paramphisopus	*subtenuis*	*0*	*0.5*	*2.21*	*0.88*	*2.76*	*29.24*
Ferrisia	*sp.*	*0.33*	*0.5*	*2.04*	*0.85*	*2.55*	*31.8*
Allodessus	*bistrigatus*	*0.33*	*0.5*	*2.04*	*0.85*	*2.55*	*34.35*
Paramphisopus	*palustris*	*0.67*	*0.5*	*1.88*	*0.91*	*2.35*	*36.7*
Oligochaeta	*sp.*	*0.33*	*0.5*	*1.85*	*0.82*	*2.32*	*39.02*
Scirtidae	*sp.*	*0.67*	*0.5*	*1.85*	*0.82*	*2.32*	*41.33*
Chironomus	*alternans*	*0.33*	*0.5*	*1.85*	*0.82*	*2.32*	*43.65*
Micronecta	*robusta*	*0.33*	*0.5*	*1.85*	*0.82*	*2.32*	*45.97*
Microvelia	*sp.*	*0.67*	*0.5*	*1.85*	*0.82*	*2.32*	*48.28*
Austrolestes	*analis*	*0.67*	*0.5*	*1.85*	*0.82*	*2.32*	*50.6*

Groups	North	Lake	&	Lower	Swamp		
Average	Dissimilarity	=	75.22				

Species		Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Pleuroxus	*sp.*	*0.75*	*0*	*2.23*	*1.52*	*2.97*	*2.97*
Bennelongia	*australis*	*0.25*	*1*	*2.23*	*1.52*	*2.97*	*5.94*
Liodessus	*dispar*	*0.25*	*1*	*2.2*	*1.51*	*2.92*	*8.86*
Anisops	*sp.*	*0.75*	*0*	*2.2*	*1.51*	*2.92*	*11.78*
Microvelia	*(Pacificovelia)*	*0.25*	*1*	*2.2*	*1.51*	*2.92*	*14.7*
Cherax	*quinquecarinatus*	*0*	*0.5*	*1.66*	*0.92*	*2.21*	*16.91*
Ferrisia	*sp.*	*0*	*0.5*	*1.66*	*0.92*	*2.21*	*19.12*
Physa	*acuta*	*1*	*0.5*	*1.66*	*0.92*	*2.21*	*21.32*
Physa	*sp.*	*0*	*0.5*	*1.66*	*0.92*	*2.21*	*23.53*
Allodessus	*bistrigatus*	*0*	*0.5*	*1.66*	*0.92*	*2.21*	*25.74*
Scirtidae	*sp.*	*0*	*0.5*	*1.66*	*0.92*	*2.21*	*27.95*
Anisops	*thienemanni*	*1*	*0.5*	*1.66*	*0.92*	*2.21*	*30.15*
Lectrides	*sp*	*0*	*0.5*	*1.66*	*0.92*	*2.21*	*32.36*
Paramphisopus	*subtenuis*	*0*	*0.5*	*1.66*	*0.92*	*2.21*	*34.57*
Paramphisopus	*palustris*	*1*	*0.5*	*1.66*	*0.92*	*2.21*	*36.78*
Oligochaeta	*sp.*	*0.75*	*0.5*	*1.57*	*0.9*	*2.09*	*38.87*
Arrenurus	*sp.*	*0.5*	*0*	*1.57*	*0.91*	*2.08*	*40.95*
Microvelia	*sp.*	*0.25*	*0.5*	*1.56*	*0.91*	*2.08*	*43.03*
Austrolestes	*analis*	*0.25*	*0.5*	*1.56*	*0.91*	*2.08*	*45.1*
Xanthagion	*erythroneurum*	*0.5*	*0*	*1.53*	*0.9*	*2.03*	*47.13*
Ilyodromus	*viridulus*	*0.5*	*0*	*1.53*	*0.9*	*2.03*	*49.16*
Micronecta	*robusta*	*0.75*	*0.5*	*1.52*	*0.93*	*2.02*	*51.18*

Groups	South	Lake	&	Lower	Swamp		
Average	Dissimilarity	=	78.48				
Species		Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Liodessus	*dispar*	*0*	*1*	*2.74*	*6.5*	*3.49*	*3.49*
Microvelia	*(Pacificovelia) oceanica*	*0*	*1*	*2.74*	*6.5*	*3.49*	*6.98*
Austrochiltonia	*subtenuis*	*1*	*0*	*2.74*	*6.5*	*3.49*	*10.48*
Agraptacorixa	*eurynome*	*0.75*	*0*	*2.11*	*1.56*	*2.68*	*13.16*
Anisops	*sp.*	*0.75*	*0*	*2.05*	*1.55*	*2.61*	*15.77*
Austrolestes	*annulosus*	*0.75*	*0*	*2.05*	*1.55*	*2.61*	*18.39*
Bennelongia	*australis*	*0.25*	*1*	*2.05*	*1.55*	*2.61*	*21*
Cherax	*quinquecarinatus*	*0*	*0.5*	*1.56*	*0.93*	*1.98*	*22.98*
Ferrisia	*sp.*	*0*	*0.5*	*1.56*	*0.93*	*1.98*	*24.97*
Physa	*acuta*	*1*	*0.5*	*1.56*	*0.93*	*1.98*	*26.95*
Physa	*sp.*	*0*	*0.5*	*1.56*	*0.93*	*1.98*	*28.93*
Allodessus	*bistrigatus*	*0*	*0.5*	*1.56*	*0.93*	*1.98*	*30.91*
Scirtidae	*sp.*	*0*	*0.5*	*1.56*	*0.93*	*1.98*	*32.89*
Microvelia	*sp.*	*0*	*0.5*	*1.56*	*0.93*	*1.98*	*34.87*
Lectrides	*sp*	*0*	*0.5*	*1.56*	*0.93*	*1.98*	*36.85*
Paramphisopus	*subtenuis*	*0*	*0.5*	*1.56*	*0.93*	*1.98*	*38.84*
Sarscypridopsis	*aculeata*	*1*	*0.5*	*1.56*	*0.93*	*1.98*	*40.82*
Austrolestes	*analis*	*0.25*	*0.5*	*1.48*	*0.92*	*1.88*	*42.7*
Chironomus	*alternans*	*0.75*	*0.5*	*1.45*	*0.93*	*1.85*	*44.55*
Triplectides	*australis*	*0.75*	*0.5*	*1.45*	*0.93*	*1.85*	*46.39*
Paramphisopus	*palustris*	*0.75*	*0.5*	*1.45*	*0.93*	*1.85*	*48.24*
Hydrachna	*sp.*	*0.5*	*0*	*1.42*	*0.92*	*1.81*	*50.05*

APPENDIX 6: HISTORIC DATA COMPARISONS

	Phoenix 2010					Wild and Davis 2006; Giles and Davis 2005				
Family	Bibra Lake	Melaleuca Swamp	North Lake	South	Lower Swamp	Bibra Lake	Thomsons Lake	Kogolup South	Kogolup North	Yangebup
Aeshnidae	✓		✓	✓	✓	+				
Ameronothridae						+	+	+	+	
Amphisopidae	✓	✓	✓	✓	✓	+	+	+	+	
Ancylidae		✓				+				
Arrenuridae	✓	✓	✓	✓		+	+			
Brachionidae	✓									
Baetidae										
Caenidae						+	+			
Canthocamptidae		✓								
Calanoida	✓					+	+	+		
Ceinidae	✓	✓		✓		+	+	+	+	
Centropagidae	✓									
Ceratopogonidae				✓						
Chironomidae	✓	✓	✓	✓	✓					
Chydoridae	✓		✓			+	+	+		
Coenagrionidae	✓		✓	✓		+	+			
Corixidae	✓	✓	✓	✓	✓	+	+	+	+	+
Culicidae	✓			✓						
Cyclopidae	✓		✓	✓						
Cyclopoida	✓		✓	✓		+	+	+	+	+
Cyprididae	✓	✓	✓	✓	✓	+	+	+	+	+
Daphniidae	✓					+	+	+	+	+
Dytiscidae	✓	✓	✓	✓	✓					
Erpobdellidae	✓									
Eylaidae				✓	✓					
Glossiphoniidae	✓			✓	✓	+	+	+		
Haliplidae			✓							
Hirudinidae		✓								
Hydrachnidae	✓		✓	✓		+				
Hydraenidae		✓								
Hydrophilidae	✓	✓	✓	✓	✓					
Hydridae										
Hydromidae				✓		+				
Hydryphantidae						+				
Hydrazoa			✓							
Hypogastruridae						+				
Leptoceridae	✓		✓	✓	✓					
Lestidae	✓	✓	✓	✓	✓	+	+	+		
Libellulidae										
Limnesidae						+	+	+		
Limnocharidae	✓									
Lymnaeidae						+	+	+		
Megapodagrionidae		✓								
Moinidae										
Muscidae				✓						
Naididae	✓		✓		✓					
Nepidae				✓						

	Phoenix 2010					Wild and Davis 2006; Giles and Davis 2005				
Family	**Bibra Lake**	**Melaleuca Swamp**	**North Lake**	**South**	**Lower Swamp**	**Bibra Lake**	**Thomsons Lake**	**Kogolup South**	**Kogolup North**	**Yangebup**
Notodromadidae						+	+			
Notonectidae	✓		✓	✓	✓	+	+	+	+	+
Oligochaeta	✓	✓	✓	✓	✓	+				
Oniscidae										
Parastacidae		✓				+				
Perthidae		✓								
Physidae	✓		✓	✓	✓	+	+	+	+	+
Pionidae	✓		✓	✓	✓	+	+	+	+	+
Planorbidae	✓		✓	✓		+				
Scirtidae	✓	✓			✓					
Stratiomyidae	✓			✓						
Tubificidae	✓	✓	✓			+				
Turbellaria	✓									
Veliidae		✓	✓		✓	+				
Family Richness	**34**	**20**	**25**	**28**	**18**	**31**	**20**	**16**	**10**	**7**

Note: Family names in bold represent families not recorded in Giles and Davis 2005.

APPENDIX 7: BRAY-CURTIS SIMILARITY MATRIX

Site	Bibra Lake S1 R2	Bibra Lake S1 R1	Bibra Lake S2 R2	Bibra Lake S2 R1	Bibra Lake S3 R1	Bibra Lake S5 R1	Bibra Lake S3 R2	Bibra Lake S4 R1	Mel Swamp S1 R1	Mel Swamp S1 R2	Mel Swamp S2 R1	North Lake S1 R1	North Lake S2 R1	North Lake S2 R2	North Lake S3 R2	South Lake S1 R1	South Lake S1 R2	South Lake S2 R1	South Lake S2 R2	Lower Swamp S1 R1	Lower Swamp S2 R1
Bibra Lake S1 R2																					
Bibra Lake S1 R1	50																				
Bibra Lake S2 R2	38.89	46.67																			
Bibra Lake S2 R1	26.09	50.00	55.56																		
Bibra Lake S3 R1	30.77	39.13	47.62	65.38																	
Bibra Lake S5 R1	35.00	35.29	46.67	40.00	39.13																
Bibra Lake S3 R2	55.00	41.18	53.33	45.00	43.48	41.18															
Bibra Lake S4 R1	38.89	40.00	38.46	38.89	38.10	46.67	40.00														
Mel Swamp S1 R1	16.67	13.33	0.00	16.67	4.76	6.67	6.67	15.38													
Mel Swamp S1 R2	13.79	8.70	31.58	20.69	11.43	17.39	26.09	21.05	10.53												
Mel Swamp S2 R1	5.26	0.00	7.14	15.79	4.55	0.00	6.25	7.14	50.00	0.00											
North Lake S1 R1	14.29	16.67	25.00	33.33	16.67	16.67	16.67	12.50	37.50	24.00	29.41										
North Lake S2 R1	22.73	36.84	41.18	50.00	40.00	26.32	26.32	35.29	5.88	22.22	5.56	30.00									
North Lake S2 R2	22.22	26.67	38.46	33.33	23.81	13.33	26.67	15.38	15.38	10.53	14.29	37.50	47.06								
North Lake S3 R2	40.91	36.84	29.41	27.27	28.00	21.05	26.32	29.41	11.76	14.81	5.56	30.00	38.10	35.29							
South Lake S1 R1	27.91	32.43	30.30	46.51	32.65	37.84	32.43	30.30	18.18	7.69	17.14	20.51	29.27	24.24	19.51						
South Lake S1 R2	39.02	28.57	32.26	29.27	34.04	28.57	28.57	38.71	6.45	8.33	6.06	16.22	30.77	25.81	41.03	36.84					
South Lake S2 R1	30.43	45.00	38.89	47.83	46.15	25.00	35.00	27.78	22.22	20.69	15.79	28.57	36.36	27.78	40.91	37.21	29.27				
South Lake S2 R2	55.81	32.43	36.36	32.56	28.57	27.03	48.65	30.30	12.12	7.69	5.71	15.38	24.39	36.36	39.02	35.00	42.11	41.86			
Lower Swamp S1 R1	22.22	35.90	45.71	62.22	47.06	41.03	35.90	40.00	11.43	21.43	10.81	39.02	60.47	34.29	32.56	47.62	30.00	44.44	38.10		
Lower Swamp S2 R1	0.00	0.00	0.00	11.43	4.88	0.00	0.00	8.00	32.00	0.00	44.44	25.81	6.06	0.00	0.00	6.25	0.00	5.71	0.00	17.65