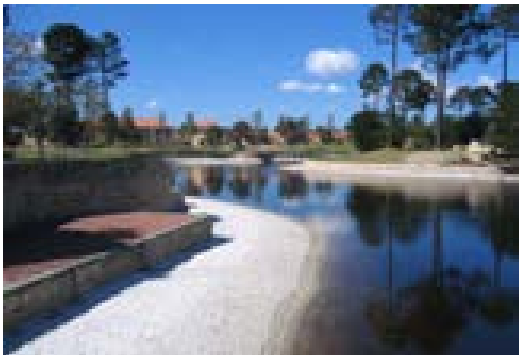
CONSTRUCTED LAKES IN THE PERTH METROPOLITAN AREA AND SOUTH WEST REGION

LITERATURE REVIEW AND INTERVIEW PROJECT

Prepared for

Department of Water

Western Australian Local Government Association

Urban Development Institute of Australia

CONSTRUCTED LAKES IN THE PERTH METROPOLITAN AREA AND SOUTH-WEST REGION

LITERATURE REVIEW AND INTERVIEW PROJECT

Prepared for

DEPARTMENT OF WATER
WESTERN AUSTRALIAN LOCAL GOVERNMENT ASSOCIATION
URBAN DEVELOPMENT INSTITUTE OF AUSTRALIA

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Date:	*6 November 2008*

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STATEMENT OF LIMITATIONS

Scope of Services

This environmental site assessment report ("the report") has been prepared in accordance with the scope of services set out in the contract, or as otherwise agreed, between the Client and ENV. Australia Pty Ltd (ENV) ("scope of services"). In some circumstances the scope of services may have been limited by factors such as time, budget, access and/or site disturbance constraints.

Reliance on Data

In preparing the report, ENV has relied on data, surveys, analyses, designs, plans and other information provided by the Client and other individuals and organisations, most of which are referred to in the report ("the data"). Except as otherwise stated in the report, ENV has not verified the accuracy or completeness of the data. To the extent that the statements, opinions, facts, information, conclusions and/or recommendations in the report ("conclusions") are based in whole or in part on the data, those conclusions are contingent upon the accuracy and completeness of the data. ENV will not be liable in relation to incorrect conclusions should any data, information or condition be incorrect or have been concealed, withheld, unavailable, misrepresented or otherwise not fully disclosed to ENV.

Environmental Conclusions

In accordance with the scope of services, ENV has relied on the data and has conducted environmental field monitoring and/or testing in the preparation of the report. The nature and extent of monitoring and/or testing conducted is described in the report.

On all sites, varying degrees of non-uniformity of the vertical and horizontal soil or groundwater conditions are encountered. Hence no monitoring, common testing or sampling technique can eliminate the possibility that monitoring or testing results/samples are not totally representative of soil and/or groundwater conditions encountered. The conclusions are based upon the data and the environmental field monitoring and/or testing and are therefore merely indicative of the environmental condition of the site at the time of preparing the report, including the presence or otherwise of contaminants or emissions. Also it should be recognised that site conditions, including the extent and concentration of contaminants, can change with time.

Within the limitations imposed by the scope of services, the monitoring, testing, sampling and preparation of this report have been undertaken and performed in a professional manner, in accordance with generally accepted practices and using a degree of skill and care ordinarily exercised by reputable environmental consultants under similar circumstances. No other warranty, express or implied, is made.

Report for Benefit of Client

The report has been prepared for the benefit of the Client and for no other party. ENV assumes no responsibility and will not be liable to any other person or organisation for or in relation to any matter dealt with or conclusions expressed in the report, or for any loss or damage suffered by any other person or organisation arising from matters dealt with or conclusions expressed in the report (including without limitation matters arising from any negligent act or omission of ENV or for any loss or damage suffered by any other party relying upon the matters dealt with or conclusions expressed in the report). Other parties should not rely upon the report or the accuracy or completeness of any conclusions and should make their own enquiries and obtain independent advice in relation to such matters.

Other Limitations

ENV will not be liable to update or revise the report to take into account any events or emergent circumstances or facts occurring or becoming apparent after the date of the report.

The scope of services did not include any assessment of the title to or ownership of the properties, buildings and structures referred to in the report, nor the application or interpretation of laws in the jurisdiction in which those properties, buildings and structures are located.

EXECUTIVE SUMMARY

ENV Australia (ENV) was commissioned by the Department of Water, Urban Development Institute of Australia and the Western Australian Local Government Association to undertake a study of 46 perennial constructed lakes, with the aim of improving guidelines for their construction and management in the future. A variety of constructed lakes were selected to represent the range of different types of lakes in the south-west of Western Australia. All lakes selected for the study are permanently inundated basins of open water.

The primary aim of the study was to collect information on lake characteristics and management problems. Some examination of the data was conducted to distinguish critical success factors for lake management, reasons for problems and gaps in knowledge and to make recommendations for future field assessment of the lakes.

Data was collected through comprehensive interviews with lake managers, site inspections and a literature review. The majority of the data collected was qualitative, with historical water quality data available for half of the lakes. Reports, including management plans, monitoring programs and specific lake studies, were provided for a third of the lakes. Whilst historical data and reports were requested for all lakes, previous studies had either not been conducted or could not be located by the lake manager in 21 of the 46 lakes. The selection of lakes was biased towards those with data therefore this is likely to be an atypically high proportion.

Approximately three quarters of the lakes were a prominent feature within residential developments. These lakes were highly valued within the community for their recreational and aesthetic function. The aesthetic and recreational value was compromised in many of the lakes with 37 of the 46 lakes having reported problems of some kind that would require a management response. Problems may not have been reported by lake managers interviewed during the study as they may not be aware of them.

In approximately half of the 46 lakes studied, the management problems were dominated by issues associated with eutrophication (excessive nutrients) including algae, midges and odour. These issues were of the highest concern to lake managers due to their potentially serious environmental, health and aesthetic effects as well as being the most commonly reported. There were several other management issues reported including gross pollutants (10 lakes), invasion of exotic vegetation (9 lakes), invasion of feral fish (9 lakes) and problems associated with infrastructure maintenance (9 lakes) and these were also assessed in the study.

Previous literature has identified specific design features, such as a lack of hard vertical edges and a shape that restricts water circulation, increases the risk of mosquito and midge problems (Department of Water, 2004-2007 and Midge Research Group of Western Australia, 2007). This study found no clear links between particular design features, such as lake edge or shape, and issues associated with eutrophication including

algal blooms, mosquitoes and midges. Issues were reported in lakes with a wide range of features, for example, in lined lakes, in groundwater through-flow lakes, and lakes with a regular shape, while other lakes with these same features may have been free of problems.

The central finding of the study was that the eutrophication issues were not limited to particular types of constructed lakes and appeared to be driven by the water-nutrient balance more than any other design features.

It is likely that when the water-nutrient balance allows nutrients to accumulate, problems typically occur. The accumulation rate will generally dictate the time to the onset of problems, so typically older constructed lakes and those with long water residence times experience more problems. Of the 25 lakes that were older than 10 years, 11 reported problems with algal blooms, whereas only 5 of the 21 lakes that were 10 years or younger reported similar issues. While age may be related to the nutrient accumulation, many other factors, such as inflow nutrient concentrations and percentage of volume that evaporates in summer, also influence the water-nutrient balance.

Guidelines applicable to constructed lakes on the east coast of Australia (Breen et al. 1996 and Melbourne Water, 2005) recommend lake residence times as a simple indicator of lake performance i.e. the shorter the residence time, the better the water quality and therefore the overall health of the constructed lake. These guidelines also focus on managing nutrient loads in surface water inflows rather than groundwater.

This study showed very clearly that groundwater inflows and outflows were a substantial consideration in most of the Western Australian lakes with approximately three quarters of the lakes receiving groundwater inflows. While groundwater may not be such an important factor in residence time in the Eastern States, it is a factor which cannot be ignored in Western Australian lakes.

The data required to complete a water and nutrient balance was absent in all but 2 of the 46 lakes in this study. ENV has conducted a water and nutrient balance for one of the lakes, Emu Lake in Ballajura in a separate study (ENV, 2008). JDA Consultant Hydrologists completed a water and nutrient balance for Jackadder Lake for the City of Stirling (JDA, 1992). Preliminary study of the water and nutrient balance has been conducted at Prior Close Reserve Lake in Brookland Greens in Canning Vale (Terra Consulting and Murdoch University Aquatic Ecosystems Research Group, 2003). These studies reinforce that the water and nutrient balance is the key factor for predicting the effective performance of constructed lakes and can be a useful tool for managing problems such as algal blooms and midges.

Management measures such as community catchment management were recommended for Emu Lake based on findings that groundwater and stormwater were major sources of nutrients driving blue-green algal blooms in the lake (ENV, 2008). The water and nutrient balance conducted for Jackadder Lake informed the decision to reduce the volume of nutrient-rich water redirected into the lake from the Osborne Park Main Drain, which has been successful in eliminating algal problems in the lake. Preliminary investigation of water and nutrient balance at Prior Close Reserve Lake in Brookland Greens in Canning Vale has guided management recommendations for midge problems.

It is currently required under the *Better Urban Water Management* guideline (Department of Planning and Infrastructure, Department of Water, Western Australian Local Government Authority and Department of Environment, Water, Heritage and the Arts, 2008) for developers to provide details on the purpose and design of the water body and a proposed schedule for management and ongoing maintenance, however, the guideline does not specifically require that a water and nutrient balance is conducted. For the many hundreds of existing constructed lakes, data required to determine the water-nutrient balance appears to be unknown or inadequate.

Guidelines for urban water management should be revised to specify that water and nutrient balances are conducted for new constructed lakes so this can be considered by regulatory authorities and local government during the approval process.

It is not economically feasible to recommend collecting data and conducting water-nutrient balances in all existing lakes. ENV therefore recommends that lake managers prioritise lakes where a water and nutrient balance should be conducted according to the severity of the management problems. Prioritising existing lakes for a water and nutrient balance assessment would require the collection of basic water quality data in lakes that have not previously been sampled, possibly a single event nutrient and chlorophyll *a* sampling program during summer.

A full water-nutrient data collection process would involve seasonal measurements of groundwater and surface inflow volumes and associated water quality parameters such as nutrient concentrations including total phosphorus and total nitrogen.

The water-nutrient balance data should be then analysed and a targeted management response can then be developed to rectify any imbalance. It is expected that in some instances these responses will be short-term actions, while the majority will be long-term and broader reaching changes to the surface and groundwater catchments of the constructed lake.

1 INTRODUCTION

1.1 BACKGROUND

The Department of Water has prepared an *Interim Drainage and Water Management Position Statement: Constructed Lakes* (Department of Water, 2007) to guide developers, landowners, and local government and State Government agencies on the Department of Water's position on perennial constructed lakes. In this study, perennial constructed lakes, thereafter called "constructed lakes" are defined as constructed, permanently-inundated basins of open water, formed by simple dam walls or by excavation below ground level. Not all constructed lakes are permanently inundated however this study only assessed those that are.

Constructed lakes differ from constructed wetlands as constructed wetlands are vegetated detention areas that are either permanent or ephemeral and are designed and built specifically to remove pollutants from drainage runoff or for their ecological functions. Advice about constructed wetlands is available in Chapter 9 of the *Stormwater Management Manual for Western Australia* (Department of Water, 2004-2007). Constructed lakes do not have either of these primary purposes therefore tend to have much less fringing vegetation or wetland vegetation with the lake shallows.

The Department of Water recognises that constructed lakes can have both positive and negative impacts. Well-designed and maintained constructed lakes can have community benefits similar to those gained from natural wetlands, such as aesthetic and recreational values, and health benefits associated with passive recreation (Department of Water, 2007).

The interim position statement (Department of Water, 2007) is intended to contribute to the design and management of constructed lakes created in urban (i.e. residential, commercial and industrial) areas for surface water and groundwater management, irrigation storage, recreation or aesthetic purposes and in rural areas if they are created solely or partly for recreation or aesthetic purposes, e.g. adjacent to wineries, restaurants, accommodation and tourism facilities (Department of Water, 2007). It is not intended to be used to manage constructed lakes in rural areas that are created solely for drainage, dewatering, irrigation storage or stock watering, as other conditions may apply.

The Department of Water recognises that constructed lakes can have both positive and negative impacts. Well-designed and maintained constructed lakes can have community benefits similar to those gained from natural wetlands, such as aesthetic and recreational values, and health benefits associated with passive recreation (Department of Water, 2007).

Poorly designed and/or managed constructed lakes may experience problems such as eutrophication, algal blooms, midge and mosquito plagues, odours, exposure of acid sulfate soils and acidification. Typically, there are high maintenance costs associated with these problems. Water conservation issues can also be associated with constructed lakes. Constructed lakes can result in the loss of water resources through increased exposure and evaporation of intercepted groundwater or using scheme water or groundwater to artificially top up lakes.

1.2 AIM

The information gathered in this study is intended to contribute to the Department of Water's final position statement on constructed lakes. The study aimed to identify lake characteristics that were neutral, beneficial or detrimental to lake function. The goal was to distinguish critical success factors for lake management, reasons why management problems occurred and gaps in knowledge and to make recommendations for future field assessment of the lakes. Factors to be investigated included:

- lake design, including features such as shape, area, lining and hydraulic characteristics;
- lake function, for example drainage collection or irrigation use;
- catchment characteristics and issues likely to influence the lake such as acid sulfate soils;
- whether the constructed lake was created by changing the geomorphology or hydrology of a natural wetland or waterway;
- water conservation issues, including the use of water to top up the lakes;
- lake management history and maintenance regime;
- social amenity value, including aesthetic and recreational significance; and
- whether management problems had been experienced.

1.3 STUDY AREA

The study included constructed lakes in residential areas in Metropolitan Perth and in urban and rural areas in the south-west of Western Australia, as shown on Figures 1 to 4.

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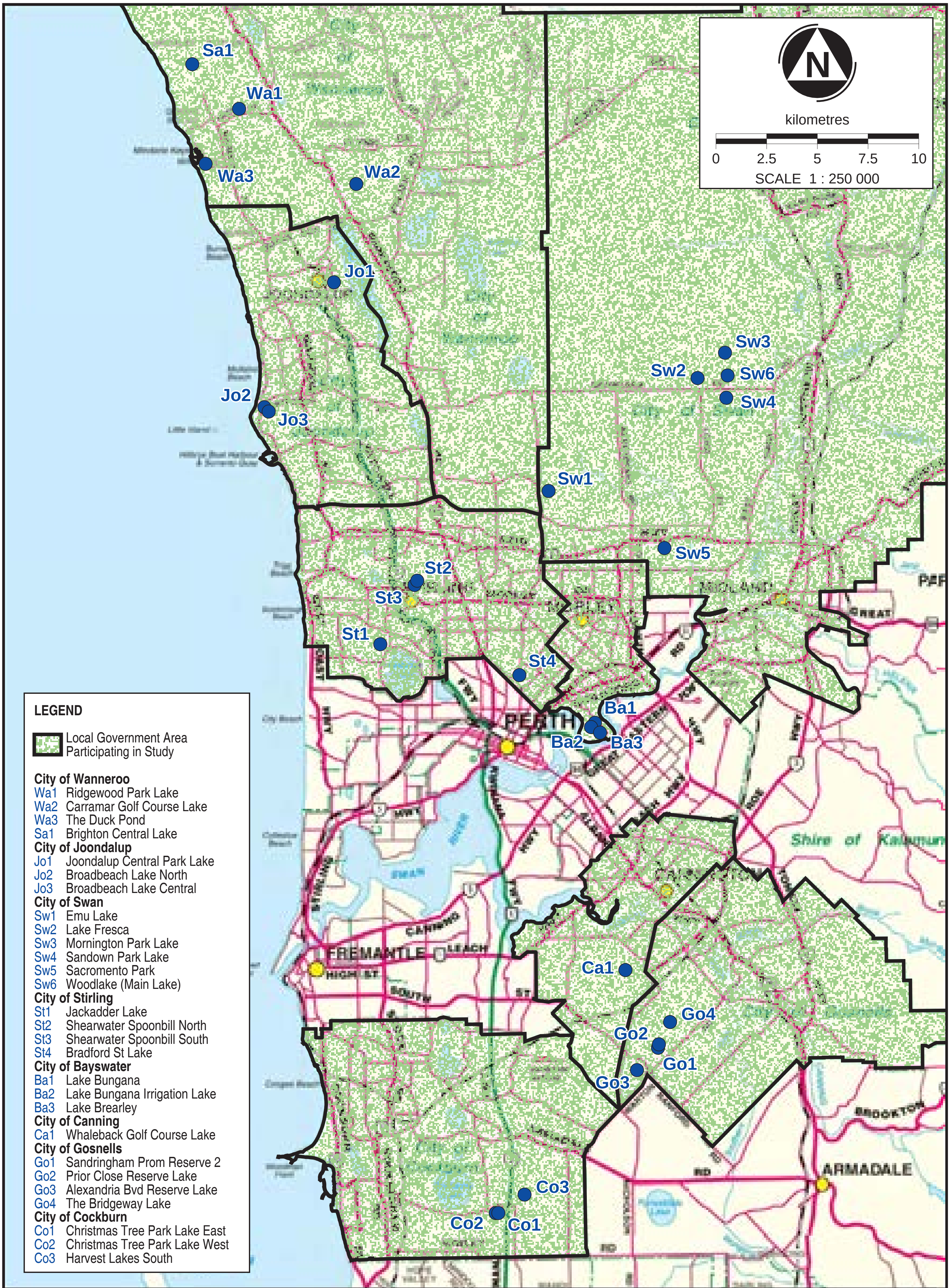

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DRAWN: CR 18-08-08
AUTHOR: BW 18-08-08

BASE SOURCE: Landgate, StreetExpress, 2007.

Department of Water
CONSTRUCTED LAKES STUDY

LAKE LOCATIONS
FIGURE 1

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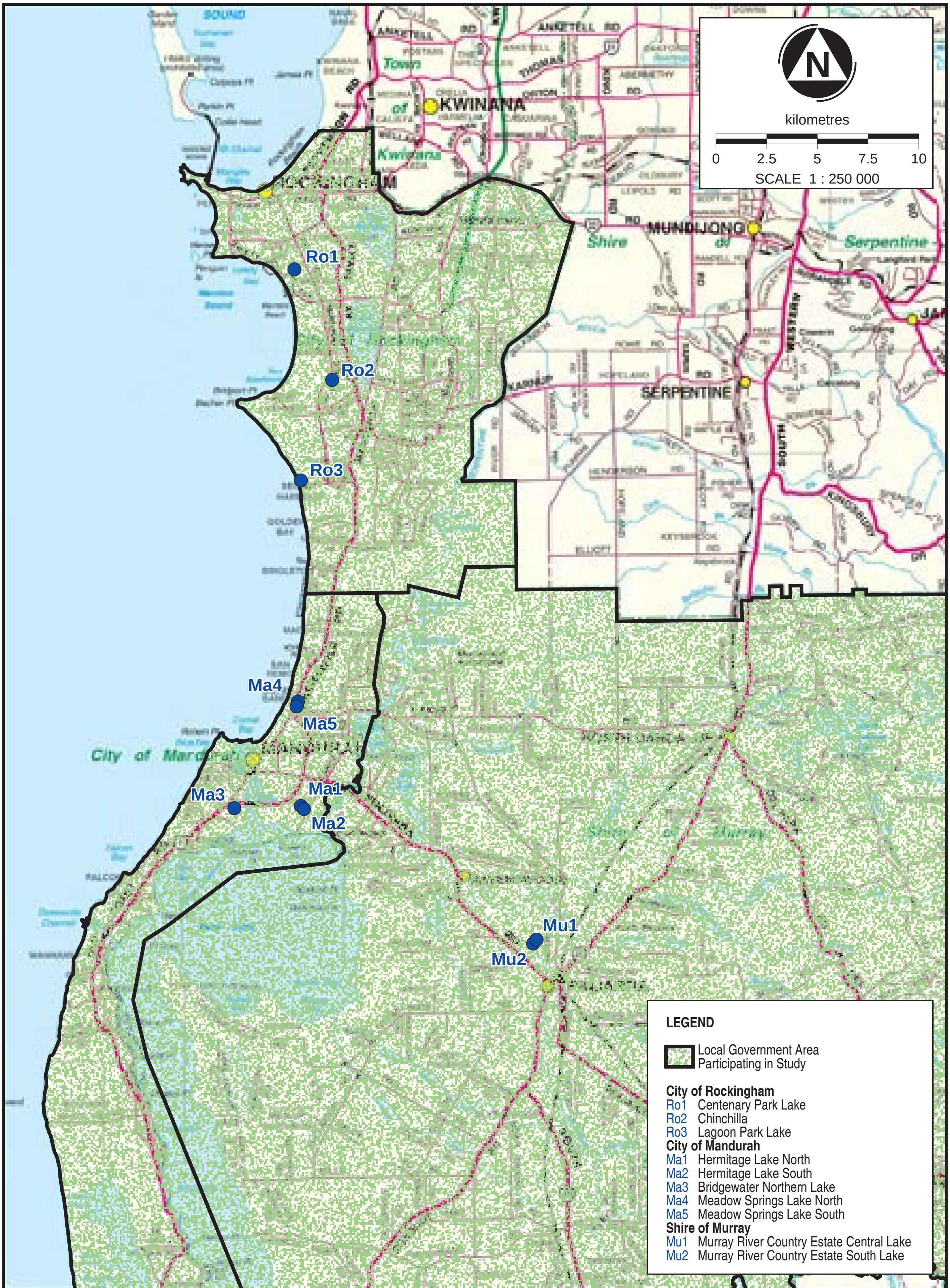

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DRAWN: CR 18-08-08
AUTHOR: BW 18-08-08

BASE SOURCE: Landgate, StreetExpress, 2007.

Department of Water
CONSTRUCTED LAKES STUDY

LAKE LOCATIONS
FIGURE 2

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DATUM: MGA50
DRAWN: CR 18-08-08
AUTHOR: BW 18-08-08

BASE SOURCE: Landgate, StreetExpress, 2007.

Department of Water
CONSTRUCTED LAKES STUDY

LAKE LOCATIONS
FIGURE 3

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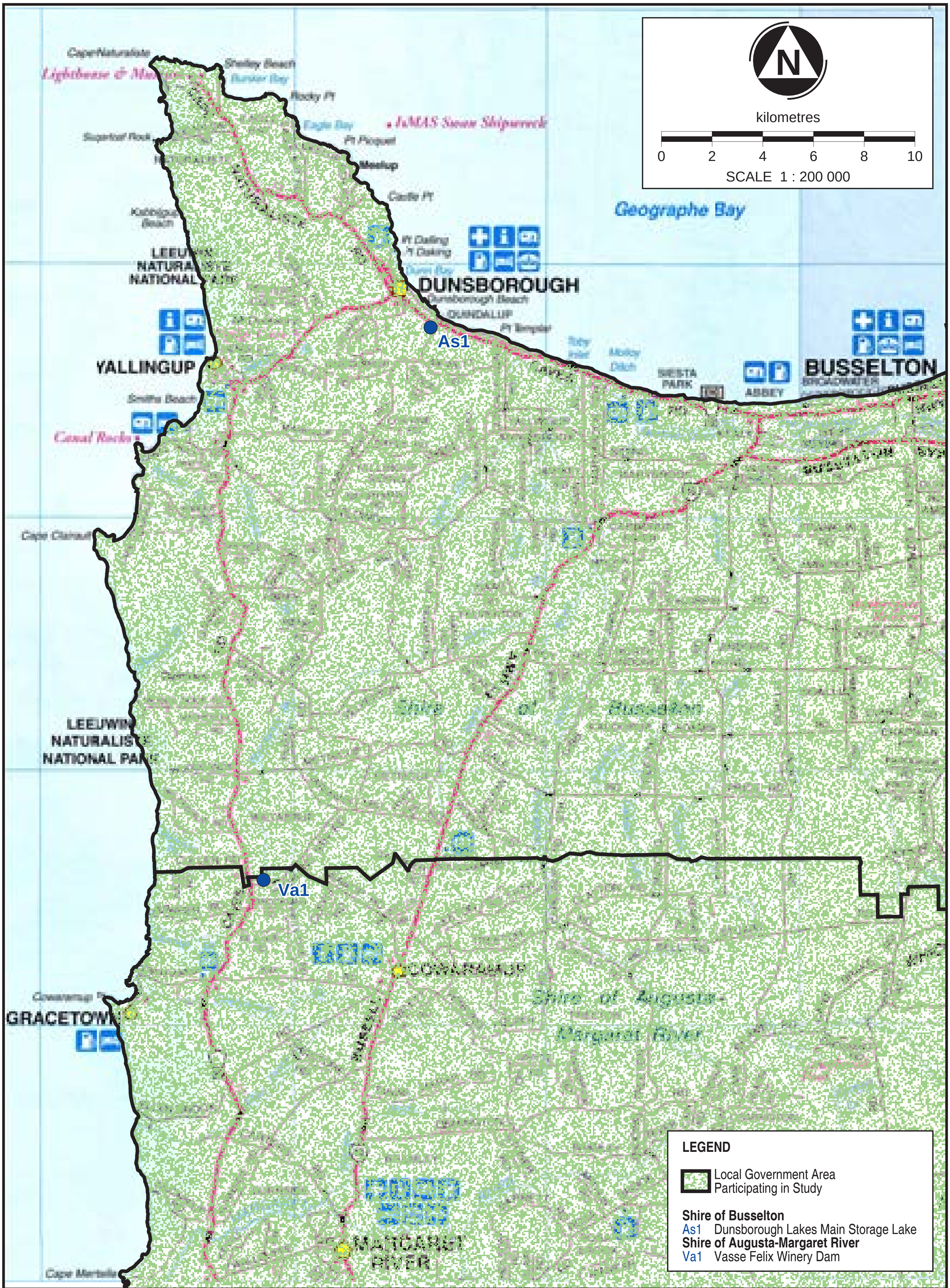


07-126-f04.dgn
DATUM: MGA50
DRAWN: CR 18-08-08
AUTHOR: BW 18-08-08

BASE SOURCE: DOLA, StreetSmart Travellers Atlas of WA, 2002.

Department of Water
CONSTRUCTED LAKES STUDY

LAKE LOCATIONS
FIGURE 4

env Australia

1.4 REPORT STRUCTURE

This report is divided in to eleven sections, including the introduction as Section 1. The main body begins with a description of the study methodology (Section 2).

Section 3 presents, a summary of four key studies of constructed lakes that were examined as part of the literature review. Key issues from relevant guidance documents on constructed water bodies and urban water management are also discussed in this section.

The key findings of the desktop study, site assessment, interviews and review of individual lake studies are described in Section 4.

Management of common problems experienced by constructed lakes, including algal blooms, midges, mosquitoes and invasion of exotic plant and fish species and the causes of these problems, are discussed in detail in Sections 5 to 8.

Section 9 outlines challenges and gaps in information identified by the study. Recommendations for future field assessment to close these gaps are in Section 10 and the final section summarises the key conclusions of the study.

2 STUDY METHODOLOGY

Forty-six constructed lakes were included in the study. The location of each lake is shown on Figures 1 to 4. Information on each of the constructed lakes was sought in relation to their design, features, function and values and whether any management problems had been experienced. Characteristics of each of the lakes were determined through reference to mapping and government databases, site assessment, interviews and review of relevant reports.

2.1 SELECTION OF LAKES

Representatives from local councils, wetland groups, the Department of Water, developers and landowners were contacted and asked to recommend lakes, with and without management problems, to be included in the study. A list of more than one hundred lakes was generated from this process.

The list of lakes was narrowed down to around 50 lakes, giving preference to lakes that were known to have been monitored or studied. The selection process aimed to include lakes with a variety of characteristics and uses, in a range of localities and with and without management problems.

The inclusion of lakes more than five years old was favoured, as it was assumed that management problems are more likely to become apparent with age. Lakes with management problems were not given preference because the aim of the study was to include lakes both with and without management problems.

Letters were sent to the owners of each of the lakes requesting formal permission to include the lakes in the study. Permission was given for most of the lakes to be included in the study. One of the lakes was not included due to resourcing issues identified by the lake manager.

Some of the lakes were removed from the study because when they were inspected it became obvious they did not fit the Department of Water's definition of a constructed lake. These were:

- Cressida Gardens "Lake" in the City of Cockburn: this is a temporarily inundated vegetated drainage basin rather than a lake. It was completely dry when visited on 18 September 2007.
- Harvest Lakes (North) in the City of Cockburn: the lake dries out in summer, and therefore is not a permanent water body.
- Dianella Regional Open Space "Lake" in the City of Stirling: this lake's primary function is to intercept drainage. It dries out in summer and therefore is not a permanent water body.

- Tom Bateman Sports Complex's two "Lakes" in the City of Gosnells: the primary function of these two water bodies is to treat stormwater, and they were primarily built for this purpose. One treats stormwater from an industrial catchment, and the other from a residential catchment. They are constructed wetlands rather than lakes under the Department of Water's definition.

The final number of lakes included in each locality is as follows:

- City of Wanneroo 4
- City of Joondalup 3
- City of Swan 6
- City of Stirling 4
- City of Bayswater 3
- City of Canning 1
- City of Gosnells 4
- City of Cockburn 3
- City of Rockingham 3
- City of Mandurah 5
- Shire of Murray 2
- City of Bunbury 4
- Shire of Capel 2
- Shire of Busselton 1
- Shire of Augusta-Margaret River 1

TOTAL 46

Some of the lakes selected consisted of more than one water body joined by short channels or piped connections and in many cases only one or two of the sections were studied, especially if the sections were considered to be functioning as separate lakes. This was to ensure that the lakes could be evaluated to a suitable level of detail in the timeframe of the project.

2.2 DESKTOP DATA COLLECTION

The desktop study involved sourcing information on the lake characteristics via sources such as geological mapping, acid sulfate soil mapping and the Department of Environment and Conservation (DEC) Wetland Base an on-line database that provides information of a number of Western Australian wetlands. The characteristics investigated for each lake during the desk top study included:

- approximate area (through examination of aerial photography);
- catchment characteristics, including catchment size and soil types;
- identification of significant catchment management issues that are likely to impact on the health of the constructed lakes;
- catchment area (not known for most of the lakes connected to drainage);
- estimation of residence time (where possible). There was sufficient information to calculate residence time for just 2 of the 46 lakes; and
- location on acid sulfate soil risk mapping.

Standardised forms were produced to record the information obtained during the study. The standardised forms are included in Appendix A.

2.3 SITE ASSESSMENT AND INTERVIEWS

Each of the constructed lakes was assessed on-site. The assessment was conducted once for each lake and included a site walkover covering the entire lake perimeter to inspect lake characteristics and validate desk-top information. The on-site assessments were conducted in spring between late August and October 2007. At this time of the year water quality would be expected to be near its best as a result of flushing from winter rain and cooler than average water temperatures.

The site visit included an on-site interview with representatives from local government or developers responsible for lake management. This interview provided additional information on the lake characteristics and management history. The representatives were asked to provide any studies relevant to the lakes during the interview.

The following characteristics were investigated during the on-site inspection and interviews:

- water level on staff gauge (if installed) and estimated depth of water;
- description of the lake edge and surrounds;

- visual observations of water quality, field measurements of water quality including pH, electrical conductivity (EC), total dissolved solids (TDS) and temperature using a water quality meter;

- visual observations of vegetation types (broad descriptions, but not a detailed botanical assessment);and

- visual evidence of above-ground or aquatic fauna both within and around the lake (terrestrial fauna and aquatic fauna assessed by observation only). This included observations of adult midge, mosquitos, birds. No sampling was undertaken.

- naturalness (subjective rating 1 to 5, from highly ornamental to ‘relatively’ natural);

- location of stormwater inlets and outlets, bores and other infrastructure;

- whether the lake outlet is visibly connected to a constructed drain, waterway or wetland (some sub-surface drains may be unknown or not visible);

- shape and presence of stagnant areas;

- evidence of acid sulfate soil impacts (e.g. visual observation of iron precipitates in water, sediments and banks) or iron monosulfide formation in sediments;

- whether the constructed lake was created by changing the geomorphology or hydrology of a natural wetland or waterway;

- other flow modification methods (e.g. transferring water between lakes or periodically drying out lakes for maintenance);

- functions/primary purposes of the constructed lake (e.g. surface water and groundwater management, irrigation storage, recreation or aesthetic purposes), generally assessed by lake managers;

- water use (e.g. how much groundwater or surface water source is used to maintain the water level);

- water balance (i.e. advice about water balance calculations, if these have been undertaken);

- age (years);

- lining and interaction of constructed lakes with the groundwater table, if known or observed;

- aeration/agitation (present/absent and type if present (e.g. fountain or riffles/waterfalls);
- other structural or non-structural management measures used or trialled and the performance of these measures (e.g. amended soils, oxygenation, gross pollutant traps, bubble-up pits at inlets, ultrasonic devices and bioremediation methods);
- fertiliser application, irrigation and lawn-mowing practices adjacent to the constructed lake;
- history of problems with odour, algal blooms, surface scums, floating plants, water quality (e.g. nutrients and suspended sediments), mosquitoes or midges, fauna deaths and dead or dying vegetation, where relevant;
- maintenance history (e.g. replacement or repair of infrastructure, cleaning, revegetation, management of erosion and vandalism, bank reformation, periodic excavation of sediment deposits, harvesting of vegetation, infill planting, litter removal and weed, algae and pest control);
- ongoing maintenance requirements and estimates of lifecycle costs;
- visual record (photographs);
- social amenity;
- community attitude towards the constructed lake and community use of the lake (e.g. walking, exercising dogs and other forms of recreation) and anti-social behaviour (if relevant); and
- known episodes of stocking the lake with appropriate fish species.

It was initially intended that the lakes would be examined for evidence of short circuiting. Short circuiting is defined as velocity heterogeneity in which some influent water remains in the wetland for a shorter time than the design residence time. In wetlands designed for water treatment this results in reduced contaminant removal (Lightbody, 2007). The constructed lakes in this study were created primarily for aesthetic purposes rather than water treatment, therefore they generally comprised of open water lacking constructed flow paths and it was considered not applicable to assess this characteristic.

The interview involved direct questions about each of the items on the standardised form (Appendix A). All interviews were recorded as MP3 files with the permission of each interviewee. The interviews are archived digitally.

Key data from both the interviews and ENV's observations and measurements were compiled onto the standardised forms contained in Appendix A. These forms give a detailed picture of the known status of each lake.

2.4 LITERATURE REVIEW

For each lake, individual studies including monitoring data and operational reports were located and reviewed, where available. Additional data on lake characteristics and management problems not identified during the desk-top study, site inspection and interviews was collated.

In addition to individual lake reports, general studies on constructed lakes were sourced to see what earlier findings were available relating to constructed lakes in general. Very few of the lake managers knew of studies with general application, although they were asked about relevant studies, and these were sourced primarily by ENV. These previous studies are discussed in Section 3.

3 PREVIOUS STUDIES AND GUIDANCE DOCUMENTS

Seven general studies related to constructed lakes were located and reviewed as part of the literature review portion of this study. These included relevant volumes of the Wetlands of the Swan Coastal Plain Series, a document providing general information and management advice for wetlands ranging from natural to highly modified water bodies, as well as three studies specific to constructed lakes.

Applicable sections of water sensitive urban design (WSUD) guidance documents are reviewed including Chapter 12 of the Australian Runoff Quality (ARQ) guide (Breen et al. 2006), the Stormwater Management Manual for Western Australia (Department of Water, 2004-2007) and Better Urban Water Management (Department of Planning and Infrastructure, Department of Water, Western Australian Local Government Authority and Department of Environment, Water, Heritage and the Arts, 2008).

In addition to the general studies and guidance documents, individual lake studies including results of water quality sampling were also reviewed. The majority of the individual studies available were in the form of monitoring data or very specific operational studies.

3.1 INDIVIDUAL LAKE STUDIES

Individual lake studies have been conducted on just over half (54%) of the lakes (Table 1). More than half (52%) of the constructed lakes in the study have never been sampled and only about a quarter (28%) are monitored regularly 1). Consequently, the lakes were not always well understood by lake managers.

Table 1: Previous Study Conducted on Constructed Lakes

	Monitored, sampled or studied to any extent (%)	*Water and nutrient balance conducted (%)*	*Sampled (%)*	*Regular water quality monitoring (%)*	*Environmental management plan report/ recommendations prepared (%)*	*Other study on lake following construction (%)*
Lakes with management problems (n=37)	62	5	57	32	16	27
Lakes without management problems (n=9)	33	0	11	11	0	33
All lakes (n=46)	54	4	48	28	13	28

While 28% of the lakes were sampled on a regular basis, sampling at other lakes was sporadic and only occurred on one or two occasions.

Nutrient (nitrogen and phosphorus) concentrations were known for only 24% of the constructed lakes. Chlorophyll *a* concentrations (an indicator of algae levels) were only known for 20% of the lakes. The amount of water quality data available varied for lakes with or without management problems.

Due to its specific nature, information from the individual lake studies is cited where relevant in other sections of the report. All previous studies on individual lakes are listed in Appendix A under individual summary reports that have been produced for each of the lakes.

3.2 WETLANDS OF THE SWAN COASTAL PLAIN SERIES

The Wetlands of the Swan Coastal Plain series published between 1993 and 1996 provide a synthesis of technical information on wetlands of the Swan Coastal Plain and a tool for wetland managers. Although the series largely focuses on natural rather than constructed water bodies, several highly modified wetlands are included as case studies, including Herdsman Lake, Lake Monger and Malaga Wetland. The following volumes were of particular relevance to this study:

- *Wetlands of the Swan Coastal Plain Volume 1: Their Nature and Management* (Balla, 1994); and
- *Wetlands of the Swan Coastal Plain Volume 6: Wetland Classification on the Basis of Water Quality and Invertebrate Community Data* (Davis et al. 1993).

Volume 1 of the series (Balla, 1994) contains general information about the wetlands of the Swan Coastal Plain and discusses issues and problems that wetland managers must be aware of including nutrient enrichment, algal blooms, midges and mosquitoes.

The key to long-term control of algal blooms in wetlands is the reduction of nutrient levels (Balla, 1994). This can be achieved via implementation of the following management measures:

- physical diversion of incoming stormwater (if contaminated due to poor management) or other nutrient rich waters, or pre-treatment of inflows, for example via buffer strips, vegetated swales or settling and infiltration areas;
- catchment management using water sensitive urban design. Water sensitive urban design includes numerous planning and design options to improve stormwater quality and reduce quantity, for example by planting native vegetation instead of deciduous trees, and directing drainage into detention and infiltration areas that recharge to groundwater rather than piped systems;
- capping or removal of nutrient rich sediments;
- flushing using good quality or pre-treated stormwater; and

- controlling erosion.

The document describes how algal blooms can also be controlled using biological techniques, for example biomanipulation, the manipulation of the lake's food chain to encourage the growth of organisms that graze on algae. Algal blooms can be controlled in the short-term using algicides however their use is not recommended due to toxic side effects on other wetland flora and fauna, including crustaceans, fish, birds and other aquatic species. This is particularly an issue with established constructed lakes that are directly connected by piped drainage to receiving natural water bodies.

In deep wetlands that undergo stratification, nutrient release from sediments can also be controlled using aeration. Stratification is the layering of water with different temperatures and/or salinity. This can result in higher concentrations of dissolved oxygen in the upper layer being prevented from mixing into the lower layer. Nutrients are released from wetland sediments when the water overlying the sediments becomes low in oxygen (anoxic). Aeration mixes the water so that more oxygen-rich water contacts the sediments causing fewer nutrients to be released from sediments.

Further sections in the document detail how midges and mosquitoes can be managed by spraying of insecticides, however, this is only considered a short-term solution that can have detrimental effects on the wetland ecosystem. Balla (1994) recommends that alternative management measures that control midges and mosquitoes in the long-term are implemented and this is confirmed by sampling of larval populations.

Further details present long-term management measures recommended for midges include:

- reducing nutrient levels, which reduces algal growth hence food availability;
- manipulating water levels so that the wetland dries out in summer;
- planting fringing native vegetation to help absorb nutrients and provide a physical barrier to the movement of midges from the wetland to residential areas.

In wetlands where mosquitoes are a problem, planting of continuous belts of dense fringing vegetation should be avoided, as the vegetation joins breeding areas with urban development therefore, providing sheltered fly paths.

The following measures are also recommended for the long-term control of mosquito populations:

- filling or draining breeding areas where this does not have an unacceptable impact on the natural environment;
- runnelling (construction of small channels to connect low lying residual pools) to flush out mosquito larvae and allow entry of predatory fish;
- the establishment of adequate buffers (at least 1.5 km) between residential areas and wetlands at the urban planning stage; and
- wetland rehabilitation to encourage natural predators of mosquito larvae, for example small crustaceans like copepods, beetles and dragonflies.

Volume 1 states that attempted control with the introduced mosquito fish, *Gambusia holbrooki,* is not permitted under any circumstances because the fish causes ecological harm and is not an effective form of control given that it preys on many species other than mosquito larvae, including native wetland invertebrates. *Gambusia* has been found to cause caudal fin damage and death to native fish species (Morgan et al. 2004). *Gambusia* also has the potential to escape into connected water bodies including natural wetlands. Populations of *Gambusia* tend to breed out of control in wetlands of the Swan Coastal Plain given they have few natural predators and are able to tolerate highly degraded and saline conditions (Morgan et al. 2004). Native fish and other native aquatic fauna are recommended to effectively and safely control mosquito larvae.

Volume 6 of the series (Davis et al. 1993) details a comprehensive study of the physical, chemical and biological attributes of 41 representative wetlands of the Swan Coastal Plain. Based on the examination of these wetlands, some very general water quality objectives and criteria are proposed for wetlands of the Swan Coastal Plain including:

- annual maximum concentrations of total phosphorus should not exceed 100 µg/L in non-coloured wetlands for prevention of problems with nuisance midges
- maximum summer total phosphorus concentrations should not exceed 165 µg/L in non-coloured wetlands to avoid the problems of excessive algal growth
- concentrations of chlorophyll *a* should not exceed 100 µg/L to avoid nuisance midges. Balla (1994) states that wetlands on the Swan Coastal Plain with chlorophyll *a* concentrations around 20 µg/L are generally healthy.

3.3 CITY OF ROCKINGHAM URBAN WETLANDS STUDY

ATA Environmental studied 73 urban wetlands in the City of Rockingham in 2003. The wetlands included:

- Drainage basins, referred to as 'created basins' that receive stormwater runoff; and
- 'Wetlands', which the study defined very broadly as created, modified and natural water bodies, including constructed lakes.

It is noted that permanent and seasonally inundated water bodies were examined in the ATA (2003) study, while in this study the definition of a constructed lake is restricted to lakes that contain water on a permanent basis. Twenty two of the urban wetlands included in the ATA (2003) study were constructed lakes by the definition in this scope of work.

The aim of the ATA (2003) study was to gain an understanding of wetlands and drainage features in urban areas within the City of Rockingham and identify measures to manage issues thereby limiting the potential for ongoing problems (ATA, 2003).

Approximately 37% of the urban wetlands and 54% of constructed lakes in the City of Rockingham were experiencing or had previously experienced management problems, indicating that man-made water bodies are more problematic. Review of the features of the urban wetlands did not reveal any specific design elements that were clearly indicative of management problems; however, certain aspects were more commonly associated with problems.

ATA (2003) found that problems of odour, algae, midges and mosquitoes in drainage basins were generally associated with poor infiltration, causing them to become boggy and causing stagnant pools to form in drier periods. The main attributes of created and modified water bodies were summarised as follows:

- water bodies more than five years old have more algal problems;
- water bodies less than 1 ha have more problems with mosquitoes and midges;
- unlined water bodies have more problems with mosquitoes and midges. The reason for this was not determined in the study, but it may be because the sediment in unlined water bodies provides a habitat for the larval stages of midges. This habitat may be limited or absent in lined water bodies;
- permanent water bodies have more problems with algal growth;
- there are fewer mosquito and midge problems in water bodies where aeration features are installed; and
- water bodies that have more natural features have fewer problems.

Based on these findings, a series of possible remedial actions in respect to the specific problems were developed, for example, installing aeration to improve circulation and to discourage midge and mosquito breeding.

Design considerations for future constructed lakes and constructed wetlands were also suggested in the ATA (2003) report. For example, they recommend undertaking geotechnical or geological investigations before construction of drainage basins to determine the soil profile and properties and to ensure the soils are suitable for infiltration. They also recommend designing and siting to promote infiltration so that they more closely replicate natural systems because natural systems reported fewer problems.

3.4 CHIRONOMID MIDGE AND MOSQUITO RISK ASSESSMENT GUIDE FOR CONSTRUCTED WATER BODIES

A risk assessment guide has been developed by the Midge Research Group of Western Australia (2007) to provide assistance to approving agencies, developers and landscape designers when assessing design characteristics of constructed water bodies in relation to midge and mosquito problems. The guide advised that midge and mosquitoes are more likely to be a problem in water bodies that:

- do not dry out and have fluctuating water levels;
- have residential housing located close (<100m) to the water's edge;
- have sloping lake edges rather than hard vertical edges (however, as outlined in Section 4.1 of the report, in healthy functioning wetlands, the presence of sloping vegetated banks do not necessarily present a midge and mosquito risk because vegetation can filter and reduce nutrients entering the lake, as well as create favourable conditions for the growth of natural predators of mosquito larvae);
- have an intricate shape or a shape that includes angles that may restrict water circulation;
- have a long axis perpendicular to prevailing wind directions;
- have a water depth less than 30 cm or greater than 2 m;
- have poor water circulation, or no mechanical aeration;
- have an absence of aquatic vegetation, or have aquatic vegetation planted in large dense stands so that mosquitoes and midges are free to colonise other parts of the water body;

- are surrounded by insufficient density or random stands of fringing vegetation that is unable to provide an effective buffer between lake and residential areas; and
- Receive inflow water with high levels of nutrients.

The guide states that there are a number of conflicts between water body design parameters directed to minimising midges as opposed to those for minimising mosquitoes. For example, midge management promotes the use of emergent vegetation for nutrient stripping because algal blooms (fueled by nutrients) provide food for midge larvae (Strano, 2001). Mosquito management, however, recognise the importance of limiting the density and area of emergent vegetation because it provides protected habitat for mosquito larvae and prevents predator access.

The guide advises that midges and mosquitoes are least likely to be a problem in water bodies that have emergent vegetation in small stands parallel to predominant wind direction, particularly where measures have been taken to reduce vegetation colonisation of remaining water body. It should also be noted that in healthy functioning wetlands, the presence of sloping vegetated banks does not necessarily present a midge and mosquito risk because favourable conditions are also provided for the growth of natural predators of mosquito larvae.

A risk matrix was presented in the guide that assigned various risk ratings to the design elements that contribute to the number of nuisance midge and mosquitoes. The risk matrix allowed a total rating score for water bodies by adding up the selected risk ratings.

The risk assessment guide can be used in assessing design characteristics for new water bodies as well as existing water bodies where there are already midge and/or mosquito problems. The determination of high-scoring parameters may allow modifications to be made to the design of the water body, for example, manipulation of water levels so that the water body dries out in summer may be required in a particular case to lower the risk rating and reduce the insect productivity of the water body.

3.5 CONSTRUCTED SHALLOW LAKE SYSTEMS – DESIGN GUIDELINES FOR DEVELOPERS, VERSION 2

The Constructed Shallow Lake Systems – Design Guidelines for Developers, Version 2 (Melbourne Water, 2005) are designed to apply to constructed lake systems in Victoria. These design guidelines are not necessarily appropriate to constructed lakes in south-west of Western Australia due to different prevailing environmental conditions including:

- interaction with superficial groundwater that often accounts for significant inflow or outflow volumes at very different water quality to the surface inflows and outflows (a major issue in south-west of Western Australia);
- different soil conditions (primarily clay soils in Victoria that have limited infiltration capacity, compared to primarily sandy soils on the Swan Coastal Plain that have high infiltration capacity); and
- relatively low summer rainfall and stormwater runoff in Western Australia compared with the Victorian climate.

Melbourne Water (2005) focused most attention on three main factors to control algal blooms in shallow constructed lakes in the Eastern States – residence time, nutrients and light availability as determined by macrophyte cover.

The residence time is the average length of time that water spends in a lake and it is a function of the volume of the lake and its inflows and outflows. Analysis of residence time in water bodies provide a very useful indicator as to whether the water body is at significant risk of algal blooms in Victoria. Long residence times (>30 days) result in a higher risk of algal blooms (Melbourne Water, 2005).

The Victorian guidelines showed that algal blooms in constructed lakes are driven by nutrients such as nitrogen and phosphorus, primarily in surface water inflows. Lakes with higher nutrient concentrations are therefore more likely to experience algal blooms. A lack of pre-treatment of inflows was considered to increase the risk of algal blooms due to the increase in nutrient inputs.

An emergent macrophyte cover of >50% of the lake area was recommended to shade the water body and to discourage algal growth. However, it was also noted that in Australian climatic conditions, surface light is rarely a limiting factor for algal growth, especially for cyanobacteria (blue green algae) because they can regulate cell buoyancy and migrate vertically, increasing their exposure to optimum light intensities.

As part of the risk assessment, it was recommended that the catchment and the lake system be modelled using an appropriate software package to predict the likely evolution of water quality and water residence time. The guidelines recommend more sophisticated water and nutrient balance studies to be undertaken triggered by adverse results from the simple residence time calculation.

The following recommendations were made for lake design and operation in Victoria:

- planting of rooted macrophytes to include a minimum of 50% aerial cover and 50% volumetric cover of the lake. Volumetric cover is the volume of the lake that is occupied by submerged macrophytes;
- pre-treatment of inflow water to reduce sediment, organic load and nutrient levels;
- design of surrounding open space to incorporate low, or preferably no fertiliser requirements;
- design the lake to take account of the likely yield of treated stormwater from the catchment so that the lake does not generally rely on top-up water from other sources;
- inclusion of indigenous flora and fauna species only;
- establishment of a maintenance agreement with the developer, council or other relevant authority; and
- development and implementation of a lake monitoring program.

3.6 AUSTRALIAN RUNOFF QUALITY – CHAPTER 12: CONSTRUCTED WETLANDS AND PONDS

Australian Runoff Quality (ARQ) is a design guideline that provides an overview of current best practice in the management of urban stormwater in Australia (Engineers Australia, 2006). Chapter 12 (Breen et al., 2006) of the document provides guidance on the design of constructed wetlands and ponds intended for stormwater management. Although this study focuses on waterbodies designed primarily for aesthetic purposes, many of the suggestions for design improvement in constructed wetlands and ponds intended for urban stormwater management are relevant to constructed lakes.

Breen et al. (2006) state that constructed wetlands and ponds can improve stormwater quality and provide wildlife habitat, however, if design is inadequate they can experience problems including:

- accumulation of litter and oil and scum at ‘dead zones’ in the wetland;
- infestation of weeds or dominance of certain species of vegetation;
- mosquito problems;
- algal blooms; and
- scouring of sediments and banks.

Breen et al. (2006) suggest that most of the above management problems could be minimised or avoided by the incorporation of design principals that lower residence times, increase the diversity of fringing vegetation and slow peak inflows. The guide considered high residence time to be a key cause of water quality problems.

Breen et al. (2006) recommend that the pond/wetland size and design of outlet control is selected with consideration to the hydrology and size of the catchment. The ratio between these factors should be sufficient to encourage regular flushing and a sufficiently lower residence time to avoid problems associated with stagnant water such as algal blooms, mosquito breeding, and oil and scum accumulation.

Water body residence time (or turnover frequency) analysis can be a useful ‘first pass’ indicator as to whether the water body is at a significant risk of water quality problems (especially associated with algal growth). The residence times of a larger water body are generally more sensitive to seasonality of rainfall.

Additional recommendations include consideration of the design of pond/wetland shape, inlet and outlet placement and morphology to eliminate short-circuit flow paths and dead zones. This can be achieved by aligning the long axis of the water body to the predominant wind direction to encourage mixing. Elimination of dead zones can also be achieved by aligning the inlets opposite to outlets along the water body’s long axis to maximise the area of the water body that is flushed. Alignment of inlets and outlets along the long axis rather than the short axis can help to minimise scouring effects.

Breen et al. (2006) advise that constructed ponds and wetlands should also be designed with a range of depths to support a specific range of plants and increased biodiversity. It is suggested the design pays adequate attention to the inundation depth, wetness gradient and the frequency of inundation to prevent a dominance of certain plant species, especially weed species over time.

Breen et al. (2006) provide advice on many small details of the design, e.g. inlet and outlet structures and erosion protection of banks should also be constructed to prevent erosion during periods of high inflow rates.

3.7 STORMWATER MANAGEMENT MANUAL FOR WESTERN AUSTRALIA

The Stormwater Management Manual for Western Australia (Department of Water, 2004-2007) strongly favours on-site infiltration or recycling of stormwater over the construction of permanent water bodies, such as artificial ponds and lakes and modified natural wetlands for the treatment or detention of stormwater. Permanent water bodies generally are not recommended due to the risk of problems with algae blooms, mosquitoes and midges. It is suggested that these problems may be a result of poorly designed systems or high nutrient inputs from the catchment to the water body.

Common examples of poor design and associated problems in permanent water bodies are described, including:

- Creation of stagnant, shallow pools of warm water, which provides ideal conditions for breeding of mosquitoes;
- Excavation of acid sulfate soils, generating large amounts of sulfuric acid and leaching contaminants naturally occurring in the soils, such as arsenic, aluminium and heavy metals; and
- The requirement for artificial maintenance of permanent water during the dry season by topping up with groundwater. This is an inefficient use of water resources and if the groundwater pumped into these lakes and ponds is nutrient-rich or contaminated with other pollutants, then it can cause further water quality problems.

A number of in-system management measures available to improve the water quality, health and environmental value of existing permanent water bodies, if they are used contrary to best practice, are recommended such as:

- Flow modification, for example, topping up lakes, transferring water between lakes or periodically drying out lakes;
- Altering the shape or depth of the open water body by excavating sediment deposits and planting or harvesting vegetation; and
- Aerators, amended soils, oxygenation, ultrasonic devices and bioremediation methods.

It is important to identify pollutant sources to select the best approaches for managing the water body. Different approaches are required depending on whether the pollutants are derived from the catchment or if there is an internal supply of pollutants from the sediments. Collection of data helps to correctly identify the causes of water quality problems, as well as assess the effectiveness of any remedial action taken.

It is suggested in the manual that these remediation techniques should be part of an integrated approach that determines the site-specific causes of the water quality problems and then seeks to remove these causes. Care should be taken to correctly apply remedial actions because some can have negative effects if applied inappropriately. For example:

- Topping up lakes with bore water that is high in nutrients can result in further water quality problems when it was expected that the decrease in residence time would be beneficial; and
- Changing water levels or water salinity can be detrimental to existing vegetation.

3.8 BETTER URBAN WATER MANAGEMENT

Better Urban Water Management (Department of Planning and Infrastructure, Department of Water, Western Australian Local Government Authority and Department of Environment, Water, Heritage and the Arts, 2008) is a guidance document designed to facilitate better management and use of urban water resources by ensuring an appropriate level of consideration is give to the total water cycle at each stage of the planning process.

The guidance document specifies special requirements for new constructed water bodies throughout the integrated water management and planning stages. At the local planning stage, which is where a constructed water body is initially proposed, the guideline requires that it is depicted on the structure plan, together with information in the local water management strategy outlining the purpose and design of the waterbody. The guidance document also requires a proposed schedule for management and ongoing maintenance of the constructed water body and the recommended transfer process to local government, including funding requirements.

At the subdivision stage, detailed information supporting the purpose, design and the management of any proposed constructed water body, including an assessment of lifecycle costs (including replacement) is required in an urban water management plan (UWMP). While a water and nutrient seasonal balance is not specified for the scope of the UWMP, it can sometimes be added as part of a planning condition imposed by the Western Australian Planning Commission (WAPC).

4 KEY FINDINGS

The key findings of the desktop study, site assessment, interviews and review of individual studies for the 46 constructed lakes investigated are summarised in Table 2 and described in the sections below.

4.1 PHYSICAL LAKE CHARACTERISTICS

4.1.1 Drainage and Irrigation Function

Most lakes (approximately three quarters) are a central feature within residential developments and considered highly valued within the community for their aesthetic and recreational value. However, the majority of the constructed lakes included in the study serve a purpose beyond the purely aesthetic:

- most of the lakes (87%) are connected to drainage, although, this does not necessarily mean they perform a significant drainage function. For example the lake may not provide any storage for detention and flood control if water levels are artificially maintained;
- almost half of the constructed lakes (46%) are used for irrigation. Just over half (11) of the 21 irrigation lakes are lined and are topped up with bore water;
- three of the 14 lined lakes are not used for irrigation;
- many of the lakes (37%) serve a dual purpose, being connected to drainage and also used for irrigation; and
- only two of the 46 lakes (4%) are not connected to drainage or used for irrigation.

At least 11 of the 46 lakes are known to be connected to natural wetlands via the drainage system and 34 of the 46 lakes intercept groundwater.

4.1.2 Age, Size and Depth

Just over one third (35%) of lakes included in the study were between five and ten years old. Approximately 37% were between ten and twenty years old, and 20% were more than 20 years old. Only one lake under five years old was included in the study because older lakes were chosen preferentially. The age of 7% of the lakes was unknown.

The lakes ranged in area from very small (0.05 ha) to over 12 ha, and their shape also varied. An approximately equal proportion of the lakes were rounded or oval (33%), irregular (33%) or linear/elongated (30%) and a few (4%) were triangular.

Most of the constructed lakes in the study were shallow systems with almost half (48%) with estimated depths of 2m of less. The estimated depth of the deepest lakes was under 8m.

4.1.3 Modification of Natural Waterways

Based on interviews with lake managers, at least eight of the 46 of the constructed lakes were created by the modification of natural water bodies, although these lakes retained few of the original wetland features. The previous land use of 17 of the lakes was unknown therefore it is likely that there are more lakes that were created from natural water bodies. Generally, an ornamental lake appearance was favoured over a more natural one. Very few of the lakes were located in a natural setting, with the majority of the perimeter of most lakes comprising of sloping earth banks with some or with minimal fringing native vegetation.

4.1.4 Ground Maintenance

More than 90% of the constructed lakes in the study are surrounded by grassed and landscaped public open space ('POS') areas that require maintenance. Ground maintenance typically involves a combination of fertilisation, mowing of turf and spraying to eliminate weeds. In many cases, lake managers were unfamiliar with the ground maintenance practices around the lakes because lawn maintenance was the responsibility of a different section within the local government.

Where fertilisation regimes were known, 29% of POS areas adjacent to the lakes were not fertilised and 45% were subject to minimal fertilisation regimes and/or fertilised using low phosphate, phosphate-free or slow-release forms of fertiliser. The remaining 26% lakes had a more conventional fertiliser regime, centred on the use of phosphate based fertilisers. This indicates awareness by lake managers that fertiliser use near water bodies can result in water quality problems because a minimal fertiliser regime is most common.

4.1.5 Aeration

Aeration features are installed in just over half (59%) of the lakes included in the study. In approximately half of the 27 artificially-aerated lakes, the aeration features serve an ornamental rather than a functional purpose because they produce visible surface features, such as small fountains or landscaped waterfalls, but do not appear to create substantial subsurface mixing. Aeration in at least eight of the lakes was installed to deliberately serve a functional purpose, including the management of algal blooms, and iron and heavy metal removal.

Table 2: Summary of Key Lake Characteristics

Local Government Area (Listed from North to South)	Lake Name	Lake ID	Connected to Drainage (Y/N)	Used for Irrigation (Y/N)	Lined (Y/N)	Aeration Present (Y/N)	Recorded Management Problems (Y/N)	Algal Blooms Reported (Y/N)	Approximate Age (Years)	Approximate Area (ha)	Shape*	Naturalness Rating**	ASS Risk***	# Inlets	# Outlets
City of Wanneroo	Ridgewood Park Lake	Wa1	Y	Y	Y	N	Y	Y	15	0.19	R	1	0	-	-
	Carramar Golf Course Lake	Wa2	N	Y	Y	N	N	N	16	2.05	R	3	0	0	0
	The Duck Pond	Wa3	N	Y	Y	Y	Y	Y	-	0.18	R	1	0	0	0
	Brighton Central Lake	Sa1	Y	Y	Y	Y	Y	Y	6.5	1.64	I	1.5	0	-	1
City of Joondalup	Joondalup Central Park Lake	Jo1	N	Y	Y	Y	Y	Y	15	0.75	I	2	0	0	0
	Broadbeach Lake North	Jo2	Y	N	N	N	Y	Y	-	0.52	I	3	0	-	-
	Broadbeach Lake Central	Jo3	Y	N	N	Y	Y	Y	-	0.26	L	3	0	-	-
City of Swan	Emu Lake	Sw1	Y	N	N	Y	Y	Y	27	12.80	I	2.5	2	11	0
	Lake Fresca	Sw2	Y	N	Y	N	Y	N	9	2.88	I	1	1	7	1
	Mornington Park Lake	Sw3	N	N	N	Y	N	N	9	0.13	I	2	2	0	0
	Sandown Park Lake	Sw4	Y	Y	Y	Y	Y	N	5.5	4.05	I	1	1	3	0
	Sacromento Park	Sw5	Y	N	N	N	N	N	22	0.66	R	3	1	1	1
	Woodlake (Main Lake)	Sw6	Y	Y	N	Y	Y	Y	12	5.71	I	2	1	5	2
City of Stirling	Jackadder Lake	St1	Y	N	N	N	Y	Y	50	7.43	R	3.5	2	8	1
	Shearwater Spoonbill North	St2	Y	N	N	Y	Y	N	> 20	0.90	L	3.5	2	3	1
	Shearwater Spoonbill South	St3	Y	N	N	Y	Y	N	> 20	1.30	L	3.5	2	4	1
	Bradford St Lake	St4	Y	Y	Y	N	Y	Y	> 20	0.36	R	2	2	4	1
City of Bayswater	Lake Bungana	Ba1	Y	N	N	Y	Y	N	8	-	I	3	2	3	-
	Lake Bungana Irrigation Lake	Ba2	Y	Y	N	Y	Y	Y	8	-	R	3	2	3	1
	Lake Brearley	Ba3	Y	N	N	N	Y	N	7	9.02	I	3	2	2	1
City of Canning	Whaleback Golf Course Lake	Ca1	Y	Y	N	N	Y	N	28	1.15	L	3	1	1	1
City of Gosnells	Sandringham Prom Reserve 2	Go1	N	Y	Y	Y	N	N	11	0. 868	L	1	1	0	1
	Prior Close Reserve Lake	Go2	Y	N	N	Y	Y	Y	11	1.69	L	2	1	1	1
	Alexandria Bvd Reserve Lake	Go3	Y	N	N	Y	Y	Y	12	6.44	I	2	1	7	1
	The Bridgeway Lake	Go4	Y	N	N	Y	Y	Y	6.5	1.63	L	2	2	1	1
City of Cockburn	Christmas Tree Park Lake East	Co1	Y	N	N	N	N	N	6	0.18	L	3.5	1	1	1
	Christmas Tree Park Lake West	Co2	Y	Y	Y	Y	Y	N	6	0.31	R	2.5	1	2	0
	Harvest Lakes South	Co3	Y	Y	Y	Y	Y	Y	3.5	1.47	R	2	1.5	4	0
City of Rockingham	Centenary Park Lake	Ro1	N	N	N	Y	Y	Y	8	0.30	L	1.5	0	0	0
	Chinchilla	Ro2	Y	N	N	Y	N	N	5	0.08	R	1	0	3	0
	Lagoon Park Lake	Ro3	Y	Y	N	Y	N	N	11	1.05	I	3.5	0	1	0
City of Mandurah	Hermitage Lake North	Ma1	Y	Y	N	N	Y	N	17	0.74	R	3	0	2	1
	Hermitage Lake South	Ma2	Y	N	N	N	Y	N	17	0.59	R	3	0	2	1
	Bridgewater Northern Lake	Ma3	Y	Y	N	Y	Y	Y	17	1.25	I	3	2	3	1
	Meadow Springs Lake North	Ma4	Y	N	N	N	Y	Y	13.5	0.78	L	3	0	2	1
	Meadow Springs Lake South	Ma5	Y	Y	N	N	Y	Y	13.5	0.70	L	3	0	3	0
Shire of Murray	Murray River Country Estate Central Lake	Mu1	Y	Y	N	Y	Y	N	12	0.57	R	3	1	3	1
	Murray River Country Estate South Lake	Mu2	Y	Y	N	Y	Y	N	12	1.71	L	3	1	3	1
City of Bunbury	Pelican Point Lake	Bu1	Y	N	Y	Y	Y	Y	12	1.65	T	1	2	3	1
	Queens Gardens Lake	Bu2	Y	N	N	N	Y	N	22	-	I	3	2	1	1
	West Road Lake	Bu3	Y	N	N	N	Y	N	50	0.05	R	2	1	2	1
	Fenian Park Lake	Bu4	Y	N	N	N	Y	N	20	2.37	L	3	1	4	0
Shire of Capel	Dalyellup Beach Central Park North Lake	Sa1	Y	Y	N	Y	Y	N	7	2.50	I	3	1.5	4	1
	Dalyellup Beach Fountain Lake	Sa2	Y	Y	Y	Y	N	N	8	0.12	R	1	1.5	1	0
Shire of Busselton	Dunsborough Lakes Main Storage Lake	As1	Y	N	Y	N	Y	N	10	3.07	L	3	2	6	1
Shire of Augusta-Margaret River	Vasse Felix Winery Dam	Va1	Y	Y	N	N	N	N	20	1.50	T	3-4	0-1	2	1
	TOTAL (Y)		40	21	14	27	37	20							
	TOTAL NUMBER OF LAKES		46	46	46	46	46	46							
	PERCENTAGE (Y)		87	46	30	59	80	43							

Notes:

* Shape:
R - Rounded/ Oval
L - Linear/ Elongate
I - Irregular
T - Triangular

** Naturalness Rating
1 - Highly ornamental
5 - Natural or natural like

*** ASS Risk:
0 - No known risk of ASS
1 - Low-moderate risk of ASS
3 - Moderate to high risk of ASS

\- Data not available within timeframe of study

4.2 NUTRIENT AND CHLOROPHYLL *A* CONCENTRATIONS

Nutrient (nitrogen and phosphorus) levels and chlorophyll *a* concentrations (an indicator of algal levels) were known for less than a quarter of the lakes. Nutrient and chlorophyll *a* concentrations are summarised in Tables 3, 4 and 5 and compared to local target levels set by the Davis et al. (1993), Balla (1994) ,reviewed in Section 3.1, and by the Environmental Protection Authority (1993). Due to the lack of data and to allow for comparison with guidelines, nutrient and chlorophyll *a* are summarised as maximums rather than averages.

Table 3: Total Nitrogen Concentrations in 11 Constructed Lakes (µg/L)

	*EPA (1993) Target Levels **	*Range of Maximums*	*Average Maximum*
Lakes with previous reports of algal blooms	100 – 500	<110 - 17,000	4,600
Lakes with no previous reports of algal blooms		16 - 1,700	1000

* Target levels vary for particular site-specific conditions

Table 4: Total Phosphorus Concentrations in 11 Constructed Lakes (µg/L)

	Davis et al. (1993) *Target Level*	*Range of Maximums*	*Average Maximum*
Lakes with previous reports of algal blooms	165	17 - 7,600	1,300
Lakes with no previous reports of algal blooms		20 - 1,700	800

Maximum total nitrogen and total phosphorus concentrations were higher in lakes that had reported algal blooms than in lakes with no reported blooms (Tables 3 and 4). This supports the widely endorsed link between higher nutrient concentrations and algal blooms.

The target levels for total nitrogen and total phosphorus have been substantially exceeded and have occurred in lakes even when no algae blooms are reported. However, the maximum concentration of total nitrogen recorded in the lakes that had reported algal blooms (17,000 µg/L) was approximately 34 times the maximum target level of 500 µg/L set by the Environmental Protection Authority (1993) and the maximum concentration of total phosphorus (7,600 µg/L) was 46 times the target level set by Davis et al. (1993).

Chlorophyll *a* concentrations in lakes that had not reported algal blooms were at healthy levels (<20 µg/L) (Balla, 1994) (Table 5). The maximum concentration of chlorophyll *a* recorded in the lakes that had reported algal blooms (340 µg/L) was approximately 17 times healthy levels for Swan Coastal Plain wetlands (Balla, 1994) and over three times higher than levels recommended to avoid problems with nuisance midges (Davis, 1993).

Table 5: Chlorophyll *a* Concentrations in 9 Constructed Lakes (µg/L)

	Balla (1994) Target Level	*Davis (1993) Target Level*	*Range of Maximums*	*Average Maximum*
Lakes with previous reports of algal blooms	20	100	5-340	101
Lakes with no previous reports of algal blooms			4-14	9

4.3 MANAGEMENT PROBLEMS

In this study, a management problem is defined as any issue experienced by a constructed lake that:

- is perceived by the lake manager to pose public health or amenity issue or compromise the ecological integrity of the lake or any connected water bodies; and
- has been reported to the lake manager.

Because of their aesthetic and recreational values, management issues related to constructed lakes are typically of great concern to the community. Lake managers commonly become aware of problems following complaints from surrounding residents.

Most of the constructed lakes studied (80%) have experienced or are experiencing management problems of some type, not just eutrophication issues. This is higher than the 54% of constructed lakes in the City of Rockingham identified by ATA (2003) to have past or present management problems. As with the ATA (2003) study, the management problems were dominated by issues associated with eutrophication (excessive nutrients) including algae blooms and midges. One or more of these problems were reported in half (23 of the 46) lakes (Table 6). Not only were the eutrophication issues the most common, they were also considered by lake managers to be the most pressing due to their potentially serious environmental, health and aesthetic effects.

It is noted that the frequency of management problems in lakes may be higher than is indicated by the results of the field survey, interviews and literature review. Very few of the lakes are monitored on a regular basis therefore most problems are only identified when local residents complain and it is possible management problems have gone unreported.

Table 6: Frequency of Management Problems

Management problem	*Number of lakes reported to have problem*
Nuisance algal growth	20
Gross pollutants	10
Mosquitos/ midges	9
Feral Fish i.e. Koi carp	9
Invasion of exotic plant species	9
Infrastructure maintenance e.g. fountains, pumps, swales	9
Odour	6
Poor visual appearance, including drying out	5
Issues associated with bore water top up	5
Acidity	3
Iron monosulfides	2
High bacteria levels	2
Oil slicks	2
Flooding	2
Fish deaths	1
Fire	1

The most frequent management issues not associated with eutrophication are gross pollutants, invasion of feral fish and exotic plant species and the maintenance of infrastructure (Table 6).

Odour, poor visual appearance, mainly associated with lakes drying out and issues associated with bore water top-up were also frequently reported issues.

Acidity and associated problems with iron monosulfides, high bacteria levels, oil slicks, fish deaths and fire were serious, but less frequently reported problems. Each of these problems was recorded in three or fewer of the lakes. Interestingly, flooding was a less frequently reported problem than drying.

Common issues, their causes and approaches to management are discussed in more detail in Sections 5 to 8.

4.4 COST OF PROBLEM MANAGEMENT

Local government representatives responsible for managing constructed lakes indicated that councils usually feel burdened with the cost of dealing with the management issues, which they feel they had little ability to prevent because of the lack of involvement in the design and construction of the lakes.

Previous work conducted by ENV indicates that the cost of managing problems that occur in constructed lakes can be in the order of several hundred thousand dollars per lake per year. For example, the cost of applying Phoslock to control algal blooms at Emu Lake (an approximately 12.8 ha water body) in the City of Swan was more than $140 000 per application (ENV, 2008). This does not include associated monitoring costs. Preliminary water quality monitoring data indicates repeated treatment or alternative nutrient controls may be required, possibly within a year of application (ENV, 2008).

Lake managers reported that the capital cost of installing aerators and ultrasonics to control algal blooms in Central Lake in Joondalup was over $30,000 and $8,000 respectively (date of installation is uncertain).

Management measures to control algal growth often have only temporary success and need to be repeated. The recent use of cupricide, a copper-based algicide to control blue-green algal blooms in the Bridgeway Lake in the City of Gosnells cost only $400 per application according to the developer although it is understood that repeated annual treatments are required. Algicide application is not recommended as it can result in other costs, such as death of native aquatic flora and fauna.

Costs could not be readily provided by lake managers for any of the other management measures cited in the study. Generally the cost was absorbed into other budgets, such as parks and garden budgets or general maintenance budgets for local authorities.

5 ALGAL BLOOMS

As shown in Table 6 almost half (20 of the 46) of the lakes in the study had reported problems with algal blooms. Algal blooms can have significant ecological and aesthetic impacts. Potentially toxic species of blue green algae can pose a serious public health risk.

5.1 CAUSES

In order to grow and reproduce, algae require water, nutrients and light. Nitrogen and phosphorus are the most important nutrients because these are required in large quantities for cell development, yet, they are often in short supply under natural conditions. Other common nutrients needed in large quantities for algal cell development include iron and oxides of sulphur and silicon. Important minor nutrients include manganese, cobalt, molybdenum, copper and zinc (Horne and Goldman, 1994).

Factors reported to encourage algal blooms (Balla, 1994, Boulton and Brock, 1999 and Breen et al. 2006) include:

- poor turnover (long hydraulic residence time);
- high concentrations of nitrogen (>100 - 500 µg/L – Environmental Protection Authority, 1993);
- high concentrations of phosphorus (>165 µg/L – Davis et al. 1993);
- still water;
- low turbidity and lack of shading enabling more light penetration;
- stratification (associated with deeper water bodies);
- warm temperatures (algal blooms are more common in summer); and
- a lack of zooplankton grazing.

The first three factors are discussed below because they are the ones identified by the literature to be the most useful indicators of the risk of algal blooms in constructed lakes.

5.1.1 Residence Time

Long residence times (>30 days) result in a higher risk of algal blooms (Boulton and Brock, 1999 and Melbourne Water, 2005). Of the 46 lakes in the study, it was possible to calculate the residence time only for Emu Lake, as for the other lakes there was insufficient information to quantify the volume of the lakes and their inflows and outflows, particularly the groundwater contributions.

The residence time of Emu Lake was estimated to be approximately 82 days, which is considered long by the Melbourne Water (2005) standards. The primary reason for Emu Lake's long residence time is the fact the lake does not have an outlet. Water can only leave the lake through groundwater outflow and evaporation. The lake is experiencing major problems with cyanobacteria (blue green algae) blooms and the long residence time, combined with high nutrient concentrations, is likely to be the cause.

5.1.2 Nutrients

High concentrations of the major nutrients, nitrogen and phosphorus, result in a higher risk of algal blooms in water ways (Balla, 1994 and Boulton and Brock, 1999). As discussed in Section 3.1, most of the constructed lakes in the study have not been sampled. Nutrient (nitrogen and phosphorus) concentrations were known for only 24% of the constructed lakes. Maximum recorded concentrations of nitrogen and phosphorus were higher in lakes that had reported algal blooms than in lakes with no reported blooms (Table 3 and 4). This indicates a link between high nutrient concentrations and algal blooms in constructed lakes.

5.1.3 Age

Typically older constructed lakes experienced more problems with algal blooms as older lakes would have more time to accumulate nutrients. Of the 25 lakes that were older than 10 years, 11 reported problems with algal blooms, whereas only 5 of the 21 lakes that were 10 years or younger reported similar issues.

5.1.4 Design Characteristics

Selected design characteristics of lakes with and without algal blooms were examined to identify whether there were any key features that may be conducive or preventative to algal blooms that were worthy of further investigation.

These factors included:

- Location on the acid sulfate soil (ASS) risk map;
- Geology;
- Drainage features, including number of inlets and outlets;
- Shape;
- Alignment of lake to predominant wind direction;

- Irrigation use;
- Mechanical aeration;
- Fertilisation of lake surrounds;
- Naturalness rating;
- Lining; and
- Area.

The link between these design factors and algal blooms was examined qualitatively by visually examining the data plotted on graphs (Appendix B). The analysis found no clear links between particular design features and algal blooms.

Some preliminary statistical analysis was undertaken to determine whether factors were significantly different for the groups with and without algal blooms. No substantial differences were revealed and there were interdependences between the factors making analysis more complex.

The statistical analysis was not continued further as a larger sample size would be required to statistically analyse the information due to the large number of factors.

Algal blooms were reported in lakes with a wide range of features. For example, both lined and in unlined lakes and lakes with both a regular and irregular shapes had reported algal blooms. Therefore no particular design feature could be conclusively linked to algal blooms.

5.2 MANAGEMENT

As discussed in Section 4.3, algal blooms were the most common management problems affecting constructed lakes. A variety of management measures have been implemented to control algal blooms in the lakes examined in the study (Table 7).

Table 7: Management Measures Implemented to Control Algal Blooms

Management measure	*No. of lakes technique trialled*
Aeration	5
Sediment capping using Phoslock	4
Planting of native vegetation to uptake nutrients	3
Algicide	2
Sludge/sediment removal or deepening of lake	2
Installation of gross pollutant traps (GPTs) to reduce nutrient loads associated with gross pollutants, such as organic debris from stormwater	2
Manual removal/ weed harvesting	2
Filtration/particulate settling to remove nutrients in particulate matter	1
Ultrasonics	1
Volcanic ash	1
Modification of water and nutrient balance to reduce nutrient loads	1
Hay bales to remove nutrients	1
Artificial colorants to reduce light penetration	1
Alum dosing	1

Management measures had not been implemented at seven of the twenty lakes that had reported algal blooms. Eight lakes had multiple measures tried and five lakes had one measure applied. Information was not available for two of the lakes.

The effectiveness of many of the management measures in controlling algal blooms is uncertain, especially in the long-term, because many measures were implemented only recently and most of the lakes were not monitored following the implementation. There was enough information to determine if all of the management measures had been effective or not in the long-term in only four of the lakes as outlined below.

5.2.1 Jackadder Lake (City of Stirling) – Example of Successful Algae Control

The only management measure that appeared to have long-term success in controlling algal blooms was the modification of the water and nutrient balance to reduce nutrient loads in Jackadder Lake. The water that was normally redirected into the lake from the Osborne Park Main Drain outlet to maintain water levels in summer was identified by a water and nutrient balance study (JDA, 1992) to be a major source of nitrogen and phosphorus.

Following the findings of the 1992 water and nutrient balance the redirection of nutrient rich water from the Osborne Park Main Drain into the lake in summer was reduced. In addition, community catchment management measures (i.e. education of the public to modify household and business practices, such as reducing fertiliser use) contributed to reduction of nutrients levels in the lake. The management measures implemented, altered the water-nutrient balance and have successfully reduced the susceptibility of Jackadder Lake to algal blooms.

5.2.2 Artificial Aeration

Artificial aeration was the most common management measure implemented to control algal blooms. Submerged aerators or recirculation systems have been installed to encourage circulation and oxygenation of the water to discourage algal blooms in five lakes.

As discussed in Section 3.1, aeration brings oxygen-rich water in contact with the sediment in otherwise stratified water bodies. This further discourages nutrient release from the sediment (Davis et al. 1993).

Aeration and mixing of a stagnant or thermally-stratified eutrophic water body can further discourage algal blooms by creating an oxidising environment in the water column. This shifts the chemical balance from soluble phosphorus to insoluble forms by reducing the surface water temperature. Aeration and mixing can also encourage green algae to come to the lake surface and compete with more buoyant, and potentially toxic, blue-green algae. Violent mixing can also physically damage algae (Kirke, 2001).

Aeration was observed by lake managers to be successful in reducing algal blooms in two of the five lakes (Joondalup Central Park Lake and The Duck Pond in the City of Wanneroo). The lake manager reported that aeration was unsuccessful in preventing algal blooms in one lake (Brighton Central Lake) (Mike Williams pers. comm. 10/10/2007). The effect of aeration in two lakes (Broadbeach Central Lake and Harvest Lakes South) was unknown as sufficient information to substantiate the effect of aeration on algal levels was not available for these lakes.

Installation of five submerged aerators in Joondalup Central Park Lake in combination with other management measures, including planting of native vegetation and sludge removal, was claimed to have eliminated algal problems, in the short-term. According to the council's Parks Supervisor responsible for the management of the lake, aeration has improved circulation, increased dissolved oxygen levels and made the water temperature more even, and this has reduced algal levels. Sludge removal and planting of reeds around the lake also is considered to have assisted in controlling algal growth and these actions are likely to have removed nutrients from the system.

In The Duck Pond, an aeration and recirculation system was installed in about 2004 to treat algal blooms in the lake. Water is pumped into a settling tank to remove nutrients bound in particulate matter, then oxygenated via an ozone treatment and finally flows over a waterfall back into the lake. It is claimed that water quality improved following installation of the aeration/recirculation and settling tank system (Aquatic Solutions and Mirvac, 2006). However, when the site was visited on 28 August 2007 the water appeared turbid and green, indicating elevated levels of algae.

A recirculation system and submerged aerator were installed at Brighton Central Lake to oxygenate the water to treat algal problems, however, this does not appear to have reduced algal levels. Recently the water has been turbid and green/brown, indicating high concentrations of microalgae.

A submerged aerator was installed at the end of the 2006/2007 summer in Broadbeach Central Lake. It is not known whether the aeration has been successful in reducing algal blooms because at the time of the site visit and interview the aerator had not been in place for the entire summer, which is when algal blooms normally occur in the lake.

It is also not certain whether the single submerged aerator at Harvest Lakes South has had any effect on algal blooms. Water quality has been monitored at Harvest Lakes South and results show that chlorophyll *a* concentrations have been lower in 2006 and 2007 than in 2005. Nuisance algal growth also has not been reported as a problem recently by local residents. However, the local government representative did not know if the reduced algal concentrations are due to aeration as the installation date of the aerator was not known.

5.2.3 Sediment Capping using Phoslock

Sediment capping using Phoslock was the second most popular measure for managing algal blooms, after aeration. Phoslock is a modified clay compound that binds dissolved phosphorus from the water column and inhibits the release of phosphorus from the sediment.

Sediment capping using Phoslock is costly (thousands of dollars per hectare) and often only provides a short term solution to algal problems due to its limited capacity to bind new inputs of phosphate such as those in stormwater and groundwater inflows. Available data on constructed lakes indicates if Phoslock is used as the sole management option in lakes with serious eutrophication problems, repeated treatments are likely to be required on an annual basis to control algal blooms in the long- term.

Phoslock reduced algal levels in Emu Lake (City of Swan) and Centenary Park Lake (City of Rockingham) only in the short-term. Algal levels subsequently increased within a month of application at Emu Lake and within a year of application at Centenary Park.

Phoslock applied to the Lake Bungana irrigation lake in Maylands in early 2007 worked in the short-term to eliminate a blue-green algae bloom, however insufficient information was available within the timeframe of reporting to establish its long-term effect. The effect of Phoslock in the Prior Close Reserve Lake in the City of Gosnells is unknown because algal levels were not monitored after the application.

5.2.4 Native Vegetation

Planting native vegetation to take up nutrients in Emu Lake appeared to have no effect in reducing blue-green algal blooms. In Joondalup Park Central Lake it was claimed to have some effect, combined with aeration and removal of sludge from the bottom of the lake. In Jackadder Lake its effect is unknown, because planting of fringing vegetation around the lake was undertaken in conjunction with the reduction of the volume of nutrient-rich water redirected into the lake from the Osborne Park Main Drain outlet, which is discussed in Section 5.2.1.

Most of the lakes were surrounded by walls or grassed banks. The benefits of native vegetation can not be assessed in this study because the presence of fringing vegetation was generally nonexistent or minimal.

5.2.5 Algicide and Alum Dosing

Algicide reduced algal levels only in the short-term in Joondalup Central Park Lake and The Bridgeway Lake in the City of Gosnells and required repeated applications in both cases. Alum dosing in the late 1980s also had only short-term impacts on reducing algal levels in Jackadder Lake (Lund and Chester, 1989). Algal levels increased once nutrient-rich water from the Osborne Park Main Drain outlet was redirected into the lake to maintain water levels during the following summer (Section 5.2.1).

Algicides should not be used to control algal blooms, especially if a constructed lake is directly connected to the natural system. Algicides are toxic to aquatic flora and fauna, including crustaceans, fish, wetland birds and other aquatic species (Department of Water, 2007).

5.2.6 Particulate Removal

Particle removal was the only other management tool in Table 7 that reported any measure of success. It was used in one lake. Particulate removal via a settling pond was used in conjunction with aeration in Duck Lake and was claimed to have short-term success in reducing algal levels. However, its long-term success is questionable because algal levels appear to have increased in the lake again, as discussed in Section 5.2.2.

5.2.7 Management Tools with No Proven Impact

In many cases, the monitoring and/or observations were insufficient to demonstrate efficacy of the measures at reducing algal levels. Some examples include:

- The effect of deepening of Bridgewater Northern Lake, combined with the installation of gross pollutant traps (GPTs) and manual removal of macroalgae, on algal levels is unknown because the lake is not monitored. It is noted that GPTs are not designed to remove nutrients and there is no expected removal of nutrients using these devices (Fletcher et al. 2003 and Martens et al. 2005); and

- Harvest Lakes South was the only lake known where hay bales were used to remove nutrients. The effect of the hay bales on nutrient levels is unknown due to a lack of adequate monitoring data and the date when the hay bales were introduced being unclear.

Some management measures did not demonstrate any effects, for example:

- the installation of GPTs in Emu Lake (as discussed above, GPTs are not designed to remove nutrients because the nutrients are generally soluble or in particulate matter that is too small to be captured by GPTs);

- manual removal of algae and the application of a blue dye to reduce light penetration, which was not successful in eliminating filamentous green algae from Centenary Park Lake because observed algae remained;

- the use of ultrasonics (high-intensity acoustic energy designed to damage algal cells) in Joondalup Central Park Lake was reportedly unsuccessful however details could not be sourced; and

- a trial of the application of volcanic ash (possibly due to its phosphorus binding capacity) in Broadbeach Central Lake was also not reported in detail by the lake manager who indicated that it was unsuccessful.

6 MIDGE AND MOSQUITOES

Table 6 shows that 9 of the 46 lakes in the study had reported problems with midges and mosquitoes. Midges and mosquitoes breed in water bodies, including constructed lakes, and excessive numbers cause nuisance and amenity issues, commonly resulting in public complaints. Mosquitoes can also be vectors of Ross River Virus and other diseases.

6.1 CAUSES

The presence of algae caused by nutrient enrichment is generally associated with midge problems. This is because algae provides favourable environmental conditions that encourage the rapid growth of midge larva (Strano, 2001).

Different mosquito species vary in their breeding habits, however as with midges, mosquito larvae numbers increase with increased nutrient availability in water bodies. Warm water temperatures also encourage both midge and mosquito breeding (Strano, 2001 and Department of Health, 2004).

A risk assessment guide developed by the Midge Research Group of Western Australia (2006) provides assistance to approving agencies, developers and landscape designers in assessing design characteristics of constructed water bodies in relation to midge and mosquito problems. Several design factors are said to increase the risk of midge and mosquito problems in constructed water bodies and they are very similar to those for algae prevention:

- a permanent water regime with fluctuating water levels;
- a location close (<100m) to residential housing;
- a low proportion of hard vertical edge;
- a long lake axis perpendicular to prevailing wind directions;
- a depression, so surrounding land slopes down to the water's edge;
- a water depth less than 30 cm or greater than 2 m;
- poor water circulation or no mechanical aeration;
- an absence of aquatic vegetation or aquatic vegetation planted in large dense stands that are free to colonize other parts of the water body;
- surrounded by insufficient density or random stands of fringing vegetation that is unable to provide an effective buffer between lake and residential areas; and

- receives inflow water with high levels of nutrients.

ATA (2003) identified several design factors associated with midge and mosquito problems. These included small lake size (<1 ha), lack of lining (provides better sediment habitat for midge larvae), a low naturalness rating and a lack of fringing vegetation.

As with algal blooms, qualitative analysis found no clear links between particular design features, such as size and naturalness rating of constructed lakes, and midges and mosquitoes. Midges and mosquitoes were reported in lakes with a wide range of features, for example, in lined and unlined lakes, in lakes with and without sloping earth banks and with and without hard vertical edges.

Many lakes that reported mosquito and midge problems had similar features to lakes that were free of problems. For example, Harvest Lakes South is a reasonably large (>1 ha), lined lake with a lack of fringing vegetation and small stands of emergent vegetation (reeds) surrounding the lake and exhibited problems. Dunsborough Lakes Main Storage Lake shares these characteristics, however the lake did not report midge and mosquito problems.

The limited water quality data available indicates higher nutrient levels may be linked with an increased risk of midge and mosquito levels in the lakes in this study. From the water quality data available, the average maximum total phosphorus (TP) concentration in lakes that had reported midge and mosquito problems was 2,100 µg/L and was ten times more than the maximum TP concentration in lakes that had not reported midge and mosquitoes, which average 230 µg/L. It is understood that high nutrient levels fuel algal blooms which provide food for midge larvae.

Although the average maximum chlorophyll *a* concentration was lower in lakes that had mosquito and midge problems (60 µg/L) than those that didn't (100 µg/L), two thirds of lakes with midge and mosquito problems had experienced algal blooms. Only 14 of the 37 lakes without midge and mosquito problems had experienced algal blooms. It appears that the presence of some algae as a food source appears to support midges and mosquitoes, but higher levels do not necessarily result in problems with midge and mosquitoes.

The small samples size (9 lakes that had reported midge and mosquito problems and 37 lakes that hadn't) and qualitative nature of the data meant that it was not possible to analyse any trends statistically.

6.2 MIDGE AND MOSQUITO MANAGEMENT

Mosquitoes and midges are often managed by spraying with insecticides, such as Abate. As with any chemical measures to treat algal blooms, insecticides are only a short-term solution to mosquito and midge problems therefore require repeated treatments.

Based on the recommendations of the draft Chironomid Midge and Mosquito Risk Assessment Guide for Constructed Water Bodies (Midge Research Group of Western Australia, 2006), the City of Gosnells has modified some of its constructed lakes, including those in the study. For example, additional limestone walls were constructed around the perimeter of the Prior Close Reserve Lake in Brookland Greens, Canning Vale because vertical hard edges discourage midge breeding. This lake presents a case study for managers of midge and mosquitoes that is applicable to other lakes. It focuses on investigation and site-specific response informed by monitoring data.

A comprehensive midge mitigation study conducted for the chain of three connected lakes within Brookland Greens found the Prior Close Reserve Lake to be the lake in most need of management to control midge numbers (Terra Consulting and Murdoch University Aquatic Ecosystems Research Group, 2003). The top lake (Sandringham Promenade Reserve 2) and the middle water body (a natural like ephemeral wetland) were not experiencing major problems with nuisance midges.

The midge mitigation study estimated the average nutrient generation from the Brookland Greens catchment using the Model for Urban Stormwater Improvement Conceptualisation (MUSIC). The modelling indicated that elevated nutrient generation from stormwater flowing through the natural wetland in the middle of the lake system was contributing to midge problems in the Prior Close Reserve Lake.

To control midge and mosquito problems in the Prior Close Reserve Lake, it was recommended that nutrient loads into the lake system be controlled through measures such as community education. It was also proposed that monitoring, including an assessment of nutrient loads from bore water top up and sediment release, be conducted to better understand the water and nutrient balance of the lake. It was suggested that Abate continue to be used on an '*as needs*' basis at the Prior Close Reserve Lake and that the community be consulted regarding the suitability of buffer plantings.

The Prior Close Reserve Lake was later treated with Phoslock in October 2006 to bind dissolved phosphorus from the water column and prevent its release from the sediment. It was not known by the lake manager whether the Phoslock application was successful in reducing midge numbers or whether any of the community management measures have been implemented.

7 INVASION OF FERAL FISH

Invasion of lakes with feral fish, particularly koi carp, was a common problem in constructed lakes (9 of 46 lakes each). Koi carp are a large freshwater fish native to central Asia and are typically introduced by local residents or the developer as an ornamental feature. The introduced mosquito fish, *Gambusia holbrooki* was also observed during the site visits in ten lakes however none of the lake managers reported this as a problem, despite its potential negative ecological effects outlined in Section 3.2.

Koi carp can tolerate a wide range of environmental conditions and therefore cope well in degraded habitats. Consequently, koi carp are the dominant fish species in many water bodies (NSW Department of Primary Industries, 2008). They are believed to have detrimental effects on the general health of water bodies and native fish species.

Koi carp are widely believed to have harmful effects on lake health, mainly through their destructive feeding habits. When feeding, koi carp uproot vegetation and stir up sediments, leading to increased turbidity. This in turn reduces light penetration, which can make it difficult for native fish that rely on sight to feed. Reduced light can also decreases plant growth and suspended sediments can smother plants and clog fish gills.

Koi carp are also thought to compete with native fish species for food and there is strong evidence that koi carp consume native invertebrates in still waters. There have been suggestions that carp may increase the likelihood of algal blooms by preying on animals that eat algae and by stirring up nutrients trapped in bottom sediments.

The destructive habits of the koi carp were not always considered a problem by the lake managers interviewed because the lakes are often highly artificial environments with few native species. However, it is a major concern if koi carp make their way into a natural water body, and many constructed lakes are connected to natural water bodies via the drainage system.

7.1 MANAGEMENT

Management measures to control carp in constructed lakes include manual removal using netting, application of a piscicide (for example, Rotenone) or public education. Manual removal and piscicide application are often unsuccessful on their own in eliminating carp in the long-term because the koi carp eggs are not removed by these methods and often people release more koi carp into the lake.

In this study, removal of carp by manual methods and piscicides has been successful only if complemented by public education that informs local residents of the koi carp's destructive effects and instructs them not to release further koi carp into the lake. For example, netting complemented by the placement of educational signage around the Meadow Springs Lakes in Mandurah has been successful in eliminating koi carp from the lake.

8 INVASION OF EXOTIC PLANTS

The most common exotic plant invading constructed lakes was the emergent bullrush *Typha orientalis*. *Typha* has the ability to rapidly colonise disturbed water bodies, often displacing other vegetation, reducing habitat and fauna diversity (Sharma & Gopal 1978, Grase 1987 in Balla, 1994). Exotic vegetation such as *Typha* can cause significant environmental issues where the lakes are connected to downstream environments and can potentially spread pest species to other waterways and wetlands.

An identified species of exotic water lily was identified to be a potential problem in Fenian Park Lake in the City of Bunbury. In some lakes such as Lake Bungana and Lake Brearley in the City or Bayswater exotic terrestrial tree species and weeds amongst fringing vegetation has been identified as a problem by lake managers.

8.1 MANAGEMENT

Invasion of exotic plants is typically managed by manual removal, spraying or both. Based on the interviews with lake managers, removal by these methods is often unsuccessful in the long-term, particularly for highly invasive species such as *Typha* and repeated treatments or manual removal is required.

In Lake Bungana and Lake Brearley removal of exotic plants was accompanied by revegetation programs to replace the removed exotics with native species.

9 OTHER MANAGEMENT ISSUES

9.1 INFRASTRUCTURE MAINTENANCE

Nine of the 46 lakes reported experiencing problems with the maintenance of infrastructure such as liners, aeration and irrigation equipment, swales and limestone walls.

The Main Storage Lake at Dunsborough Lakes has had problems with methane bubbles forming under the liner, which had to be popped. There was concern that breaking of the liner would cause the lake to become saline due to the intrusion of underlying salty groundwater, however, to date the lake remains fresh and its storage capacity has not been compromised.

The Pelican Point Lake in Bunbury required top up with bore water to maintain the lake at an adequate level due to leaks in the liner.

At the Alexandria Boulevard Lake in the City of Gosnells, high water velocity of stormwater inflow has broken through swales that have been constructed to treat stormwater inputs. In addition, limestone walls that surround the lake are experiencing decay.

The lakes in the Murray River Country Estate in Pinjarra have also had problems with the decay of limestone infrastructure.

The recirculation pump at the Centenary Park Lake in Rockingham has broken down due to blockages with particulate matter and algae.

The western water body in the Christmas Tree Park Lakes in the City of Cockburn and the Duck Pond in the City of Wanneroo have had similar issues with aeration equipment breaking down.

9.2 GROSS POLLUTANTS

Ten of the 46 lakes experienced problems with the build up of gross pollutants, including rubbish and leaf litter. Gross pollutants in water bodies are unsightly therefore often attract public complaints. Gross pollutants also pose a threat to aquatic ecosystems through a combination of physical impact on aquatic habitat and contamination. Contaminants such as oxygen-demanding material, hydrocarbons and metals can be associated with the gross pollutants (Lawrence and Breen et al. 2006).

Most of the problems with gross pollutants are related problems to rubbish build up both from stormwater inflows and littering.

Some of the lakes, such as Emu Lake and Fenian Park Lake, have also experienced issues with leaf litter accumulating in the lake. Leaf litter falling into Joondalup Central Park Lake may have contributed to a sludge that formed on the bottom of the lake. This sludge was removed as part of remediation measures to reduce nutrient levels in the lake.

Gross pollutants are usually managed through the installation of gross pollutant traps on stormwater inlets, however this does not stop wind-blown leaf litter or rubbish being thrown into the lake. For example, gross pollutant traps have been installed at Emu Lake to manage gross pollutants from stormwater inflows, however leaf litter still fall into the lake from deciduous plane trees that line the streets in the residential area surrounding the lake. Street sweeping is conducted on a regular basis to help manage this issue. Public education may also be necessary at some lakes to reduce littering.

9.3 ODOUR

Odour problems in constructed lakes were mostly associated with algal blooms. This was the case for five of the six lakes that had reported problems with odours. According to lake manager odour problems ensuing from the one remaining lake (Whaleback Golf Course Lake) was due to hydrocarbon contamination (Don Fleming pers. comm. 26/9/08). The Whaleback Golf Course Lake receives poor quality surface water runoff from a large industrial catchment in Canning Vale.

As odours were most related to algal blooms, they were typically managed through the management of algal blooms, which is discussed in Section 5.1.

9.4 POOR VISUAL APPEARANCE, INCLUDING DRYING OUT

Concern about poor visual appearance of the lakes, not related to water quality issues, was a problem reported in 5 of the 46 lakes. In four of these cases the concerns were due to the lakes drying out. This reflects the high aesthetic value of the lakes and the perceptions of some members of the community that a permanent water body is more visually pleasing than an ephemeral one.

Preferences towards permanent water bodies over ephemeral ones vary within the community. For example, some members of the public voiced concern with regards to the declining water levels in Jackadder Lake when the volume of nutrient rich water redirected from the Osborne Park Main Drain was reduced to combat algal problems in the lake. Other members of the community were pleased with the lower water levels due to the new found presence of wading wetland bird species and reduced algal levels.

In some cases objections to a constructed lake drying out, were strong enough to drive public initiatives for modification to ensure that the lakes contain permanent water. Seasonal drying of Bradford Street Lake in Menora was managed by lining the lake with clay. The City of Swan is considering partially lining Lake Fresca to address community discontent with low water levels. Maintenance of water levels in Lake Fresca with bore water was previously trialled, however this had water quality implications as discussed in Section 8.5.

While the drying out of many constructed lakes, such as the Bradford Street Lake and Lake Fresca appears to be related to the current trend of declining rainfall in the south-west of Western Australia, drying out of lakes can sometimes be due to poor management of activities such as irrigation extraction and dewatering. For example, Wood Lake in Ellenbrook was recently pumped dry due to over extraction of water for irrigation of surrounding parkland.

Dewatering at the Port Mandurah canal development caused death of fringing vegetation around the Bridgewater Northern Lake approximately four years ago. This case demonstrates that although drying out is usually beneficial to the ecology of water bodies on the Swan Coastal Plain, if permanent water bodies suddenly dry out this can also cause ecological harm through vegetation death. Certain species of wetland plants require periods of inundation to survive therefore may not cope well with sudden changes in water regime (Froend et al. 1993).

The study found that lake managers acknowledge the aesthetic value of constructed lakes and go to great effort to maintain the visual appearance of the lakes in line with community expectations. West Road Lake in Bunbury was the only lake that has recorded complaints about its visual appearance that were not related to water quality or drying out.

The West Road Lake has collected drainage from a residential area in South Bunbury for over 50 years. The lake has a poor visual appearance and is currently fenced off due to its steep earth banks that pose a potential risk to public safety. In response to requests from surrounding residents, the City of Bunbury would like to improve the aesthetic, recreational and habitat value of the lake.

9.5 BORE WATER TOP-UP

Almost half of the constructed lakes in the study (46%) are used for irrigation and most of these irrigation lakes are lined and topped up with bore water. Maintaining water levels with bore water can result in the loss of local groundwater resources through increased exposure and evaporation, however the primary issue of concern to lake managers relating to bore water top-up was poor bore water quality (reported in 5 of the lakes).

A trial of pumping bore water into stormwater inlets to maintain water levels in Lake Fresca was abandoned due to problems with the water turning milky due to the death of anaerobic bacteria.

Brighton Central Lake has experienced problems with calcium precipitate from bore water top up clogging the irrigation system. This was managed by installing a recirculation system and submerged aerator to oxygenate the water.

Precipitation of iron from borewater top up has contributed to turbidity and sludge problems in Joondalup Central Park Lake and Pelican Point Lake in Bunbury.

Problems with iron and calcium precipitate at Dalyellup Central Park Lake were managed by directing bore water through a bubble up/rip rap system.

9.6 ACIDITY AND ASSOCIATED PROBLEMS

Although 17 of the 46 lakes were located on areas mapped as a high risk of acid sulfate soil (ASS), only two (Shearwood Spoonbill Lakes in the City of Stirling) have reported problems with acidity associated with the disturbance of acid sulfate soils.

The Shearwater Spoonbill Lakes are impacted by acid groundwater that has occurred due to lowered water table levels within acid sulfate soils. The lakes have a very low pH (below 4) and this has resulted in the death of fringing vegetation and mobilisation of metals and metalloids, including arsenic.

Construction of a treatment system to intercept and treat acid groundwater flowing in the southern lake of the Shearwood Spoonbill Lakes was completed in early 2006 as part of a joint project run by Edith Cowan and Curtin Universities and the City of Stirling. The treatment system involves lime dosing and bioremediation to take dissolved metals out of solution.

The Whaleback Golf Course also experienced a period of acidity resulting from low pH surface water inputs from the Canning Vale Industrial Area. The acidity mobilised metals in the lake and caused tissue death in plants irrigated with the lake water. No treatment system was reported.

10 CHALLENGES AND GAPS IN KNOWLEDGE

Obtaining information on the lakes was a challenge because most of the lakes had not been monitored or studied (Section 3.1), despite the preference given to selecting lakes that had been investigated (information on each lake is outlined in Appendix A). Study and management of constructed lakes seemed to occur in a reactive manner when problems occur and more information was available for lakes that have experienced problems. Approximately 62% of lakes with management problems have been monitored, sampled or studied, compared to 33% of lakes without problems (Table 1).

Other data, such as design and drainage plans, was also not readily available. Even if a lake had been sampled, the results were generally not on hand and there were difficulties locating some of the past reports (outlined in Appendix A). Often, local government records on the lakes were held by several different departments (e.g. Engineering, Environmental and Parks and Gardens), and this made obtaining information a challenge for this study and for lake managers.

Nutrient concentrations and residence time are considered useful indicators of the risk of algal blooms, the most common management problem in constructed lakes. However, because of the lack of available information, these factors were unknown for most of the lakes. Residence time was calculated for only one of the forty-six lakes included in the study.

Only 28% of the lakes were sampled on a regular basis and nutrient levels in the surface water were known for less than a quarter of the lakes. Nutrient concentrations in groundwater and stormwater inputs were known for just two of the 46 lakes. Stormwater and groundwater catchment areas were also unknown for most of the lakes therefore the link between catchment characteristics was not adequately assessed.

In many cases, lake managers were unfamiliar with the ground maintenance practices around the lakes because lawn maintenance was the responsibility of a different section within the local government.

Lake managers tended to knowledgeable in specific aspects of lake management and could provide detailed and useful information on these areas while in other areas they were less well-informed. For example, some lake managers were able to provide reasonably detailed information on lake water quality issues and their management however were unfamiliar with management of the lake surrounds such as fertiliser use and vice versa. This is because different issues are managed by different branches within the local government and there may be a lack of communication between the different sectors.

There were insufficient previous studies on the link between algal blooms and lake characteristics including a lake's water and nutrient balance. The studies available provided general information on lake management issues and their causes but did not provide evidence of examination of these trends through focused study on multiple lakes.

The lack of linkages in the guidelines documents between problems in constructed lakes and management responses is a serious gap that limits the usefulness of the documents from the lake managers' perspective. This study confirms the complex and site-specific nature of the management responses. This means that prescriptive linkages are unlikely to provide the best outcome for every lake. There are no easy solutions and lake managers need data and scientific knowledge and/or advice to fill this particular gap on a case by case basis.

11 RECOMMENDATIONS FOR FUTURE FIELD ASSESSMENT

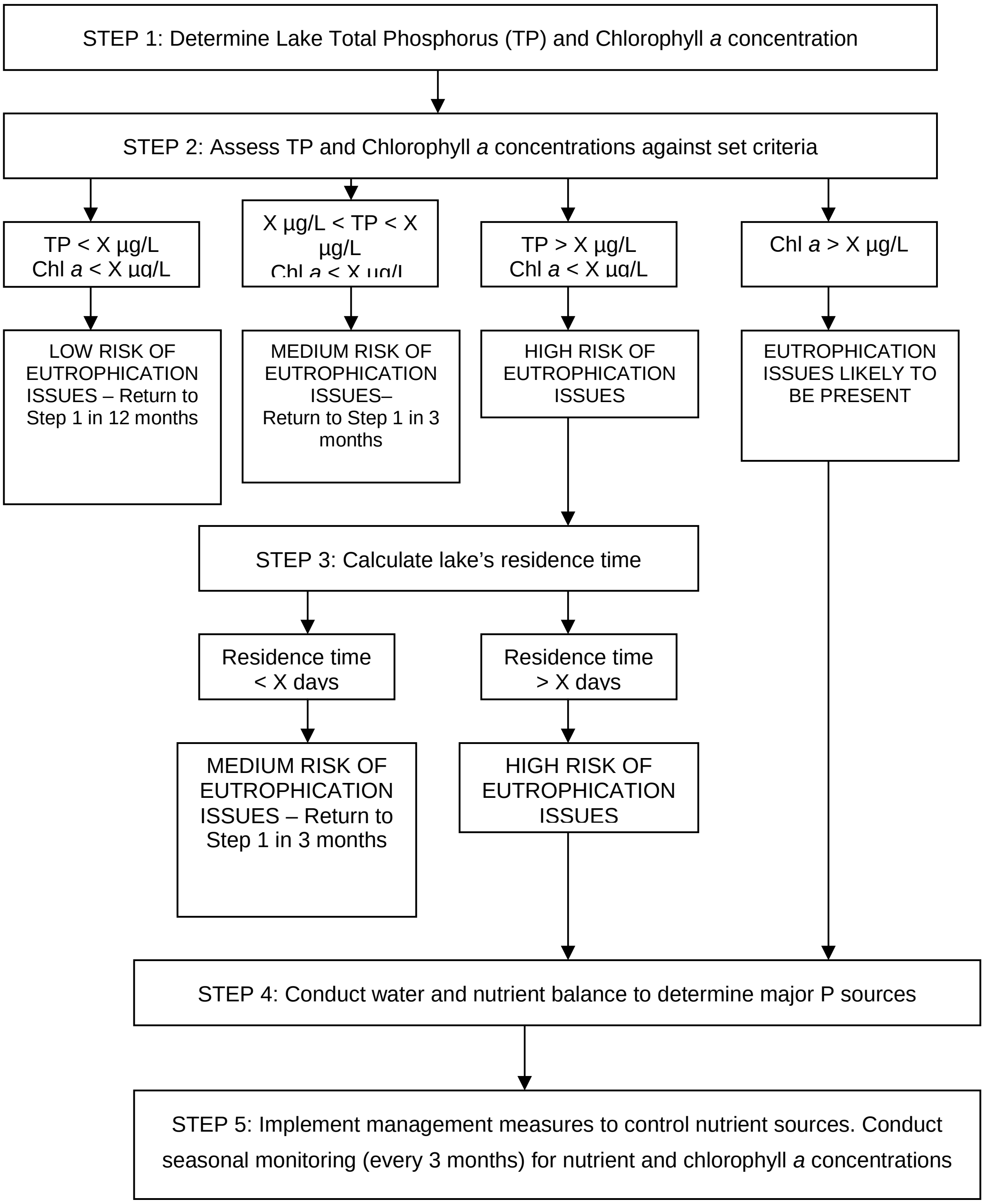
Issues associated with eutrophication, including algal blooms and midges, were the most common management problem recorded in the constructed lakes in this study. Determination of a lake's water and nutrient balance is considered the most useful predictor of a lake's risk of water quality problems, better than qualitative characteristics such as shape or area. However, the water and nutrient balance was unknown for most of the lakes. The primary recommendation is that further study should focus on quantifying the factors necessary for calculation of a lake's water and nutrient balance in existing lakes.

It is not economically feasible to recommend collecting data and conducting water-nutrient balances in all existing lakes. ENV therefore recommends that lake managers prioritise lakes where a water and nutrient balance should be conducted according to the severity of the management problems. Prioritising existing lakes for a water and nutrient balance assessment would require the collection of basic water quality data in lakes that have not previously been sampled, possibly a single sampling event for nutrient and chlorophyll *a* (as an indicator of algal concentrations) concentrations in summer or at the end of autumn, when water quality problems, such as algal blooms, are most likely to be present.

As well as conducting basic water quality sampling it should be noted if the lake is connected to down-gradient natural wetland or waterway and if eutrophication issues have been experienced at the lake previously. Depending on council budgets, sampling for heavy metals could be conducted and other observations of the lake such as the presence of feral fish could also be made. Sampling for nutrients and chlorophyll *a* should be the primary objective given that eutrophication issues were identified to be the major water quality issue impacting constructed lakes.

An example sampling guide for prioritising constructed lakes for further study based on nutrient and chlorophyll *a* results is presented in the diagram below. Interim criteria for total phosphorus and chlorophyll *a* should initially be set based on the information contained within this study however it should be revised once preliminary water quality data has been collated for a total of one hundred lakes

Diagram 1: Example Sampling Guide for Constructed Lakes



For lakes where residence time is to be calculated the following needs to be determined:

- lake volume;
- catchment area;

- inflow volumes i.e. rainfall, bore water top up, stormwater and groundwater inflow; and
- outflow volumes i.e. drainage outflows, groundwater outflow, extraction of irrigation water and evaporation.

For the lakes where a water and nutrient balance are to be conducted the following needs to be determined as a minimum (bearing in mind that data collection is expensive and difficult for most lake managers):

- the parameters required to calculate residence time outlined above;
- lake water quality;
- inflow quality; and
- outflow quality.

The following paragraphs outline a sampling regime to determine the water quality of the lake and its inflows and outflows for a water and nutrient balance analysis. It is noted that some lakes may already be monitored and the sampling should not duplicate information that is already known.

Surface water samples should be collected from each of the lakes and analysed for:

- Total nitrogen;
- Total phosphorus;
- Chlorophyll *a* concentrations; and
- Field water quality parameters including pH.

Lake inflows and outflows should be analysed for nutrient concentrations to allow for a preliminary assessment of the lakes' water and nutrient balance. Sampling of lake stormwater inflows would best take place at the end of autumn or early winter when the first major rainfall event occurs to capture first-flush effects. It is recommended the surface water is sampled at the same time this time to compare inflow concentrations to the lake water quality.

For lakes that receive stormwater drainage, the relationship between algal blooms and the level of water sensitive urban design features in the lake catchment should be examined. Water sensitive urban design involves designing urban drainage system and suburbs to minimise the amount of nutrients entering the stormwater drainage system, and ultimately the water bodies in the catchment. Lower nutrient loads reduce the risk of algal blooms. Residential fertiliser use in the catchment, which is influenced by block sizes, will also affect nutrient loads in incoming stormwater and this should also be assessed.

The water-nutrient balance data should be then analysed and a targeted management response can then be developed to rectify any imbalance. It is expected that in some instances these responses will be short-term actions, while the majority will be long-term and broader reaching changes to the surface and groundwater catchments of the constructed lake.

The information collected on the presence of algal blooms, the water and nutrient balance and catchment characteristics of existing constructed lakes should be used to develop guidelines to assist councils to assess proposals to build new lakes. Approvals should consider the potential health risks and maintenance burden of the constructed lake. There should be a requirement for a developer to conduct a water and nutrient balance assessment to be conducted for all new lakes so that sufficient information is available to inform the approval process.

12 CONCLUSIONS

A total of 46 constructed lakes were studied as part of this work. Of these, 80% were known to have experienced problems of some sort. In approximately half the lakes, management problems were dominated by issues associated with eutrophication (excessive nutrients) including algae, midges and odour. These issues were considered by the lake managers to be the most pressing due to their potentially serious environmental, health and aesthetic effects.

Previous literature has identified specific design features, such as a lack of hard vertical edges and a shape that restricts water circulation, to increase the risk of mosquito and midge problems (Department of Water, 2004-2006 and Midge Research Group of Western Australia, 2007). This study found no clear links between particular design features, such as lake edge or shape and issues associated with eutrophication including algal blooms, mosquitoes and midges. Issues were reported in lakes with a wide range of features, for example, in lined lakes, in groundwater through-flow lakes, and lakes with a regular shape, while other lakes with these same features may have been free of problems.

The study indicated that the eutrophication issues were not limited to particular types of constructed lakes because the drivers for eutrophication appeared to be driven by the water-nutrient balance more than any other design features. This was the central finding of the study.

It is likely that when nutrients accumulate due to water-nutrient balance,, problems typically occur. The accumulation rate will generally dictate the time to the onset of problems, so typically older constructed lakes and those with long water residence times experience more problems. Of the 25 lakes that were older than 10 years, 11 reported problems with algal blooms, whereas only 5 of the 21 lakes that were 10 years or younger reported similar issues. While age may be related to the nutrient accumulation, many other factors such as inflow nutrient concentrations and percentage of volume that evaporates in summer also influence the water-nutrient balance.

Guidelines applicable to constructed lakes on the east coast of Australia (Melbourne Water, 2005 and Breen et al. 2006) recommend lake residence time as a simple indicator of lake performance i.e. the lower the residence time, the better the water quality and therefore the overall health of the constructed lake. These guidelines also focus on managing nutrient loads in surface water inflows rather than groundwater.

This study clearly showed that groundwater inflows and outflows were a substantial consideration in most of the Western Australian lakes with approximately three quarters of the lakes receiving groundwater inflows (Section 4.1.1). While groundwater may not be such an important factor in residence in the Eastern States, it is a factor which can not be ignored in Western Australian lakes.

The data required to complete a water and nutrient balance was absent in all but 2 of the 46 lakes in this study. ENV has conducted a water and nutrient balance for one of the lakes, Emu Lake in Ballajura in a separate study (ENV, 2008). JDA Consultant Hydrologists completed a water and nutrient balance for Jackadder Lake for the City of Stirling (JDA, 1992). Preliminary study of the water and nutrient balance has been conducted at Prior Close Reserve Lake in Brookland Greens in Canning Vale (Terra Consulting and Murdoch University Aquatic Ecosystems Research Group, 2003). These studies reinforced that the water and nutrient balance is the key factor for predicting the effective performance of constructed lakes and can be a useful tool for managing problems such as algal blooms and midges.

Guidelines for urban water management should be revised to specify that water and nutrient balances are conducted for new constructed lakes so this can be considered by regulatory authorities and local government during the approval process. Further study should focus on quantifying the water and nutrient balance for existing lakes on a case by case basis.

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APPENDIX A

CONSTRUCTED LAKE SUMMARY REPORTS

Aspen Group

- Dunsborough Lakes - Lake 10 (Main Storage Lake)

Dunsborough Lakes - Lake 10 (Main Storage Lake) – Summary Report

The Dunsborough Lakes are a group of thirteen interconnected water bodies located within a residential and golf course development. The lake system collects stormwater drainage and is used for irrigation. Overflow from the system is discharged to Toby's inlet to the south east.

Lake 10 or the Main Storage Lake is immediately upstream of the end lake in the system. The lake is lined and used for backup irrigation storage. It has not had any major management problems apart the suspected presence of koi carp and methane bubbles forming beneath the liner which had to be pierced. There was concern that breaking of the liner would cause the lake to become saline due to the intrusion of salty groundwater however to date the lake remains fresh and the storage capacity has not been compromised.

Previous Studies/ Monitoring:

JDA (2007) *Dunsborough Lakes Water Source Scheme Review*. Report prepared for Aspen Group.

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Dunsborough Lakes - Lake 10 (Main Storage Lake)**

1. Basic Details	
Location (street and suburb)	Caves Rd, Dunsborough
Location (coordinates)	6277933.7 N, 325183.3 E
2007 Streetsmart page number	D4, R17
Local Government	Shire of Busselton
Owner	Aspen Group
Function*	D, A, I - backup storage only
Age (years)	~10
2. Physical Features	
Lining (y/n)	Y - to avoid intrusion of saline groundwater but has holes (see management problems)
Area (ha)	3.07
Shape (eg. linear, round, irregular)	Linear, slightly irregular
Depth range (estimate) (m)	~ 2
"Naturalness" rating (1 to 5)*	3
Social amenity value (High, Medium, Low)	High - scenic value, also used for model boat racing
Edging (eg. wall, trees, reeds, sloping banks, turf)	Walled (100%) concrete edging completely surrounds lake; Vegetated (10%) sparse cover of sedges growing adjacent to concrete edge
Vegetation type adjacent to lake*	N, X. Sedges (invaded with grass, in some places burnt, removal attempts evident), *Typha* , sparse distribution of fringing trees- bottlebrush, *eucalyptus* (flooded gum), introduced golf course trees, occasional paperbark, *allocasuarina* , Arum lily
Vegetation condition adjacent to lake*	F-G
Potential acid sulfate soil (ASS) risk (according to ASS risk map)	high to moderate risk of ASS occurring within 3 m of natural soil surface

* Notes:

Function
D - Drainage
C - Conservation
A - Aesthetic (and recreational)
I - Irrigation Storage

Naturalness rating
1 - Highly ornamental
2 - Mostly ornamental with some natural features
3 - Some ornamenatal and some natural features
4 - Natural or natural like with some ornamental features
5 - Natural or natural like

Vegetation type
N - Native
X - Exotic

Vegetation condition
P - Poor
F- Fair
G - Good
E - Excellent

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Dunsborough Lakes - Lake 10 (Main Storage Lake)**

3. Catchment and Hydrology	
Catchment type (eg.industrial, residential)	Golf course/ residential
Prior land use	ND
Catchment size (ha)	ND
Geology (unit)	Guildford Formation (Qpa) and Sand derived from Tamala Limestone (Qts)
(Description)	Sm2 - SILTY SAND, brown to yellow-grey, fine to medium grained quartz sand with variable silt content and S7 - SAND, white to pale and olive-yellow, medium to coarse grained, sub-angular quartz, moderated sorted
No. Inlets	6 located on site
Inlet volume/ size	one large pipe <0.5m diameter, 1 small inlet trench ~0.15m width, 4 small PVC pipes ~0.05m diameter - possibly collect subsoil drainage
No. outlets	1 - connected to another lake. Overflow from whole system is directed to Toby's Inlet
Outlet volume/ size	Width ~0.5m
Drainage connection Flow Through (FT) or End Point (EP) or No Drainage (NDr)	FT
Approximate volume of water extracted for irrigation	25000kL (rough estimate based on estimate by JDA (2007) that 40% storage volume of the lakes is used for irrigation)
Water level top up (y/n)?	N
Estimated residence time	ND
Water or nutrient balance undertaken (y/n)?	N
4. Management	
Aeration/agitation present/absent?	Absent
Aeration type if present* How many?	NA
Fertiliser Application adjacent to lake (y/n)?	Y - trace elements (e.g. iron and manganese) and minimal phosphate applications to golf course
Irrigation adjacent to lake (y/n)?	Y - use lake water
Lawn mowing/ weed control	ND
Management problems*	11. May have koi carp - were released by a local resident in water body downstream. 12. Had problems with liner - methane bubbles formed underneath which had to be popped. To date this has not caused the lake to become saline or compromised storage capacity.
Maintenance and effectiveness	No special maintenance has been required
Monitoring frequency	Do not monitor lake itself however regular water quality samples are taken at outlet to Toby's inlet.

* Notes:

Aeration Features
F - Fountain
R - Rocks/waterfall
C - Circulation by pumping
A - Submerged aerator

ND - Data not available within timeframe of study
NA - Not applicable

Management Problems
1. Flooding
2. Drying Out
3. Slow infiltration
4. Odour
5. Nuisance algal growth
6. Fish deaths
7. Bird deaths
8. Mosquitos or midges
9. Acid Sulfate Soils
10. Iron Monosulfides
11. Feral Fish
12. Other (describe)

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Dunsborough Lakes - Lake 10 (Main Storage Lake)**

5. Water Quality (if known)	**A**	**B**
Total Nitrogen (µg/L)	NT	NT
Total Phosphorus (µg/L)	NT	NT
Chlorophyll *a* (µg/L)	NT	NT
pH	8.04*	8.17*
EC (mS)	0.74*	0.74*
TDS (ppt)	0.37*	0.37*
Temperature (°C)	18.7*	18.7*
Algae/ aquatic plants, water clarity	Fairly clear but with a slight green tinge low levels of phytoplankton growth.*	
6.Fauna		
Macroinvertebrates eg. midges and mosquitos	None observed during site visit.* Stocked with yabbies, marron and koonacs.	
Macrofauna	Eurasian coot, geese, black 'bearded' bird, 'black and white ibis', could hear the occasional call of quacking frogs, pair of Pacific black ducks (birds do not appear to be used to people, not tame).* May have koi.	

Notes:

* Field pH, EC, TDS and temperature measured during site visit on 18/10/07. Observations of algae, aquatic plants, water clarity and fauna also recorded on this day.
NT = Not tested

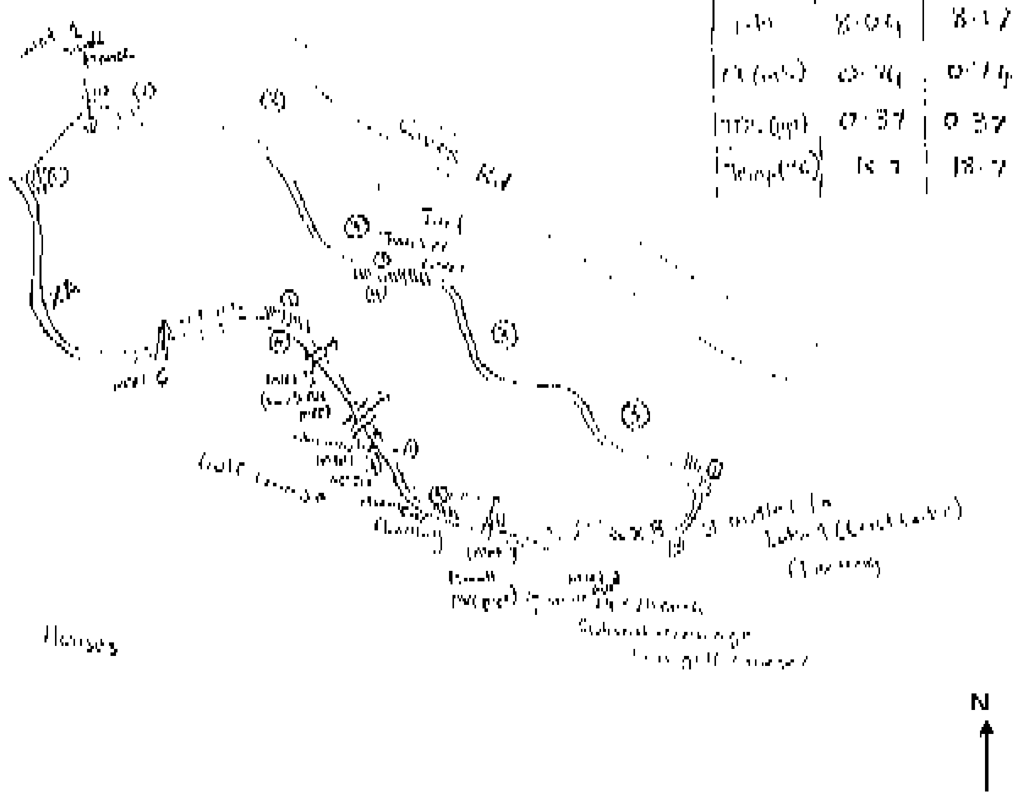
Constructed Lake Study
Field Survey Form

Lake Name and Location: Dunsborough Lakes, Dunsborough – Lake 10 (Main Storage Lake)

Date: 18/10/2007 Recorded By: Bronwyn Woodward

SKETCH:

	A	B
pH	8.04	8.17
EC (mS/cm)	0.74	0.74
TDS (ppt)	0.37	0.37
Temp (°C)	18.7	18.7



Water Level (mark location of staff gauges): None located

Estimated Depth of Water: ~ 2m

Lake Edge	%	Notes
Walled	100	Concrete edging completely surrounds lake
Vegetated	(10?)	Sparse cover of sedges [illegible] concrete edge
Grassed		
Earth		

Water quality: (scums, water clarity, algae, mosquitoes, pH, EC?) Fairly clear [illegible] appears to brown ... [illegible]

Fauna: [illegible]

Vegetation Type(s) adjacent to lake – (annotate with numbers) [illegible]

(2) Typha (3) [illegible]

(4) [illegible]

Other Comments: [illegible]

Dunsborough Lakes - Lake 10 (Main Storage Lake)
Photographic Plates

PLATE 1 – The lined lake receives drainage from a golf course to the west.

PLATE 2– The exotic Arum lily was observed growing amongst reeds in the lake. This invasive plant is common in wetlands of the south west of Western Australia however the lake manager did not highlight it as a problem in the lake.

City of Bayswater

- Lake Bungana
- Lake Bungana Irrigation Lake
- Lake Brearley

Lake Bungana and Lake Brearley – Summary Report

Lake Bungana and Lake Brearley were constructed c. 2000 from abandoned clay pits formerly servicing the Maylands Brick Kiln. The purpose of the lakes was to provide a scenic recreational feature amongst a residential development, improve the quality of drainage water entering the Swan River and create fauna habitat.

The lakes have experienced problems with rubbish build up contributed by stormwater and littering. A small irrigation lake located to the north of Lake Bungana has also experienced a blue green algae problem in early 2007. Following the bloom Phoslock was applied to the irrigation lake and this appeared to control algae growth until at least spring 2007.

Previous Studies/ Monitoring:

ATA (1998) *Peninsula Estate, Maylands Mosquito Management Plan*. Report prepared for the City of Stirling and the Ministry for Planning.

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Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Lake Bungana**

1. Basic Details	**Main Lake**	**Small Irrigation Lake**
Location (street and suburb)	Peninsula Road, Maylands	
Location (coordinates)	396518.6 E, 6465188.3 N	396442.6 E, 6465490.4 N
2007 Streetsmart page number	344, A10	
Local Government	City of Bayswater	
Owner	City of Bayswater	
Function*	D, A	I, D, A
Age (years)	~ 8	

2. Physical Features	**Main Lake**	**Small Irrigation Lake**
Lining (y/n)	N	
Area (ha)	~7?	>1
Shape (eg. linear, round, irregular)	Irregular	Oval
Depth Range (estimate) (m)	up to 8	
"Naturalness" rating (1 to 5)*	3	3
Social Amenity Value (High, Medium, Low)	H	H
Edging (eg. wall, trees, reeds, sloping banks, turf)	25% concrete wall, 75% vegetated with sedges & trees	35% limestone wall, 65% vegetated with sedges & trees
Vegetation type adjacent to lake*	Mostly N, some X - native sedges (*Baumea preissii, schoenoplectus validus*), *Typha domingus* in irrigation lake, paperbarks, *Allocasuarina huegeliana*, bottlebrush (*Calothamnus quadrifidus*, *Callistemon phoeniceus*), banksia	
Vegetation condition adjacent to lake*	G	
Potential acid sulfate soil (ASS) risk (according to ASS risk map)	High to moderate risk of ASS occurring within 3 m of the natural soil surface	

* Notes:

Function
D - Drainage
C - Conservation
A - Aesthetic (and recreational)
I - Irrigation Storage

Naturalness rating
1 - Highly ornamental
2 - Mostly ornamental with some natural features
3 - Some ornamenatal and some natural features features
5 - Natural or natural like

Vegetation type
N - Native
X - Exotic

Vegetation condition
P - Poor
F- Fair
G - Good
E - Excellent

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Lake Bungana**

3. Catchment and Hydrology	**Main Lake**	**Small Irrigation Lake**
Catchment type (eg. industrial, residential)	Residential	
Prior land use	Clay pit for Maylands Brick Kiln	
Catchment size (ha)	ND	ND
Geology (unit)	Guildford Formation (Qpa)	
(Description)	Ms_2 - SANDY SILT - strong brown to mid grey, mottled, blocky, desseminated fine sand, hard when dry, variable clay content of alluvial origin	
No. inlets	3 - overflow from irrigation lake, 2 stormwater inlets indicated on plans (only 1 located on site)	3 stormwater inlets indicated by plans however none were located on site
Inlet volume/size	ND	ND
No. outlets	ND	1 - to main lake
Outlet volume/size	ND	ND
Drainage connection flow through (FT) or End Point (EP) or No Drainage (NDr)	EP (assuming no connection to Lake Brearley)	FT
Approximate volume of water extracted for irrigation	0	21,209 kL in Jul 03 to Jun 04
Water level top up (y/n)?	N	Y - water extracted for irrigation is replaced with bore water pumped from the superficial aquifer
Estimated residence time	ND	ND
Water or nutrient balance undertaken (y/n)?	N	

4. Management	**Main Lake**	**Small Irrigation Lake**
Aeration/agitation present/absent?	Present	Present
Aeration type if present* How many?	1F, 1R (stream that flows from irrigation lake)	1F (not operating due to algal problems)
Fertiliser application adjacent to lake (y/n)?	Y - Turf fertilised 6 x per year according to public open space maintenance schedule. Turf special 2 x per year in Jan/Feb and October Nitrogen 3 x per year in April, Aug/Sept and November N.P.K (CSP) Blue Special once per year in May Trees fertilised 2 x per year (April & October) with 4 x 20g "Langley" tree tablets Shrubs fertilised 2 x per year (May & October) with 20g slow release N.P.K (nitrogen, phosphorus and potassium) fertiliser	
Irrigation adjacent to lake (y/n)?	Y. Surrounding parkland irrigated with water from irrigation lake	
Lawn mowing/ weed control	Turf is mowed using cylinder, kubota or rotary mowers. Spraying of weeds (according to public open space maintenance schedule)	
Management problems*	12 - rubbish, exotic plant species including *Typha* and terrestrial species in fringing vegetation	5 - blue green algal bloom January 2007, 12 - rubbish, exotic plant speciesincluding *Typha* and terrestrial species in fringing vegetation
Maintenance and effectiveness	Planting of native species and removal of exotics. Phoslock in irrigation lake (appears to have controlled algal growth so far)	
Monitoring frequency	A commitment to water quality monitoring of the Lakes Bungana and Brearley was required for conditional approval of the development of the clay pits. A lake monitoring program was developed by JDA (1998) which stipulated monthly measurement of water levels and collection of water quality samples three times per year. However no records of any monitoring were able to be located within the timeframe of this study.	

* Notes:

Aeration Features
F - Fountain
R - Rocks/waterfall
C - Circulation by pumping
A - Submerged aerator

Management Problems
1. Flooding
2. Drying Out
3. Slow infiltration
4. Odour
5. Nuisance algal growth
6. Fish deaths
7. Bird deaths
8. Mosquitos or midges
9. Acid Sulfate Soils
10. Iron Monosulfides
11. Feral Fish
12. Other (describe)

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Lake Bungana**

5. Water Quality (if known)	**Main Lake**	**Small Irrigation Lake**
Total Nitrogen (µg/L)	ND	
Total Phosphorus (µg/L)	ND	
Chlorophyll *a* (µg/L)	NT	NT
pH	8.70*, 8.62**	9.07*
EC (mS)	1.38*, 1.54**	0.70*
TDS (ppt)	0.69*	0.35*
Temperature (°C)	19.3*, 14.1**	19.0*
Algae/ aquatic plants, water clarity	Fairly clear, slightly elongated green flecks - possible phytoplankton*. *Myriopyllum variifolium* most abundant aquatic macrophyte taxa.**	Slightly turbid and green/brown in colour indicating moderate levels of phytoplankton growth, *Lemna*, thick pond weed growing on bottom*.
6.Fauna	**Main Lake**	**Small Irrigation Lake**
Macroinvertebrates eg. midges and mosquitos	None observed	None observed
Macrofauna	Black swan, Pacific Black duck/ducklings, Eurasian coot, purple swamp hen with chicks	Juvenile *Gambusia*, large grey "stork-like" bird, red beaked coot

Notes:

* Field pH, EC, TDS and temperature measured during site visit on 25/9/07. Observations of algae, aquatic plants, water clarity and fauna also recorded on this day.
** Water quality parameters and observations of algae and aquatic plants recorded by A. Betti (Murdoch University student) on 20/9/06
ND = Data not available within timeframe of study
NT = not tested

Constructed Lake Study
Field Survey Form

Lake Name and Location: Lake Bungana, Maylands

Date: 25/09/2007 Recorded By: Bronwyn Woodward

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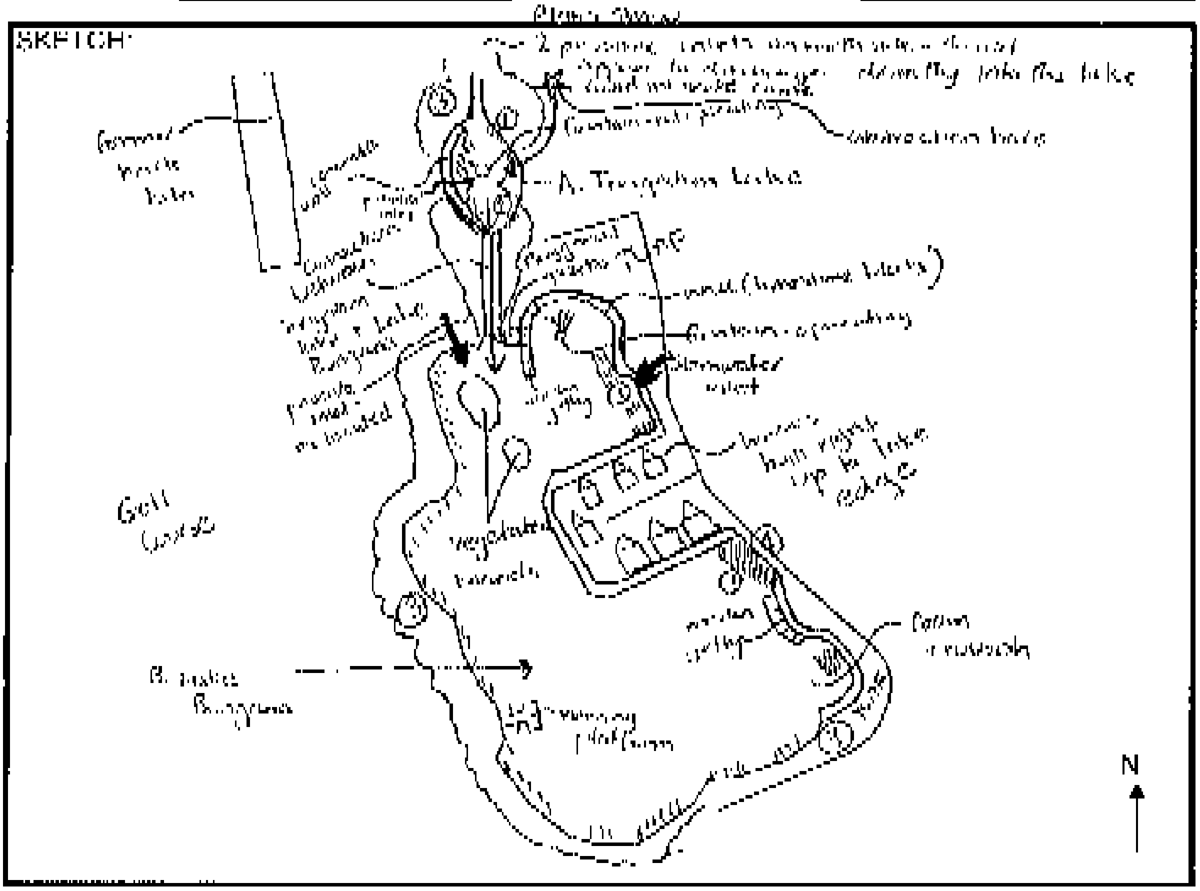

Water Level (mark location of staff gauges): None located

Estimated Depth of Water: ~2.8m (both lakes)

Lake Edge	% Main	Irrigation	Notes
Walled	35	45	[illegible] wall
Vegetated	65	55	sedges & trees (see below)
Grassed	0		
Earth	0		

Water quality: (scums, water clarity, algae, mosquitoes, pH, EC?) A. [illegible] pH: 9.07 EC: [illegible] TDS: [illegible] Temp: [illegible]
B. [illegible] pH: 9.10 EC: [illegible] Temp: [illegible]

Fauna: A. [illegible]
B. black swan, [illegible] coot, [illegible]

Vegetation Type(s) adjacent to lake - [illegible] *Typha domingensis*
(annotate with numbers) [illegible]
(3) Trees - [illegible]
(4) [illegible] - [illegible] planted in this area [illegible]

Other Comments: [illegible]

eny

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Lake Brearley**

1. Basic Details	
Location (street and suburb)	Peninsula Road, Maylands
Location (coordinates)	396762.8 E, 6464812 N
2007 Streetsmart page number	344, A10
Local Government	City of Bayswater
Owner	City of Bayswater
Function*	A, D
Age (years)	7
2. Physical Features	
Lining (y/n)	N
Area (ha)	9.015
Shape (eg. linear, round, irregular)	Irregular
Depth range (estimate) (m)	up to 8
"Naturalness" rating (1 to 5)*	3
Social amenity value (High, Medium, Low)	High
Edging (eg. wall, trees, reeds, sloping banks, turf)	65% limestone blocks, 35% vegetated with sedges and trees (see below)
Vegetation type adjacent to lake*	Mostly N, some X - native sedges (*Baumea preissii, schoenoplectus validus*), paperbarks, *Allocasuarina huegeliana* , bottlebrush (*Calothamnus quadrifidus, Callistemon phoeniceu* s), banksia
Vegetation condition adjacent to lake*	G
Potential acid sulfate soil (ASS) risk (according to ASS risk map)	High to moderate risk of ASS occurring within 3 m of the natural soil surface

* Notes:

Function
D - Drainage
C - Conservation
A - Aesthetic (and recreational)
I - Irrigation Storage

Naturalness rating
1 - Highly ornamental
2 - Mostly ornamental with some natural features
3 - Some ornamenatal and some natural features
4 - Natural or natural like with some ornamental features
5 - Natural or natural like

Vegetation type
N - Native
X - Exotic

Vegetation condition
P - Poor
F- Fair
G - Good
E - Excellent

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Lake Brearley**

3. Catchment and Hydrology	
Catchment type (eg. industrial, residential)	Residential
Prior land use	Clay pit for Maylands Brick Kiln
Catchment size (ha)	ND
Geology (unit)	Guildford Formation (Qpa)
(description)	Ms_2 - SANDY SILT - strong brown to mid grey, mottled, blocky, desseminated fine sand, hard when dry, variable clay content of alluvial origin
No. inlets	2
Inlet volume/size	ND
No. outlets	1 leading to Swan River
Outlet volume/size	ND
Drainage connection flow through (FT) or end point (EP) or no drainage (NDr)	FT
Approximate volume of water extracted for irrigation	0
Water level top up (y/n)?	N
Estimated residence time	ND
Water or nutrient balance undertaken (y/n)?	N
4. Management	
Aeration/agitation present/absent?	Absent
Aeration type if present* How many?	NA
Fertiliser application adjacent to lake (y/n)?	Y - Turf fertilised 6 x per year according to public open space maintenance schedule. Turf special 2 x per year in Jan/Feb and October Nitrogen 3 x per year in April, Aug/Sept and November N.P.K (Nitrogen, Phosphorus, Potassium) (CSP) Blue Special once per year in May Trees fertilised 2 x per year (April & October) with 4 x 20g "Langley" tree tablets Shrubs fertilised 2 x per year (May & October) with 20g slow release N.P.K
Irrigation adjacent to lake (y/n)?	Y - using water from irrigation lake
Lawn mowing/ weed control	Turf is mowed using cylinder, kubota or rotary mowers. Spraying of weeds. (according to public open space maintenance schedule)
Management problems*	12 - rubbish, exotic plant species
Maintenance and effectiveness	Planting of native species and removal of exotics
Monitoring frequency	A commitment to water quality monitoring of the Lakes Bungana and Brearley was required fo conditional approval of the development of the clay pits. A lake monitoring program was developed by JDA (1998) which stipulated monthly measurement of water levels and collection of water quality samples three times per year. However no records of any monitoring were able to be located within the timeframe of this study.

* Notes:

Aeration Features
F - Fountain
R - Rocks/waterfall
C - Circulation by pumping
A - Submerged aerator

Management Problems
1. Flooding
2. Drying Out
3. Slow infiltration
4. Odour
5. Nuisance algal growth
6. Fish deaths
7. Bird deaths
8. Mosquitos or midges
9. Acid Sulfate Soils
10. Iron Monosulfides
11. Feral Fish
12. Other (describe)

ND - Data not available within timeframe of study
NA - Not applicable

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Lake Brearley**

5. Water Quality (if known)	
Total Nitrogen (µg/L)	NT
Total Phosphorus (µg/L)	NT
Chlorophyll *a* (µg/L)	NT
pH	8.97*
EC (mS)	3.63*
TDS (ppt)	1.82*
Temperature (°C)	19.7*
Algae/ aquatic plants, water clarity	Fairly clear but with a slight green tinge low levels of phytoplankton growth.*
6.Fauna	
Macroinvertebrates eg. midges and mosquitos	Adult midges observed*
Macrofauna	Could hear motorbike frogs, Eurasian coot, Pacific Black duck, unidentified grey duck, unidentified black bird with long beak, fragments of a turtle's shell*

Notes:

* Field pH, EC, TDS and temperature measured during site visit on 25/9/07. Observations of algae, aquatic plants, water clarity and fauna also recorded on this day.
NT = Not tested

Constructed Lake Study
Field Survey Form

Lake Name and Location: Lake Brearley, Maylands

Date: 25/09/2007   Recorded By: Bronwyn Woodward

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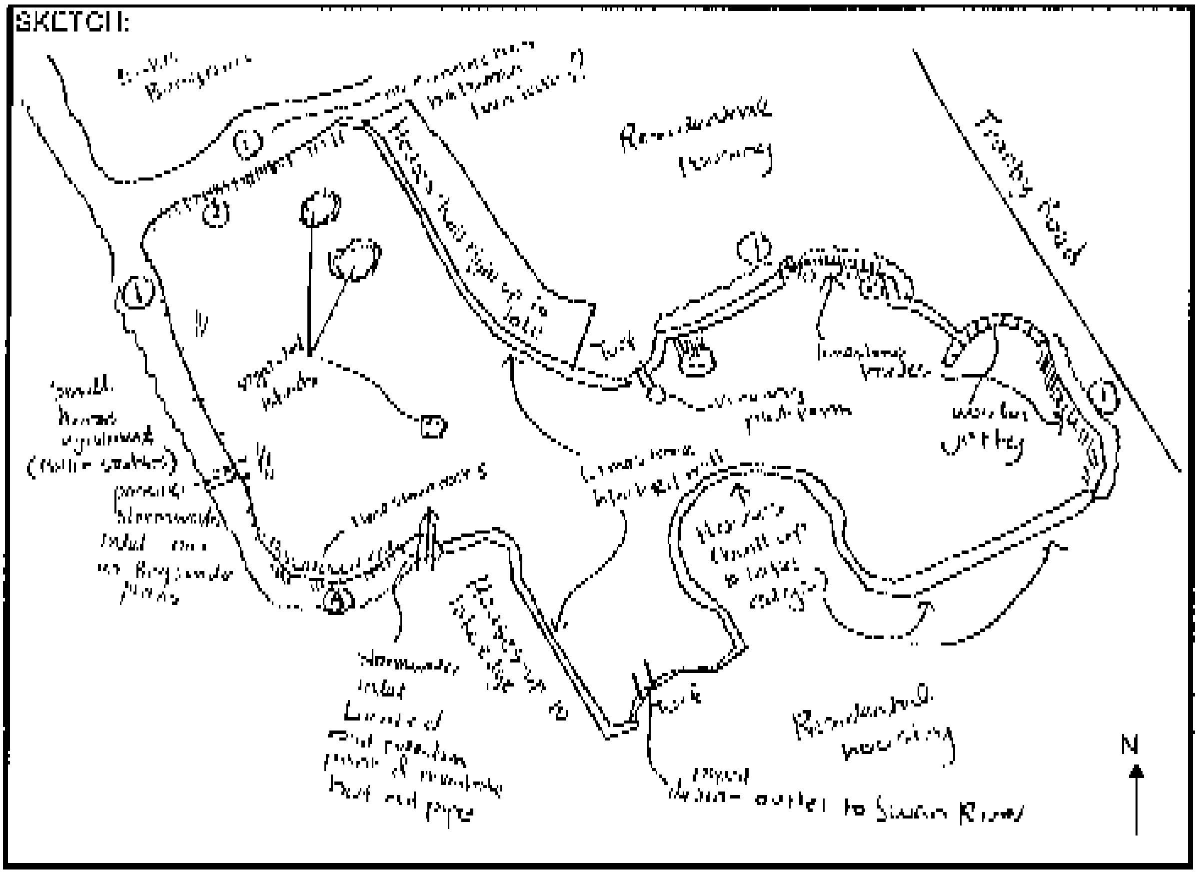


Water Level (mark location of staff gauges): None located

Estimated Depth of Water: 2-8 m

Lake Edge	%	Notes
Walled	65	limestone blocks
Vegetated	35	see below
Grassed		
Earth		

Water quality: (scums, water clarity, algae, mosquitoes, pH, EC?) pH= 8.47 EC= 3.63mS

TDS = 1.82 ppt temp = 18.7°C Fairly clear, slight green tinge

Fauna: midges, [illegible] frogs, Eurasian coot, Pacific black duck, wood duck, black winged stilt

Vegetation Type(s) adjacent to lake (annotate with numbers) (1) Trees, paperbarks (>1 species), [illegible] [illegible]

Shrubs (Calothamnus quadrifidus, callistemon phoeniceus), banksia

(2) Native sedges - Baumea [illegible], (3) Paperbarks (>1 species) dominant

Other Comments: Fragments of a turtle shell on [illegible] bank

[illegible] for birds

Lake Bungana and Lake Brearley - Photographic Plates

PLATE 1 – Although the lakes are a highly artificial environment surrounded by limestone walls and houses built up to the water's edge, the developer has taken efforts to create fauna habitat through the construction of vegetated islands and roosting poles. Examples of such features in Lake Brearley are shown in the photo above.

PLATE 2– The lakes were once abandoned clay pits however now they provide a breeding habitat for birds such as this Purple Swamp Hen with its chick observed in Lake Bungana.

Lake Bungana and Lake Brearley - Photographic Plates

PLATE 3– The aesthetic and habitat value of the lakes has been compromised by problems such as invasion by *Typha* and algal blooms in the irrigation lake to the north of Lake Bungana.

PLATE 4 – Rubbish from stormwater inputs and littering is a problem in the lakes. The photo above shows rubbish collecting around stormwater inlet in the north eastern corner of Lake Bungana.

City of Bunbury

- Fenian Park Lake
- Pelican Point Lake
- Queens Gardens Lake
- West Road Lake

Fenian Park Lake – Summary Report

Fenian Park Lake is located within Glen Iris, an outer suburb of Bunbury and is surrounded by farmland and bushland that is being developed for residential housing. For the last twenty years, the main purpose of the lake has been is to collect and infiltrate stormwater drainage however as the area becomes more developed the aesthetic and recreational importance of the lake is expected to increase, as is the risk of water quality problems.

To date the lake has not experienced any management problems aside from minor amounts of rubbish and leaf litter build up, invasion by exotic plants and proliferation of the water plant *Azolla spp*. The City of Bunbury proposed to spray the *Azolla spp.* towards the end of 2007 and was also considering spraying an exotic water lily.

Previous Studies/ Monitoring:

Single sampling event by City of Bunbury for mosquito larvae (results not available within time frame of study).

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Fenian Park Lake**

1. Basic Details	
Location (street and suburb)	Erica Entrance, Glen Iris, Bunbury
Location (coordinates)	377286 E, 6309486.7 N
2007 Streetsmart page number	B10, V38
Local Government	City of Bunbury
Owner	City of Bunbury
Function*	D, A
Age (years)	~20
2. Physical Features	
Lining (y/n)	N
Area (ha)	~2.37
Shape (eg. linear, round, irregular)	Linear
Depth range (estimate) (m)	2.5-3
"Naturalness" rating (1 to 5)*	3
Social amenity value (High, Medium, Low)	Low (will probably increase as nearby residential housing is developed)
Edging (eg. wall, trees, reeds, sloping banks, turf)	Gently sloping grass banks (100%)
Vegetation type adjacent to lake*	*Typha spp* ., Fringing trees including Marri and *Banksia* , Tubular green reed.
Vegetation condition adjacent to lake*	G
Potential acid sulfate soil (ASS) risk (according to ASS risk map)	moderate to low risk of ASS occurring within 3 m of natural soil surface

* Notes:

Function
D - Drainage
C - Conservation
A - Aesthetic (and recreational)
I - Irrigation Storage

Naturalness rating
1 - Highly ornamental
2 - Mostly ornamental with some natural features
3 - Some ornamenatal and some natural features
4 - Natural or natural like with some ornamental features
5 - Natural or natural like

Vegetation type
N - Native
X - Exotic

Vegetation condition
P - Poor
F- Fair
G - Good
E - Excellent

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Fenian Park Lake**

3. Catchment and Hydrology	
Catchment type (eg. industrial, residential)	Transforming to residential
Prior land use	Bushland/farmland
Catchment size (ha)	ND
Geology (unit)	Thin Bassendean Sand over Guildford Formation (Qpb/Qpa)
(description)	S8 - SAND - white to pale grey at surface, yellow at depth, fine to medium grained, moderately sorted, subangular to subrounded, minor heavy minerals, of aeolian origin over SANDY CLAY (Sc) to CLAYEY SAND (Cs) of the Guildford Formation, of aeolian origin
No. inlets	4 based on engineering drawings although not all located on site
Inlet volume/size	Inlet 1 - pipe diameter = 750 mm Inlet 2 - pipe diameter = 450 mm Inlet 2 - drain width = ~ 750 mm Inlet 4 - ND
No. outlets	0
Outlet volume/size	NA
Drainage connection flow through (FT) or end point (EP) or no drainage (NDr)	EP
Approximate volume of water extracted for irrigation	0
Water level top up (y/n)?	N
Estimated residence time	ND
Water or nutrient balance undertaken (y/n)?	N
4. Management	
Aeration/agitation present/absent?	Absent
Aeration type if present* How many?	NA
Fertiliser application adjacent to lake (y/n)?	N
Irrigation adjacent to lake (y/n)?	N
Lawn mowing/ weed control	Undertake mowing, were planning to spray *Azolla*.
Management problems*	12. Some rubbish and leaf litter build up, exotic plants. Council has concerns that more serious problems may occur in the future as the area around the lake is developed for residential housing
Maintenance and effectiveness	Spraying of *Azolla* scheduled despite it being a native plant. Considering spraying exotic water lily.
Monitoring frequency	Not monitored aside from one sampling round for mosquito larvae.

* Notes:

Aeration Features
F - Fountain
R - Rocks/waterfall
C - Circulation by pumping
A - Submerged aerator

ND - Data not available within timeframe of study
NA - Not applicable

Management Problems
1. Flooding
2. Drying Out
3. Slow infiltration
4. Odour
5. Nuisance algal growth
6. Fish deaths
7. Bird deaths
8. Mosquitos or midges
9. Acid Sulfate Soils
10. Iron Monosulfides
11. Feral Fish
12. Other (describe)

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Fenian Park Lake**

5. Water Quality (if known)	**A**	**B**
Total Nitrogen (μ/L)	NT	NT
Total Phosphorus (μ/L)	NT	NT
Chlorophyll *a* (μg/L)	NT	NT
pH	7.6	7.96
EC (mS)	0.52	0.47
TDS (ppt)	0.26	0.23
Temperature (°C)	18.9	19.6
Algae/ aquatic plants, water clarity	Clear water, mild yellow tannin staining. No algae observed. Exotic water lily (~2m^2), Azolla, *Potamogeton crispus**	
6.Fauna		
Macroinvertebrates eg. midges and mosquitos	None observed during site visit. Has been sampled for mosquito larvae on one occasion and none were detected.	
Macrofauna	A few Eurasian coot (including 1 chick), couple of Pacific Black ducks, occasional call of a clicking froglet	

Notes:

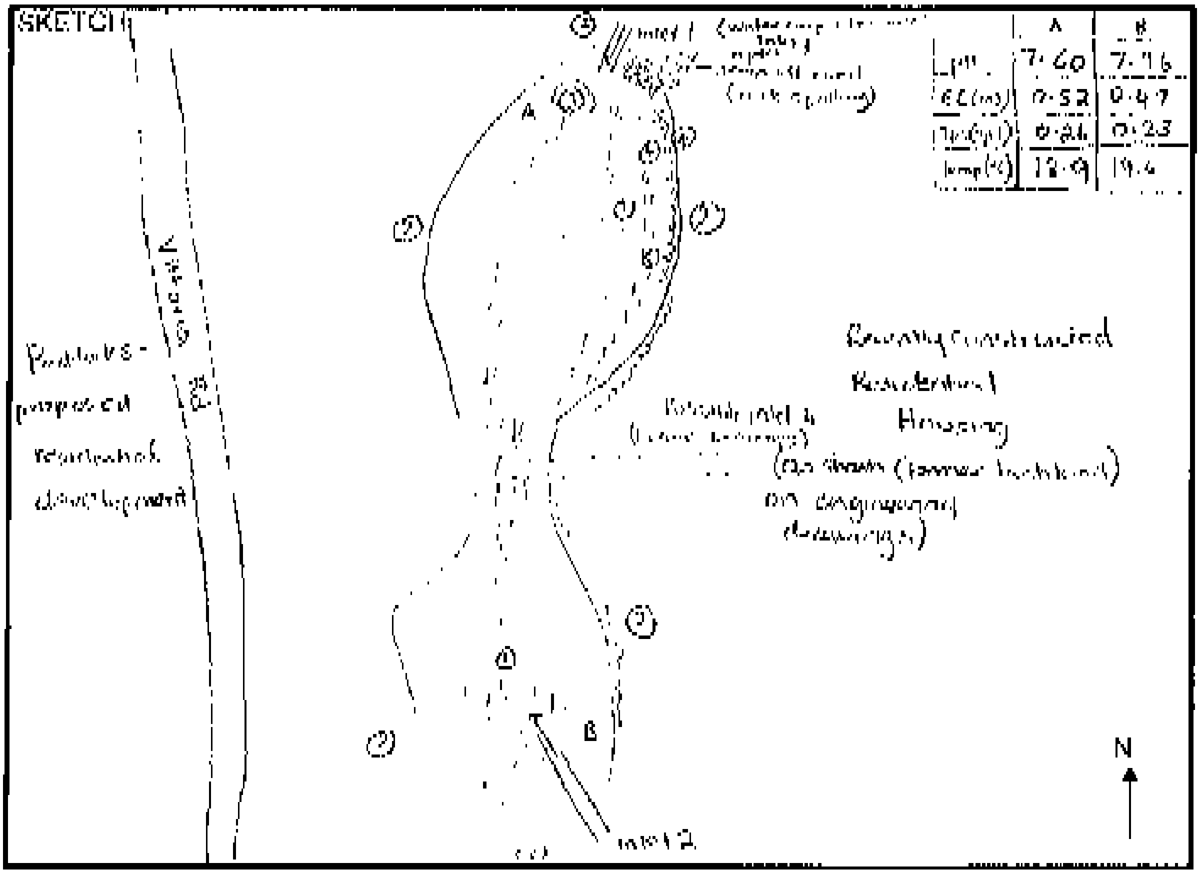
* Mean field pH, EC, TDS and temperature measured during site visit on 17/10/07. Observations of algae, aquatic plants, water clarity and fauna also recorded on this day.
NT = Not tested

Constructed Lake Study
Field Survey Form

Lake Name and Location: **Fenian Park Lake, Bunbury**

Date: 17/10/2007 Recorded By: Bronwyn Woodward

SKETCH



	A	B
pH	7.60	7.76
EC (ms)	0.52	0.47
TDS (g/L)	0.24	0.23
temp (°C)	12.9	19.4

Water Level (mark location of staff gauges): None located

Estimated Depth of Water: 2.5-3m

Lake Edge	%	Notes
Walled	0	
Vegetated	0	Submerged veg. (Typha) & trees further out but no veg. apart from grass fringing lake edge.
Grassed	100	
Earth	0	

Water quality: (scums, water clarity, algae, mosquitoes, pH, EC?) clear, some rubbish, leaf litter collecting around edges, midges flying over water (watching & catch)

Fauna: 1 a few Eurasian coot, pair of Pacific Black duck, occasional call of Clicking froglet

Vegetation Type(s) adjacent to lake - (annotate with numbers) (1) Typha (2) Fringing trees - marri, Melaleuca, Redgum? (3) Exotic water lily (×2 sm²) (4) Azolla (5) Jointed rush (6) Potamogeton Crispus

Other Comments: Inlets 1 + 2 on plans but not located on site (probably submerged). "Future drainage" likely to be constructed already as residential housing construction is mostly complete although not located on site.

Fenian Park Lake - Photographic Plates

PLATE 1 – The lake receives drainage from a residential area to the east.

PLATE 2 – The lake has been invaded with *Typha* and an exotic water lily. It is proposed to develop farmland to the west of the lake, in background of photo, which is likely to increase the aesthetic importance of the lake.

Pelican Point Lake – Summary Report

The Pelican Point Lake is a central feature of a residential estate within Bunbury. The highly ornamental lined lake is privately owned and managed by a body corporate of surrounding residents. Due to leaks in the lake's liner, groundwater is required to maintain the lake at an adequate level. The groundwater used to top up the lake is sourced from a brackish bore and consequently the lake is saline.

Surrounding residents have reported discoloured water, algae, midges and odours in the lake and in spring 2006 fish kills occurred. As no sampling occurred at the time of the fish deaths, the cause is unknown. The City of Bunbury is keen to know the reason for the fish kills due to some residents raising the possibility that toxic stormwater was the cause.

Previous Studies/ Monitoring:

Le Provo, Semeniuk and Chalmer (1986) *Pelican Point Country Club Development Public Environmental Report*, Report No R132

Le Provo (1991) *Pelican Point Bunbury Public Environmental Review*, Report No R320

Le Provo (1991) *Pelican Point Environmental Management Programme*, Report No R397

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Pelican Point Lake**

1. Basic Details	
Location (street and suburb)	Pickworth Rtt, Pelican Point, Bunbury
Location (coordinates)	378139.3 E, 6312922.7 N
2007 Streetsmart page number	B8, X31
Local Government	City of Bunbury
Owner	City of Bunbury
Function*	A, D
Age (years)	~12
2. Physical Features	
Lining (y/n)	N
Area (ha)	~1.65 (TME, 2000)
Shape (eg. linear, round, irregular)	Triangular
Depth range (estimate) (m)	~2-2.5
"Naturalness" rating (1 to 5)*	1
Social amenity value (High, Medium, Low)	High
Edging (eg. wall, trees, reeds, sloping banks, turf)	Walled (95%), Earth (5%)
Vegetation type adjacent to lake*	X. Turf in parks, residential gardens, some landscaped shrubs and small trees, palm trees (highly artificial)
Vegetation condition adjacent to lake*	G
Potential acid sulfate soils (ASS) risk (according to ASS risk map)	high to moderate risk of ASS occurring within 3 m of natural soil surface

* Notes:

Function
D - Drainage
C - Conservation
A - Aesthetic (and recreational)
I - Irrigation Storage

Naturalness rating
1 - Highly ornamental
2 - Mostly ornamental with some natural features
3 - Some ornamenatal and some natural features
4 - Natural or natural like with some ornamental features
5 - Natural or natural like

Vegetation type
N - Native
X - Exotic

Vegetation condition
P - Poor
F- Fair
G - Good
E - Excellent

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Pelican Point Lake**

3. Catchment and Hydrology	
Catchment type (eg. industrial, residential)	Residential
Prior land use	Natural wetland
Catchment size (ha)	ND
Geology (unit)	Alluvium River Terraces (Qha)
(description)	ND
No. inlets	3
Inlet volume/size	Inlet 1 - pipe diameter = 375 mm Inlet 2 - pipe diameter = 375 mm Inlet 3 - pipe diameter = 450 mm
No. outlets	1
Outlet volume/size	Pipe diameter = 300 mm
Drainage connection flow through (FT) or End Point (EP) or No Drainage (NDr)	FT
Approximate volume of water extracted for irrigation	0
Water level top up (y/n)?	Y - with borewater
Estimated residence time	ND
Water or nutrient balance undertaken (y/n)?	N
4. Management	
Aeration/agitation present/absent?	Present
Aeration type if present* How many?	2F (vertical spray type aerators), 3 "water wheels". Thought to have only a low impact on aeration of water
Fertiliser application adjacent to lake (y/n)?	ND
Irrigation adjacent to lake (y/n)?	ND
Lawn mowing/ weed control	ND
Management problems*	4, 5, 6, 8 (midges), 12 (leaking liner), high bacteria levels, turbidity possibly due to precipitation of iron from borewater top up
Maintenance and effectiveness	ND
Monitoring frequency	Sampled on at least one occasion for nutrients and bacteria.

* Notes:

Aeration Features
F - Fountain
R - Rocks/waterfall
C - Circulation by pumping
A- Submerged aerator

ND - Data not available within timeframe of study

Management Problems
1. Flooding
2. Drying Out
3. Slow infiltration
4. Odour
5. Nuisance algal growth
6. Fish deaths
7. Bird deaths
8. Mosquitos or midges
9. Acid Sulfate Soils
10. Iron Monosulfides
11. Feral Fish
12. Other (describe)

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Pelican Point Lake**

5. Water Quality (if known)	
Total Nitrogen (µ/L)	ND
Total Phosphorus (µ/L)	ND
Chlorophyll *a* (µg/L)	NT
pH	8.25*
EC (mS)	> 20*
TDS (ppt)	> 10*
Temperature (°C)	19.7*
Algae/ aquatic plants, water clarity	Water green and turbid, foam - indicating possible algal bloom.* Anecdotal reports of algal blooms.
6.Fauna	
Macroinvertebrates eg. midges and mosquitos	None observed during site visit.* Previous midge complaints.
Macrofauna	A couple of Pacific Black ducks, seagulls. No fish observed.

Notes:

* Field pH, EC, TDS and temperature measured during site visit on 17/10/07. Observations of algae, aquatic plants, water clarity and fauna also recorded on this day.
ND - Data not available within timeframe of study

Constructed Lake Study
Field Survey Form

Lake Name and Location: **Pelican Point Lake, Bunbury**

Date: 17/10/2007   Recorded By: Bronwyn Woodward

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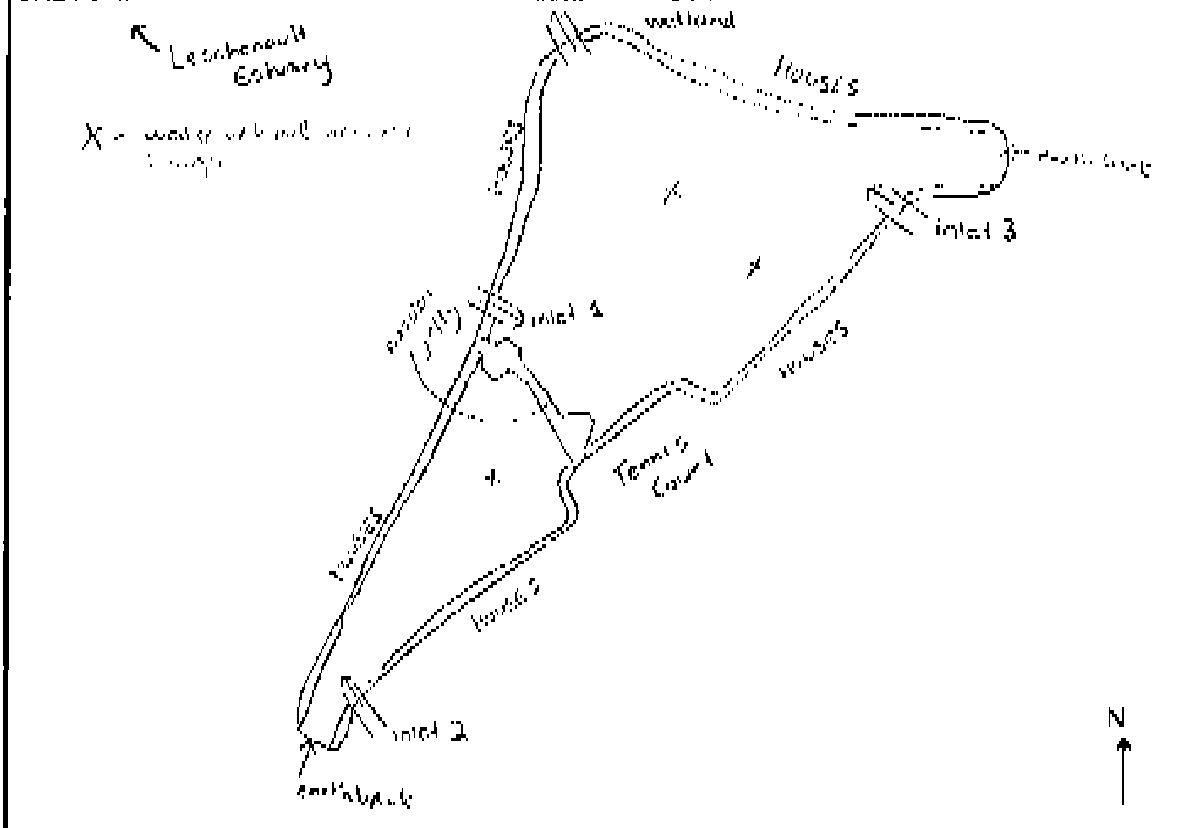


Water Level (mark location of staff gauges): None located

Estimated Depth of Water: ~2.5m

Lake Edge	%	Notes
Walled	95	limestone blocks
Vegetated	0	
Grassed	0	
Earth	5	sand beach

Water quality: (scums, water clarity, algae, mosquitoes, pH, EC?) green [illegible], [illegible], pH 8.20 EC > 20mS, TDS > 10 ppt, Temp = 19.7°C

Fauna: [illegible]

Vegetation Type(s) adjacent to lake - (annotate with numbers) [illegible] planted [illegible] [illegible] [illegible] [illegible] [illegible]

Other Comments: Houses built right up to edge of lake
[illegible] [illegible] [illegible] channel [illegible] [illegible] created waves

Pelican Point Lake - Photographic Plates

PLATE 1 – The lake is privately owned by the local residents

PLATE 2 – Fish kills in the lake in spring 2006 (provided by City of Bunbury)

Queens Gardens Lake – Summary Report

The Queens Gardens Lake intercepts drainage from the Bunbury Central Business District commercial area prior to discharge into the Leschenault Inlet. Rubbish is known to collect in the lake and high pathogen levels have been recorded at the lake outlet. Much of the lake bed is covered with a dense growth of reeds however the City of Bunbury is not aware of this creating any problems such as blocking flow through the lake or compromising its storage capacity.

Previous Studies/ Monitoring:

Single sampling event for pathogens at lake outlet (results not available within time frame of study).

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Queens Garden Lake**

1. Basic Details	
Location (street and suburb)	Stirling St, Bunbury
Location (coordinates)	373588.3 E, 6311766.5 N
2007 Streetsmart page number	B7,O33
Local Government	City of Bunbury
Owner	City of Bunbury
Function*	D, A
Age (years)	22
2. Physical Features	
Lining (y/n)	N
Area (ha)	~5
Shape (eg. linear, round, irregular)	Irregular
Depth range (estimate) (m)	2m max. Most areas appear <1
"Naturalness" rating (1 to 5)*	3
Social amenity value (High, Medium, Low)	Low-Medium (in a park area but has a poor visual appearance)
Edging (eg. wall, trees, reeds, sloping banks, turf)	100% turf edge although entire lake bed is vegetated with a thick growth of reeds
Vegetation type adjacent to lake*	Reeds, a few trees in park area surrounding the lake eg. peppermint, wattle, sheoak, paperbark
Vegetation condition adjacent to lake*	G
Potential acid sulfate soils (ASS) risk (according to ASS risk map)	high to moderate risk of ASS occurring within 3 m of natural soil surface

* Notes:

Function
D - Drainage
C - Conservation
A - Aesthetic (and recreational)
I - Irrigation Storage

Naturalness rating
1 - Highly ornamental
2 - Mostly ornamental with some natural features
3 - Some ornamenatal and some natural features
4 - Natural or natural like with some ornamental features
5 - Natural or natural like

Vegetation type
N - Native
X - Exotic

Vegetation condition
P - Poor
F- Fair
G - Good
E - Excellent

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Queens Garden Lake**

3. Catchment and Hydrology	
Catchment type (eg. industrial, residential)	Commercial (Bunbury CBD)
Prior land use	Old railway marshalling yards
Catchment size (ha)	ND
Geology (unit)	Alluvium River Terraces (Qha), possible fill
(description)	ND
No. inlets	1
Inlet volume/size	~1.8m width vee drain connecting to ~1.8m diameter pipe
No. outlets	1
Outlet volume/size	~2.5m width vee drain connecting to 2 x ~700mm diameter pipes
Drainage connection flow through (FT) or End Point (EP) or No Drainage (NDr)	FT
Approximate volume of water extracted for irrigation	0
Water level top up (y/n)?	N
Estimated residence time	ND
Water or nutrient balance undertaken (y/n)?	N
4. Management	
Aeration/agitation present/absent?	Absent
Aeration type if present* How many?	NA
Fertiliser application adjacent to lake (y/n)?	ND
Irrigation adjacent to lake (y/n)?	ND
Lawn mowing/ weed control	ND
Management problems*	12 - high pathogen levels, rubbish
Maintenance and effectiveness	No special maintenance/ management measures used to date
Monitoring frequency	Not monitored

* Notes:

Aeration Features
F - Fountain
R - Rocks/waterfall
C - Circulation by pumping
A - Submerged aerator

ND - Data not available within timeframe of study
NA - Not applicable

Management Problems
1. Flooding
2. Drying Out
3. Slow infiltration
4. Odour
5. Nuisance algal growth
6. Fish deaths
7. Bird deaths
8. Mosquitos or midges
9. Acid Sulfate Soils
10. Iron Monosulfides
11. Feral Fish
12. Other (describe)

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Queens Garden Lake**

5. Water Quality (if known)	
Total Nitrogen (µ/L)	NT
Total Phosphorus (µ/L)	NT
Chlorophyll *a* (µg/L)	NT
pH	7.98*
EC (mS)	0.70*
TDS (ppt)	0.39*
Temperature (°C)	18.0*
Algae/aquatic plants, water clarity	Lake water has a murky dark green appearance but appears clear in cup. Benthic algae attached to grass runners floating on lake*
6.Fauna	
Macroinvertebrates eg. midges and mosquitos	None observed during site visit.*
Macrofauna	None observed during site visit.*

Notes:

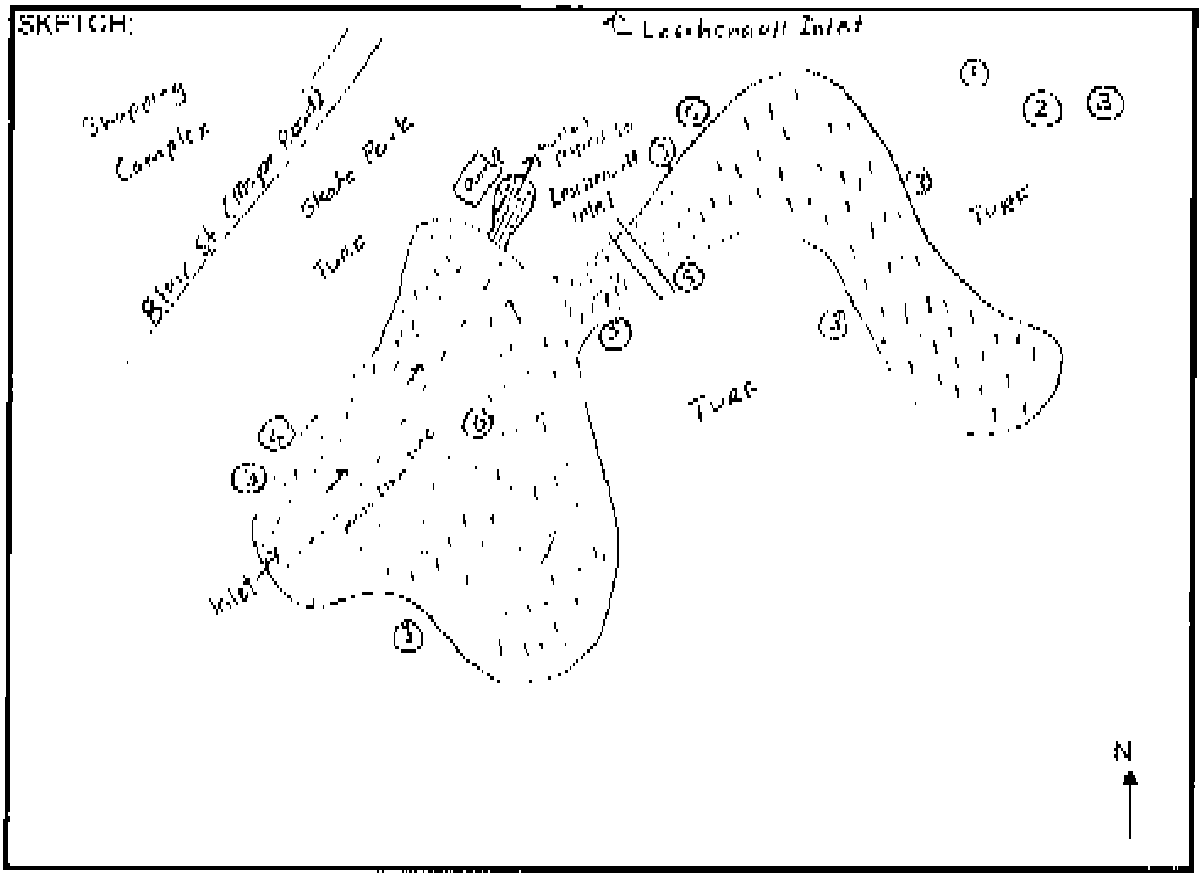
* Field pH, EC, TDS and temperature measured during site visit on 17/10/07. Observations of algae, aquatic plants, water clarity and fauna also recorded on this day.
NT = Not tested

Constructed Lake Study
Field Survey Form

Lake Name and Location: **Queens Garden Lake, Bunbury**

Date: 17/10/2007 Recorded By: Bronwyn Woodward

SKETCH:



Water Level (mark location of staff gauges): None located

Estimated Depth of Water: 2m max

Lake Edge	%	Notes
Walled		
Vegetated		
Grassed	100	Turf edge although almost 100% of lake bed is vegetated
Earth		

Water quality: (scums, water clarity, algae, mosquitoes, pH, EC?) murky dark green brown benthic algae attached to grass runners (looking on lake), relatively quite clear in cup pH: 7.98 EC: 0.70 mS TDS: 0.49 ppt Temp: 18.0°C

Fauna: Didn't observe any

Vegetation Type(s) adjacent to lake - (annotate with numbers) (1) (a few trees) Peppermint (2) Wattle (3) She oak (4) Paperbark (5) [illegible] (6) Entire lake bed is covered in a thick growth of weeds. Weed invasion

Other Comments.

Queens Gardens Lake - Photographic Plates

PLATE 1 – Water from the lake discharges through this outlet to the Leschenault Inlet. The lake bed is heavily vegetated with reeds.

PLATE 2 – Rubbish collecting around the lake outlet.

West Road Lake – Summary Report

The West Road Lake has collected drainage from a residential area in South Bunbury for over 50 years. The lake has a poor visual appearance and is currently fenced off due to its steep earth banks which pose a potential risk to public safety. In response to requests from surrounding residents the City of Bunbury would like to improve the aesthetic, recreational and habitat value of the lake and are keen for guidance on how to achieve this.

Previous Studies/ Monitoring:

One or two sampling event for mosquito larvae (none detected).

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **West Road Lake**

1. Basic Details	
Location (street and suburb)	West Rd, South Bunbury
Location (coordinates)	372529.9 E, 6308887.9 N
2007 Streetsmart page number	B9, M39
Local Government	City of Bunbury
Owner	City of Bunbury
Function*	D
Age (years)	~50
2. Physical Features	
Lining (y/n)	N
Area (ha)	~0.05384
Shape (e.g. linear, round, irregular)	Round
Depth range (estimate) (m)	1 to 2
"Naturalness" rating (1 to 5)*	2
Social amenity value (High, Medium, Low)	Medium - residents would like to see its visual appearance improved
Edging (e.g. wall, trees, reeds, sloping banks, turf)	Vegetated (7%), Grassed (43%) and Earth (50%)
Vegetation type adjacent to lake*	N/X (Trees- White gums, Bottlebrush, Redgum, *Typha* , 2 Reed species)
Vegetation condition adjacent to lake*	F
Potential acid sulfate soil (ASS) risk (according to ASS risk map)	on edge of moderate to low risk of ASS occurring within 3 m of natural soil surface

* Notes:

Function
D - Drainage
C - Conservation
A - Aesthetic (and recreational)
I - Irrigation Storage

Naturalness rating
1 - Highly ornamental
2 - Mostly ornamental with some natural features
3 - Some ornamenatal and some natural features
4 - Natural or natural like with some ornamental features
5 - Natural or natural like

Vegetation type
N - Native
X - Exotic

Vegetation condition
P - Poor
F- Fair
G - Good
E - Excellent

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **West Road Lake**

3. Catchment and Hydrology	
Catchment type (e.g. industrial, residential)	Residential
Prior land use	Farmland
Catchment size (ha)	ND
Geology (unit)	Safety Bay Sand (Qhs)
(description)	Calcareous quartz sand dunes
No. inlets	2
Inlet volume/size	Inlet 1 - pipe diameter = ~ 450 mm Inlet 2 - pipe diameter = 450 mm
No. Outlets	1 (pumped)
Outlet Volume/ Size	Pipe diameter = 900 mm
Drainage connection flow through (FT) or End Point (EP) or No Drainage (NDr)	FT
Approximate volume of water extracted for irrigation	0
Water level top up (y/n)?	N
Estimated residence time	ND
Water or nutrient balance undertaken (y/n)?	N
4. Management	
Aeration/agitation present/absent?	Absent
Aeration type if present* How many?	NA
Fertiliser application adjacent to lake (y/n)?	N
Irrigation adjacent to lake (y/n)?	N
Lawn mowing/ weed control	Mow when needed. Unlikely to undertake weed control.
Management problems*	8, 12 Resident complaints about poor visual appearance and mosquitos although none detected by previous sampling. *Typha* invasion is also a problem.
Maintenance and effectiveness	Future management by council aims to improve the aesthetic and habitat value of the lake, would like some more guidance. Manual removal of *Typha* .
Monitoring frequency	Not monitored aside from one or two sampling events for mosquito larvae

* Notes:

Aeration Features
F - Fountain
R - Rocks/waterfall
C - Circulation by pumping
A - Submerged aerator

ND - Data not available within timeframe of study
NA - Not applicable

Management Problems
1. Flooding
2. Drying Out
3. Slow infiltration
4. Odour
5. Nuisance algal growth
6. Fish deaths
7. Bird deaths
8. Mosquitos or midges
9. Acid Sulfate Soils
10. Iron Monosulfides
11. Feral Fish
12. Other (describe)

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **West Road Lake**

5. Water Quality (if known)	
Total Nitrogen (µ/L)	NT
Total Phosphorus (µ/L)	NT
Chlorophyll *a* (µg/L)	NT
pH	8.13*
EC (mS)	0.93*
TDS (ppt)	0.47*
Temperature (°C)	19.3*
Algae/ aquatic plants, water clarity	Filamentous green algae attached to submerged plants/stick and some floating.*
6.Fauna	
Macroinvertebrates e.g. midges and mosquitoes	Complaints about mosquitos although none detected by City of Bunbury sampling
Macrofauna	A few greyish brown ducks, occasional call of motorbike frog

Depth range (estimate) (m)

Notes:

* Field pH, EC, TDS and temperature measured during site visit on 17/10/07. Observations of algae, aquatic plants, water clarity and fauna also recorded on this day.

NT = Not tested

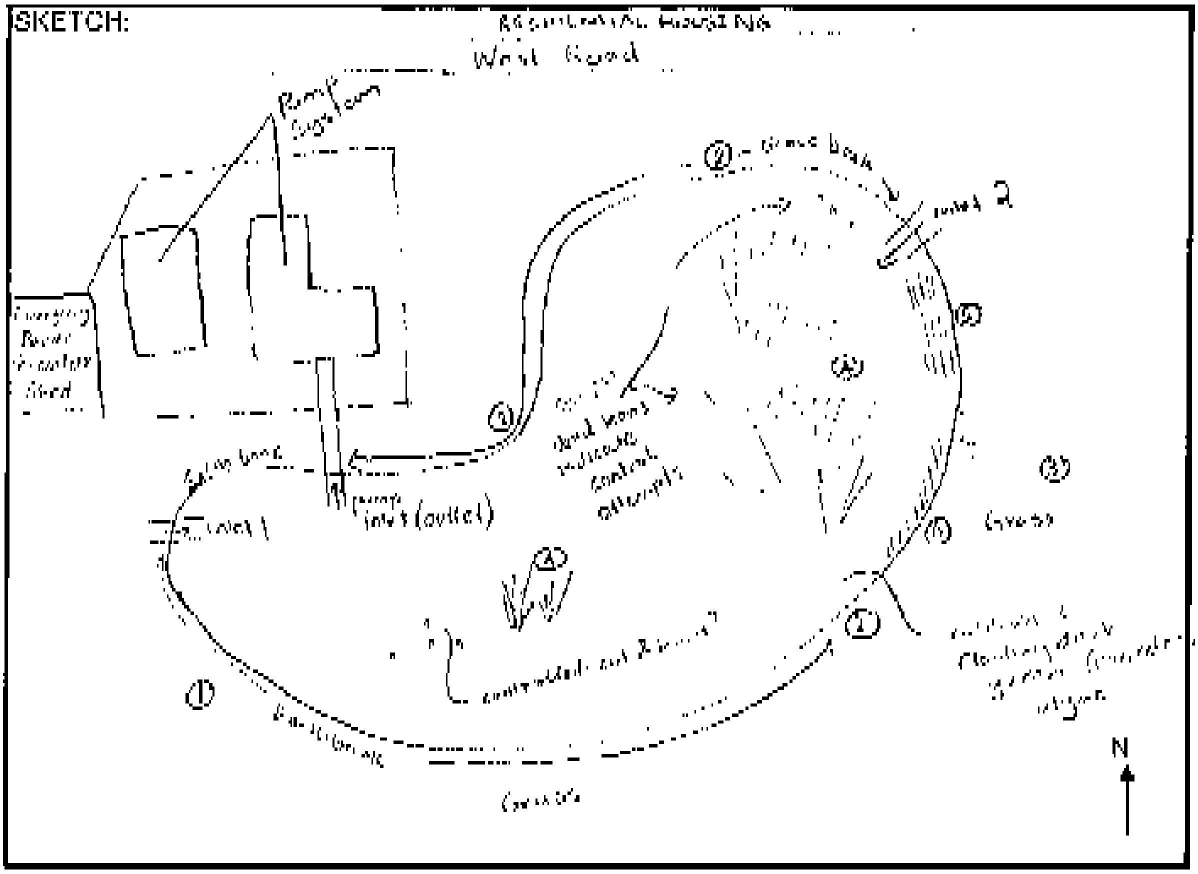
Constructed Lake Study
Field Survey Form

Lake Name and Location: **West Road Lake, Bunbury**

Date: 17/10/2007

Recorded By: Bronwyn Woodward

SKETCH:



Water Level (mark location of staff gauges): None located

Estimated Depth of Water: ~1-2

Lake Edge	%	Notes
Walled	0	
Vegetated	7	a few reeds
Grassed	43	steep banks
Earth	50	[illegible]

Water quality: (scums, water clarity, algae, mosquitoes, pH, EC?) Fairly clear, [illegible]

Fauna: a few [illegible] ducks, occasional [illegible]

Vegetation Type(s) adjacent to lake (annotate with numbers) (1) White gums (2) Bottlebrush (3) [illegible]
(4) Typha (5) Reed species 1 (6) Reed species 2

Other Comments: [illegible]

West Road Lake - Photographic Plates

PLATE 1 – Residents would like to see the visual appearance of the lake improved.

PLATE 2– Typha invasion is a problem in the lake. In some areas it has been manually removed.

City of Canning

- Whaleback Golf Course Lake

Whaleback Golf Course Lake – Summary Report

This lake is located within the Whaleback Public Golf Course in Parkwood within the City of Canning. It intercepts large amounts of industrial drainage from the Canning Vale Gardens Industrial Estate and is also used to irrigate the golf course. The lake has experienced problems resulting from the poor quality of the water discharging into the lake including oil slicks, rubbish buildup and hydrocarbons odours.

Due to the poor and variable quality of the incoming drainage water and its short retention time water quality problems are almost always present in the lake but individual problems are usually short lived. On some occasions pollution events have been severe and persistent. For example waste oil discharge caused an unsightly slick and caused harm to birds by coating their feathers approximately eight years ago. The lake also experienced a period of acidity which mobilized metals and caused tissue death in irrigated plants.

To help improve the water quality in the lake and improve habitat, native fringing vegetation was recently planted around most of the lake's perimeter as part of a joint restoration project run by The Bannister Catchment Group, the City of Canning and the South East Regional Centre of Urban Landcare (SERCUL). In 2006 a boom was also installed near the inlet to collect oil and particulate matter and safety grills were removed and replaced with fencing to prevent rubbish build up blocking the drains.

Previous Studies/ Monitoring:

Monitored by SERCUL. Monitoring data was not available within the time frame of the study.

Some monitoring by Sports Turf Technology on behalf of City of Canning

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Whaleback Golf Course Lake**

1. Basic Details	
Location (street and suburb)	Whaleback Ave, Parkwood
Location (coordinates)	398053.3 E, 6453120.6 N
2007 Streetsmart page number	434, C5
Local Government	City of Canning
Owner	City of Canning
Function*	D, I, A
Age (years)	28
2. Physical Features	
Lining (y/n)	N
Area (ha)	1.152
Shape (e.g. linear, round, irregular)	Elongate, slightly irregular, 1 island
Depth range (estimate) (m)	1 (average) 1.5 (max)
"Naturalness" rating (1 to 5)*	3
Social amenity value (High, Medium, Low)	Medium
Edging (e.g. wall, trees, reeds, sloping banks, turf)	85% vegetated, 5% walled, 5% earth, 5% turf
Vegetation type adjacent to lake*	N (~80%), X (~20%) Sedges, Bullrushes ('sword grass'), trees (Sheoaks, Eucalyptus, Bottlebrush, Acacia, some exotic species), young planted saplings/herbs
Vegetation condition adjacent to lake*	F - weeds and some deaths amongst planted vegetation
Potential acid sulfate soil (ASS) risk (according to ASS risk map)	Moderate to low risk of ASS occurring within 3 m of the natural soil surface

* Notes:

Function
D - Drainage
C - Conservation
A - Aesthetic (and recreational)
I - Irrigation Storage

Naturalness rating
1 - Highly ornamental
2 - Mostly ornamental with some natural features
3 - Some ornamenatal and some natural features
4 - Natural or natural like with some ornamental features
5 - Natural or natural like

Vegetation type
N - Native
X - Exotic

Vegetation condition
P - Poor
F- Fair
G - Good
E - Excellent

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Whaleback Golf Course Lake**

3. Catchment and Hydrology	
Catchment type (e.g. Industrial, Residential)	Industrial
Prior land use	Use to be a drain before the golf course was constructed. Possibly a natural stream prior to that.
Catchment size (ha)	ND
Geology (unit)	Bassendean Sand (Qpb)
(description)	S_8 - SAND - white to pale grey at surface, yellow at depth, fine to medium grained, moderately sorted, subangular to subrounded, minor heavy minerals, of aeolian origin
No. inlets	1 - constantly flowing
Inlet volume/size	1200 mm diameter
No. outlets	1 - constantly flowing
Outlet volume/size	2100 mm diameter
Drainage connection flow through (FT) or End Point (EP) or No Drainage (NDr)	FT
Approximate volume of water extracted for irrigation	290, 000 kL/yr (maximum)
Water level top up (y/n)?	Y. Topped up with water from an artesian bore to maintain flow during summer (130,000 to 195,000 kL/yr).
Estimated residence time	ND
Water or nutrient balance undertaken (y/n)?	N
4. Management	
Aeration/agitation present/absent?	Absent
Aeration type if present* How many?	NA
Fertiliser application adjacent to lake (y/n)?	No fertiliser applied within 15m of the lake. Slow release fertiliser only in areas close to the lake 2x per year. Putting greens are fertilised more often with fast uptake fertiliser to reduce leaching to the water table.
Irrigation adjacent to lake (y/n)?	Y with lake water
Lawn mowing/ weed control	ND
Management problems*	1. due to outlet getting blocked 4. occasional hydrocarbon odours 12. oil and rubbish, silt build up, waste oil contamination ~ 8 years ago, major clean up required. Another time high acidity mobilised metals e.g. iron and zinc and caused blackening of the leaves of irrigated plants for ~2 weeks.
Maintenance and effectiveness	Boom installed in 2006 to collect oil/particulate matter, safety grills on inlet and outlet removed to prevent rubbish becoming trapped and blocking flow and replaced with barrier fencing, revegetation
Monitoring frequency	Monitored by South East Regional Centre of Urban Landcare (SERCUL), some monitoring (approximately yearly between 1998-2003) by Sports Turf Technology on behalf of City of Canning

* Notes:

Aeration Features
F - Fountain
R - Rocks/waterfall
C - Circulation by pumping
A - Submerged aerator

Management Problems
1. Flooding
2. Drying Out
3. Slow infiltration
4. Odour
5. Nuisance algal growth
6. Fish deaths
7. Bird deaths
8. Mosquitos or midges
9. Acidity
10. Iron Monosulfides
11. Feral Fish
12. Other (describe)

ND - Data not available within timeframe of study
NA - Not applicable

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Whaleback Golf Course Lake**

5. Water Quality (if known)	**Inlet**	**Outlet**
Inorganic nitrogen (Ammonium + Nitrate) (µ/L)	440-2700**	400 -1700**
Total Phosphorus (µ/L)	80-200**	80-410**
Chlorophyll *a* (µg/L)	ND	ND
pH	7.70* (5.66-7.5**)	7.31* (6.65-7.7**)
EC (mS)	0.54* (0.21-0.78**)	0.61* (0.35-0.91**)
TDS (ppt)	0.27*	0.3*
Temperature (°C)	18.1*	17.5*
Algae/ aquatic plants, water clarity	Small of clumps of dark green filamentous algae, possibly cyanobacteria, observed in stagnant area to south of island, limited distribution.*	
6.Fauna		
Macroinvertebrates e.g. midges and mosquitos	None observed during site visit, no reported problems with mosquitos or midges	
Macrofauna	Eurasian coot, purple swamp hen, Pacific Black duck, unidentified duck	

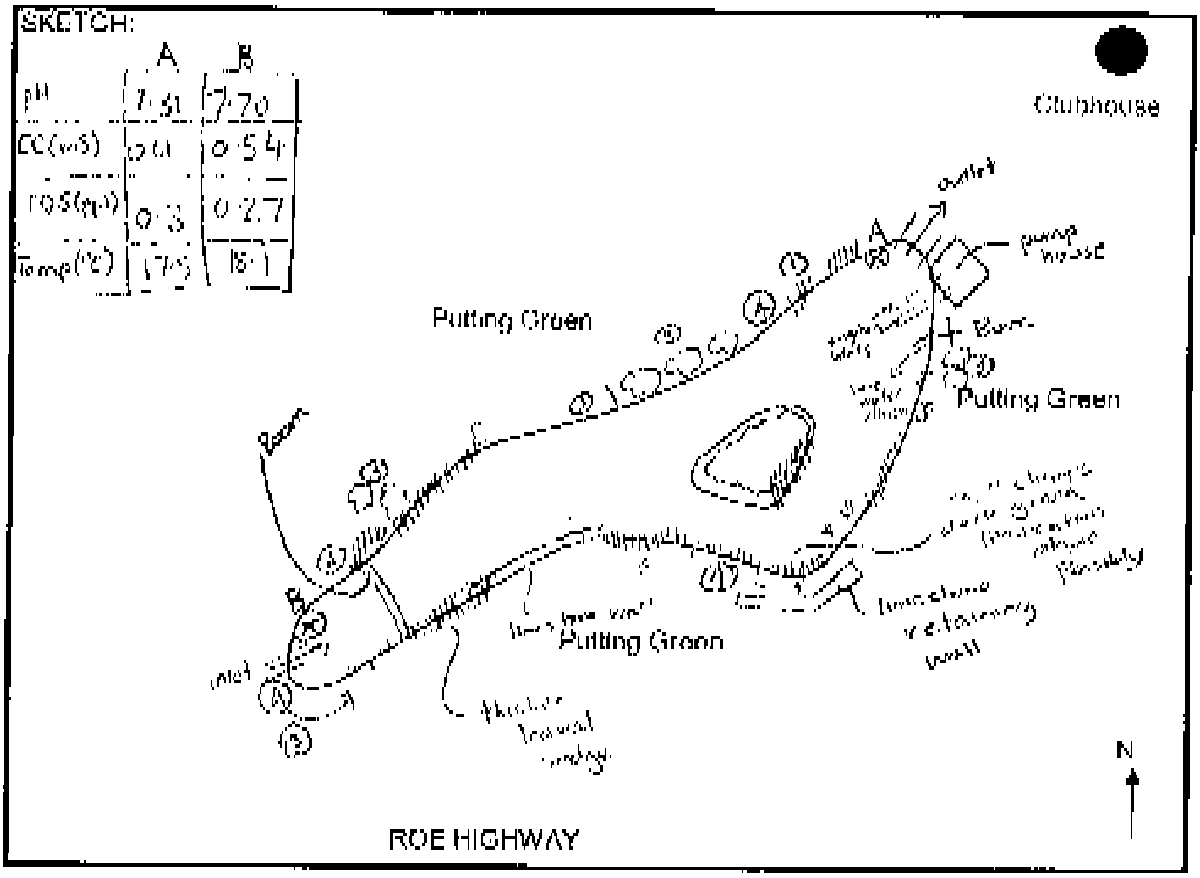
Notes:

* Field pH, EC, TDS and temperature measured during site visit on 26/9/07. Observations of algae, aquatic plants, water clarity and fauna also recorded on this day.
** Range of values recorded by Sports Turf Technology sampling
ND - May have been tested by SERCUL however data not available within time frame of study

Constructed Lake Study
Field Survey Form

Lake Name and Location: **Whaleback Golf Course Lake, Canning Vale**

Date: 26/09/2007   Recorded By: Bronwyn Woodward



Water Level (mark location of staff gauges): None located

Estimated Depth of Water: 1m (average) 1.5m max

Lake Edge	%	Notes
Walled	5	1 limestone wall
Vegetated	85	See below - mostly sedges, some trees
Grassed	5	gaps in vegetation
Earth	5	" " "

Water quality: (scums, water clarity, algae, mosquitoes, pH, EC?) yellow colour, cloudy water column - black appearance, minor sheen near edges - rotting vegetation odour

Fauna: Eurasian coot, swamphen, Pacific black duck, large duck w/white band on neck & colourful feathers

Vegetation Type(s) adjacent to lake - (annotate with numbers) ① Sedges

② Island veg - bottlebrush, melaleucas (swamp paperbark), shrub

③ Trees - sheoak, eucalypts, some exotic species, bottlebrush, Acacia

(4) Young planted saplings / herbs

Other Comments:

Whaleback Golf Course Lake - Photographic Plates

PLATE 1 – A boom installed was installed at the lake inlet in 2006 to collect oil/particulate matter in incoming industrial drainage.

PLATE 2 – The South East Regional Centre of Urban Landcare (SERCUL) has undertaken revegetation works to improve the fringing vegetation around the lake.

City of Cockburn

- Christmas Tree Park Lake West
- Christmas Tree Park Lake East
- Harvest Lakes South

Christmas Tree Park Lakes – Summary Report

The Christmas Tree Park lakes were constructed to collect stormwater from the eastern portion of the Frankland Springs residential development in Hammond Park. The eastern most lake receives stormwater and is unlined to allow infiltration to the superficial aquifer. Infrequent overflow is directed to the west into a second lined lake which is used to irrigate the park area and is topped up with groundwater to maintain water levels.

It is understood that the currently overflow from the western lined lake is directed towards dampland to the north of the park. It is proposed to build an infiltration basin would be built to intercept overflow before it discharges into the dampland. Midge populations have previously been high at lakes however there have been no recent complaints from residents. This may have been due to deepening of the eastern infiltration lake which has discouraged midge breeding.

Previous Studies/ Monitoring:

ATA (2002) *Lot 202 Russell Road, Banjup Drainage and Nutrient Management Plan*. Report prepared for Australand.

City of Cockburn sampling for midges and water quality in west lake (May 2004 to September 2007)

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Christmas Tree Park Lakes**

1. Basic Details	**West Lake**	**East Lake**
Location (street and suburb)	Serenity Pwy, Hammond Park	
Location (coordinates)	391717.1 E, 6441155.5 N	391747.2 E, 6441157.5 N
2007 Streetsmart page number	492, E8&E9	
Local Government	City of Cockburn	
Owner	City of Cockburn	
Function*	D, A, I	D, A
Age (years)	~6	
2. Physical Features	**West Lake**	**East Lake**
Lining (y/n)	Y - XLPE PVC	N
Area (ha)	0.307	0.184
Shape (e.g. linear, round, irregular)	oval	linear, slightly curved
Depth range (estimate) (m)	3.5 (max)	originally 1.5. Do not know how deep it is after being dug out.
"Naturalness" rating (1 to 5)*	2.5	3.5
Social amenity value (High, Medium, Low)	High	High
Edging (e.g. wall, trees, reeds, sloping banks, turf)	5% walled, 95% vegetated	100% vegetated
Vegetation type adjacent to lake*	Mostly N. 2 types of reeds (*Lomandra longifolia* and *baumea*), broadleaf paperbark, ornamental shrubs	Mostly N. 2 types of reeds (*Lomandra longifolia* and *baumea)*, *Typha*, natural remnant vegetation (paperbark & sheoak)
Vegetation condition adjacent to lake*	G	G
Potential acid sulfate soil (ASS) risk (according to ASS risk map)	Moderate to low risk of ASS occurring within 3m of natural soil surface	

* Notes:

Function
D - Drainage
C - Conservation
A - Aesthetic (and recreational)
I - Irrigation Storage

Naturalness rating
1 - Highly ornamental
features
features
ornamental features
5 - Natural or natural like

Vegetation type
N - Native
X - Exotic

Vegetation condition
P - Poor
F- Fair
G - Good
E - Excellent

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Christmas Tree Park Lakes**

3. Catchment and Hydrology	**West Lake**	**East Lake**
Catchment type (e.g. industrial, residential)	Residential	
Prior land use	Bushland	
Catchment size (ha)	ND	ND
Geology (unit)	Bassendean Sand (Qpb) and Swamp deposits (Qhw)	
(description)	S_8 - SAND - white to pale grey at surface, yellow at depth, fine to medium grained, moderately sorted, subangular to subrounded, minor heavy minerals, of aeolian origin and Ms_5 - SANDY SILT - dark brownish grey, silt, with desseminated fine-grained quartz sand, firm, variable clay content of lacustrine origin	
No. inlets	1 stormwater drain, also receives infrequent overflow from East Lake)	1
Inlet volume/size	ND	ND
No. outlets	0	1 (infrequently overflows to West Lake)
Outlet volume/size	NA	ND
Drainage connection flow through (FT) or End Point (EP) or No Drainage (NDr)	EP	FT
Approximate volume of water extracted for irrigation	ND	0
Water level top up (y/n)?	Y - with bore water	N
Estimated residence time	ND	ND
Water or nutrient balance undertaken (y/n)?	N	N
4. Management	**West Lake**	**East Lake**
Aeration/agitation present/absent?	Present	Absent
Aeration type if present* How many?	1F	NA
Fertiliser application adjacent to lake (y/n)?	Y (using only slow release fertiliser 1-2 times per year)	
Irrigation adjacent to lake (y/n)?	Y (using water from west lake)	
Lawn mowing/ weed control	Mow fortnightly. Spray broadleaf weeds with Spearhead.	
Management problems*	Issue with fountain in west lake. Midge populations have previously been high, but no recent complaints from residents.	
Maintenance and Effectiveness	Dug out Lake B to reduce midge breeding	
Monitoring frequency	Since May 2004 has been monitored approximately monthly between August and March with one or two samples collected between April and July. Samples analysed for midges and water quality.	Not monitored

* Notes:

Aeration Features
F - Fountain
R - Rocks/waterfall
C - Circulation by pumping
A - Submerged aerator

Management Problems
1. Flooding
2. Drying Out
3. Slow infiltration
4. Odour
5. Nuisance algal growth
6. Fish deaths
7. Bird deaths
8. Mosquitos or midges
9. Acid Sulfate Soils
10. Iron Monosulfides
11. Feral Fish
12. Other (describe)

ND - Data not available within timeframe of study
NA - Not applicable

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Christmas Tree Park Lakes**

5. Water Quality (if known)	**West Lake**	**East Lake**
Total Nitrogen (μ/L)	16-200**	NT
Total Phosphorus (μ/L)	810-1700**	NT
Chlorophyll *a* (μg/L)	1.1-14**	NT
pH	7.49* (6.53-8.85**)	7.43*
EC (mS)	0.43* (0.41-0.67**)	0.41*
TDS (ppt)	0.21*	0.2*
Temperature (°C)	18.1* (11.9-25.2**)	19.5*
Algae/ aquatic plants, water clarity	Tannin stained water. No algae observed during site visit.* No algae observed during City of Cockburn sampling.	
6.Fauna	**West Lake**	**East Lake**
Macroinvertebrates e.g. midges and mosquitos	Previous midge problems however none observed during site visit.* Highest recorded midge larvae number = 1614 midges/m^2.	
Macrofauna	Could hear clicking froglet, banjo frogs, juvenile gambusia.	

Notes:

* Field pH, EC, TDS and temperature measured during site visit on 18/9/07. Observations of algae, aquatic plants, water clarity and fauna also recorded on this day.

** Range of values recorded by City of Cockburn sampling (May 2004 to September 2007)

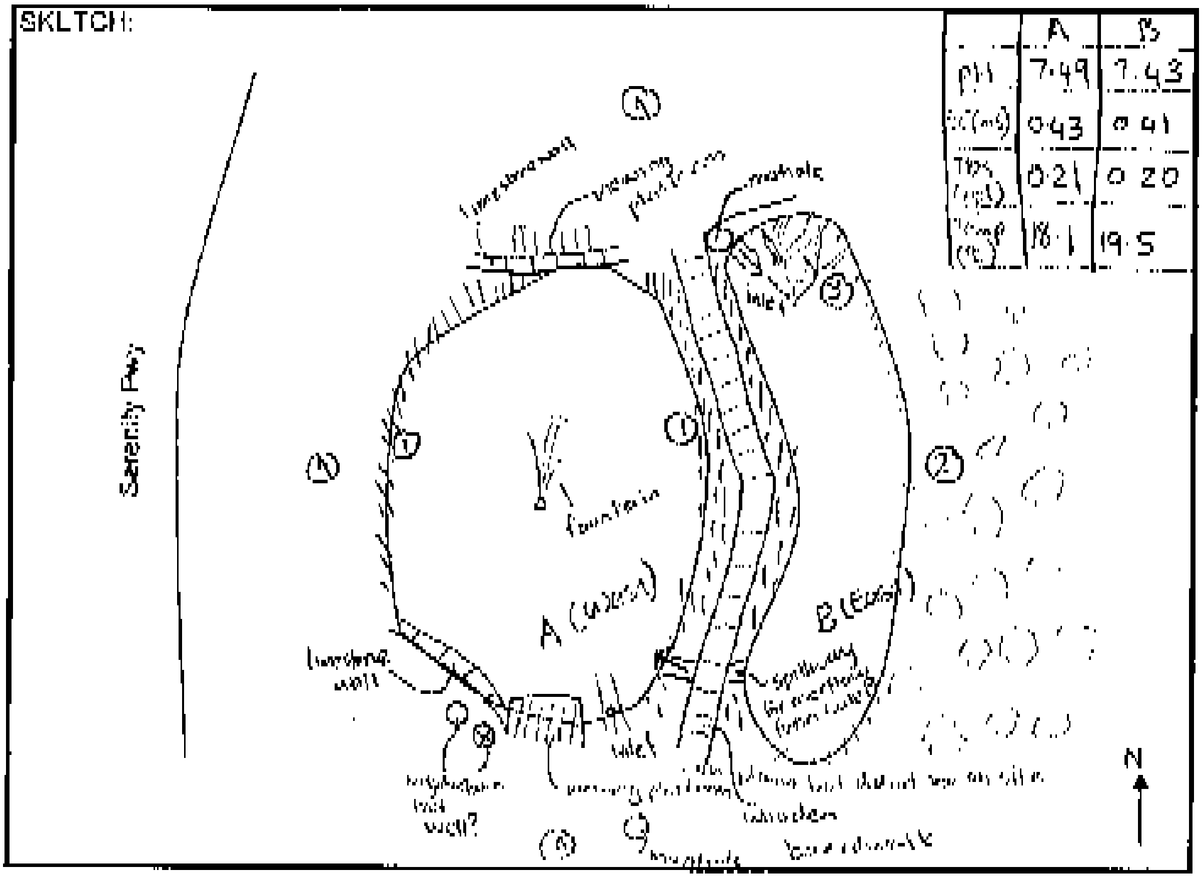
NT = Not tested

Constructed Lake Study
Field Survey Form

Lake Name and Location: Christmas Tree Park Lake, Hammond Park

Date: 18/09/2007 Recorded By: Bronwyn Woodward

SKETCH:



Water Level (mark location of staff gauges): No gauge located

Estimated Depth of Water: WEST ~ 3.5m max EAST ~ 2m max?

Lake Edge	WEST %	EAST	Notes
Walled	5		A - limestone blocks
Vegetated	95	100	Reeds etc (see below)
Grassed			
Earth			

Water quality: (scums, water clarity, algae, mosquitoes, pH, EC?) A. [illegible]

B. Dark reddish brown colour [illegible]

Fauna: [illegible] → Gambusia?

Vegetation Type(s) adjacent to lake - (annotate with numbers) (1) Reeds - [illegible] [illegible] Bunnings?

(2) Natural remnant veg - [illegible]

(3) Typha (4) Landscaping - ornamental shrubs

Other Comments:

Christmas Tree Park Lakes - Photographic Plates

PLATE 1 – The eastern lake has a more ornamental appearance than the western lake.

PLATE 2 – Natural vegetation surrounding the western lake. Some *Typha* is visible in the left side of the photograph.

Harvest Lakes (South) – Summary Report

The Harvest Lakes were created approximately three years ago within the first 'GreenSmart Village' residential development in Western Australia designed to minimise impacts on the environment and promote sustainability. The southern lake is lined, used for irrigation and receives stormwater runoff. The northern water body is an ephemeral wetland.

Drainage into the lakes has been designed to reduce stormwater flow and improve quality using the principals of water sensitive urban design as outlined in drainage and nutrient management plans prepared for the development. Drainage enters the southern lake via bubble ups and reed beds. Despite measures to improve the quality of stormwater entering the lake and its young age and it has experienced problems associated with nutrient enrichment including midge plagues, blooms of filamentous green algae and odours.

Previous Studies/ Monitoring:

BBG (2002) *Atwell South Drainage and Nutrient Management Plan*. Report prepared for Landcorp.

City of Cockburn sampling for midges and water quality in south lake (February 2003 to September 2007)

Davis, J. (2006) *Harvest Lakes (southern wetland) Bioassessment*. Aquatic Ecosystems Research Group School of Environmental Science, Murdoch University. Report prepared for Bowman Bishaw Gorham.

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Harvest Lakes (South)**

1. Basic Details	
Location (street and suburb)	Harmony Ave, Atwell
Location (coordinates)	393072.9 E, 6442069.9 N
2007 Streetsmart page number	493, B7
Local Government	City of Cockburn
Owner	City of Cockburn
Function*	D, A, I
Age (years)	~ 3 to 4
2. Physical Features	
Lining (y/n)	Y - XLPE PVC
Area (ha)	1.47 [@ annual average maximum groundwater level (AAMGL)] (BBG, 2003)
Shape (e.g. linear, round, irregular)	round, slightly pinched in the middle
Depth range (estimate) (m)	5 (max at AAMGL) (BBG, 2003)
"Naturalness" rating (1 to 5)*	2
Social amenity value (High, Medium, Low)	High
Edging (e.g. wall, trees, reeds, sloping banks, turf)	100% walled (concrete kerb/limestone wall) (80% vegetated, reeds)
Vegetation type adjacent to lake*	N (60%), X (40%) Island veg: mature *Eucalyptus rudis* (natural remnant), understorey of young planted *Eucalyptus* , reeds; Fringing veg: Reeds (monoculture of *Baumea*), Mature stand of *E. rudis*
Vegetation condition adjacent to lake*	G
Potential acid sulfate soil (ASS) risk (according to ASS risk map)	Majority high to moderate risk of ASS occurring within 3 m of natural surface. Remaining moderate to low risk of ASS occurring within 3m of natural surface

* Notes:

Function
D - Drainage
C - Conservation
A - Aesthetic (and recreational)
I - Irrigation Storage

Naturalness rating
1 - Highly ornamental
2 - Mostly ornamental with some natural features
3 - Some ornamenatal and some natural features
4 - Natural or natural like with some ornamental features
5 - Natural or natural like

Vegetation type
N - Native
X - Exotic

Vegetation condition
P - Poor
F- Fair
G - Good
E - Excellent

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Harvest Lakes (South)**

3. Catchment and Hydrology	
Catchment type (e.g. industrial, residential)	Residential
Prior land use	Cleared bushland, EPP wetland
Catchment size (ha)	ND
Geology (unit)	Bassendean Sand (Qpb)
(Description)	S_8 - SAND - white to pale grey at surface, yellow at depth, fine to medium grained, moderately sorted, subangular to subrounded, minor heavy minerals, of aeolian origin
No. Inlets	3 stormwater inlets (vegetated bubble ups) and 1 vegetated swale (connected to Harvest Lakes North)
Inlet Volume/ Size	bubble up grates ~1 to 2m^2
No. Outlets	0
Outlet Volume/ Size	NA
Drainage Connection Flow through (FT) or End Point (EP) or No Drainage (NDr)	EP
Approximate volume of water extracted for irrigation	ND
Water level top up (y/n)?	Y - with bore water
Estimated residence time	ND
Water or nutrient balance undertaken (y/n)?	N
4. Management	
Aeration/agitation present/absent?	Present
Aeration type if present* How many?	1A
Fertiliser application adjacent to lake (y/n)?	Y (1-2 times per year)
Irrigation adjacent to lake (y/n)?	Y - using lake water
Lawn mowing/ weed control	Mow fortnightly. Spray broadleaf weeds with Spearhead.
Management problems*	4, 5 & 8- Past odour problems, major problems with midge plagues and filamentous green algae blooms
Maintenance and effectiveness	Hay bales used to remove nutrients. Developer may have netted koi.
Monitoring frequency	Regular monitoring for midges and water quality by City of Cockburn since mid 2004. Samples collected approximately monthly in spring/summer with occasional samples also collected in autumn and winter.

* Notes:

Aeration Features
F - Fountain
R - Rocks/waterfall
C - Circulation by pumping
A - Submerged Aerator

ND - Data not available within timeframe of study
NA - Not applicable

Management Problems
1. Flooding
2. Drying Out
3. Slow infiltration
4. Odour
5. Nuisance algal growth
6. Fish deaths
7. Bird deaths
8. Mosquitos or midges
9. Acid Sulfate Soils
10. Iron Monosulfides
11. Feral Fish
12. Other (describe)

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Harvest Lakes (South)**

5. Water Quality (if known)	
Total Nitrogen (µg/L)	420-1100**, 700***
Total Phosphorus (µg/L)	16-70**, 35***
Chlorophyll *a* (µg/L)	1.4-45**, 8.2&32
pH	8.65* (7.20-9.35**)
EC (mS)	0.94* (0.74-1.15**)
TDS (ppt)	0.47*
Temperature (°C)	17.4* (12.3-25.1**)
Algae/ aquatic plants, water clarity	Very slight yellowy/green tinge indicating presence of phytoplankton, small amounts of filamentous green algae growing near wall.* In October 2005 *Potamogeton crispus* and high levels of filamentous green algae (Davis, 2006)
6.Fauna	
Macroinvertebrates eg. midges and mosquitos	None observed during site visit. Survey conducted on 13/10/05 recorded 18 species of aquatic invertebrates, relatively high proportion of predators indicating a complex food web (Davis, 2006)
Macrofauna	Ducks, 1 Eurasian coot

Notes:

* Field pH, EC, TDS and temperature measured during site visit on 18/9/07. Observations of algae, aquatic plants, water clarity and fauna also recorded on this day.
** Range of values recorded by City of Cockburn sampling (February 2003 to September 2007).
*** Values recorded by Davis (2006). TN and TP are mean values. Chlorophyll *a* was measured on two bulk samples.
NT = Not tested

Constructed Lake Study
Field Survey Form

Lake Name and Location: **Harvest Lakes (South), Atwell**

Date: 18/09/2007   Recorded By: Bronwyn Woodward

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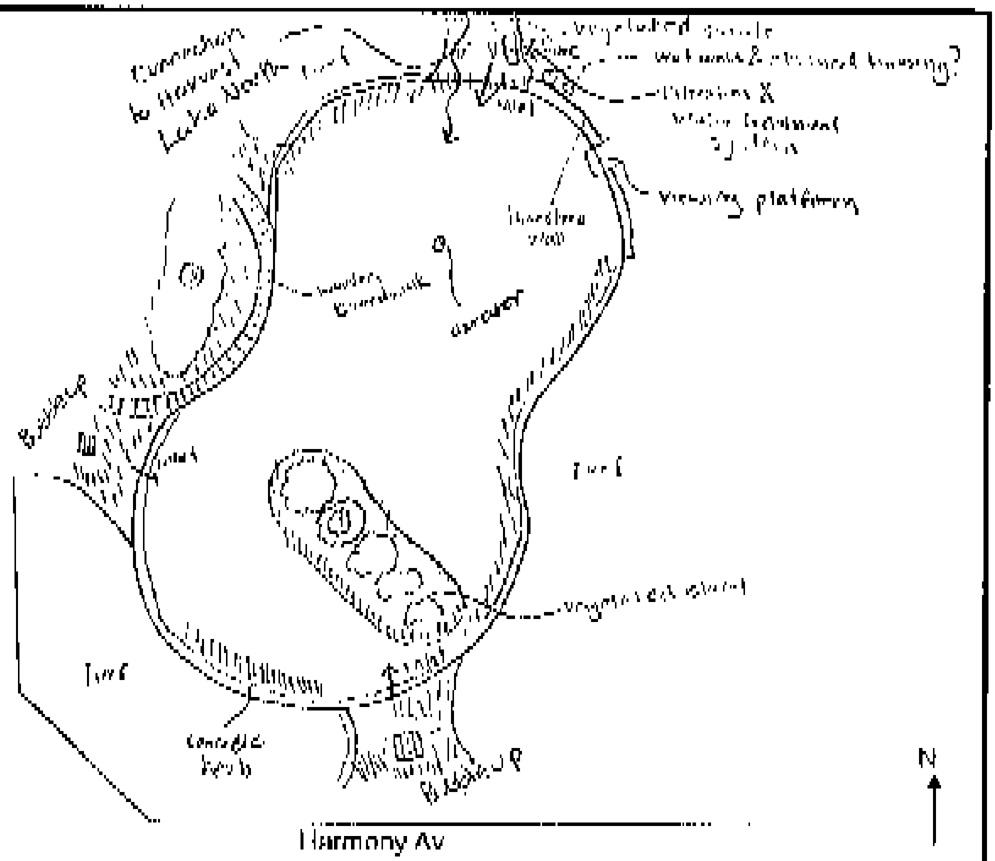


Water Level (mark location of staff gauges): None located

Estimated Depth of Water: Shallow close to shore. Deeper further out

Lake Edge	%	Notes
Walled	100	Concrete kerb / limestone wall
Vegetated	(80) – emergent	Reeds
Grassed	0	
Earth	0	

Water quality: (scums, water clarity, algae, mosquitoes, pH, EC?) Cloudy, some algae, yellowy green fringes, filamentous green algae

pH = 8.65 EC = 0.94 mS TDS: 0.47 ppt Temp: 17.4 °C

Fauna: ducks, 1 Eurasian coot

Vegetation type(s) adjacent to lake - (annotate with numbers) (1) Island vege mature Eucalyptus, reeds - natural remnant. Understorey of young planted / Eucalyptus, reeds

(2) Reeds - Bauera? / emergent (3) mature planted Eucalyptus

Other Comments: Lead into wetlands, emergent reeds - acting as a gross pollutant filter. Promoted as an example of urban water management.

Harvest Lakes (South) - Photographic Plates

PLATE 1 – The lake is surrounded by some native vegetation. An aerator is visible in the foreground and the 'GreenSmart Village' residential development in the background.

PLATE 2– Drainage enters the lake via bubble ups and reed beds.

City of Gosnells

- Alexandria Bvd Reserve Lake
- Brookland Greens - Prior Close Reserve Lake
- Brookland Greens - Sandringham Promenade Reserve 2
- The Bridgeway Lake

Alexandria Boulevard Reserve Lake – Summary Report

The Alexandria Boulevard Reserve Lake intercepts drainage from the suburb of Canning Vale in the City of Gosnells. The lake is valued by surrounding residents for its aesthetic and recreational importance. Prior to entering the lake stormwater should flow through vegetated swales that encircle its perimeter however the high water velocity has broken through swales at most locations.

Limestone walls around the lake edge have decayed in many areas, possibly due to mild acidity. The lake also experiences problems with *Typha* invasion and there have been occasional complaints about mosquitoes. The City of Gosnells proposes to replace the walls at badly decayed locations. Currently, *Typha* is treated in sections of the lake with round up bioactive followed by manual removal and then more spraying. Attempts were made by the City of Gosnells to repair swales however they soon broke open again.

Previous Studies/ Monitoring:

City of Gosnells water quality monitoring (March 2003 to June 2007)

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Alexandria Boulevard Reserve Lake**

1. Basic Details	
Location (street and suburb)	Alexandria Boulevard, Canning Vale
Location (coordinates)	398622.7 E, 6448184.4 N
2007 Streetsmart page number	464, D4
Local Government	City of Gosnells
Owner	City of Gosnells
Function*	D, A
Age (years)	12
2. Physical Features	
Lining (y/n)	N
Area (ha)	~ 6.4394
Shape (e.g. linear, round, irregular)	linear/irregular, small island
Depth range (estimate) (m)	7-8 (max)
"Naturalness" rating (1 to 5)*	2
Social amenity value (High, Medium, Low)	High
Edging (e.g. wall, trees, reeds, sloping banks, turf)	15% walled (limestone blocks), 70% vegetated, 15% grassed
Vegetation type adjacent to lake*	Mix of N and X - *Typha* , *Juncus* , *Allocasuarina* , paperbark (*Melaleuca raphiophylla*), flooded gum, European trees (plane trees and willow), broadleaf paperbark, bottlebrush
Vegetation condition adjacent to lake*	G
Potential acid sulfate soil (ASS) risk (according to ASS risk map)	Moderate to low risk of ASS occurring within 3 m of natural surface

* Notes:

Function
D - Drainage
C - Conservation
A - Aesthetic (and recreational)
I - Irrigation Storage

Naturalness rating
1 - Highly ornamental
2 - Mostly ornamental with some natural features
3 - Some ornamenatal and some natural features
4 - Natural or natural like with some ornamental features
5 - Natural or natural like

Vegetation type
N - Native
X - Exotic

Vegetation condition
P - Poor
F- Fair
G - Good
E - Excellent

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Alexandria Boulevard Reserve Lake**

3. Catchment and Hydrology	
Catchment type (eg. Industrial, Residential)	Residential
Prior land use	Sand mine (former sand dune), flattened dune was dug out further to create lake
Catchment size (ha)	ND
Geology (unit)	Bassendean Sand (Qpb)
(description)	S_8 - SAND - white to pale grey at surface, yellow at depth, fine to medium grained, moderately sorted, subangular to subrounded, minor heavy minerals, of aeolian origin
No. inlets	7 - most drainage is supposed to flow through vegetated swales that encircle the lake however these are not functioning
Inlet volume/size	Inlets observed on site had ~500mm diameter
No. outlets	1
Outlet volume/size	~ 400mm diameter pipe
Drainage connection flow through (FT) or End Point (EP) or No Drainage (NDr)	FT
Approximate volume of water extracted for irrigation	0
Water level top up (y/n)?	N
Estimated residence time	ND
Water or nutrient balance undertaken (y/n)?	N
4. Management	
Aeration/agitation present/absent?	Present
Aeration type if present* How many?	2F
Fertiliser application adjacent to lake (y/n)?	Y - low nitrogen slow release fertiliser applied once per year at the end of winter
Irrigation adjacent to lake (y/n)?	Y
Lawn mowing/ weed control	Mow lawns around lake.
Management problems*	5 (according to SERCUL), 8 - occasional complaints about mosquitoes, 12 - decay of limestone walls (may be due to acidity), invasion by *Typha* , high water velocity of stormwater inflow has broken through swales at most locations
Maintenance and effectiveness	Propose to replace walls at badly decayed locations. Treat *Typha* in sections with round up bioactive followed by manual removal then more spraying. Have attempted to repair swales however soon broke again. Used to have catcher baskets on drains but clogged up too quickly so were removed.
Monitoring frequency	Water samples collected near stormwater inlets by City of Gosnells approximately twice per year since March 2003. Samples analysed for pH, EC, dissolved oxygen, temperature, turbidity, nutrients and chlorophyll *a* .

* Notes:

Aeration Features
F - Fountain
R - Rocks/waterfall
C - Circulation by pumping
A - Submerged aerator

Management Problems
1. Flooding
2. Drying Out
3. Slow inflitration
4. Odour
5. Nuisance algal growth
6. Fish deaths
7. Bird deaths
8. Mosquitos or midges
9. Acid Sulfate Soils
10. Iron Monosulfides
11. Feral Fish
12. Other (describe)

ND - Data not available within timeframe of study

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Alexandria Boulevard Reserve Lake**

5. Water Quality (if known)	
Inorganic nitrogen (Ammonium + NOx) (μ/L)	440-1940**
Total Phosphorus (μ/L)	10-160**
Chlorophyll *a* (μg/L)	3.78-5.04**
pH	8.32* (7.36-7.95**)
EC (mS)	0.52* (0.66-0.88**)
TDS (ppt)	0.26*
Temperature (°C)	21.6* (15.5-29.6**)
Algae/ aquatic plants, water clarity	Filamentous green algae collecting around edges in some areas, brown benthic macroalgae. Slight yellow/brown tinge and mild decaying organic odour on eastern side indicating possible presence of algal bloom.* Has had algal blooms according to South East Regional Centre for Urban Landcare (SERCUL).
6.Fauna	
Macroinvertebrates e.g. midges and mosquitos	Adult dragonflies
Macrofauna	Juvenile *Gambusia*, could hear calls of quacking frogs, pair of Muscovy ducks, Eurasian coot, Pacific Black ducks, grey ibis.

Notes:

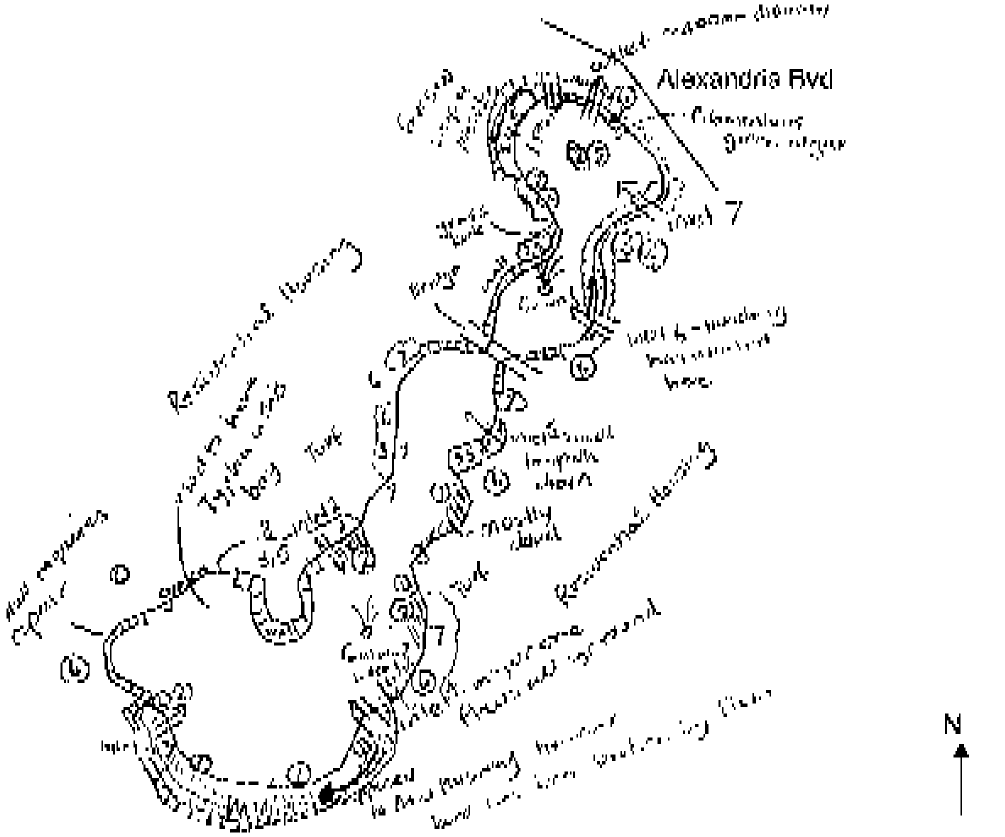
* Field pH, EC, TDS and temperature measured during site visit on 4/10/07. Observations of algae, aquatic plants, water clarity and fauna also recorded on this day.
** Range of values recorded by City of Gosnells sampling (March 2003 to June 2007). Chlorophyll *a* only analysed in early summer 2005 and early autumn 2006.

Constructed Lake Study
Field Survey Form

Lake Name and Location: **Alexandria Bvd Reserve Lake, Canning Vale**

Date: 11/10/07 Recorded By: Bronwyn Woodward

SKETCH:



Water Level (mark location of staff gauges): None located

Estimated Depth of Water: 1-8 m (max)

Lake Edge	%	Notes
Walled	15	limestone blocks
Vegetated	70	See below
Grassed	15	gaps of sloping grass banks
Earth	0	

Water quality: (scums, water clarity, algae, mosquitoes, pH, EC?) [illegible] collecting [illegible] algae [illegible] water clarity [illegible] slight yellow [illegible]
pH 8.32 EC 0.52 TDS 0.26 ppt Temp 21.6°C [illegible]

Fauna: [illegible] (Muscovy) [illegible]
juvenile gambusia [illegible]

Vegetation Type(s) adjacent to lake - (annotate with numbers) (1) Typha [illegible] (2) Sedges - juncus
(3) Alis[illegible] (4) Paperbark ([illegible])
(5) [illegible] gum (6) [illegible] (7) [illegible]
(8) Bottlebrush

Other Comments: [illegible] on lake bed around bottom to stop lapping to stop wear on walls

Alexandria Boulevard Reserve Lake - Photographic Plates

PLATE 1 – The lake is in close proximity to residential housing and has received occasional complaints about mosquitos and midges.

PLATE 2 – Decay of limestone walls at one of the lake inlets.

Alexandria Boulevard Reserve Lake - Photographic Plates

PLATE 3 – Vegetated swale. Water has broken the swales in places therefore flows directly into the lake rather than through the swale.

PLATE 4 – Bloom of filamentous green algae in the lake in October 2007.

Brookland Greens – Summary Report

There are two constructed lakes within the Brookland Greens Estate connected by a remnant of natural ephemeral wetland that receives stormwater drainage. The most southern upstream lake (Sandringham 2) is a lined irrigation lake that does not receive drainage. No management problems have been recorded in this lake.

The most northern and downstream lake (Prior Close Reserve Lake) serves a secondary drainage function receiving overflow from the ephemeral wetland which discharges via an outlet on the southern side of the lake. This lake has experienced management problems including blooms of filamentous green algae and midge plagues.

A comprehensive midge mitigation mitigation study conducted by Terra Consulting and the Murdoch University Aquatic Ecosystems Research Group in 2003 estimated the average nutrient generation from the Brookland Greens catchment using the Model for Urban Stormwater Improvement Conceptualisation (MUSIC). The modelling indicated that elevated nutrients in stormwater flowing through the natural wetland in the middle of the lake system were contributing to midge problems in the Prior Close Reserve Lake.

To control midge and mosquito problems in the Prior Close Reserve Lake, it was recommended that nutrient loads into the lake system be controlled through measures such as community education. It was proposed that monitoring, including an assessment of nutrient loads from bore water top up and sediment release, be conducted to better understand the water and nutrient balance of the lake. It was also recommended that Abate continue to be used on an as needs basis at the Prior Close Reserve Lake and the community be consulted regarding the suitability of buffer plantings.

The Prior Close Reserve Lake was treated with Phoslock in October 2006 to bind dissolved phosphorus from the water column and prevent its release from the sediment. It is not known by the lake manager whether the Phoslock application was successful in reducing midge numbers or whether any of the other management measures recommended in the midge mitigation study have been implemented.

Previous Studies/ Monitoring:

City of Gosnells water quality monitoring (March 2003 to June 2007)

Terra Consulting and Murdoch University Aquatic Ecosystems Research Group (2003) *Brookland Greens Midge Mitigation Study*. Report prepared for City of Gosnells

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Prior Close Reserve Lake**

1. Basic Details	
Location (street and suburb)	Prior Close, Canning Vale
Location (coordinates)	399692.6 E, 6449486.8 N
2007 Streetsmart page number	464, E2
Local Government	City of Gosnells
Owner	City of Gosnells
Function*	A, D
Age (years)	11
2. Physical Features	
Lining (y/n)	N
Area (ha)	~ 1.6924
Shape (e.g. linear, round, irregular)	elongated, slightly irregular
Depth range (estimate) (m)	7.5 (max)
"Naturalness" rating (1 to 5)*	2
Social amenity value (High, Medium, Low)	High
Edging (e.g. wall, trees, reeds, sloping banks, turf)	40% walled (limestone blocks/ concrete kerb), 30% vegetated (paperbarks & sedges), 30% sloping grass banks.
Vegetation type adjacent to lake*	N (20%), X (80%) - Riparian planting (using dampland species native to area eg. a*startea fascicularis, juncus krausii*), paperbark, *Juncus acutus* (none native sedge), planted *Eucalypts* e.g. river redgum & flooded gum, a few sedges, planted ornamental shrubs, flame trees.
Vegetation condition adjacent to lake*	G
Potential acid sulfate soil (ASS) risk (according to ASS risk map)	Moderate to low risk of ASS occurring within 3m of natural soil surface

* Notes:

Function
D - Drainage
C - Conservation
A - Aesthetic (and recreational)
I - Irrigation Storage

Naturalness rating
1 - Highly ornamental
2 - Mostly ornamental with some natural features
3 - Some ornamenatal and some natural features
4 - Natural or natural like with some ornamental features
5 - Natural or natural like

Vegetation type
N - Native
X - Exotic

Vegetation condition
P - Poor
F- Fair
G - Good
E - Excellent

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Prior Close Reserve Lake**

3. Catchment and Hydrology	
Catchment type (e.g. industrial, residential)	Residential
Prior land use	Natural ephemeral wetland surrounded by farmland
Catchment size (ha)	Inflow volume from Sandringham 1 (upstream) and Prior Close Reserve catchments estimated to be 345ML/year (Terra Consulting and Murdoch University, 2003)
Geology (Unit)	Thin Bassendean Sand over Guildford Formation (Qpb/Qpa)/ Bassendean Sand (Qpb)
(Description)	S_8 - SAND - white to pale grey at surface, yellow at depth, fine to medium grained, moderately sorted, subangular to subrounded, minor heavy minerals, of aeolian origin over SANDY CLAY (Sc) to CLAYEY SAND (Cs) of the Guildford Formation, of aeolian origin
No. Inlets	1 - receives overflow from Sandringham 1
Inlet Volume/ Size	2-3m wide drain
No. Outlets	1
Outlet Volume/ Size	2-3m wide drain
Drainage Connection Flow through (FT) or End Point (EP) or No Drainage (NDr)	FT
Approximate volume of water extracted for irrigation	0
Water level to up (y/n)	N
Estimated residence time	ND
Water or nutrient balance undertaken (y/n)?	Average nutrient generation from the catchment was estimates using the Model for Urban Stormwater Improvement Conceptualisation (MUSIC) (Terra Consulting and Murdoch University, 2003) - stormwater found to be a major source of nutrients.
4. Management	
Aeration/agitation present/absent?	Present
Aeration type if present* How many?	2F
Fertiliser application adjacent to lake (y/n)	Y - not phosphorus based
Irrigation adjacent to lake (y/n)?	Y - with water from Sandringham 2
Lawn mowing/ weed control	ND
Management problems*	5. Algal blooms- filamentous green algae, 8. Midge plagues
Maintenance and effectiveness	Phoslock ~ October 2006 effect unknown. Constructed additional walls around the lake edge to discourage midge breeding.
Monitoring frequency	Water samples collected near stormwater inlets by City of Gosnells approximately twice per year since March 2003. Samples analysed for pH, EC, dissolved oxygen, temperature, turbidity, nutrients and chlorophyll *a*.

* Notes:

Aeration Features
F - Fountain
R - Rocks/waterfall
C - Circulation by pumping
A - Submerged aerator

Management Problems
1. Flooding
2. Drying Out
3. Slow infiltration
4. Odour
5. Nuisance algal growth
6. Fish deaths
7. Bird deaths
8. Mosquitos or midges
9. Acid Sulfate Soils
10. Iron Monosulfides
11. Feral Fish
12. Other (describe)

ND - Data not available within timeframe of study

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Prior Close Reserve Lake**

5. Water Quality (if known)	
Location (street and suburb)	Ammonium-N + NOx = <35-5100**, Total N = 790***
Location (coordinates)	60-985**, 18***
2007 Streetsmart page number	56.5-170**
pH	7.47*, (7.23-9.13**)
EC (mS)	0.60*, (0.56-0.97**)
TDS (ppt)	0.29*
Temperature (°C)	17.9*, (15.0-27.8**)
Algae/ aquatic plants, water clarity	Dark colour. Filamentous greens algae growing at some points along the edge of the lake.*
6.Fauna	
Macroinvertebrates e.g. midges and mosquitos	None observed during site visit. Previous midge plagues. Mean midge density of 164.11/m2 recorded on 20/7/07.
Macrofauna	Eurasian coot

Notes:

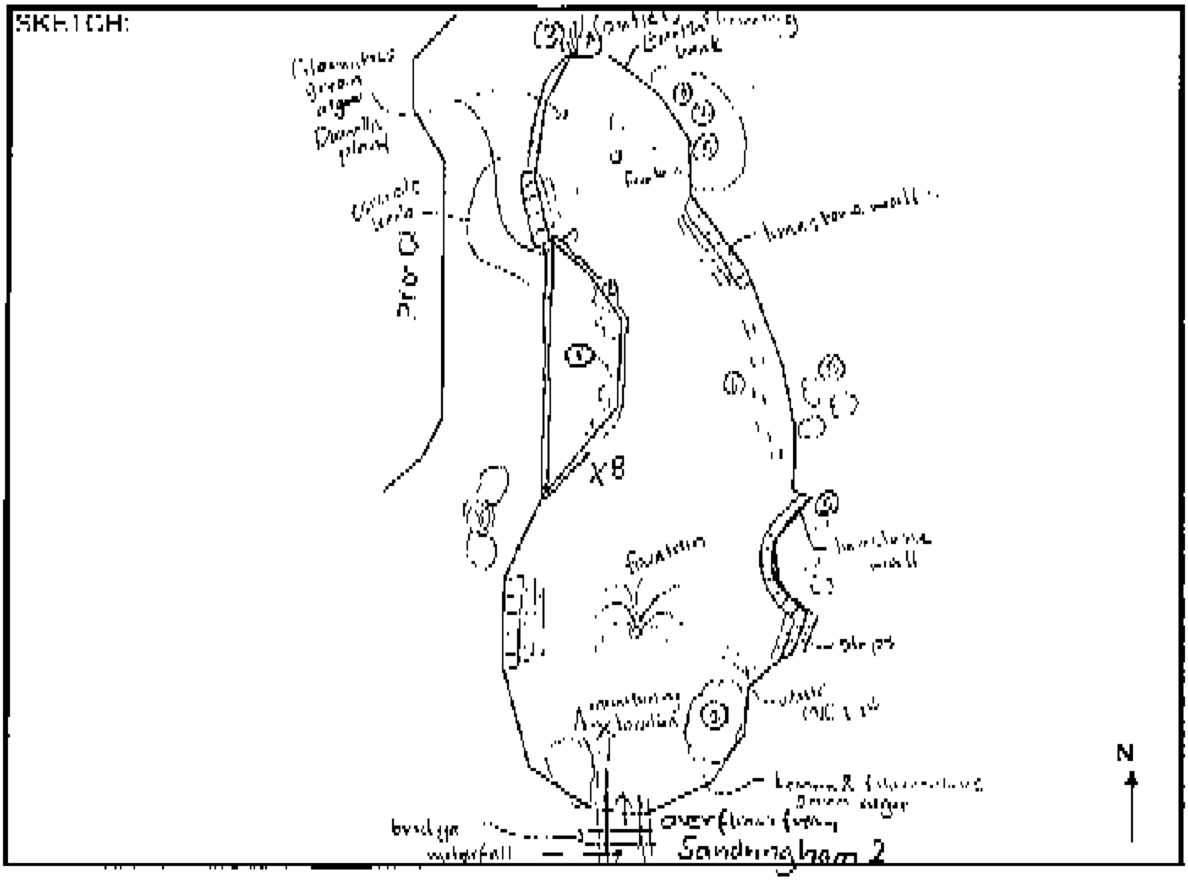
* Average field pH, EC, TDS and temperature measured during site visit on 17/9/07. Observations of algae, aquatic plants, water clarity and fauna also recorded on this day.
** Range of values recorded by City of Gosnells sampling (March 2003 to June 2007). Chlorophyll *a* only analysed in early summer 2005 and early autumn 2006.
*** Recorded on 20/7/07 by Terra Consulting and Murdoch University (2003)

Constructed Lake Study
Field Survey Form

Lake Name and Location: **Prior Close Reserve Lake, Canning Vale**

Date: 17/5/07 Recorded By: Bronwyn Woodward

SKETCH:



Water Level (mark location of staff gauges): None located

Estimated Depth of Water: Max Depth = 1.5m

Lake Edge	%	Notes
Walled	50	limestone blocks, stepped, terraced, 2 raised water features
Vegetated	25	Paperbarks, sedges
Grassed	25	Sloping grass banks
Earth		

Water quality: (scums, water clarity, algae, mosquitoes, pH, EC?) dark colour, filamentous green algae growing in small patches along the edge of the lake.
Measure water quality (2) locations (see below)

Fauna: Eurasian coot

Vegetation Type(s) adjacent to lake (annotate with numbers) ① Riparian planting – casuarina fascicularis, juncus kraussii (dominant species that are native to the area)
② Paperbarks ⑥ Sumac as native (weed from Europe)
③ Planted, Eucalyptus, river red gum? ④ Native sedges ⑦ Planted ornamental shrubs
(lined gum) ⑧ Flame trees

Other Comments: A. City of Gosnells monitoring... Water level influenced by overflow from Sandringham 2
B New sample location

	A	B
pH	7.44	7.51
EC (mS)	0.60	0.59
TDS (ppt)	0.29	0.29
Temp (°C)	17.8	17.9

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Sandringham Promenade Reserve 2**

1. Basic Details	
Location (street and suburb)	Sandringham Promenade, Canning Vale
Location (coordinates)	399566.3 E, 6449214.2 N
2007 Streetsmart page number	464, E2
Local Government	City of Gosnells
Owner	City of Gosnells
Function*	I, A
Age (years)	11
2. Physical Features	
Lining (y/n)	Y
Area (ha)	~ 0. 868
Shape (e.g. linear, round, irregular)	linear, slightly oval
Depth range (estimate) (m)	3.5 (max)
"Naturalness" rating (1 to 5)*	1
Social amenity value (High, Medium, Low)	High
Edging (e.g. wall, trees, reeds, sloping banks, turf)	60% walled (limestone blocks), 8% vegetated (some reeds), 32% grass
Vegetation type adjacent to lake*	N (50%), X (50%): Reeds (*Juncus krausii* - naturally recruited), trees (*Eucalyptus* species), landscaped area (Flame trees, shrubs, flowers, bottlebrush)
Vegetation condition adjacent to lake*	G
Potential acid sulfate soil (ASS) risk (according to ASS risk map)	Moderate to low risk of ASS occurring within 3 m of natural soil surface

* Notes:

Function
D - Drainage
C - Conservation
A - Aesthetic (and recreational)
I - Irrigation Storage

Naturalness rating
1 - Highly ornamental
2 - Mostly ornamental with some natural features
3 - Some ornamenatal and some natural features
4 - Natural or natural like with some ornamental features
5 - Natural or natural like

Vegetation type
N - Native
X - Exotic

Vegetation condition
P - Poor
F- Fair
G - Good
E - Excellent

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Sandringham Promenade Reserve 2**

3. Catchment and Hydrology	
Catchment type (eg. Industrial, Residential)	Residential
Prior land use	Natural ephemeral wetland surrounded by farmland
Catchment size (ha)	NA - does not receive drainage
Geology (unit)	Thin Bassendean Sand over Guildford Formation (Qpb/Qpa)/ Bassendean Sand (Qpb)
(description)	S_8 - SAND - white to pale grey at surface, yellow at depth, fine to medium grained, moderately sorted, subangular to subrounded, minor heavy minerals, of aeolian origin over SANDY CLAY (Sc) to CLAYEY SAND (Cs) of the Guildford Formation, of aeolian origin
No. inlets	NA
Inlet volume/size	NA
No. outlets	1 - overflow to Sandringham 1
Outlet volume/size	~0.5-2m wide drain
Drainage connection flow through (FT) or End Point (EP) or No Drainage (NDr)	NDr
Approximate volume of water extracted for irrigation	ND
Water level top up (y/n)?	Y - with borewater
Estimated residence time	ND
Water or nutrient balance undertaken (y/n)?	N
4. Management	
Aeration/agitation present/absent?	Present
Aeration type if present* How many?	2F
Fertiliser application adjacent to lake (y/n)?	Y - not phosphorus based
Irrigation adjacent to lake (y/n)?	Y - with lake water
Lawn mowing/ weed control	ND
Management problems*	None recorded
Maintenance and effectiveness	No special maintenance has been required
Monitoring frequency	Water samples collected by City of Gosnells approximately twice per year since March 2003. Samples analysed for pH, EC, dissolved oxygen, temperature, turbidity, nutrients and chlorophyll *a* .

* Notes:

Aeration Features
F - Fountain
R - Rocks/waterfall
C - Circulation by pumping
A - Submerged aerator

ND - Data not available within timeframe of study
NA - Not applicable

Management Problems
1. Flooding
2. Drying Out
3. Slow inflitration
4. Odour
5. Nuisance algal growth
6. Fish deaths
7. Bird deaths
8. Mosquitos or midges
9. Acid Sulfate Soils
10. Iron Monosulfides
11. Feral Fish
12. Other (describe)

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Sandringham Promenade Reserve 2**

5. Water Quality (if known)	
Nitrogen (N) (µ/L)	Ammonium-N + NOx =<16.5-440**, Total N = 1000***
Total Phosphorus (µ/L)	20-180**, 61***
Chlorophyll *a* (µg/L)	1.45-3.5**
pH	8.75* (7.83-8.95**)
EC (mS)	1.12* (0.96-1.50**)
TDS (ppt)	0.56*
Temperature (°C)	18.6* (14.0-26.8**)
Algae/ aquatic plants, water clarity	Small amount of benthic filamentous green algae growing attached to wall/sticks, clear water.*
6.Fauna	
Macroinvertebrates e.g. midges and mosquitos	None observed during site visit. Mean midge density of 56.59/m2.**
Macrofauna	A few ducks

Notes:

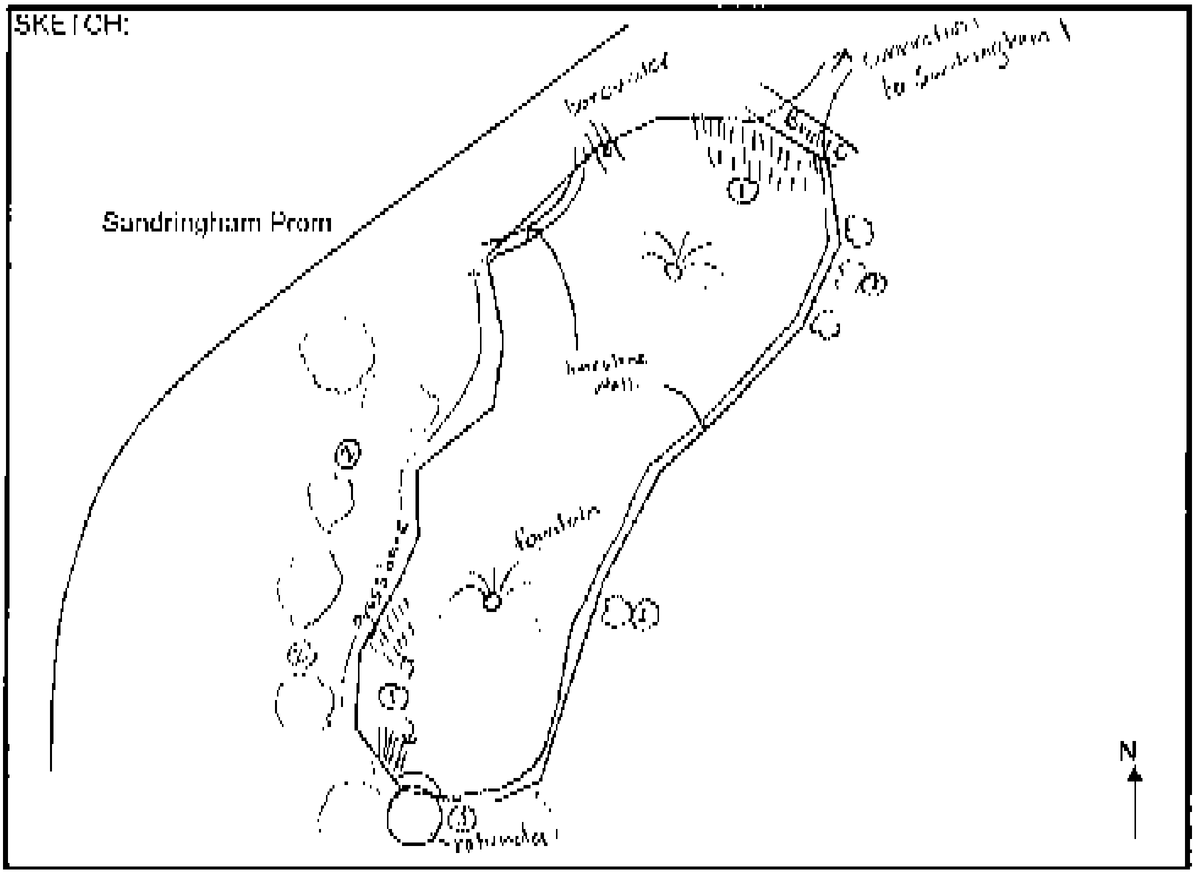
* Field pH, EC, TDS and temperature measured during site visit on 17/9/07. Observations of algae, aquatic plants, water clarity and fauna also recorded on this day.
** Range of values recorded by City of Gosnells sampling (March 2003 to June 2007). Chlorophyll *a* only analysed in early summer 2005 and early autumn 2006.
*** Recorded on 20/7/07 by Terra Consulting and Murdoch University (2003)

Constructed Lake Study
Field Survey Form

Lake Name and Location: **Sandringham Promenade Reserve 2 Canning Vale**

Date: 17/9/07 Recorded By: Bronwyn Woodward

SKETCH:



Water Level (mark location of staff gauges): None located

Estimated Depth of Water: appears fairly shallow <1m? – [3.5m max]

Lake Edge	%	Notes
Walled	60	limestone blocks
Vegetated	8	reeds in some areas
Grassed	32	
Earth		

Water quality: (scums, water clarity, algae, mosquitoes, pH, EC?) Small amount of filamentous green algae growing attached to wall (blocks), clear water

pH = 8.75 EC = 1.12mS TDS = 0.56 ppt Temp. 18.6 °C

Fauna: a few ducks

Vegetation Type(s) adjacent to lake - (annotate with numbers) (1) Reeds Juncus kraussii (naturally recruited)

(2) Trees - Eucalyptus species

(3) Landscaped area - Flame trees, shrubs, flowers, bottlebrush

Other Comments: Lots of leaf litter @ bottom

Brookland Greens - Photographic Plates

PLATE 1 – Nutrient rich stormwater flows from Sandringham 2 Lake to the Prior Close Reserve Lake.

PLATE 2 – High nutrient loads have caused excessive algal growth and midge problems in the Prior Close Reserve Lake.

Brookland Greens - Photographic Plates

PLATE 3 – The City of Gosnells has constructed hard vertical edges around the Prior Close Reserve Lake to discourage midge breeding and prevent complaints from surrounding residents.

PLATE 4 – Sandringham Reserve 1, the top irrigation lake in the Brookland Greens chain, does not receive stormwater inflows and does not have problems with algal blooms or midges.

The Bridgeway Lake – Summary Report

The Bridgeway Lake was constructed around 2000 amongst residential development within the suburb of Ferndale in the City of Gosnells. The lake intercepts groundwater and receives drainage via one stormwater inlet. The lake overflows into a single outlet which eventually flows into the Canning River.

In recent years the lake has experienced problems with blooms of filamentous green algae which have been treated with cupricide. This is only a temporary solution and the algae blooms have returned after several applications. The algal blooms are a likely result of nutrient enrichment which may be due to inputs from stormwater or from fertilizer applications to surrounding residential lawns.

Previous Studies/ Monitoring:

City of Gosnells water quality monitoring (March 2003 to June 2007)

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **The Bridgeway Lake**

1. Basic Details	
Location (street and suburb)	The Bridgeway Avenue, Canning Vale
Location (coordinates)	-
2007 Streetsmart page number	435, A10
Local Government	City of Gosnells
Owner	City of Gosnells
Function*	D, A
Age (years)	~ 6 to 7 years
2. Physical Features	
Lining (y/n)	N
Area (ha)	~ 1.632
Shape (e.g. linear, round, irregular)	linear
Depth range (estimate) (m)	2-3
"Naturalness" rating (1 to 5)*	2
Social amenity value (High, Medium, Low)	High
Edging (e.g. wall, trees, reeds, sloping banks, turf)	40% walled (limestone blocks), 30% vegetated (2 reed species), 30% grassed
Vegetation type adjacent to lake*	N (70%), X (30%) Reeds (*Juncus pallidus* and *Cyperaci carix*), Planted shrubs (various species), Broadleaf Paperbark, Island vegetation - planted Sheoaks & *Eucalyptus* , Paperbarks.
Vegetation condition adjacent to lake*	G
Potential acid sulfate soil (ASS) risk (according to ASS risk map)	High to moderate risk of ASS occurring within 3 m of natural soil surface

* Notes:

Function
D - Drainage
C - Conservation
A - Aesthetic (and recreational)
I - Irrigation Storage

Naturalness rating
1 - Highly ornamental
2 - Mostly ornamental with some natural features
3 - Some ornamenatal and some natural features
4 - Natural or natural like with some ornamental features
5 - Natural or natural like

Vegetation type
N - Native
X - Exotic

Vegetation condition
P - Poor
F- Fair
G - Good
E - Excellent

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **The Bridgeway Lake**

3. Catchment and Hydrology	
Catchment type (e.g. industrial, residential)	Residential
Prior land use	Farmland
Catchment size (ha)	ND
Geology (unit)	Thin Bassendean Sand over Guildford Formation (Qpb/Qpa)/ Bassendean Sand (Qpb)/ Alluvium (Qha)
(description)	S_8 - SAND - white to pale grey at surface, yellow at depth, fine to medium grained, moderately sorted, subangular to subrounded, minor heavy minerals, of aeolian origin over SANDY CLAY (Sc) to CLAYEY SAND (Cs) of the Guildford Formation, of aeolian origin and Mps - PEATY SANDY SILT - dark grey to black, fine to medium-grained sand
No. inlets	1
Inlet volume/size	ND
No. Outlets	1
Outlet Volume/ Size	300mm
Drainage connection flow through (FT) or End Point (EP) or No Drainage (NDr)	FT
Approximate volume of water extracted for irrigation	0
Water top up (y/n)?	N
Estimated residence time	ND
Water or nutrient balance undertaken (y/n)?	N
4. Management	
Aeration/agitation present/absent?	Present
Aeration type if present* How many?	2F
Fertiliser application adjacent to lake (y/n)?	Y
Irrigation adjacent to lake (y/n)?	Y, with bore water from superficial aquifer
Lawn mowing/ weed control	Mow lawns - collect clippings although some observed around edge of lake
Management problems*	5 - blooms of filamentous green algae (at least in past 3 years)
Maintenance and effectiveness	Cupricide ($400 each time), temporary solution only
Monitoring frequency	Water samples collected by City of Gosnells approximately twice per year since March 2003. Samples analysed for pH, EC, dissolved oxygen, temperature, turbidity, nutrients and chlorophyll *a* .

* Notes:

Aeration Features
F - Fountain
R - Rocks/waterfall
C - Circulation by pumping
A - Submerged aerator

Management Problems
1. Flooding
2. Drying Out
3. Slow infiltration
4. Odour
5. Nuisance algal growth
6. Fish deaths
7. Bird deaths
8. Mosquitos or midges
9. Acid Sulfate Soils
10. Iron Monosulfides
11. Feral Fish
12. Other (describe)

ND - Data not available within timeframe of study

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **The Bridgeway Lake**

5. Water Quality (if known)	
Inorganic nitrogen (Ammonium + NOx) (µ/L)	<110-2080**
Total Phosphorus (µ/L)	40-220**
Chlorophyll *a* (µg/L)	15.5-24**
pH	7.17* (7.12-7.66**)
EC (mS)	0.11* (0.32-0.85**)
TDS (ppt)	0.2*
Temperature (°C)	18.5* (15.9-29.7**)
Algae/ aquatic plants, water clarity	Tannin stained - blackish water column, yellow colour in cup. No algae observed during site visit.*
6.Fauna	
Macroinvertebrates e.g. midges and mosquitos	None observed during site visit. No records of complaints
Macrofauna	A few ducks

Notes:

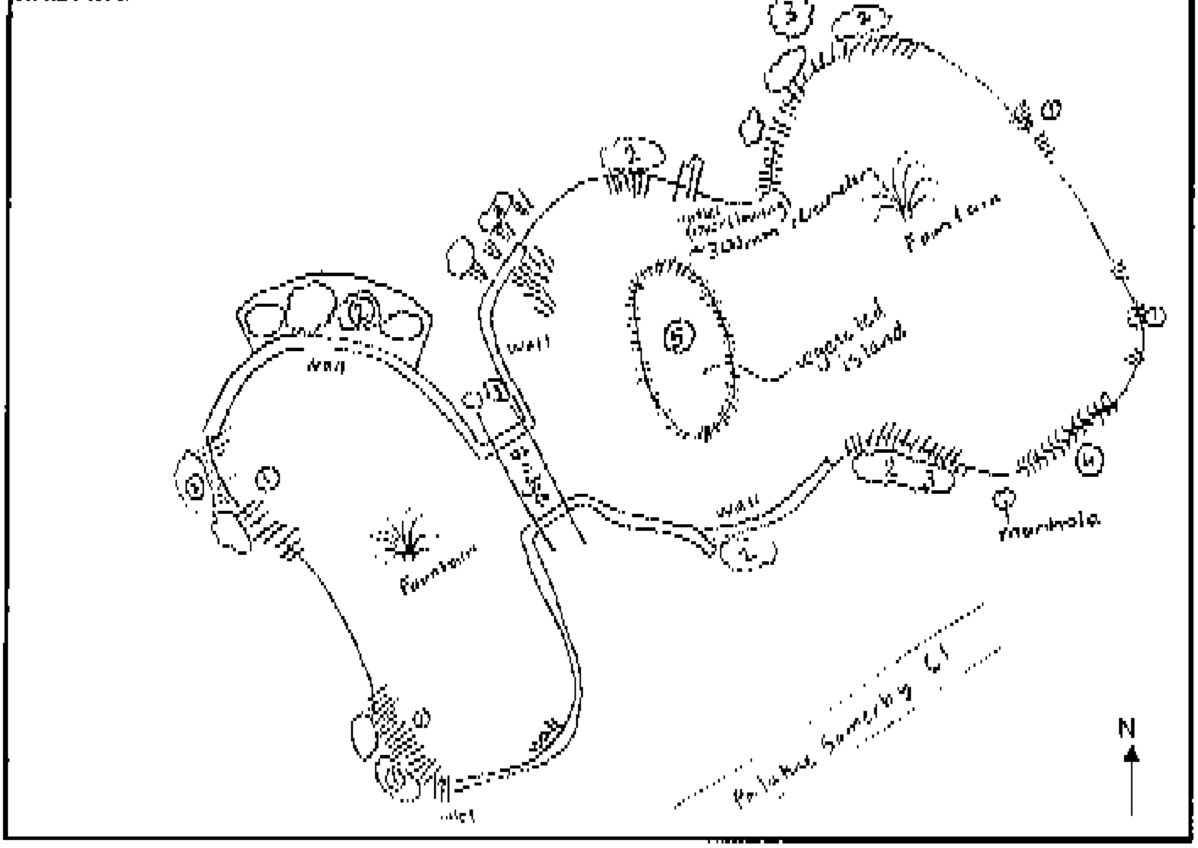
* Field pH, EC, TDS and temperature measured during site visit on 17/9/07. Observations of algae, aquatic plants, water clarity and fauna also recorded on this day.
** Range of values recorded by City of Gosnells sampling (March 2003 to June 2007). Chlorophyll *a* only analysed in early summer 2005 and early autumn 2006.

Constructed Lake Study
Field Survey Form

Lake Name and Location: The Bridgeway Lake

Date: 17/9/07   Recorded By: Bronwyn Woodward

SKETCH:



Water Level (mark location of staff gauges): None located

Estimated Depth of Water: 2-3m (rough guess)

Lake Edge	%	Notes
Walled	40	Limestone blocks
Vegetated	30	2 reed species (see below)
Grassed	30	
Earth		

Water quality: (scums, water clarity, algae, mosquitoes, pH, EC?) Tannin stained - yellow in cup, gives water body a blackish appearance.
pH = 7.17, EC = 0.61 mS, TDS = 0.20 ppt   Temp = 18.5 °C

Fauna: a few ducks

Vegetation Type(s) adjacent to lake - (annotate with numbers) ① Reeds - Juncus pallidus ② Planted shrubs (various species) ③ Broadleaf paperbark
④ Reeds - cyperacea carex? ⑤ Island vegetation - planted shrubs & eucalypts & paperbarks

Other Comments:

The Bridgeway Lake - Photographic Plates

PLATE 1 – The water was relatively clear and no algae was observed during the site visit in September 2007, however the lake has experienced problems with blooms of filamentous green algae in the past.

PLATE 2 – Outlet to the Canning River.

City of Joondalup

- Broadbeach North Lake
- Broadbeach Central Lake
- Joondalup Central Park Lake

Broadbeach Lakes – Summary Report

The two most northern lakes (Broadbeach North and Central Lakes) in the group of three lakes located within the Waterston Gardens parkland in Hillarys were examined in this study. Both lakes receive drainage from surrounding residential development and have experienced problems with excessive algal growth, although the problems in the Central Lake have been more severe. The North Lake has only experienced minor occurrences of nuisance algal growth.

The Central Lake has experienced several blooms of unicellular green algae as well as a blue green algal bloom in the 2006/2007 summer. A submerged aerator was installed in the lake following the blue green algal bloom however it is not known whether this was successful in reducing algal blooms the following summer. A volcanic ash product was also trialed to reduce algal blooms however according to the lake manager this appeared to have no observed effect on algal levels.

Previous Studies/ Monitoring:

No previous studies or monitoring records were located.

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Broadbeach Lakes**

1. Basic Details	**North**	**Central**
Location (street and suburb)	Waterston Gardens, Hillarys	
Location (coordinates)	380207.1 E, 6480899.2 N	380417.7 E, 6480705.1 N
2007 Streetsmart page number	250, A9	
Local Government	City of Joondalup	
Owner	City of Joondalup	
Function*	D, A	D, A
Age (years)	ND	ND
2. Physical Features	**North**	**Central**
Lining (y/n)	N	N
Area (ha)	~ 0.5174	~ 0.2587
Shape (e.g. linear, round, irregular)	Irregular	Linear
Depth range (estimate) (m)	1-2	<1
"Naturalness" fating (1 to 5)*	3	3
Social amenity value (High, Medium, Low)	Medium-High	Medium-High
Edging (e.g. wall, trees, reeds, sloping banks, turf)	5% walled, 35% vegetated, 60% grassed	15% walled, 60% vegetated, 25% grassed
Vegetation type adjacent to lake*	*Casuarina equesetifolia, casuarina obesa* , bottlebrush, reeds, palm trees	Reeds (*baumea*), mature *Eucalyptus* , tuart, sheoak
Vegetation condition adjacent to lake*	G	G
Potential acid sulfate soil (ASS) risk (according to ASS risk map)	No known risk of ASS occurring within 3 m of natural soil surface (or deeper)	

* Notes:

Function
D - Drainage
C - Conservation
A - Aesthetic (and recreational)
I - Irrigation Storage

Naturalness rating
1 - Highly ornamental
2 - Mostly ornamental with some natural features
3 - Some ornamenatal and some natural features
4 - Natural or natural like with some ornamental features
5 - Natural or natural like

Vegetation type
N - Native
X - Exotic

Vegetation condition
P - Poor
F- Fair
G - Good
E - Excellent

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Broadbeach Lakes**

3. Catchment and Hydrology	**North**	**Central**
Catchment type (e.g. industrial, residential)	Residential	
Prior land use	ND	ND
Catchment size (ha)	ND	ND
Geology (unit)	Safety Bay Sand (Qhs)	
(description)	S_2 - CALCAREOUS SAND - white fine to medium grained, sub rounded quartz and shell debris, of aeolian origin	
No. inlets*	2?	2?
Inlet volume/size	ND	ND
No. outlets*	ND	ND
Outlet volume/size	ND	ND
Drainage connection flow through (FT) or End Point (EP) or No Drainage (NDr)	ND	ND
Approximate volume of water extracted for irrigation	0	0
Water level top up (y/n)?	N	N
Estimated residence time	ND	ND
Water or nutrient balance undertaken (y/n)?	N	N
4. Management	**North**	**Central**
Aeration/agitation present/absent?	Absent	Present
Aeration type if present* How many?	NA	A -1
Fertiliser application adjacent to lake (y/n)?	Y - low phosphate	
Irrigation adjacent to lake (y/n)?	Y	
Lawn mowing/ weed control	ND	
Management problems*	5 -Has previously had some very limited algal growth problems	5 - algal blooms unicellar green algae, blue green algae last summer.
Maintenance and effectiveness	None	Aerator installed last summer. Have not had any algal blooms since however yet to see effect over a whole summer. Volcanic ash product trialed.
Monitoring frequency	Not monitored	Not monitored

* Notes:

Aeration Features
F - Fountain
R - Rocks/waterfall
C - Circulation by pumping
A - Submerged aerator

Management Problems
1. Flooding
2. Drying Out
3. Slow infiltration
4. Odour
5. Nuisance algal growth
6. Fish deaths
7. Bird deaths
8. Mosquitos or midges
9. Acid Sulfate Soils
10. Iron Monosulfides
11. Feral Fish
12. Other (describe)

ND - Data not available within timeframe of study. The exact number of stormwater inlets and outlets was not able to be determined as no plans were available.
NA = Not applicable

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Broadbeach Lakes**

5. Water Quality (if known)	**North**	**Central**
Total Nitrogen (µg/L)	NT	NT
Total Phosphorus (µg/L)	NT	NT
Chlorophyll *a* (µg/L)	NT	NT
pH	8.64*	8.01*
EC (mS)	0.20*	0.54*
TDS (ppt)	0.1*	0.27*
Temperature (°C)	17.8*	18.2*
Algae/ aquatic plants, water clarity	No algae observed*	Slight green tinge. No algae observed*
6.Fauna	**North**	**Central**
Macroinvertebrates eg. midges and mosquitos	None observed	None observed
Macrofauna	Eurasian coot, seagulls	1 Eurasian coot

Notes:

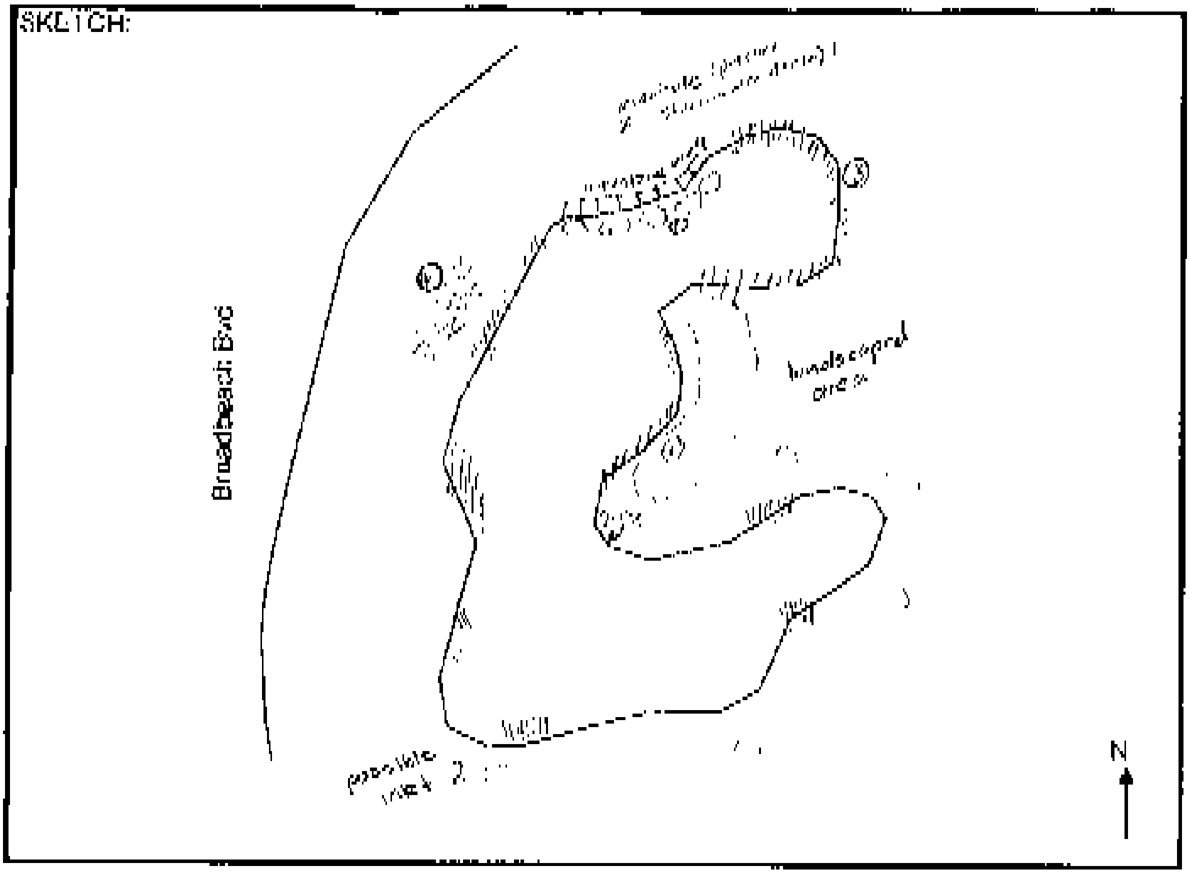
* Field pH, EC, TDS and temperature measured during site visit on 12/9/07. Observations of algae also recorded on this day.
NT = Not tested

Constructed Lake Study
Field Survey Form

Lake Name and Location: Broadbeach Lakes (North), Hillarys

Date: 12/09/2007 Recorded By: Bronwyn Woodward

SKETCH:



Water Level (mark location of staff gauges): None located

Estimated Depth of Water: ~1-2m max

Lake Edge	%	Notes
Walled	5	
Vegetated	95	Reeds
Grassed	5%	
Earth		

Water quality: (scums, water clarity, algae, mosquitoes, pH, EC?) clear pH = 8.64 EC ... 0.05 ... temp 17.8°C

Fauna: Eurasian coot, seagulls

Vegetation Type(s) adjacent to lake - (annotate with numbers) ① Casuarina equisetifolia, casuarina obesa? ② bulrush ③ Reeds ④ Palm trees

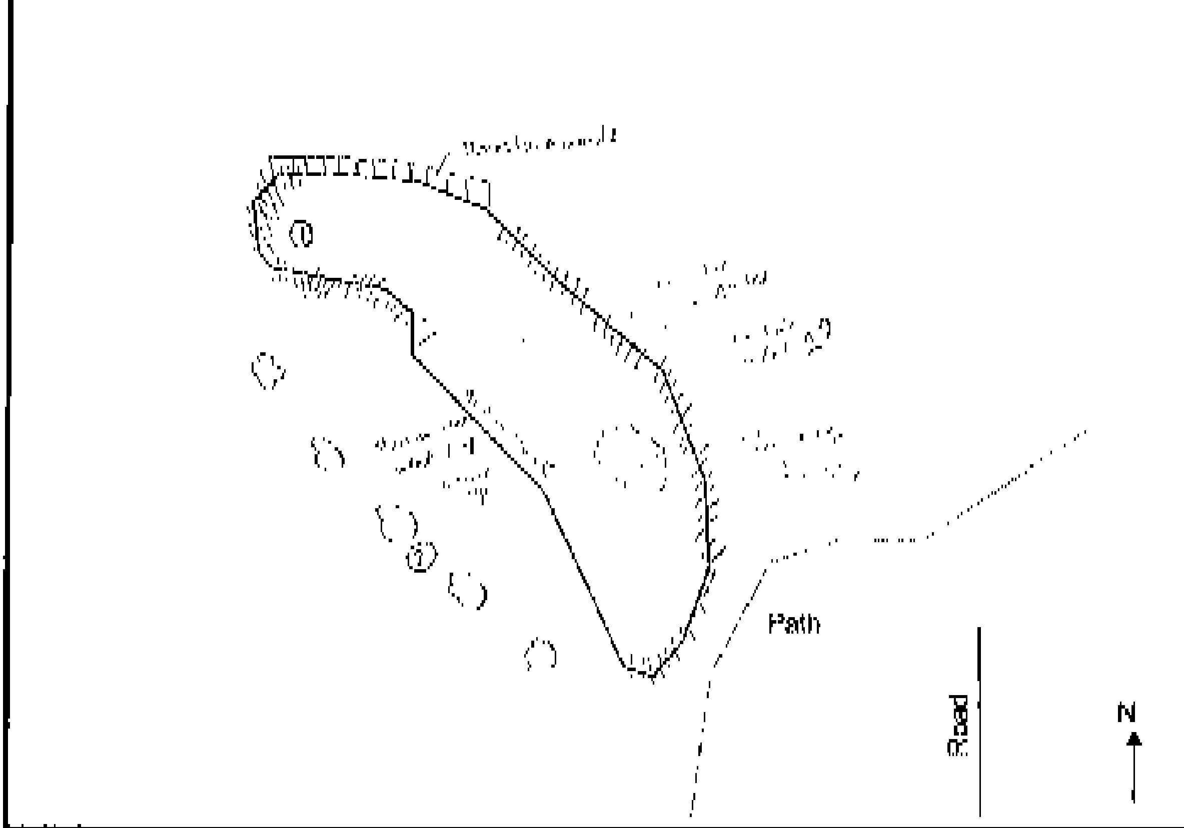
Other Comments:

Constructed Lake Study
Field Survey Form

Lake Name and Location: Broadbeach Lakes (Comm), Hillarys

Date: 12/09/2007 Recorded By: Bronwyn Woodward

SKETCH:



Water Level (mark location of staff gauges): Not located

Estimated Depth of Water: Fairly shallow <1m max?

Lake Edge	%	Notes
Walled	15	limestone wall
Vegetated	60	Reeds
Grassed	25	
Earth		

Water quality: (scums, water clarity, algae, mosquitoes, pH, EC?) pH = 7.81

EC = 0.56 mS TDS = 0.3 ppt Temp = 18.2°C

Fauna: 1 Eurasian coot

Vegetation Type(s) adjacent to lake - (annotate with numbers) ① Reeds (...)

② ... trees

Other Comments:

Broadbeach Lakes - Photographic Plates

PLATE 1 – The Central Lake has experienced several algal blooms. The water had a slight green tinge when visited in September 2007.

PLATE 2 – The North Lake has only experienced minor issues with nuisance algal growth.

Joondalup Central Park Lake – Summary Report

This constructed lake is located within the Joondalup TAFE Campus and is approximately fifteen years old. The lake, which is PVC lined, is used for irrigation and topped up with iron and nutrient rich bore water extracted from the superficial aquifer. The depth of the lake is variable with shallow sections being less than 0.5m in depth and deeper sections up to 2m. According to the City of Joondalup's Parks Supervisor, without circulation water, the temperature within these different depth zones varies greatly.

The lake has experienced past problems with algal blooms, low dissolved oxygen (DO), stagnation, high temperatures in shallow areas, fish deaths and the formation of sludge on the bottom of the lake which may have been due to the formation of iron monosulphides. Numerous management measures were trialed to combat these problems including the application of algaecide, ultrasonics, installation of aerators, planting of reeds, removal of sludge from bottom of water.

It is claimed that the algaecide reduced algal levels only in the short term while the ultrasonics had no observed effect. Following the installation of aeration, planting of reeds and removal of sludge from the bottom of the water nuisance algal growth has not been a problem. Aeration has improved circulation, increased dissolved oxygen levels and made the water a more even temperature.

Previous Studies/ Monitoring:

No previous studies or monitoring records were located.

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Joondalup Central Park Lake**

1. Basic Details	
Location (street and suburb)	Grand Boulevard, Joondalup
Location (coordinates)	383668.2 E, 6487017.9 N
2007 Streetsmart page number	220, E7
Local Government	City of Joondalup
Owner	City of Joondalup
Function*	I, A
Age (years)	~15
2. Physical Features	
Lining (y/n)	Y - PVC
Area (ha)	~ 0.750
Shape (e.g. linear, round, irregular)	Irregular, 1 island
Depth range (estimate) (m)	Shallow parts ~0.4. Deep parts ~1.5-2.
"Naturalness" rating (1 to 5)*	2
Social amenity value (High, Medium, Low)	High
Edging (e.g. wall, trees, reeds, sloping banks, turf)	70% walled, 30% wooden boardwalk
Vegetation type adjacent to lake*	Reeds (*baumea*) tuart, banksia, wattle, grass trees, paperbarks, "tropical garden" with introduced species e.g. flaxes
Vegetation condition adjacent to lake*	G
Potential acid sulfate soil (ASS) risk (according to ASS risk map)	No known risk of ASS occurring within 3 m of natural soil surface (or deeper)

* Notes:

Function
D - Drainage
C - Conservation
A - Aesthetic (and recreational)
I - Irrigation Storage

Naturalness rating
1 - Highly ornamental
2 - Mostly ornamental with some natural features
3 - Some ornamenatal and some natural features
4 - Natural or natural like with some ornamental features
5 - Natural or natural like

Vegetation type
N - Native
X - Exotic

Vegetation condition
P - Poor
F- Fair
G - Good
E - Excellent

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Joondalup Central Park Lake**

3. Catchment and Hydrology	
Catchment type (e.g. industrial, residential)	Residential
Prior land use	Bushland
Catchment size (ha)	NA - does not receive drainage
Geology (unit)	Sand derived from Tamala Limestone
(description)	S_7 - SAND - pale and olive yellow, medium to coarse grained, sub-angular to sub-rounded quartz, trace of feldspar, moderately sorted, of residual origin
No. inlets	0
Inlet volume/size	NA
No. outlets	0
Outlet volume/size	NA
Drainage connection flow through (FT) or End Point (EP) or No Drainage (NDr)	NDr
Approximate volume of water extracted for irrigation	ND
Water level top up (y/n)?	Y - filled with bore water
Estimated residence time	ND
Water or nutrient balance undertaken (y/n)?	N
4. Management	
Aeration/agitation present/absent?	Present
Aeration type if present* How many?	2 compressed air aerators, 3 Otterbine aerators
Fertiliser application adjacent to lake (y/n)?	ND
Irrigation adjacent to lake (y/n)?	Irrigated with lake water
Lawn mowing/ weed control	ND
Management problems*	4, 5 - likely types (not confirmed by testing) include filamentous green algae, unicellular green algae, pond weed. ~ 3yrs ago blue green algal bloom. 12 - build up of sludge on bottom of lake (possible iron monosulphides - 10), low DO, stagnant water and high temperatures in shallow areas.
Maintenance and effectiveness	Many management options trialed following blue green algal blooms. Algacide (Symazine) - worked in the short term. Ultrasonics - did not appear to work. Installation of aerators, planting of reeds, removal of sludge from bottom of water - the combination of these options is believed to have eliminated nuisance algal growth. Aerators have improved circulation, increased dissolved oxygen levels and made the water a more even temperature.
Monitoring rrequency	Not monitored

* Notes:

Aeration Features
F - Fountain
R - Rocks/waterfall
C - Circulation by pumping
A - Submerged aerator

Management Problems
1. Flooding
2. Drying Out
3. Slow infiltration
4. Odour
5. Nuisance algal growth
6. Fish deaths
7. Bird deaths
8. Mosquitos or midges
9. Acid Sulfate Soils
10. Iron Monosulfides
11. Feral Fish
12. Other (describe)

ND - Data not available within timeframe of study
NA - Not applicable

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Joondalup Central Park Lake**

5. Water Quality (if known)	
Total Nitrogen (µg/L)	NT
Total Phosphorus (µg/L)	NT
Chlorophyll *a* (µg/L)	NT
pH	8.04*
EC (mS)	1.60*
TDS (ppt)	0.8*
Temperature (°C)	17*
Algae/ aquatic plants, water clarity	Small amounts of benthic filamentous green algae growing on limestone steps.*
6.Fauna	
Macroinvertebrates e.g. midges and mosquitos	None observed during site visit
Macrofauna	Pacific Black ducks and ducklings, Eurasian Coot

Notes:

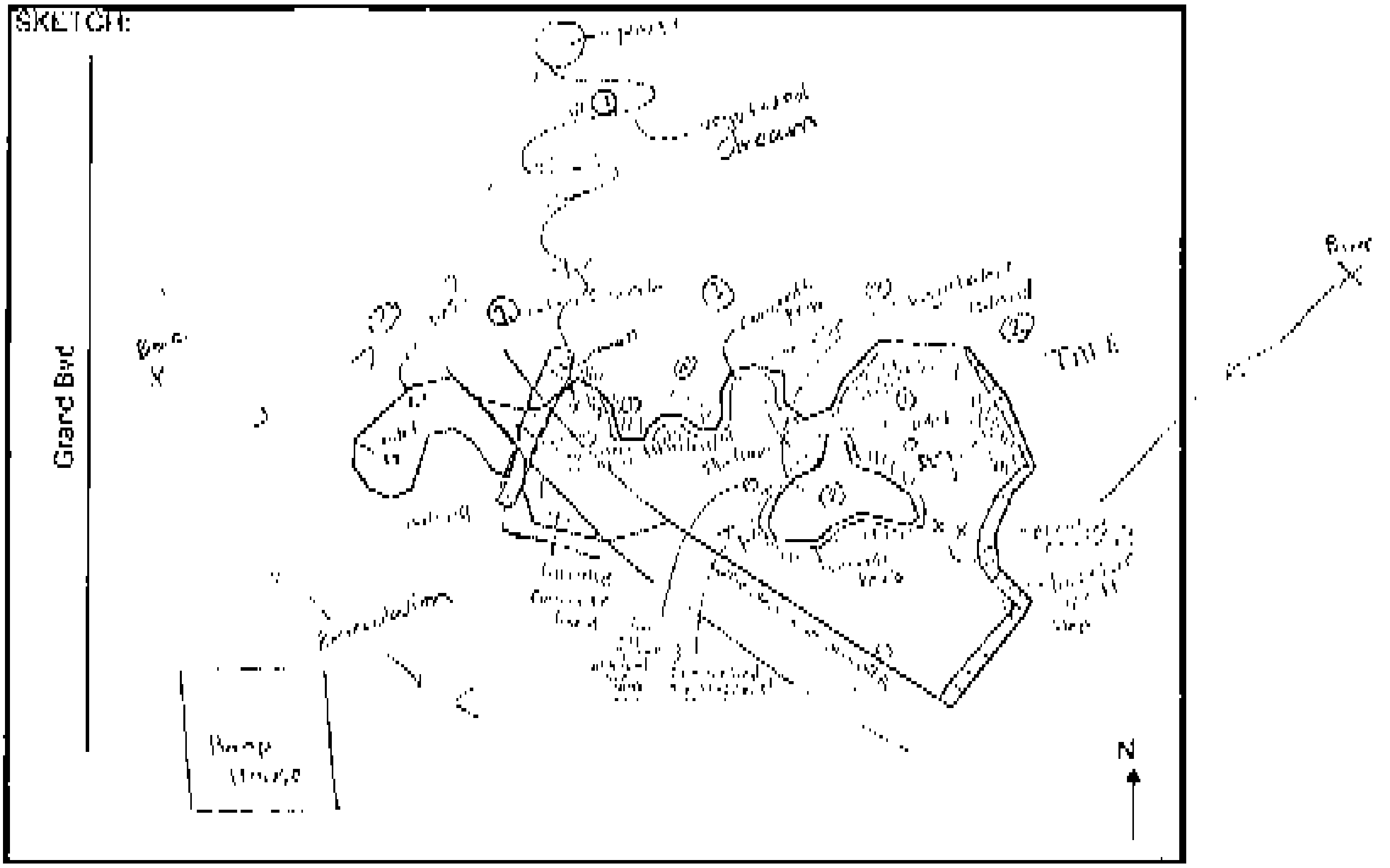
* Field pH, EC, TDS and temperature measured during site visit on 12/9/07. Observations of algae also recorded on this day.
NT = Not tested

Constructed Lake Study
Field Survey Form

Lake Name and Location: Joondalup Central Park Lake

Date: 12/09/2007 Recorded By: Bronwyn Woodward

SKETCH:



Water Level (mark location of staff gauges): [illegible]

Estimated Depth of Water: [illegible] ~0.4m [illegible] 1.5? m max

Lake Edge	%	Notes
Walled	30 / 70	[illegible]
Vegetated	0	
Grassed	0	
Earth	0	

Water quality: (scums, water clarity, algae, mosquitoes, pH, EC?) [illegible]
[illegible]
Green algae [illegible]

Fauna. Pacific black ducks, [illegible] coot, [illegible]

Vegetation Type(s) adjacent to lake - (annotate with numbers) ① [illegible]
② tuart, banksia, wattle, grass trees ③ [illegible] - flowers
④ Planted fringing veg eg. paperbarks

Other Comments:

Joondalup Central Park Lake - Photographic Plates

PLATE 1 – One of the submerged aerators installed at the lake to oxygenate a shallow stagnant section of the lake.

PLATE 2 – Reeds were planted around the lake with the intention of stripping nutrients to prevent algal blooms.

City of Mandurah

- Bridgewater Northern Lake
- Hermitage Lake North
- Hermitage Lake South
- Meadow Springs Lakes North
- Meadow Springs Lakes South

Bridgewater Northern Lake – Summary Report

The Bridgewater Northern Lake is the most northern lake within a chain of three interconnected lakes within the Bridgewater residential development in the suburb of Erskine within the City of Mandurah. The lake was constructed by excavating a portion of a natural ephemeral wetland to intercept groundwater to create a permanent water body. A remnant of this natural wetland still exists to the south of the lake and is classified as having resource enhancement value.

The lake, which serves a drainage and aesthetic function, is approximately seventeen years old and is government owned although it is still managed by the developer (Mirvac Fini). The City of Mandurah is reluctant to take over the responsibility for management of the lake as it is currently experiencing problems associated with eutrophication, fire damage and a recent temporary fall in the local water table.

Due to nutrient enrichment, blooms of macroalgae and on occasions blue green algae have been an issue since the late 1990s. Dewatering for the Port Mandurah canal development to the north of the site caused the lake to almost dry up in summer approximately three years ago. The fall in water levels and possibly saline intrusion resulted in the death or harm to much of the lake’s fringing vegetation which was further damaged by a bad fire last summer.

Stormwater and the sediments are thought to be a major source of nutrients to the lake. The inlets to the lakes have been retrofitted with gross pollutant traps (GPTs) and discharge has been directed to bubble-up pits with overland riffle zones connecting to the lakes. Macroalgae harvesting occurred in 1999 and when the lake was dried up approximately one metre of sediment were excavated and removed to landfill. According to the council despite these management efforts algal blooms continue to be an issue.

Previous Studies/ Monitoring:

Bowman Bishaw Gorham (2001) *Bridgewater North Lakes Results of Further Investigations and Recommendations for Management*. Prepared for Town & Country Landholdings.

Worley Parsons (2006a) *Erskine Developments: Health Assessment of Lakes at Bridgewater & Mandurah Quay Developments – Phase I Report*. Prepared for Mandurah City Council.

Worley Parsons (2006b) *Erskine Developments: Health Assessment of Lakes at Bridgewater & Mandurah Quay Developments – Phase II Report*. Prepared for Mandurah City Council.

Worley Parsons (2006c) *Erskine Developments: Health Assessment of Lakes at Bridgewater & Mandurah Quay Developments – Phase III Report*. Prepared for Mandurah City Council.

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Bridgewater Northern Lake**

1. Basic Details	
Location (street and suburb)	Waterston Place, Erskine
Location (coordinates)	378715.1 E, 6397701 N
2007 Streetsmart page number	759, D5
Local Government	City of Mandurah
Owner	City of Mandurah
Function*	D, A, C
Age (years)	~17
2. Physical Features	
Lining (y/n)	N
Area (ha)	1.25
Shape (eg. linear, round, irregular)	Irregular, 3 islands
Depth range (estimate) (m)	1-2
"Naturalness" rating (1 to 5)*	3
Social amenity value (High, Medium, Low)	High
Edging (eg. wall, trees, reeds, sloping banks, turf)	50% grass, 50% vegetation
Vegetation type adjacent to lake*	N - some natural remnant *Eucalyptus rudis* and *Melaleuca raphiophylla* , planted native trees, reeds
Vegetation condition adjacent to lake*	P - due to fire damage and a drop in water levels 3 years ago
Potential acid sulfate soil (ASS) risk (according to ASS risk map)	High to moderate risk of ASS occurring within 3 m of natural soil surface

* Notes:

Function
D - Drainage
C - Conservation
A - Aesthetic (and recreational)
I - Irrigation Storage

Naturalness rating
1 - Highly ornamental
2 - Mostly ornamental with some natural features
3 - Some ornamenatal and some natural features
4 - Natural or natural like with some ornamental features
5 - Natural or natural like

Vegetation type
N - Native
X - Exotic

Vegetation condition
P - Poor
F- Fair
G - Good
E - Excellent

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Bridgewater Northern Lake**

3. Catchment and Hydrology	
Catchment type (e.g. Industrial, Residential)	Residential (low density)
Prior land use	Bushland.
Catchment size (ha)	18 (Worley Parsons, 2005a)
Geology (unit)	Tamala Limestone, predominantly sand (Qts)
(description)	ND
No. inlets	3 including overflow from central lake via Resource Enhancement wetland and culvert
Inlet volume/size	ND
No. outlets	1
Outlet volume/size	ND
Drainage connection flow through (FT) or End Point (EP) or No Drainage (NDr)	FT
Approximate volume of water extracted for irrigation	0
Water level top up (y/n)?	N
Estimated residence time	ND
Water or nutrient balance undertaken (y/n)?	N
4. Management	
Aeration/agitation present/absent?	Present
Aeration type if present* How many?	3F
Fertiliser application adjacent to lake (y/n)?	ND
Irrigation adjacent to lake (y/n)?	Y - with water extracted from an artesian bore
Lawn mowing/ weed control	ND
Management problems*	2 (~ 3 years ago as a result of dewatering for canal development to the north of the lake, resulted in vegetation death), 4, 5 (macroalgae blooms since construction, microalgae blooms including bloom of potentially toxic species of blue green algae in 2001, 11 (koi carp), 12 (fire)
Maintenance and effectiveness	Weed harvesting (1999), gross pollutant traps and vegetated bubble up pits, deepening of lake ~ 3 years ago when lake dried up.
Monitoring frequency	Some sampling done by BBG in March 2001 (BBG, 2001) (ND) and February 2006 (Worley Parsons, 2006b). Parameters tested include chlorophyll *a* , nitrogen, phosphorus, pH, total dissolved solids, dissolved oxygen, conductivity, turbidity, redox potential, temperature, major cations and anions and pathogens.

* Notes:

Aeration Features
F - Fountain
R - Rocks/waterfall
C - Circulation by pumping
A - Submerged aerator

ND - Data not available within timeframe of study
NA - Not applicable

Management Problems
1. Flooding
2. Drying Out
3. Slow infiltration
4. Odour
5. Nuisance algal growth
6. Fish deaths
7. Bird deaths
8. Mosquitos or midges
9. Acid Sulfate Soils
10. Iron Monosulfides
11. Feral Fish
12. Other (describe)

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Bridgewater Northern Lake**

5. Water Quality (if known)	
Total Nitrogen (µ/L)	3206-3510**
Total Phosphorus (µ/L)	<120-<150**
Chlorophyll *a* (µg/L)	16-19**
pH	7.81* (7.01-8.7**)
EC (mS)	4.02* (1.7-3.22**)
TDS (ppt)	2.01* (0.82-0.83**)
Temperature (°C)	17.5* (22.4-25**)
Algae/ aquatic plants, water clarity	No algae observed during site visit.* Previous macroalgal and microalgae blooms. Blue-green algal bloom in 2001 dominated by *Microcystis aeruginosa* . *Anabaena spiroides* also previously identified.
6.Fauna	
Macroinvertebrates eg. midges and mosquitos	No record of problems with mosquitos or midges.
Macrofauna	Water birds eg. ducks, black swans (population estimated to be 100 (Worley Parsons, 2006a), banjo frogs, koi carp

Notes:

* Field pH, EC, TDS and temperature measured during site visit on 4/9/07. Observations of algae also recorded on this day.
** Range of values recorded by Worley Parsons (2006b) sampling

Constructed Lake Study
Field Survey Form

Lake Name and Location: Northern Lake, Erskine

Date: 4/9/07 Recorded By: Bronwyn Woodward

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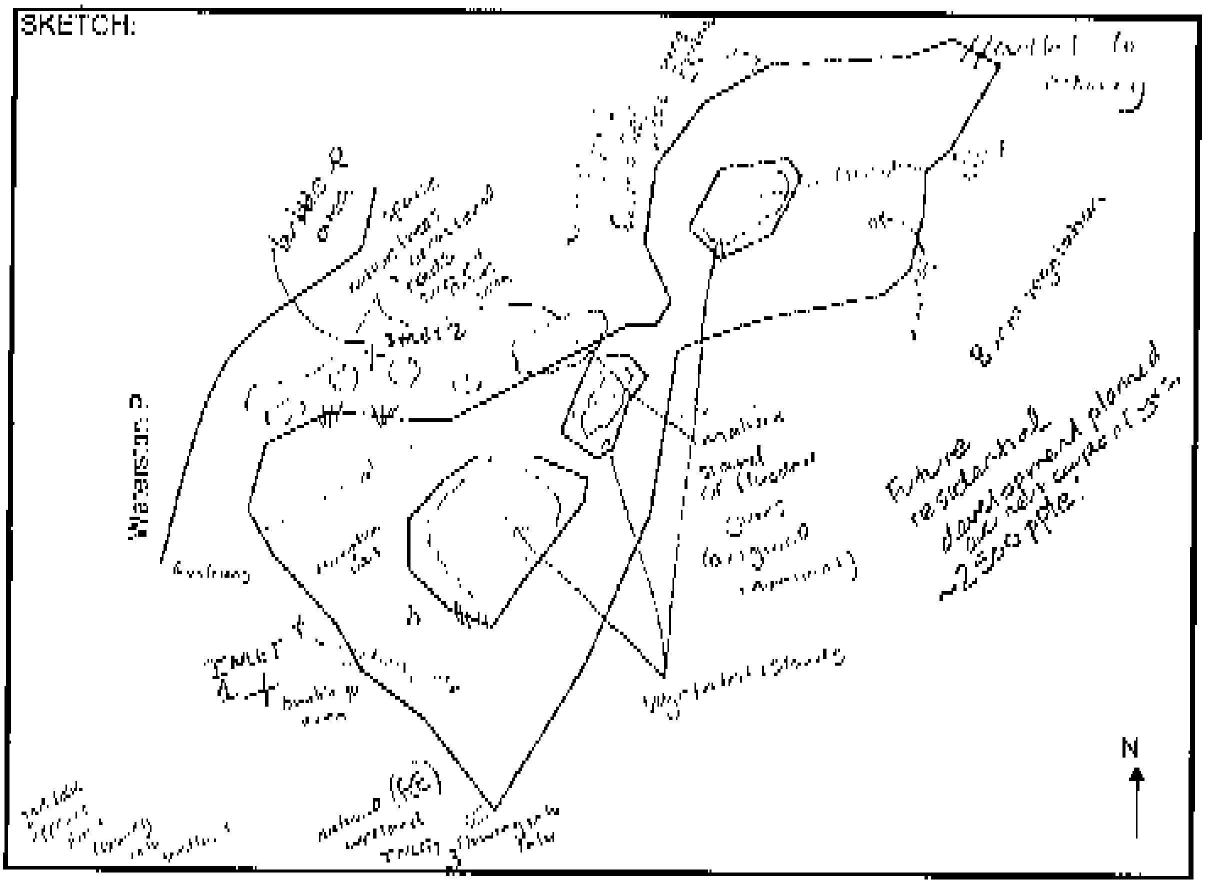

Water Level (mark location of staff gauges): No gauge located

Estimated Depth of Water: 1-2 m

Lake Edge	%	Notes
Walled	0	
Vegetated	50	[illegible]
Grassed	50	
Earth	0	

Water quality: (scums, water clarity, algae, mosquitoes, pH, EC?) [illegible]
[illegible] pH = 7.83 temp 11.5 [illegible]

Fauna: [illegible]

Vegetation Type(s) adjacent to lake - (annotate with numbers) [illegible]

[illegible]

Other Comments:

Bridgewater Northern Lake - Photographic Plates

PLATE 1 – Vegetation death resulting from fire.

PLATE 2 – Vegetation death resulting from dewatering.

Bridgewater Northern Lake - Photographic Plates

PLATE 3 – Arbour day planting of native vegetation around the lake.

PLATE 4 – Natural Resource Enhancement wetland to the south of the lake.

Hermitage Lakes – Summary Report

The Hermitage Lakes are two lakes between ten and fifteen years old, used for drainage within Dudley Park in the City of Mandurah. Both lakes intercept groundwater and the northern lake is also used for irrigation. The south lake is used for the racing of model boats.

To date, the lakes have not experienced any major management problems apart from invasion by Typha and feral koi carp. The Typha was removed approximately three years ago however has started to grow back in the northern lake. The carp have been repeatedly netted however they keep coming back, largely due to them being continually released by local residents.

Previous Studies/ Monitoring:

ENV (2006) *Stage 7, Tuckey Cove Coondanup: Water Management Plan*. Report prepared on behalf of Entourage Pty. Ltd.

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Hermitage Lakes (North)**

1. Basic Details	
Location (street and suburb)	Hermitage St, Dudley Park
Location (coordinates)	382012.5 E, 6397910 N
2007 Streetsmart page number	760, C5
Local Government	City of Mandurah
Owner	City of Mandurah
Function*	D, I, A
Age (years)	17
2. Physical Features	
Lining (y/n)	N
Area (ha)	~ 0.735
Shape (e.g. linear, round, irregular)	semi-round
Depth range (estimate) (m)	<2-3
"Naturalness" rating (1 to 5)*	3
Social amenity value (High, Medium, Low)	Low-Medium. Expected to increase as residential development around the lakes increases.
Edging (e.g. wall, trees, reeds, sloping banks, turf)	30% vegetated, 70% grassed
Vegetation type adjacent to lake*	N - reeds, planted Australian trees
Vegetation condition adjacent to lake*	G
Potential acid sulfate soil (ASS) risk (according to ASS risk map)	No known ASS

* Notes:

Function
D - Drainage
C - Conservation
A - Aesthetic (and recreational)
I - Irrigation Storage

Naturalness rating
1 - Highly ornamental
2 - Mostly ornamental with some natural features
3 - Some ornamenatal and some natural features
4 - Natural or natural like with some ornamental features
5 - Natural or natural like

Vegetation type
N - Native
X - Exotic

Vegetation condition
P - Poor
F- Fair
G - Good
E - Excellent

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Hermitage Lakes (North)**

3. Catchment and Hydrology	
Catchment type (e.g. industrial, residential)	Residential
Prior land use	ND
Catchment size (ha)	~12 (City of Mandurah)
Geology (unit)	Tamala Limestone, predominantly sand (Qts)
(description)	ND
No. inlets	3
Inlet volume/size	ND
No. outlets	1
Outlet volume/size	ND
Drainage connection flow through (FT) or End Point (EP) or No Drainage (NDr)	FT
Approximate volume of water extracted for irrigation	ND
Water level top up (y/n)?	N
Estimated residence time	ND
Water or nutrient balance undertaken (y/n)?	N
4. Management	
Aeration/agitation present/absent?	Absent
Aeration type if present* How many?	NA
Fertiliser application adjacent to lake (y/n)?	N
Irrigation adjacent to lake (y/n)?	Y - using lake water
Lawn mowing/ weed control	ND
Management problems*	11 - carp, 12 - bulrushes
Maintenance and effectiveness	Repeatedly netted carp without success.
Monitoring frequency	Not monitored.

* Notes:

Aeration Features
F - Fountain
R - Rocks/waterfall
C - Circulation by pumping
A - Submerged aerator

ND - Data not available within timeframe of study
NA - Not applicable

Management Problems
1. Flooding
2. Drying Out
3. Slow infiltration
4. Odour
5. Nuisance algal growth
6. Fish deaths
7. Bird deaths
8. Mosquitos or midges
9. Acid Sulfate Soils
10. Iron Monosulfides
11. Feral Fish
12. Other (describe)

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Hermitage Lakes (North)**

5. Water Quality (if known)	
Total Nitrogen (µ/L)	NT
Total Phosphorus (µ/L)	NT
Chlorophyll *a* (µg/L)	NT
pH	8.45*
EC (mS)	0.27*
TDS (ppt)	0.13*
Temperature (°C)	17.8*
Algae/ aquatic plants, water clarity	Water appeared fairly clear at time of site visit with a slight green tinge indicating low levels of phytoplankton growth.*
6.Fauna	
Macroinvertebrates e.g. midges and mosquitos	None observed during site visit. No reports of problems with midges or mosquitos.
Macrofauna	Ducks, seagulls, koi carp

Notes:

* Field pH, EC, TDS and temperature measured during site visit on 4/9/07. Observations of algae also recorded on this day.
NT = Not tested

Constructed Lake Study
Field Survey Form

Lake Name and Location: Hermitage Constructed Lakes, Dudley Park (North)

Date: 4/9/07 Recorded By: Bronwyn Woodward

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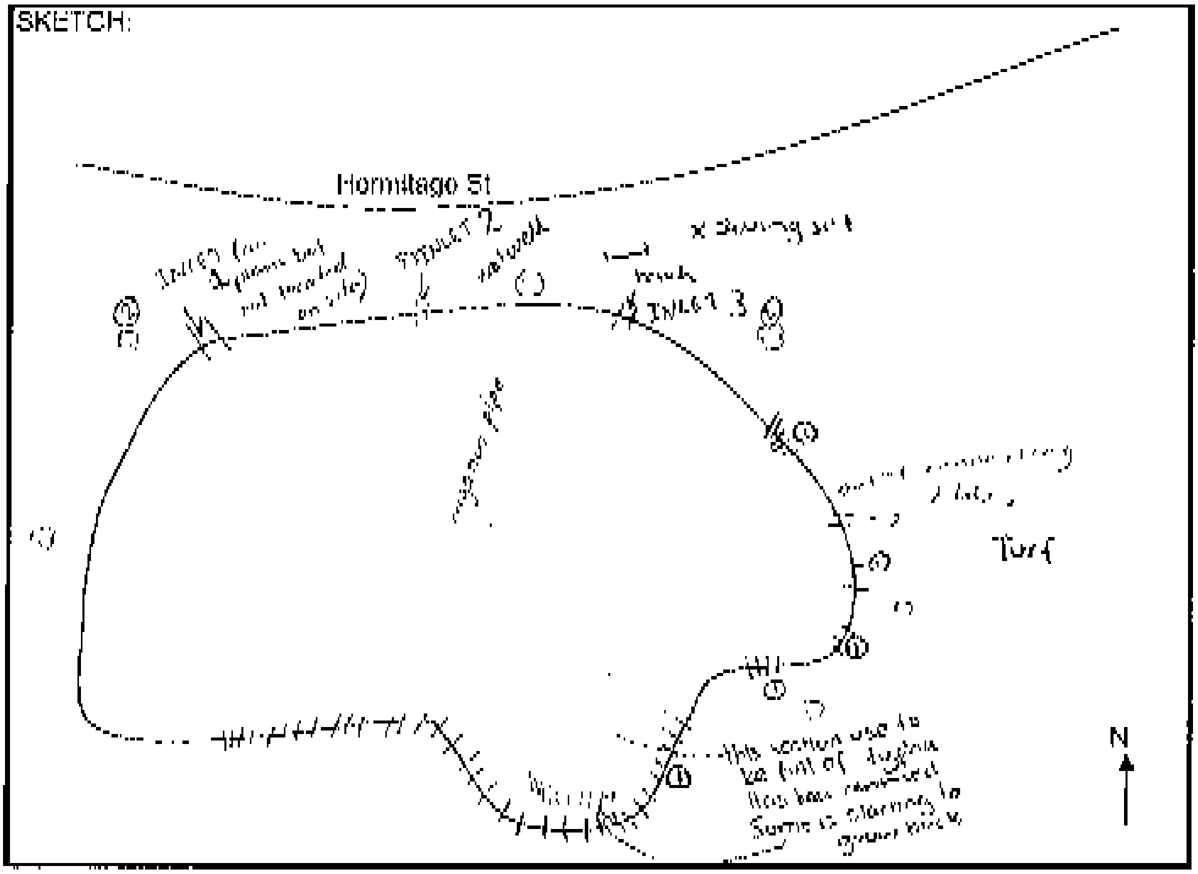

Water Level (mark location of staff gauges): None located.

Estimated Depth of Water: <2.3m

Lake Edge	%	Notes
Walled	0	
Vegetated	30	
Grassed	70	
Earth	0	

Water quality: (scums, water clarity, algae, mosquitoes, pH, EC?) pH = 8.45 EC = 0.27mS

TDS = 0.13ppt Temp = 17.8 Fairly clear Slight green algae

Fauna: Ducks, Seagulls, [illegible]

Vegetation Type(s) adjacent to lake - (annotate with numbers) (1) Reeds

(2) A few young planted Australian trees surround the lake

Other Comments:

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Hermitage Lakes (South)**

1. Basic Details	
Location (street and suburb)	Hermitage St, Dudley Park
Location (coordinates)	382204.8 E, 6397758.5 N
2007 Streetsmart page number	760, C5
Local Government	City of Mandurah
Owner	City of Mandurah
Function*	D, A (racing of model boats)
Age (years)	8-9
2. Physical Features	
Lining (y/n)	N
Area (ha)	~ 0.588
Shape (e.g. linear, round, irregular)	kidney bean
Depth range (estimate) (m)	~2
"Naturalness" rating (1 to 5)*	3
Social amenity value (High, Medium, Low)	Low-Medium. Expected to increase as residential development around the lakes increases.
Edging (e.g. wall, trees, reeds, sloping banks, turf)	40% vegetated, 60% grassed
Vegetation type adjacent to lake*	N - reeds, planted Australian trees
Vegetation condition adjacent to lake*	G
Potential acid sulfate soil (ASS) risk (according to ASS risk map)	No known ASS

* Notes:

Function
D - Drainage
C - Conservation
A - Aesthetic (and recreational)
I - Irrigation Storage

Naturalness rating
1 - Highly ornamental
2 - Mostly ornamental with some natural features
3 - Some ornamenatal and some natural features
4 - Natural or natural like with some ornamental features
5 - Natural or natural like

Vegetation type
N - Native
X - Exotic

Vegetation condition
P - Poor
F- Fair
G - Good
E - Excellent

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Hermitage Lakes (South)**

3. Catchment and Hydrology	
Catchment type (e.g. industrial, residential)	Residential
Prior land use	ND
Catchment size (ha)	~2 not including overflow from northern lake (City of Mandurah)
Geology (unit)	Tamala Limestone, predominantly sand (Qts)
(description)	ND
No. inlets	2
Inlet volume/size	ND
No. outlets	1
Outlet volume/size	ND
Drainage connection flow through (FT) or End Point (EP) or No Drainage (NDr)	FT
Approximate volume of water extracted for irrigation	0
Water level top up (y/n)?	N
Estimated residence time	ND
Water or nutrient balance undertaken (y/n)?	N
4. Management	
Aeration/agitation present/absent?	Absent
Aeration type if present* How many?	NA
Fertiliser application adjacent to lake (y/n)?	N
Irrigation adjacent to lake (y/n)?	Y - using water from northern lake
Lawn mowing/ weed control	ND
Management problems*	11 - carp, 12 - bulrushes
Maintenance and effectiveness	Repeatedly netted carp without success.
Monitoring frequency	Not monitored.

* Notes:

Aeration Features
F - Fountain
R - Rocks/waterfall
C - Circulation by pumping
A - Submerged aerator

ND - Data not available within timeframe of study
NA - Not applicable

Management Problems
1. Flooding
2. Drying Out
3. Slow infiltration
4. Odour
5. Nuisance algal growth
6. Fish deaths
7. Bird deaths
8. Mosquitos or midges
9. Acid Sulfate Soils
10. Iron Monosulfides
11. Feral Fish
12. Other (describe)

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Hermitage Lakes (South)**

5. Water Quality (if known)	
Total Nitrogen (µ/L)	NT
Total Phosphorus (µ/L)	NT
Chlorophyll *a* (µg/L)	NT
pH	8.91*
EC (mS)	0.26*
TDS (ppt)	0.13*
Temperature	17*
Algae/ aquatic plants, water clarity	Water appeared fairly clear at time of site visit with a slight green tinge indicating low levels of phytoplankton growth.*
6.Fauna	
Macroinvertebrates eg. midges and mosquitos	None observed during site visit. No reports of problems with midges or mosquitos.
Macrofauna	Ducks, seagulls, koi carp, long neck turtles

Notes:

* Field pH, EC, TDS and temperature measured during site visit on 4/9/07. Observations of algae also recorded on this day.
NT = Not tested

Constructed Lake Study
Field Survey Form

Lake Name and Location: **Hermitage Constructed Lakes, Dudley Park (South)**

Date: 14/8/07 Recorded By: B. Woodward

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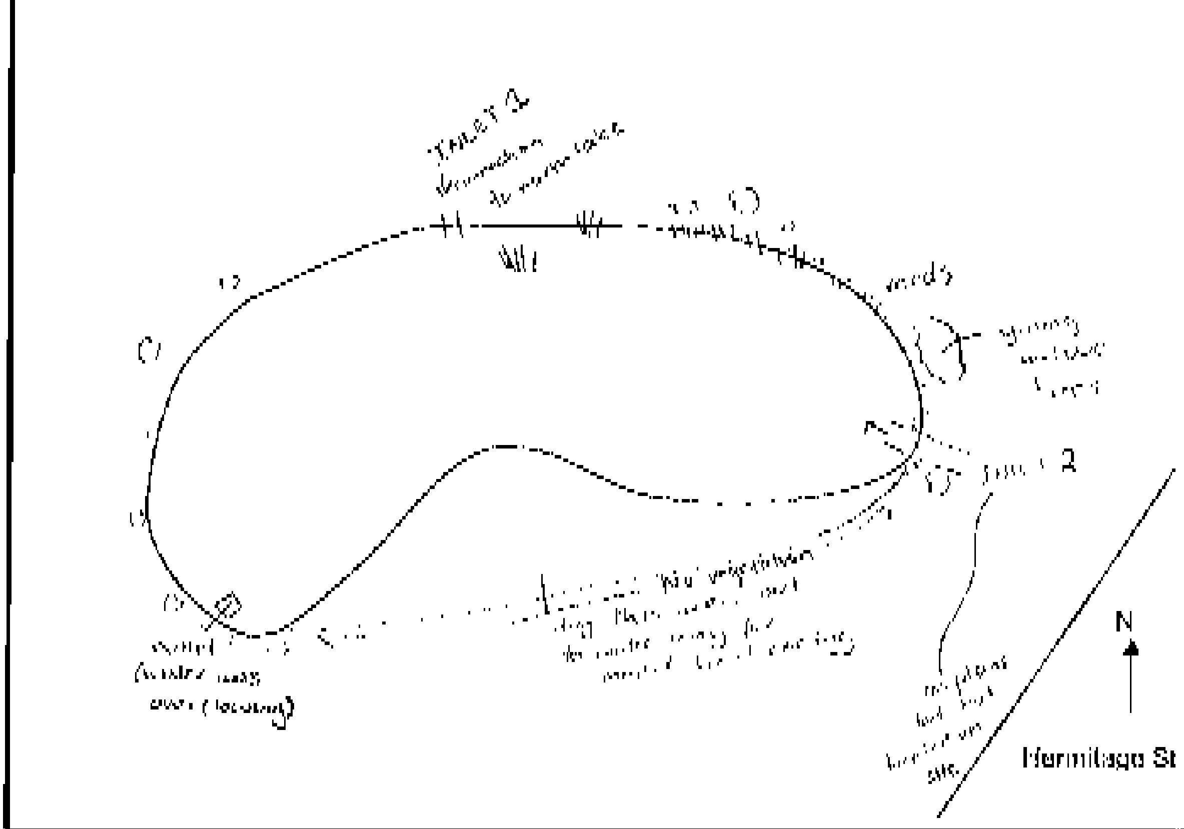

Water Level (mark location of staff gauges): None located

Estimated Depth of Water: ~2m

Lake Edge	%	Notes
Walled	0	
Vegetated	40	[illegible]
Grassed	60	[illegible]
Earth	0	

Water quality: (scums, water clarity, algae, mosquitoes, pH, EC?) [illegible]

[illegible]

Fauna: [illegible]

Vegetation Type(s) adjacent to lake - (annotate with numbers)

Other Comments:

Hermitage Lakes - Photographic Plates

PLATE 1 – Water discharging through the outlet in the south lake.

PLATE 2 – Ducks in the northern lake. *Typha* is visible growing on the southern bank of the lake.

Meadow Springs Lakes – Summary Report

The Meadow Springs Lakes are two connected lakes wedged between two major roads, Mandurah Road and Oakmont Avenue within the City of Mandurah. They receive local drainage from surrounding residential development, are used for irrigation and also intercept groundwater. The lakes have experienced problems with invasion by *Typha*, macroalgae blooms and feral koi carp.

Attempts have been made to remove the *Typha* manually with a follow up spray of round up however this has not been successful in the long term with the Typha managing to re-establish in the southern lake. The carp have been successfully controlled by netting assisted by a public education program instructing residents not to feed or release the fish into the lake.

Previous Studies/ Monitoring:

No previous studies or monitoring records were located.

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Meadow Springs Constructed Lakes (North)**

1. Basic Details	
Location (street and suburb)	Junction of Fremantle Rd and Mandurah Tce, Meadow Springs
Location (coordinates)	381891.2 E, 6403052.4 N
2007 Streetsmart page number	730, C5
Local Government	City of Mandurah
Owner	City of Mandurah
Function*	D, A
Age (years)	13-14
2. Physical Features	
Lining (y/n)	N
Area (ha)	~ 0.779
Shape (eg. linear, round, irregular)	Linear
Depth range (estimate) (m)	<2
"Naturalness" rating (1 to 5)*	3
Social amenity value (High, Medium, Low)	Low-Medium - compromised by location between 2 main roads
Edging (eg. wall, trees, reeds, sloping banks, turf)	50% vegetated, 50% grass
Vegetation type adjacent to lake*	N - reeds, M*elaleuca raphiophylla* , Australian trees
Vegetation condition adjacent to lake*	F
Potential acid sulfate soil (ASS) risk (according to ASS risk map)	No known risk of ASS occurring within 3m of the natural soil surface (or deeper)

* Notes:

Function
D - Drainage
C - Conservation
A - Aesthetic (and recreational)
I - Irrigation Storage

Naturalness rating
1 - Highly ornamental
2 - Mostly ornamental with some natural features
3 - Some ornamenatal and some natural features
4 - Natural or natural like with some ornamental features
5 - Natural or natural like

Vegetation type
N - Native
X - Exotic

Vegetation condition
P - Poor
F- Fair
G - Good
E - Excellent

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Meadow Springs Constructed Lakes (North)**

3. Catchment and Hydrology	
Catchment type (eg. Industrial, Residential)	Residential
Prior land use	ND
Catchment size (ha)	~4 (City of Mandurah)
Geology (unit)	Tamala Limestone, predominantly sand (Qts)
(description)	ND
No. inlets	2
Inlet volume/size	ND
No. outlets	1 - connection to south lake
Outlet volume/size	ND
Drainage connection flow through (FT) or End Point (EP) or No Drainage (NDr)	FT
Approximate volume of water extracted for irrigation	ND
Water level top up (y/n)?	N
Estimated residence time	ND
Water or nutrient balance undertaken (y/n)?	N
4. Management	
Aeration/agitation present/absent?	Absent
Aeration type if present* How many?	NA
Fertiliser application adjacent to lake (y/n)?	N
Irrigation adjacent to lake (y/n)?	Y - using lake water
Lawn mowing/ weed control	ND
Management problems*	5 - Macroalgae blooms, 11 - Carp, 12 - *Typha*
Maintenance and effectiveness	Typha removal. Carp netted, public education signs - this was successful in eliminating carp from the lake.
Monitoring frequency	Not monitored

* Notes:

Aeration Features
F - Fountain
R - Rocks/waterfall
C - Circulation by pumping
A - Submerged aerator

ND - Data not available within timeframe of study
NA - Not applicable

Management Problems
1. Flooding
2. Drying Out
3. Slow infiltration
4. Odour
5. Nuisance algal growth
6. Fish deaths
7. Bird deaths
8. Mosquitos or midges
9. Acid Sulfate Soils
10. Iron Monosulfides
11. Feral Fish
12. Other (describe)

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Meadow Springs Constructed Lakes (North)**

5. Water Quality (if known)	
Total Nitrogen (μ/L)	NT
Total Phosphorus (μ/L)	NT
Chlorophyll *a* (μg/L)	NT
pH	8.92*
EC (mS)	0.61*
TDS (ppt)	0.3*
Temperature (°C)	16.8*
Algae/ aquatic plants, water clarity	Macroalgae covers the lake bed.*
6.Fauna	
Macroinvertebrates eg. midges and mosquitos	None observed during site visit. No records of problems with midges or mosquitos.
Macrofauna	Ducks, banjo frogs.

Notes:

* Field pH, EC, TDS and temperature measured during site visit on 4/9/07. Observations of algae also recorded on this day.
NT = Not tested

Constructed Lake Study
Field Survey Form

Lake Name and Location: **Meadow Springs Constructed Lakes (North)**

Date: 4/9/07 Recorded By: B Woodward

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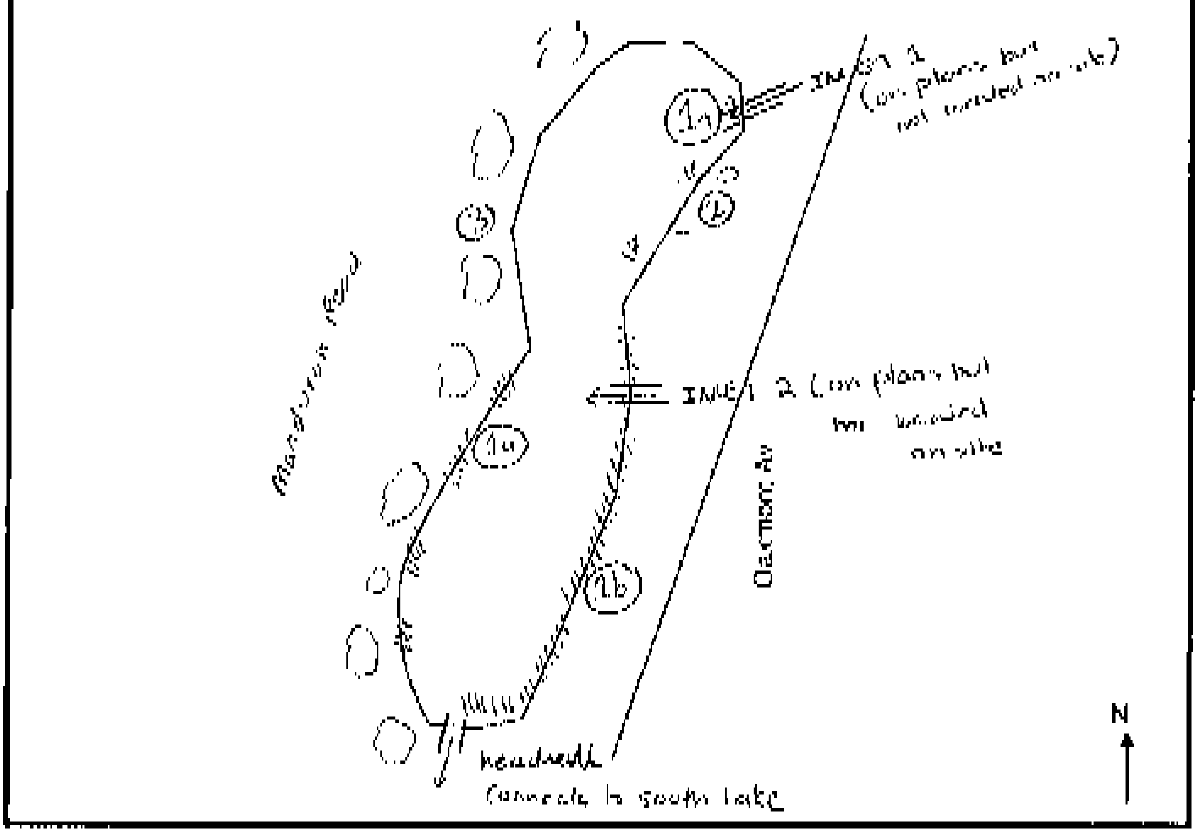


Water Level (mark location of staff gauges): None located

Estimated Depth of Water: <2m

Lake Edge	%	Notes
Walled	0	
Vegetated	50	
Grassed	50	
Earth	0	

Water quality: (scums, water clarity, algae, mosquitoes, pH, EC?) pH: 8.92 ...

TDS: 0.30 ppt Temp: 16.% Macroalgae covers lake bed

Fauna: ducks, could hear frogs, midges observed, ...

Vegetation Type(s) adjacent to lake (annotate with numbers) (1a) Scattered reeds (1b) Fairly thick (~2m) stand of reeds (2) Young Melaleuca

(3) Mature trees - appear native

Other Comments:

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Meadow Springs Constructed Lakes (South)**

1. Basic Details	
Location (street and suburb)	Junction of Fremantle Road and Mandurah Terrace, Meadow Springs
Location (coordinates)	381821.7 E, 6402816.1 N
2007 Streetsmart page number	730, C5
Local Government	City of Mandurah
Owner	City of Mandurah
Function*	D, I, A
Age (years)	13-14
2. Physical Features	
Lining (y/n)	N
Area	~ 0.701
Shape (eg. linear, round, irregular)	Linear
Depth range (estimate) (m)	<2
"Naturalness" rating (1 to 5)*	3
Social amenity value (High, Medium, Low)	Low-Medium - compromised by location between 2 main roads
Edging (eg. wall, trees, reeds, sloping banks, turf)	50% vegetated, 50% grassed
Vegetation type adjacent to lake*	*Typha* , reeds, Australian trees
Vegetation condition adjacent to lake*	F
Potential acid sulfate soil (ASS) risk (according to ASS risk map)	No known risk of ASS occurring within 3m of the natural soil surface (or deeper)

* Notes:

Function
D - Drainage
C - Conservation
A - Aesthetic (and recreational)
I - Irrigation Storage

Naturalness rating
1 - Highly ornamental
2 - Mostly ornamental with some natural features
3 - Some ornamenatal and some natural features
4 - Natural or natural like with some ornamental features
5 - Natural or natural like

Vegetation type
N - Native
X - Exotic

Vegetation condition
P - Poor
F- Fair
G - Good
E - Excellent

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Meadow Springs Constructed Lakes (South)**

3. Catchment and Hydrology	
Catchment type (eg. industrial, residential)	Residential
Prior land use	ND
Catchment size (ha)	~4 not including overflow from northern lake (City of Mandurah)
Geology (unit)	Tamala Limestone, predominantly sand (Qts)
(description)	ND
No. inlets	3 - including connection to north lake
Inlet volume/size	ND
No. outlets	0
Outlet volume/size	ND
Drainage connection flow through (FT) or End Point (EP) or No Drainage (NDr)	EP
Approximate volume of water extracted for irrigation	ND
Water level top up (y/n)?	Y - with borewater
Estimated residence time	ND
Water or nutrient balance undertaken (y/n)?	N
4. Management	
Aeration/agitation present/absent?	Absent
Aeration type if present* How many?	NA
Fertiliser application adjacent to lake (y/n)?	N
Irrigation adjacent to lake (y/n)?	Y - using lake water
Lawn mowing/ weed control	ND
Management problems*	5 - Macroalgae blooms, 11 - Carp, 12 - *Typha*
Maintenance and effectiveness	*Typha* removal. Carp netted, public education signs - this was successful in eliminating carp from the lake.
Monitoring frequency	Not monitored.

* Notes:

Aeration Features
F - Fountain
R - Rocks/waterfall
C - Circulation by pumping
A - Submerged aerator

ND - Data not available within timeframe of study
NA - Not applicable

Management Problems
1. Flooding
2. Drying Out
3. Slow infiltration
4. Odour
5. Nuisance algal growth
6. Fish deaths
7. Bird deaths
8. Mosquitos or midges
9. Acid Sulfate Soils
10. Iron Monosulfides
11. Feral Fish
12. Other (describe)

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Meadow Springs Constructed Lakes (South)**

5. Water Quality (if known)	
Total Nitrogen (µ/L)	NT
Total Phosphorus (µ/L)	NT
Chlorophyll *a* (µg/L)	NT
pH	8.92*
EC (mS)	0.45*
TDS (ppt)	0.22*
Temperature (°C)	18.6*
Algae/ aquatic plants, water clarity	Macroalgae covers the lake bed. Filamentous green algae observed in more stagnant part of lake.*
6.Fauna	
Macroinvertebrates eg. midges and mosquitos	None observed during site visit. No records of problems with midges or mosquitos.
Macrofauna	Ducks, reed warbler.

Notes:

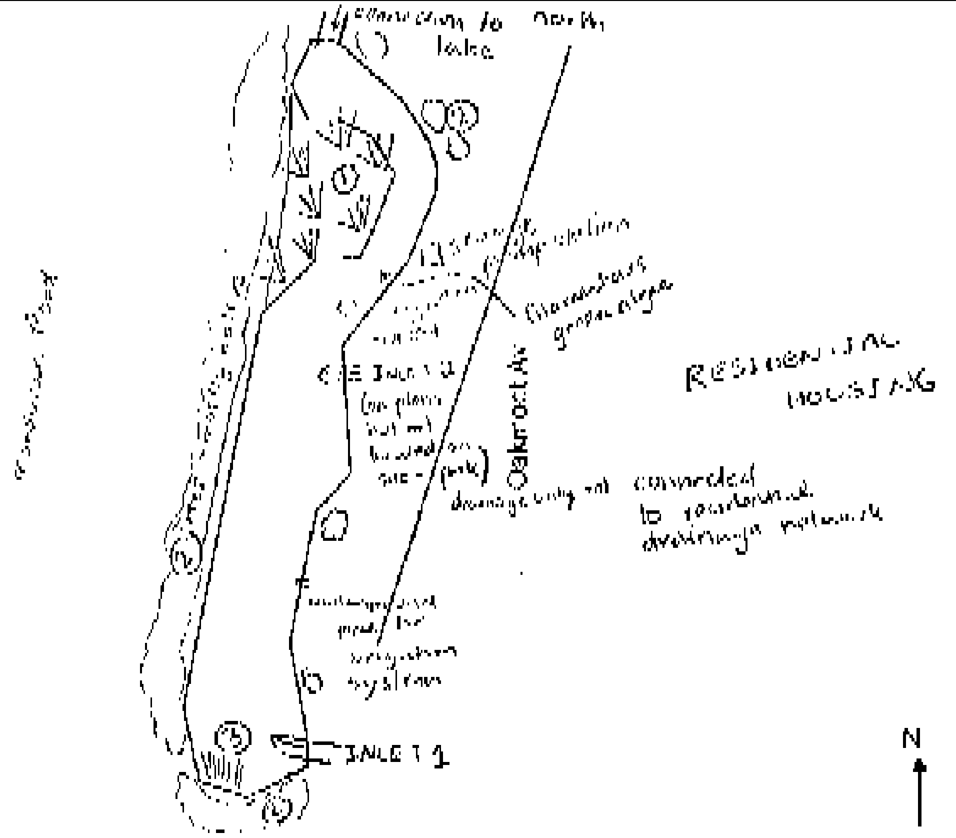
* Field pH, EC, TDS and temperature measured during site visit on 4/9/07. Observations of algae also recorded on this day.
NT - Not tested.

Constructed Lake Study
Field Survey Form

Lake Name and Location: **Meadow Springs Constructed Lakes (South)**

Date: 4/5/01 Recorded By: B. Woodward

SKETCH:



Water Level (mark location of staff gauges): None located

Estimated Depth of Water: <2 m

Lake Edge	%	Notes
Walled	0	
Vegetated	50	
Grassed	50	
Earth	0	

Water quality: (scums, water clarity, algae, mosquitoes, pH, EC?) pH = 8.92
EC = 0.45 mS TDS = 0.22 ppt temp = 18.6 macroalgae covers lake bed.

Fauna: [illegible] ducks, [illegible]

Vegetation Type(s) adjacent to lake - (annotate with numbers) (1) Typha (2)

(3)

Other Comments:

Meadow Springs Lakes - Photographic Plates

PLATE 1 – Macroalgal bloom visible on bed of Northern Lake.

PLATE 2 – *Typha* in Southern Lake.

Meadow Springs Lakes - Photographic Plates

PLATE 3 – Extraction point for irrigation water in Southern Lake.

PLATE 2 – Netting complemented by public education through methods such as signage (above) was successful in eliminating Koi Carp from the lake.

City of Rockingham

- Centenary Park Lake
- Chinchilla
- Lagoon Park Lake

Centenary Park Lake – Summary Report

This is a highly ornamental eight year old lake located within the suburb of Safety Bay in Rockingham. The lake receives drainage and being a central feature within a public park, also has a high aesthetic value. The lake is aerated by two fountains and by pumping water from the lake and directing back in over a waterfall on the northern side of the lake. The recirculation system was not operating at the time of the site visit on 10 September 2007.

A mix of Australian species of reeds and trees as well as none-native landscaping surround the lake. Half of the lake is edged with a limestone wall and a jetty and island have been constructed in the middle of the lake. The lake has experienced problems in the past with nuisance midges and mosquitoes (ATA, 2003).

Previous Studies/ Monitoring:

ATA (2003) *City of Rockingham Urban Wetlands Study*. Report prepared for the City of Rockingham.

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Centenary Park Lake**

1. Basic Details	
Location (street and suburb)	Corner of Seabreeze Street and Charthouse Road, Safety Bay
Location (coordinates)	381714.5 E, 6424366.4 N
2007 Streetsmart page number	610, B&C2
Local Government	City of Rockingham
Owner	City of Rockingham
Function*	A
Age (years)	8
2. Physical Features	
Lining (y/n)	N
Area (ha)	0.3
Shape (eg. linear, round, irregular)	Linear, slightly irregular.
Depth range (estimate) (m)	<2-3
"Naturalness" rating (1 to 5)*	1.5
Social amenity value (High, Medium, Low)	High
Edging (eg. wall, trees, reeds, sloping banks, turf)	50% limestone wall, 50% vegetated
Vegetation type adjacent to lake*	Reeds, highly artificial landscaping (palms, European shrubs and trees, Australian species including *Eucalyptus* , *Melaleuca* , wattle and native coastal shrubs.
Vegetation condition adjacent to lake*	G
Potential acid sulfate soil (ASS) risk (according to ASS risk map)	No known risk of ASS occurring within 3 m of natural soil surface (or deeper)

* Notes:

Function
D - Drainage
C - Conservation
A - Aesthetic (and recreational)
I - Irrigation Storage

Naturalness rating
1 - Highly ornamental
2 - Mostly ornamental with some natural features
3 - Some ornamenatal and some natural features
4 - Natural or natural like with some ornamental features
5 - Natural or natural like

Vegetation type
N - Native
X - Exotic

Vegetation condition
P - Poor
F- Fair
G - Good
E - Excellent

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Centenary Park Lake**

3. Catchment and Hydrology	
Catchment type (eg. industrial, residential)	Residential
Prior land use	ND
Catchment size (ha)	NA - does not receive drainage
Geology (unit)	Safety Bay Sand (Qhs)
(description)	S_{13} - CALCAREOUS SAND - white, medium-grained, rounded, quartz and shell debris, well sorted, of aeolian origin
No. inlets	0
Inlet volume/size	NA
No. outlets	0
Outlet volume/size	NA
Drainage connection flow through (FT) or End Point (EP) or No Drainage (NDr)	NDr
Approximate volume of water extracted for irrigation	0
Water level top up (y/n)?	N. Used to be topped with bore water. Stopped as Department of Water (DoW) did not allow this. Water levels are now lower.
Estimated residence time	ND
Water or nutrient balance undertaken (y/n)?	N
4. Management	
Aeration/agitation present/absent?	Present.
Aeration type if present* How many?	2F, 1R, C. Waterfall and recirculation system were not operating at time of site visit on 10/9/07- has been broken for about 4 months.
Fertiliser application adjacent to lake (y/n)?	ND
Irrigation adjacent to lake (y/n)?	ND
Lawn mowing/ weed control	ND
Management problems*	5, 8 (ATA, 2003). Scum yellowy green possibly filamentous green in summer every year. 12. Break down of recirculation pump - screen kept getting blocked with particulate matter and algae and was also sucking dry and burning out.
Maintenance and effectiveness	Horticulturalist used to scoop out algae with rake. Tried blue dye to stop sunlight penetrating didn't work as top up water was diluting it. Treated with Phoslock (cost ~ $7500) last summer - eliminated algae temporarily but has come back this spring. Are about to change the recirculation system - will replace centrifugal pump with a submersible pump to stop it burning out and clogging and move it to the bottom of the lake, further away from the waterfall to improve the circulation.
Monitoring frequency	Not monitored.

* Notes:

Aeration Features
F - Fountain
R - Rocks/waterfall
C - Circulation by pumping
A - Submerged aerator

Management Problems
1. Flooding
2. Drying Out
3. Slow infiltration
4. Odour
5. Nuisance algal growth
6. Fish deaths
7. Bird deaths
8. Mosquitos or midges
9. Acid Sulfate Soils
10. Iron Monosulfides
11. Feral Fish
12. Other (describe)

ND - Data not available within timeframe of study
NA - Not applicable

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Centenary Park Lake**

5. Water Quality (if known)	
Total Nitrogen (µ/L)	NT
Total Phosphorus (µ/L)	NT
Chlorophyll *a* (µg/L)	NT
pH	9.22*
EC (mS)	0.69*
TDS (ppt)	0.34*
Temperature (°C)	21.7*
Algae/ aquatic plants, water clarity	None observed during site visit.*
6.Fauna	
Macroinvertebrates eg. midges and mosquitos	None observed during site visit. Has experienced problems with mosquitos and midges.
Macrofauna	seagulls, ducks, black coloured bird (observed to be nesting on island at site visit)

Notes:

* Field pH, EC, TDS and temperature measured during site visit on 10/9/07. Observations of algae also recorded on this day.
NT - Not tested

Constructed Lake Study
Field Survey Form

Lake Name and Location: **Centenary Park Lake, Safety Bay**

Date: 10/09/2007 Recorded By: Bronwyn Woodward

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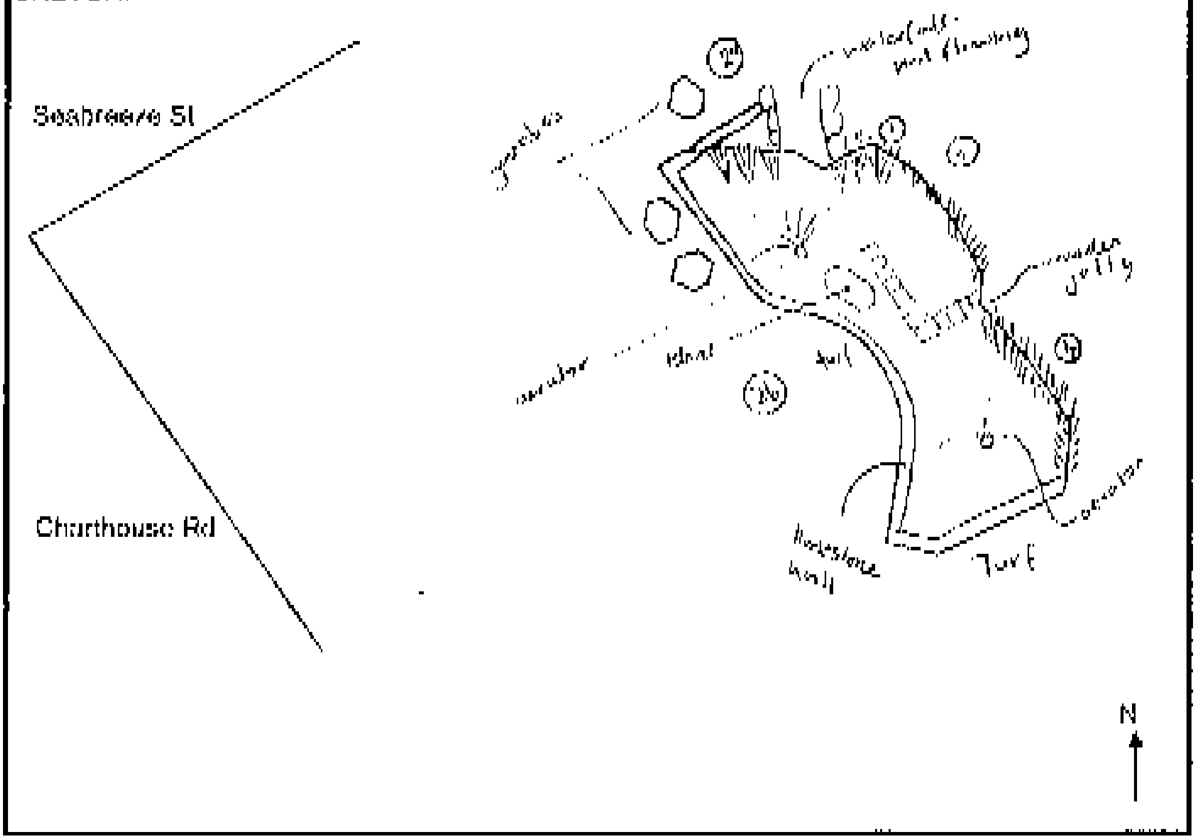


Water Level (mark location of staff gauges): no gauge located

Estimated Depth of Water: 2 - 3m max depth

Lake Edge	%	Notes
Walled	50	
Vegetated	50	
Grassed	0	
Earth	0	

Water quality: (scums, water clarity, algae, mosquitoes, pH, EC?) clear, slight dark green tinge. Benthic macroalgae growing on bottom of lake
pH= 9.22 EC= 0.69 mS TDS= 0.34 ppt Temp 20.2°C

Fauna: seagulls, ducks, [illegible]

Vegetation Type(s) adjacent to lake - (annotate with numbers) (1) Reeds
(2) highly manicured landscaping (2a) palms [illegible] shrubs (2b) [illegible]
(3) mixed eucalyptus, Melaleuca & other Australian species (4) native coastal [illegible]?

Other Comments:

Centenary Park Lake - Photographic Plates

PLATE 1 – The lake recirculation system was not operating in September 2007, although the two fountains in the lake were working.

PLATE 2 – Fringing vegetation on the eastern side of the lake.

Chinchilla – Summary Report

Chinchilla is a highly ornamental constructed lake located within a relatively new residential development in Port Kennedy, Rockingham. It is approximately five years old and is yet to experience any water quality problems. The lake collects local drainage and also serves an aesthetic purpose.

A jetty, paths, benches and a gazebo have been constructed around the lake to encourage public access. The landscaping around the lake is highly artificial consisting mainly of turf as well as a low density of introduced trees and shrubs including lavender, plane trees and willows and planted Australian trees. Some native reeds have been planted around the edge of the lake, half of which is walled.

Previous Studies/ Monitoring:

ATA (2003) *City of Rockingham Urban Wetlands Study*. Report prepared for the City of Rockingham.

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Chinchilla**

1. Basic Details	
Location (street and suburb)	Chinchilla Pwy, Port Kennedy
Location (coordinates)	383577.6 E, 6418904 N
2007 Streetsmart page number	640, E3
Local Government	City of Rockingham
Owner	City of Rockingham
Function*	A, D
Age (years)	5
2. Physical Features	
Lining (y/n)	N
Area (ha)	0.08
Shape (eg. linear, round, irregular)	Irregular - 3 linear edges, 1 curved edge
Depth range (estimate) (m)	<2-3
"Naturalness" rating (1 to 5)*	1
Social amenity value (High, Medium, Low)	High
Edging (eg. wall, trees, reeds, sloping banks, turf)	50% limestone wall, 8% reeds, 42% grassed
Vegetation type adjacent to lake*	Mix of N and X. Reeds (2 types), paperbarks (not *Melaleuca raphiophylla*), willow, plane trees, lavender, planted *Eucalyptus* and grass trees.
Vegetation condition adjacent to lake*	G
Potential acid sulfate soil (ASS) risk (according to ASS risk map)	No known risk of ASS occuring within 3 m of natural soil surface (or deeper)

* Notes:

Function
D - Drainage
C - Conservation
A - Aesthetic (and recreational)
I - Irrigation Storage

Naturalness rating
1 - Highly ornamental
2 - Mostly ornamental with some natural features
3 - Some ornamenatal and some natural features
4 - Natural or natural like with some ornamental features
5 - Natural or natural like

Vegetation type
N - Native
X - Exotic

Vegetation condition
P - Poor
F- Fair
G - Good
E - Excellent

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Chinchilla**

3. Catchment and Hydrology	
Catchment type (eg. industrial, residential)	Residential
Prior land use	ND
Catchment size (ha)	ND
Geology (unit)	Safety Bay Sand (Qhs)
(description)	S_{13} - CALCAREOUS SAND - white, medium-grained, rounded, quartz and shell debris, well sorted, of aeolian origin
No. Inlets	3
Inlet volume/size	Inlet 1 - pipe diameter = 600 mm Inlet 2 - pipe diameter = 600 mm Inlet 3 - pipe diameter = 525 mm
No. outlets	0
Outlet volume/size	NA
Drainage connection flow through (FT) or End Point (EP) or No Drainage (NDr)	EP
Approximate volume of water extracted for irrigation	0
Water level top up (y/n)?	N
Estimated residence time	ND
Water or nutrient balance undertaken (y/n)?	N
4. Management	
Aeration/agitation present/absent?	Present
Aeration type if present* How many?	1F, thinking about changing to an underwater aeration system
Fertiliser application adjacent to lake (y/n)?	Y - 3-4 times per year (311 Bailey's - no phosphorus)
Irrigation adjacent to lake (y/n)?	Y - borewater
Lawn mowing/ weed control	ND
Management problems*	None recorded.
Maintenance and effectiveness	No special management for the lake has been required outside of typical park management procedures
Monitoring frequency	Not monitored

* Notes:

Aeration Features
F - Fountain
R - Rocks/waterfall
C - Circulation by pumping
A - Submerged aerator

Management Problems
1. Flooding
2. Drying Out
3. Slow infiltration
4. Odour
5. Nuisance algal growth
6. Fish deaths
7. Bird deaths
8. Mosquitos or midges
9. Acid Sulfate Soils
10. Iron Monosulfides
11. Feral Fish
12. Other (describe)

ND - Data not available within timeframe of study
NA - Not applicable

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Chinchilla**

5. Water Quality (if known)	
Total Nitrogen (µ/L)	NT
Total Phosphorus (µ/L)	NT
Chlorophyll *a* (µg/L)	NT
pH	9.85*
EC (mS)	0.15*
TDS (ppt)	0.07*
Temperature (°C)	20.3*
Algae/ aquatic plants, water clarity	Fairly clear water during site visit with slight green tinge indicating low levels of phytoplankton growth.*
6.Fauna	
Macroinvertebrates eg. midges and mosquitos	None observed during site visit. No recorded problems with mosquitos or midges.
Macrofauna	Eurasian coot, ducks, seagull, juvenile *Gambusia* .

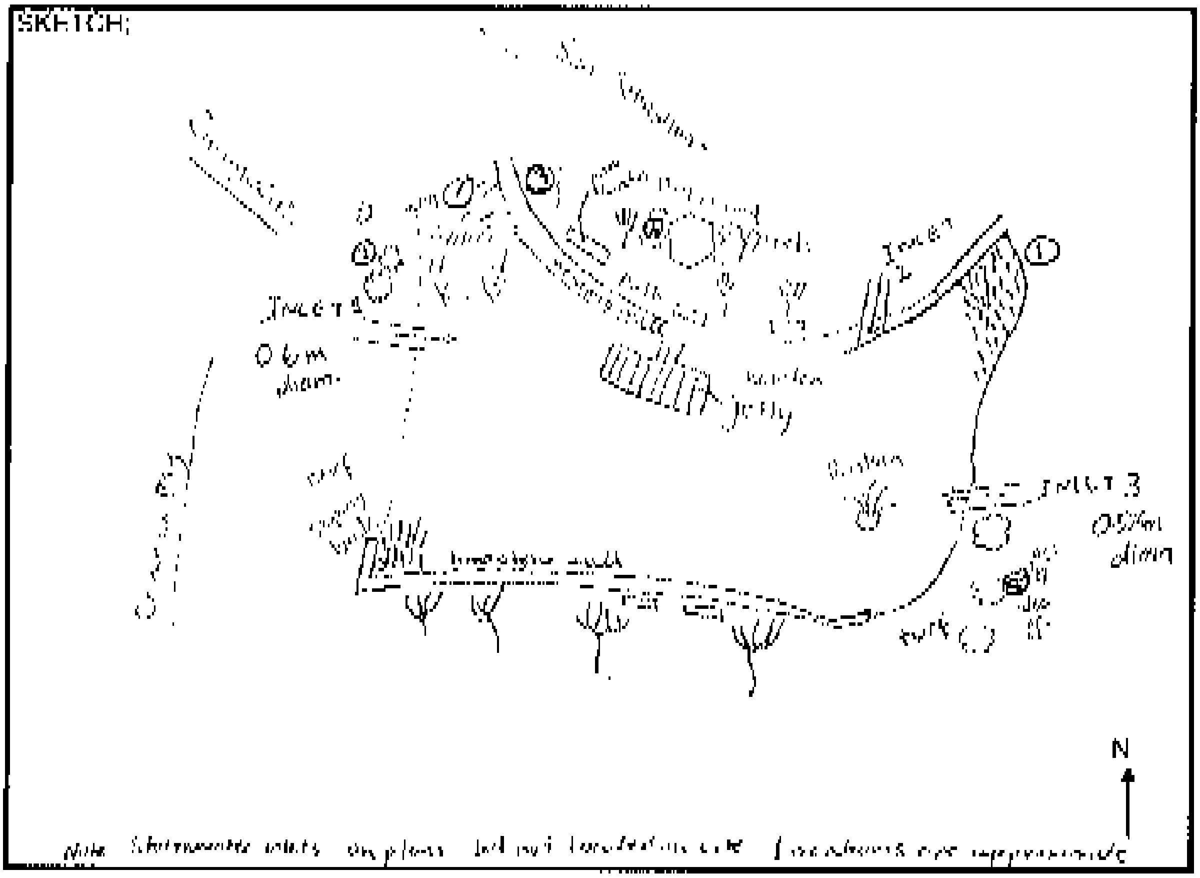
Notes:

* Field pH, EC, TDS and temperature measured during site visit on 10/9/07. Observations of algae also recorded on this day.
NT = Not tested

Constructed Lake Study
Field Survey Form

Lake Name and Location: Chinchilla, Port Kennedy

Date: 10/09/2007 Recorded By: Bronwyn Woodward



Water Level (mark location of staff gauges): No gauge located

Estimated Depth of Water: 2.5m max depth

Lake Edge	%	Notes
Walled	50	limestone [illegible]
Vegetated	8	[illegible]
Grassed	42	[illegible]
Earth		

Water quality: (scums, water clarity, algae, mosquitoes, pH, EC?) Clear [illegible]

pH = 9.85 EC = 0.5 [illegible] TDS [illegible] temp. 20.3°C

Fauna: [illegible] ducks, [illegible]

Vegetation Type(s) adjacent to lake - (annotate with numbers) (1) [illegible]

(2) [illegible] (3) [illegible]

(4) [illegible] (5) [illegible]

Other Comments: [illegible]

[illegible]

Chinchilla - Photographic Plates

PLATE 1 – The lake is highly ornamental however has some natural features such as fringing reeds.

PLATE 2– Features such as a gazebo and footpaths have been constructed around the lake to encourage public access.

Lagoon Park Lake – Summary Report

Lagoon Park Lake is located within a bush forever site and approximately 100 metres to the west of Hidden Swamp which is classified as a Threatened Ecological Community (TEC). The developer has attempted to create a natural-like lake considering its location amongst high conservation value areas. Most of the lake is surrounded by reeds and remnants of native vegetation.

The lake is used for irrigation of surrounding parkland and receives either road drainage or overflow from Hidden Swamp. The lake also provides habitat for numerous birds, banjo frogs and snakes. It is possible the lake contains feral fish as koi carp inhabit Hidden Swamp which possibly overflows into the lake and anecdotal evidence suggests goldfish have been released into the lake. Typha has also invaded some parts of the lake.

Previous Studies/ Monitoring:

ATA (2003) *City of Rockingham Urban Wetlands Study*. Report prepared for the City of Rockingham.

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Lagoon Park Lake**

1. Basic Details	
Location (street and suburb)	Siracusa Court, Secret Harbour
Location (coordinates)	382041.5 E, 6414004.7 N
2007 Streetsmart page number	670, C3
Local Government	City of Rockingham
Owner	City of Rockingham
Function*	C, A, I
Age (years)	11
2. Physical Features	
Lining (y/n)	N - main part of lake Y - small southern section
Area (ha)	1.05
Shape (eg. linear, round, irregular)	Irregular, elongated
Depth range (estimate) (m)	0.5-1.5
"Naturalness" rating (1 to 5)*	3.5
Social amenity value (High, Medium, Low)	High - popular place for recreation eg. barbecues and walking
Edging (eg. wall, trees, reeds, sloping banks, turf)	5% limestone wall, 95% vegetated
Vegetation type adjacent to lake*	Reeds, sheoaks, *Melaleuca* , teatrees, coastal shrubs, *Typha* , some is the natural remnant
Vegetation condition adjacent to lake*	G
Potential acid sulfate soil (ASS) risk (according to ASS risk map)	No known risk of ASS occuring within 3 m of natural soil surface (or deeper)

* Notes:

Function
D - Drainage
C - Conservation
A - Aesthetic (and recreational)
I - Irrigation Storage

Naturalness rating
1 - Highly ornamental
2 - Mostly ornamental with some natural features
3 - Some ornamenatal and some natural features
4 - Natural or natural like with some ornamental features
5 - Natural or natural like

Vegetation type
N - Native
X - Exotic

Vegetation condition
P - Poor
F- Fair
G - Good
E - Excellent

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Lagoon Park Lake**

3. Catchment and Hydrology	
Catchment type (eg. industrial, residential)	Residential
Prior land use	ND
Catchment size (ha)	ND
Geology (unit)	Safety Bay Sand (Qhs)
(description)	S_{13} - CALCAREOUS SAND - white, medium-grained, rounded, quartz and shell debris, well sorted, of aeolian origin
No. inlets	1 - road drainage or overflow from Hidden Swamp
Inlet volume/size	ND
No. outlets	0
Outlet volume/size	NA
Drainage connection flow through (FT) or End Point (EP) or No Drainage (NDr)	EP
Approximate volume of water extracted for irrigation	ND - 2 irrigation pumps in main lake
Water level top up (y/n)?	possibly topped up with borewater
Estimated residence time	ND
Water or nutrient balance undertaken (y/n)?	N
4. Management	
Aeration/agitation present/absent?	Present
Aeration type if present* How many?	Section 1: 1R, C, Section 2: C
Fertiliser application adjacent to lake (y/n)?	ND
Irrigation adjacent to lake (y/n)?	Y - lake water
Lawn mowing/ weed control	ND
Management problems*	11 - goldfish, possibly carp, 12 - Typha
Maintenance and effectiveness	No special management for the lake has been required outside of typical park management procedures
Monitoring frequency	Possibly sampled by ATA.

* Notes:

Aeration Features
F - Fountain
R - Rocks/waterfall
C - Circulation by pumping
A - Submerged aerator

ND - Data not available within timeframe of study
NA - Not applicable

Management Problems
1. Flooding
2. Drying Out
3. Slow infiltration
4. Odour
5. Nuisance algal growth
6. Fish deaths
7. Bird deaths
8. Mosquitos or midges
9. Acid Sulfate Soils
10. Iron Monosulfides
11. Feral Fish
12. Other (describe)

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Lagoon Park Lake**

5. Water Quality (if known)	
Total Nitrogen (µ/L)	ND
Total Phosphorus (µ/L)	ND
Chlorophyll *a* (µg/L)	ND
pH	8.69*
EC (mS)	1.11*
TDS (ppt)	0.55*
Temperature (°C)	20.4*
Algae/ aquatic plants, water clarity	Benthic and floating filamentous green algae in stagnant areas.*
6.Fauna	
Macroinvertebrates eg. midges and mosquitos	None observed during site visit. No recorded problems with mosquitos or midges.
Macrofauna	Purple swamp hen (pair), Eurasian coot, black swans, ducks, banjo frogs, pigeons, juvenile gambusia, snake, goldfish and carp possible.

Notes:

* Field pH, EC, TDS and temperature measured during site visit on 10/9/07. Observations of algae also recorded on this day.
NT - Not tested
ND - Data not available within time frame of study

Constructed Lake Study
Field Survey Form

Lake Name and Location: Lagoon Park Lake, Secret Harbour

Date: 10/09/2007 Recorded By: Bronwyn Woodward

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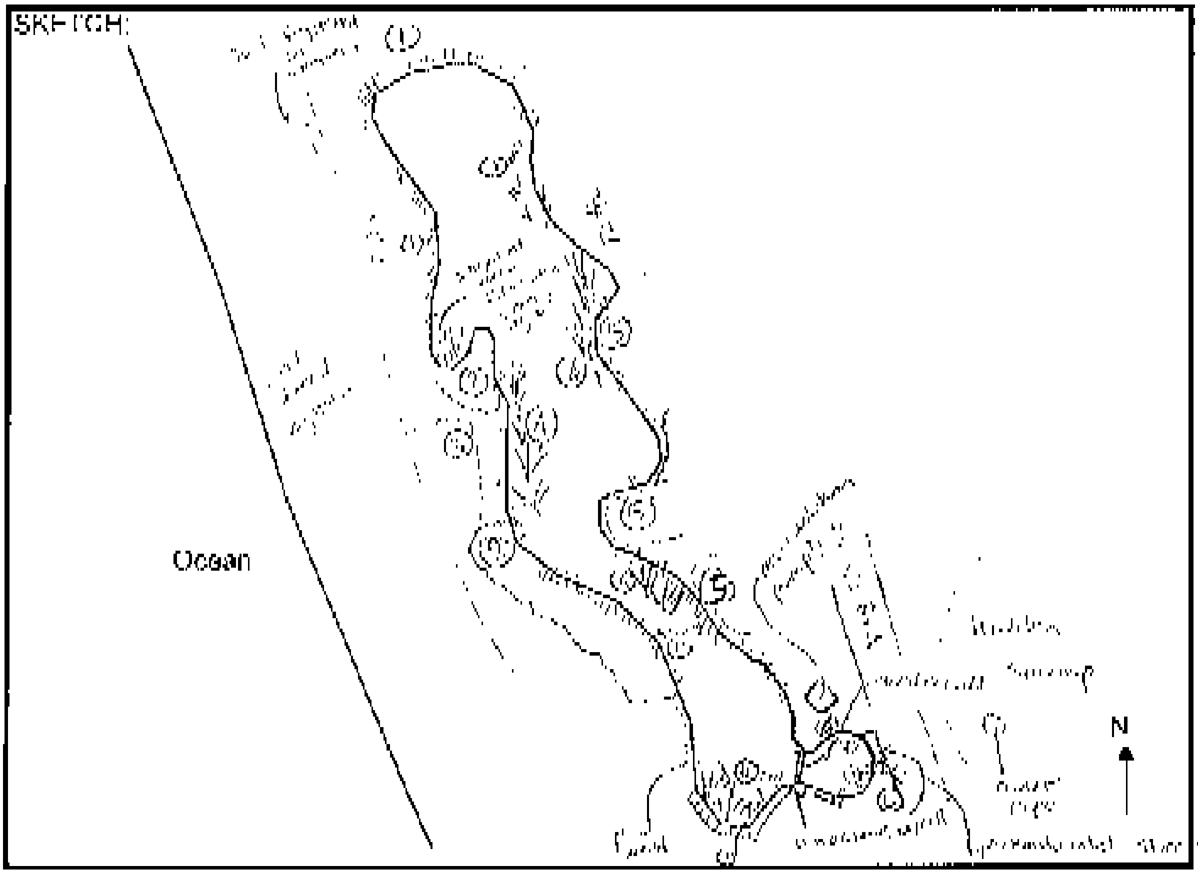


Water Level (mark location of staff gauges): No gauge located

Estimated Depth of Water: 0.5 - 1.5m

Lake Edge	%	Notes
Walled	5	limestone [illegible]
Vegetated	95	[illegible]
Grassed	0	
Earth	0	

Water quality: (scums, water clarity, algae, mosquitoes, pH, EC?) clear [illegible]
[illegible]
pH 8.69 EC = 1.18 mS TDS = 0.58 ppt Temp: 21.4 °C

Fauna: [illegible] (pair) [illegible]
[illegible]

Vegetation Type(s) adjacent to lake - (annotate with numbers) (1) Reeds
(2) shrubs [illegible] melaleuca? [illegible]
(3) Shrubs (4) Typha (5) melaleuca? / tea trees?

Other Comments: (1) [illegible]
Some people walking [illegible].

Lagoon Park Lake - Photographic Plates

PLATE 1 – *Typha* growing amongst fringing reeds. Residential housing overlooks the lake.

PLATE 2 – Koi Carp in Hidden Swamp.

City of Stirling

- Bradford St Lake
- Jackadder Lake
- Shearwater Spoonbill Lake (North)
- Shearwater Spoonbill Lake (South)

Bradford Street Lake – Summary Report

Bradford Street Lake was initially created to intercept stormwater drainage, over twenty years ago, south of Edith Cowan University, in the suburb of Menora. The lake was clay lined in the early 1990s following problems with the community complaining about it drying out in summer. Once the lake was lined and contained permanent water it began to be used to irrigate the surrounding park land.

The lake is frequently accessed by the public and has a high aesthetic value due to its conspicuous location with a residential area and proximity to a university. The lake has experienced blue green algal blooms in recent years. This is probably due to high fertilizer use within the surrounding catchment and the drying climate which has resulted in lower lake water levels, higher water temperatures and the concentration of nutrients.

Previous Studies/ Monitoring:

No previous studies or monitoring records were located.

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Bradford St Lake**

1. Basic Details	
Location (street and suburb)	Bradford St, Menora
Location (coordinates)	392794.9 E, 6467683.2 N
2007 Streetsmart page number	343, A5
Local Government	City of Stirling
Owner	City of Stirling
Function*	D, A, I
Age (years)	>20
2. Physical Features	
Lining (y/n)	Y - clay
Area (ha)	0.355
Shape (eg. linear, round, irregular)	Oval, 1 island
Depth range (estimate) (m)	1.0 - 1.5 maximum
"Naturalness" rating (1 to 5)*	2
Social amenity value (High, Medium, Low)	High
Edging (eg. wall, trees, reeds, sloping banks, turf)	5% vegetated (some reeds), 95% grassed
Vegetation type adjacent to lake*	Reeds (introduced and natural), flame trees, *Eucalyptus* species, palm trees, bottlebrush, paperbark, plane trees, willow, white gum and sheoak
Vegetation condition adjacent to lake*	G
Potential acid sulfate soil (ASS) risk (according to ASS risk map)	High to moderate risk of ASS occurring within 3 m of natural soil surface

* Notes:

Function
D - Drainage
C - Conservation
A - Aesthetic (and recreational)
I - Irrigation Storage

Naturalness rating
1 - Highly ornamental
2 - Mostly ornamental with some natural features
3 - Some ornamenatal and some natural features
4 - Natural or natural like with some ornamental features
5 - Natural or natural like

Vegetation type
N - Native
X - Exotic

Vegetation condition
P - Poor
F- Fair
G - Good
E - Excellent

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Bradford St Lake**

3. Catchment and Hydrology	
Catchment type (eg. industrial, residential)	Residential
Prior land use	ND
Catchment size (ha)	ND
Geology (unit)	Bassendean Sand (Qpb)
(description)	S_8 - SAND - white to pale grey at surface, yellow at depth, fine to medium grained, moderately sorted, subangular to subrounded, minor heavy minerals, of aeolian origin
No. inlets	4 (see sketch)
Inlet volume/size	Inlet 1 - Water Corporation MD, open swale at discharge point into lake (~2.5m wide), upstream pipe diameter = 525 mm Inlet 2 - pipe diameter = 600 mm Inlet 3 - pipe diameter = 300 mm Inlet 4 - pipe diameter = 900 mm
No. outlets	1
Outlet volume/size	Pipe diameter = 525 mm
Drainage connection flow through (FT) or End Point (EP) or No Drainage (NDr)	FT
Approximate volume of water extracted for irrigation	35mL per week during summer months
Water level top up (y/n)?	Y - topped up with bore water
Estimated residence time	ND
Water or nutrient balance undertaken (y/n)?	N
4. Management	
Aeration/agitation present/absent?	Absent
Aeration type if present* How many?	NA
Fertiliser application adjacent to lake (y/n)?	Fertilizing regimes are tailored to specific reserves with no reserve receiving fertilizer unless truly necessary. Determining whether reserves do need fertilizer is based on results taken from soil and leaf analysis. Fertilizing with ASN (ammonium, sulfate and nitrate) at 150kg/ha. These applications are usually applied in Spring and Autumn.
Irrigation adjacent to lake (y/n)?	Y - using lake water (see above)
Lawn mowing/ weed control	Mown weekly in summer and fortnightly in winter. "Spearhead", a selective herbicide to control flatweeds, clovers and bindi etc. applied once a year.
Management froblems*	2, 5 (blue green algal blooms in the last 4 summers)
Maintenance and effectiveness	Lining with clay, drying out is no longer a problem
Monitoring frequency	Not monitored

* Notes:

Aeration Features
F - Fountain
R - Rocks/waterfall
C - Circulation by pumping
A - Submerged aerator

Management Problems
1. Flooding
2. Drying Out
3. Slow inflitration
4. Odour
5. Nuisance algal growth
6. Fish deaths
7. Bird deaths
8. Mosquitos or midges
9. Acid Sulfate Soils
10. Iron Monosulfides
11. Feral Fish
12. Other (describe)

ND - Data not available within timeframe of study
NA - Not applicable

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Bradford St Lake**

5. Water Quality (if known)	
Total Nitrogen (µ/L)	NT
Total Phosphorus (µ/L)	NT
Chlorophyll *a* (µg/L)	NT
pH	7.16*
EC (mS)	0.07*
TDS (ppt)	0.03*
Temperature (°C)	18.3*
Algae/ aquatic plants, water clarity	None observed during site visit* although history of blue green algal blooms (summer only).
6.Fauna	
Macroinvertebrates eg. midges and mosquitos	None observed during site visit
Macrofauna	Eurasian coot, ducks, white bird with long black beak, head and tail and could hear banjo frogs

Notes:

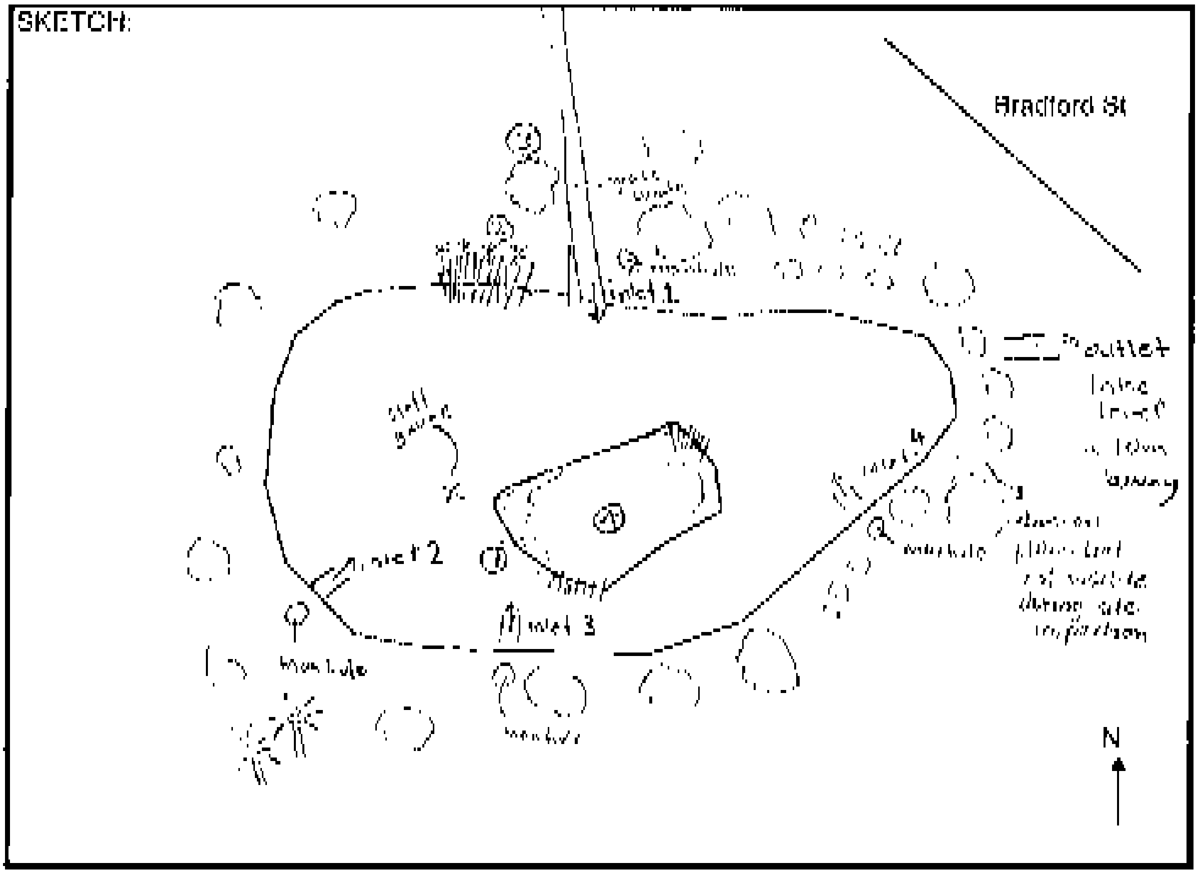
* Field pH, EC, TDS and temperature measured during site visit on 13/9/07. Observations of algae also recorded on this day.
NT = Not tested

Constructed Lake Study
Field Survey Form

Lake Name and Location: **Bradford St Lake, Monora**

Date: 13/09/2007 Recorded By: Bronwyn Woodward

SKETCH:



Water Level (mark location of staff gauges): 1.6 (m AHD?)

Estimated Depth of Water: 1-1.5m [illegible]

Lake Edge	%	Notes
Walled		
Vegetated	5	[illegible]
Grassed	95	
Earth		

Water quality: (scums, water clarity, algae, mosquitoes, pH, EC?) [illegible]

pH = 7.16, EC = 0.07 mS [illegible]

Fauna: [illegible]

Vegetation Type(s) adjacent to lake - (annotate with numbers) (1) [illegible]

(2) Reeds [illegible] (3) [illegible]

[illegible]

(4) Island [illegible]

Other Comments:

Bradford Street Lake - Photographic Plates

PLATE 1 – Following lining with clay the lake now retains permanent water.

PLATE 2 – The lake receives stormwater drainage from the surrounding residential catchment.

Jackadder Lake – Summary Report

Jackadder Lake was created over 20 years ago by deepening a natural swamp to intercept groundwater. The lake is also connected to the stormwater drainage system. Overflow leaves the lake via the Osborne Park main drain in winter and water from this drain is directed into the lake to maintain water levels in the lake over summer. A water and nutrient balance for the lake (JDA, 1992) showed that the drainage water is a major source of nutrients in the lake.

Due to high nutrient levels in the lake blooms of unicellular green algae and filamentous algae were a major problem between the mid 1980's and early 1990's. Alum dosing was trialed in the lake in the late 1980's however this had only short term impacts on reducing algal levels in Jackadder Lake (Lund and Chester, 1989). Algal levels increased once nutrient rich water from the Osborne Park Main Drain was redirected back into the lake.

Following the findings of the 1992 water and nutrient balance the redirection of water from the Osborne Park main drain was reduced. Management measures such as street sweeping, installation of sand traps and desedimentation basins in stormwater inlets and planting of native fringing vegetation were also undertaken to reduce nutrient levels in the lake.

Since the volume of water redirected from the Osborne Park main drain has been reduced algal blooms are no longer a major problem however water levels in the lake are now lower. Some members of the community are now concerned about the lower lake level in summer, particularly as the lake is an important site for model boat racing. Other members of the community appreciate the new found presence of wading birds.

Previous Studies/ Monitoring:

Lund and Chester (1989) *The use of aluminium sulphate to control algal blooms in Jackadder Lake, Western Australia*. Accessed at:
http://www.ecu.edu.au/chs/cem/research/wetlands_research/rehab/jackadder/index.htm
29 February 2008

JDA (1992) *Jackadder Lake Water and Nutrient Balance Study.*

Rajah, DT. (1991) *Jackadder Lake (A Strategy for Management of Lake Water Quality)*, City of Stirling.

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Jackadder Lake**

1. Basic Details	
Location (street and suburb)	Jackadder Wy, Woodlands
Location (coordinates)	385932.7 E, 6469219.5 N
2007 Streetsmart page number	341, C2&3
Local Government	City of Stirling
Owner	City of Stirling
Function*	D, A, C
Age (years)	>20, possibly up to 50
2. Physical Features	
Lining (y/n)	N
Area (ha)	~ 7.432
Shape (eg. linear, round, irregular)	Round, 1 island
Depth range (estimate) (m)	>2
"Naturalness" rating (1 to 5)*	3.5
Social amenity value (High, Medium, Low)	High
Edging (eg. wall, trees, reeds, sloping banks, turf)	50% vegetated, 50% grassed
Vegetation type adjacent to lake*	Reeds (*Baumea articulata, Juncus pallidus, Juncus kraussii, Schoenoplectus validus*), paperbark (2 species), flooded gum, *Typha* and sheoak
Vegetation condition adjacent to lake*	G
Potential acid sulfate soil (ASS) risk (according to ASS risk map)	high to moderate risk of ASS occurring within 3 m of natural soil surface

* Notes:

Function
D - Drainage
C - Conservation
A - Aesthetic (and recreational)
I - Irrigation Storage

Naturalness rating
1 - Highly ornamental
2 - Mostly ornamental with some natural features
3 - Some ornamenatal and some natural features
4 - Natural or natural like with some ornamental features
5 - Natural or natural like

Vegetation type
N - Native
X - Exotic

Vegetation condition
P - Poor
F- Fair
G - Good
E - Excellent

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Jackadder Lake**

3. Catchment and Hydrology	
Catchment type (eg. industrial, fesidential)	Residential, possible receives drainage from Osborne Park industrial area
Prior land use	Used to be a natural swamp, market gardening.
Catchment size (ha)	152
Geology (unit)	Swamp deposits (Qhw)
(description)	Cps - PEATY CLAY - dark grey and black with variable sand content of lacustrine origin
No. inlets	10 (JDA, 1992), only 8 located on site
Inlet volume/size	Inlet 1 - pipe diameter = 300 mm; Inlet 2 - pipe diameter = 450 mm; Inlet 3 - 2 x 600mm diameter pipes; Inlet 4 - 2 x 600mm diameter pipes; Inlet 5 - pipe diameter = 600 mm; Inlet 6 - pipe diameter = 525 mm; Inlet 7 - pipe diameter = 525 mm; Possible Inlet 8 - pipe diameter = 225 mm
No. outlets	1 - Osborne Park Main Drain
Outlet volume/size	Pipe Diameter = 450 mm
Drainage connection flow through (FT) or End Point (EP) or No Drainage (NDr)	FT
Approximate volume of water extracted for irrigation	0
Water level top up (y/n)?	Y - water level maintained in summer by redirecting water from Osborne Park main drain (MD)
Estimated residence time	ND
Water or nutrient balance undertaken (y/n)?	Y - water and nutrient balance study
4. Management	
Aeration/agitation present/absent?	Absent
Aeration type if present* How many?	NA
Fertiliser application adjacent to lake (y/n)?	Fertilizing regimes are tailored to specific reserves with no reserve receiving fertilizer unless truly necessary. Determining whether reserves do need fertilizer is based on results taken from soil and leaf analysis. Fertilizing with ASN (Ammonium, sulfate and nitrate) at 150kg/ha. These applications are usually applied in Spring and Autumn.
Irrigation adjacent to lake (y/n)?	Y (from Leederville Aquifer)- 35ml per week during summer months
Lawn mowing/ weed control	Mown fortnightly in summer and every 3 weeks in winter. "Spearhead", a selective herbicide to control flatweeds, clovers and bindi etc. applied once a year.
Management problems*	5, 8 and 11 (in the past)
Maintenance and effectiveness	Alum dosing in late 1980's - short term success only as algal levels increased once nutrient rich water from the Osborne Park main drain (MD) was redirected back into the lake. Revegetation (reeds, rushes & paperbacks), reducing the redirection of nutrient rich water from Osborne Park MD, maintenance of lower water levels (encourages wading birds to prey on koi), community catchment management. Following the redirection of water from the Osborne Park MD and community catchment management water quality improved and algal blooms are now not a major problem.
Monitoring frequency	Monitored by City of Stirling (ND), monitored between 1992 and 1993 by JDA

* Notes:

Aeration Features
F - Fountain
R - Rocks/waterfall
C - Circulation by pumping
A - Submerged aerator

Management Problems
1. Flooding
2. Drying Out
3. Slow infiltration
4. Odour
5. Nuisance algal growth
6. Fish deaths
7. Bird deaths
8. Mosquitos or midges
9. Acid Sulfate Soils
10. Iron Monosulfides
11. Feral Fish
12. Other (describe)

ND - Data not available within timeframe of study
NA - Not applicable

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Jackadder Lake**

5. Water Quality (if known)	
Total Nitrogen (µ/L)	1018 - >5874 **
Total Phosphorus (µ/L)	22 - 7580**
Chlorophyll *a* (µg/L)	NT
pH	7.7*
EC (mS)	0.44*
TDS (ppt)	0.22*
Temperature (°C)	20.1*
Algae/ aquatic plants, water clarity	None observed during site visit.*
6.Fauna	
Macroinvertebrates eg. midges and mosquitos	None observed during site visit
Macrofauna	Ducks, numerous Eurasian coot, purple Swamphen, could hear banjo frogs

Notes:

* Field pH, EC, TDS and temperature measured during site visit on 13/9/07. Observations of algae also recorded on this day.
** December 1992 to July 1993 results from JDA (1992) Jackadder Lake Water and Nutrient Balance Study.

Constructed Lake Study
Field Survey Form

Lake Name and Location: **Jackadder Lake, Woodlands**

Date: 13/05/2007 Recorded By: Bronwyn Woodward

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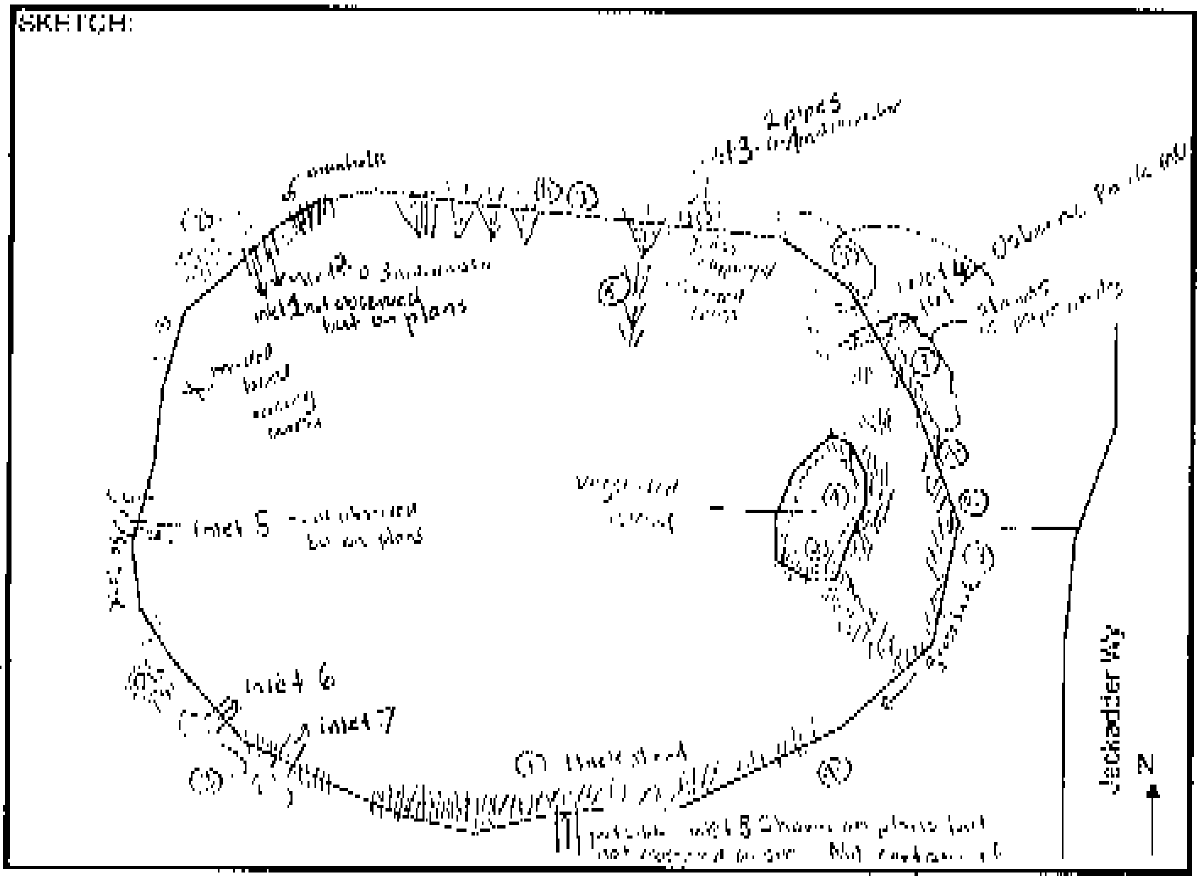

Water Level (mark location of staff gauges): None recorded

Estimated Depth of Water: >2 m?

Lake Edge	%	Notes
Walled		
Vegetated	50	
Grassed	50	
Earth		

Water quality (scums, water clarity, algae, mosquitoes, pH, EC?) clear

pH 7.70 EC 0.49 TDS 0.24 ppt Temp 20.1°C

Fauna:

Vegetation Type(s) adjacent to lake (annotate with numbers) Juncus articulata Juncus pallidus Schoenoplectus validus Juncus kraussii (6) Willows

Other Comments:

Jackadder Lake - Photographic Plates

PLATE 1 – Outlet to the Osborne Park main drain.

PLATE 2 – Reeds have been planted around the lake to reduce nutrient levels in the lake and improve its habitat value.

Jackadder Lake - Photographic Plates

PLATE 3 – The lake provides habitat for numerous birds including Eurasian Coot and Purple Swamp Hen and is a popular place for walking and barbeques.

PLATE 4 – Model boat racing in the lake.

Shearwater Spoonbill Lakes – Summary Report

The Shearwater Spoonbill Lakes are two lakes within the City of Stirling impacted by acid groundwater resulting from lowered water table levels within acid sulphate soils in the area. The lakes have a very low pH (below 4) and this has resulted in the death of fringing vegetation and mobilisation of metals and metalloids including arsenic.

A treatment system has been set up to intercept and treat acid groundwater flowing in the southern lake as part of a joint project run by Edith Cowan and Curtin Universities and the City of Stirling. The treatment system involves lime dosing and bioremediation take dissolved metals out of solution.

Previous Studies/ Monitoring

Bioremediation of Acid Lakes Project involving Edith Cowan University, Curtin University and City of Stirling.

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Shearwater Spoonbill Lake (North)**

1. Basic Details	
Location (street and suburb)	Corner of Spoonbill Rd and Shearwood Dr, Stirling
Location (coordinates)	387776.7 E, 6472334.7 N
2007 Streetsmart page number	311, E6
Local Government	City of Stirling
Owner	City of Stirling
Function*	D, A
Age (years)	>20
2. Physical Features	
Lining (y/n)	N
Area (ha)	0.9
Shape (eg. linear, round, irregular)	Linear, 2 islands
Depth range (estimate)	<1m (1m max)
"Naturalness" rating (1 to 5)*	3.5
Social amenity value (High, Medium, Low)	Medium-High
Edging (eg. wall, trees, reeds, sloping banks, turf)	20% vegetated; 80% earth
Vegetation type adjacent to lake*	N(60%) X (40%)- reeds, paperbarks, sheoaks, grass and weeds
Vegetation condition adjacent to lake*	F
Potential acid sulfate soil (ASS) risk (according to ASS risk map)	High to moderate risk of ASS occurring within 3 m of natural soil surface. ASS impacted.

* Notes:

Function
D - Drainage
C - Conservation
A - Aesthetic (and recreational)
I - Irrigation Storage

Naturalness rating
1 - Highly ornamental
2 - Mostly ornamental with some natural features
3 - Some ornamenatal and some natural features
4 - Natural or natural like with some ornamental features
5 - Natural or natural like

Vegetation type
N - Native
X - Exotic

Vegetation condition
P - Poor
F- Fair
G - Good
E - Excellent

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Shearwater Spoonbill Lake (North)**

3. Catchment and Hydrology	
Catchment type (eg. Industrial, Residential)	Residential
Prior land use	Market Gardens
Catchment size (ha)	ND
Geology (unit)	Swamp deposits (Qhw)
(description)	Cps - PEATY CLAY - dark grey and black with variable sand content of lacustrine origin
No. inlets	3
Inlet volume/size	Inlet 1 - pipe diameter = 250 mm Inlet 2 - pipe diameter = 450 mm Inlet 3 - pipe diameter = 375mm
No. outlets	1 - connection to south lake however appears overflow is infrequent
Outlet volume/size	NA
Drainage connection flow through (FT) or End Point (EP) or No Drainage (NDr)	FT (assuming overflow to south lake)
Approximate volume of water extracted for irrigation	0
Water level top up (y/n)?	N
Estimated residence time	ND
Water balance undertaken (y/n)?	N
4. Management	
Aeration/agitation present/absent?	Possible aeration through aerobic wetland
Aeration type if present* How many?	See above.
Fertiliser application adjacent to lake (y/n)?	N
Irrigation adjacent to lake (y/n)?	Y - 35ml per week during summer months
Lawn mowing/ weed control	Mown fortnightly in summer and every 3 weeks in winter. "Spearhead", a selective herbicide to control flatweeds, clovers and bindi etc. applied once a year.
Management problems*	9,10 and 12 (vegetation death)
Maintenance and effectiveness	Bioremediation of Acid Lakes Project (involving Edith Cowan University, Curtin and City of Stirling). Revegetation works (native trees/shrubs)
Monitoring frequency	Treatment system may be monitored however this was not confirmed

* Notes:

Aeration Features
F - Fountain
R - Rocks/waterfall
C - Circulation by pumping
A - Submerged aerator

Management Problems
1. Flooding
2. Drying Out
3. Slow infiltration
4. Odour
5. Nuisance algal growth
6. Fish deaths
7. Bird deaths
8. Mosquitos or midges
9. Acid Sulfate Soils
10. Iron Monosulfides
11. Feral Fish
12. Other (describe)

ND - Data not available within timeframe of study
NA - Not applicable

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Shearwater Spoonbill Lake (North)**

5. Water Quality (if known)	
Total Nitrogen (µ/L)	ND
Total Phosphorus (µ/L)	ND
Chlorophyll *a* (µg/L)	ND
pH	3.44*
EC (mS)	0.77*
TDS (ppt)	0.38*
Temperature	18.2*
Algae/ aquatic plants, water clarity	None observed during site visit.*
6.Fauna	
Macroinvertebrates eg. midges and mosquitos	None observed during site visit.*
Macrofauna	Terrestrial birds, low number of ducks

Notes:

* Field pH, EC, TDS and temperature measured during site visit on 13/9/07. Observations of algae also recorded on this day.
ND - Data not available within timeframe of study

Constructed Lake Study
Field Survey Form

Lake Name and Location: **Shearwater Spoonbill Lakes (North), Stirling**

Date: 13/09/2007 Recorded By: Bronwyn Woodward

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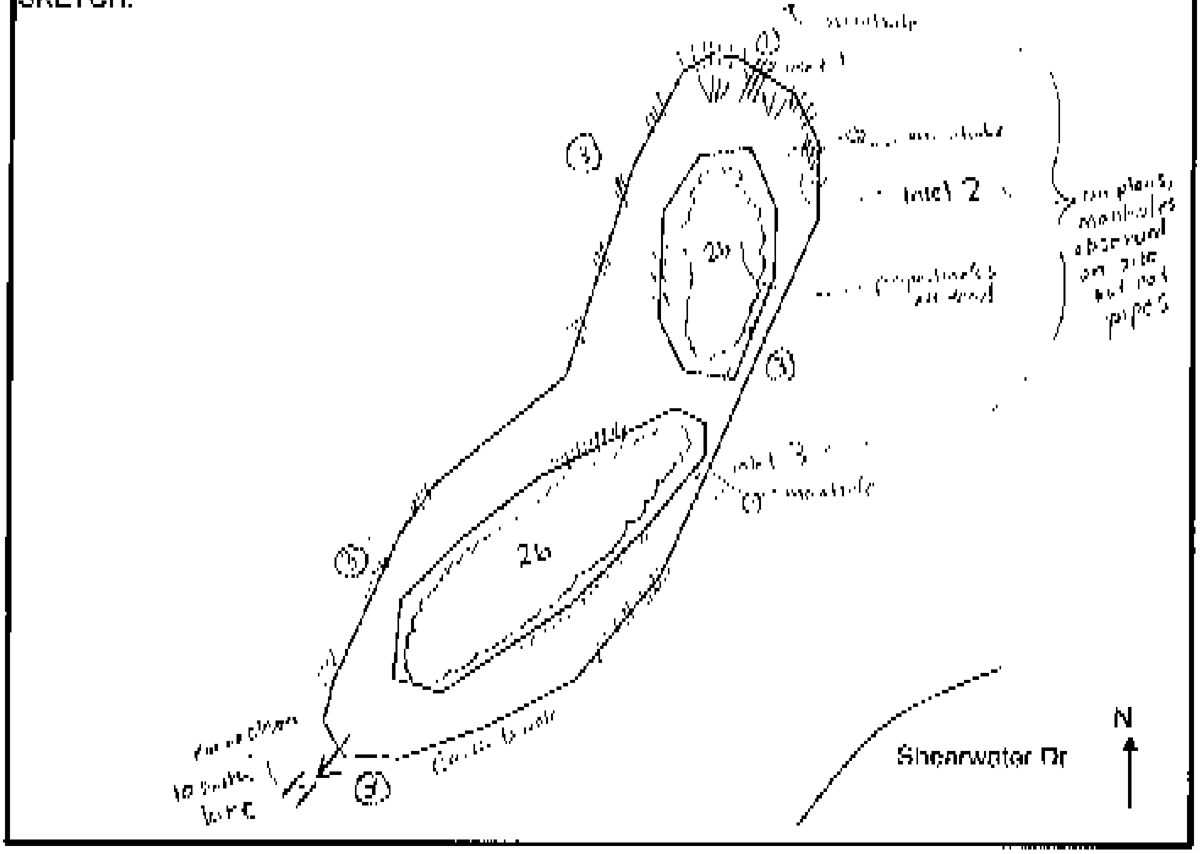

Water Level (mark location of staff gauges): No gauge located

Estimated Depth of Water: [illegible] max

Lake Edge	%	Notes
Walled		
Vegetated	20	[illegible] although [illegible] planted [illegible] lake edge
Grassed		
Earth	80	[illegible] of grass close to lake

Water quality: (scums, water clarity, algae, mosquitoes, pH, EC?) [illegible]
pH: 8 [illegible] EC: 0.77 mS TDS: 0.38 ppt Temp: 18.2 °C

Fauna: Terrestrial birds, few numbers of ducks

Vegetation Type(s) adjacent to lake (annotate with numbers): See south lake for description of (1), (2), and (3)

Other Comments:

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Shearwater Spoonbill Lake (South)**

1. Basic Details	
Location (street and suburb)	Corner Spoonbill Rd and Shearwood Dr, Stirling
Location (coordinates)	387648.5 E, 6472102.3 N
2007 Streetsmart page number	311, E6
Local Government	City of Stirling
Owner	City of Stirling
Function*	D, A
Age (years)	>20
2. Physical Features	
Lining (y/n)	N
Area (ha)	1.3
Shape (eg. linear, round, irregular)	Linear, 2 islands
Depth range (estimate) (m)	< 1m (1m max)
"Naturalness" rating (1 to 5)*	3.5
Social amenity value (High, Medium, Low)	Medium-High
Edging (eg. wall, trees, reeds, sloping banks, turf)	20% vegetated, 80% earth
Vegetation type adjacent to lake*	N(60%) X (40%) - reeds, mature *Eucalypts* , paperbarks, sheoaks, grass and weeds
Vegetation condition adjacent to lake*	P - death due to acidity
Potential acid sulfate soil (ASS) risk (according to ASS risk map)	High to moderate risk of ASS occurring within 3 m of natural soil surface. ASS impacted.

* Notes:

Function
D - Drainage
C - Conservation
A - Aesthetic (and recreational)
I - Irrigation Storage

Naturalness rating
1 - Highly ornamental
2 - Mostly ornamental with some natural features
3 - Some ornamenatal and some natural features
4 - Natural or natural like with some ornamental features
5 - Natural or natural like

Vegetation type
N - Native
X - Exotic

Vegetation condition
P - Poor
F- Fair
G - Good
E - Excellent

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Shearwater Spoonbill Lake (South)**

3. Catchment and Hydrology	
Catchment type (eg. industrial, residential)	Residential
Prior land use	Market Gardens
Catchment size (ha)	ND
Geology (unit)	Swamp deposits (Qhw)
(description)	Cps - PEATY CLAY - dark grey and black with variable sand content of lacustrine origin
No. inlets	4 - 3 stormwater inlets & connection to north lake
Inlet volume/size	Inlet 1 - pipe diameter = 300 mm Inlet 2 - pipe diameter = 375 mm Inlet 3 - pipe diameter = 375 mm
No. outlets	1
Outlet volume/size	Pipe diameter = 375 mm
Drainage connection flow through (FT) or End Point (EP) or No Drainage (NDr)	FT
Approximate volume of water extracted for irrigation	0
Water level top up (y/n)?	N
Estimated residence time	ND
Water or nutrient balance undertaken (y/n)?	N
4. Management	
Aeration/agitation present/absent?	Possible aeration theough aerobic wetland
Aeration type if present* How many?	See above.
Fertiliser application adjacent to lake (y/n)?	N
Irrigation adjacent to lake (y/n)?	Y - 35ml per week during summer months
Lawn mowing/ weed control	Mown fortnightly in summer and every 3 weeks in winter. "Spearhead", a selective herbicide to control flatweeds, clovers and bindi etc. applied once a year.
Management problems*	9,10 and 12(vegetation death)
Maintenance and effectiveness	Bioremediation of Acid Lakes Project (involving Edith Cowan University, Curtin University and the City of Striling). Revegetation works (native trees/shrubs)
Monitoring frequency	Treatment system may be monitored however this was not confirmed

* Notes:

Aeration Features
F - Fountain
R - Rocks/waterfall
C - Circulation by pumping
A - Submerged aerator

ND - Data not available within timeframe of study
NA - Not applicable

Management Problems
1. Flooding
2. Drying Out
3. Slow inflitration
4. Odour
5. Nuisance algal growth
6. Fish deaths
7. Bird deaths
8. Mosquitos or midges
9. Acid Sulfate Soils
10. Iron Monosulfides
11. Feral Fish
12. Other (describe)

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Shearwater Spoonbill Lake (South)**

5. Water Quality (if known)	
Total Nitrogen (µ/L)	ND
Total Phosphorus (µ/L)	ND
Chlorophyll *a* (µg/L)	ND
pH	3.44*
EC (mS)	1.03*
TDS (ppt)	0.51*
Temperature (°C)	18.1*
Algae/ aquatic plants, water clarity	None observed during site visit.*
6.Fauna	
Macroinvertebrates eg. midges and mosquitos	None observed during site visit.*
Macrofauna	Terrestrial birds, low number of ducks

Notes:

* Field pH, EC, TDS and temperature measured during site visit on 13/9/07. Observations of algae also recorded on this day.
NT = Not tested
ND - Data not available within timeframe of study

Constructed Lake Study
Field Survey Form

Lake Name and Location: **Shearwater Spoonbill Lakes (South), Stirling**

Date: 13/09/2007 Recorded By: Bronwyn Woodward

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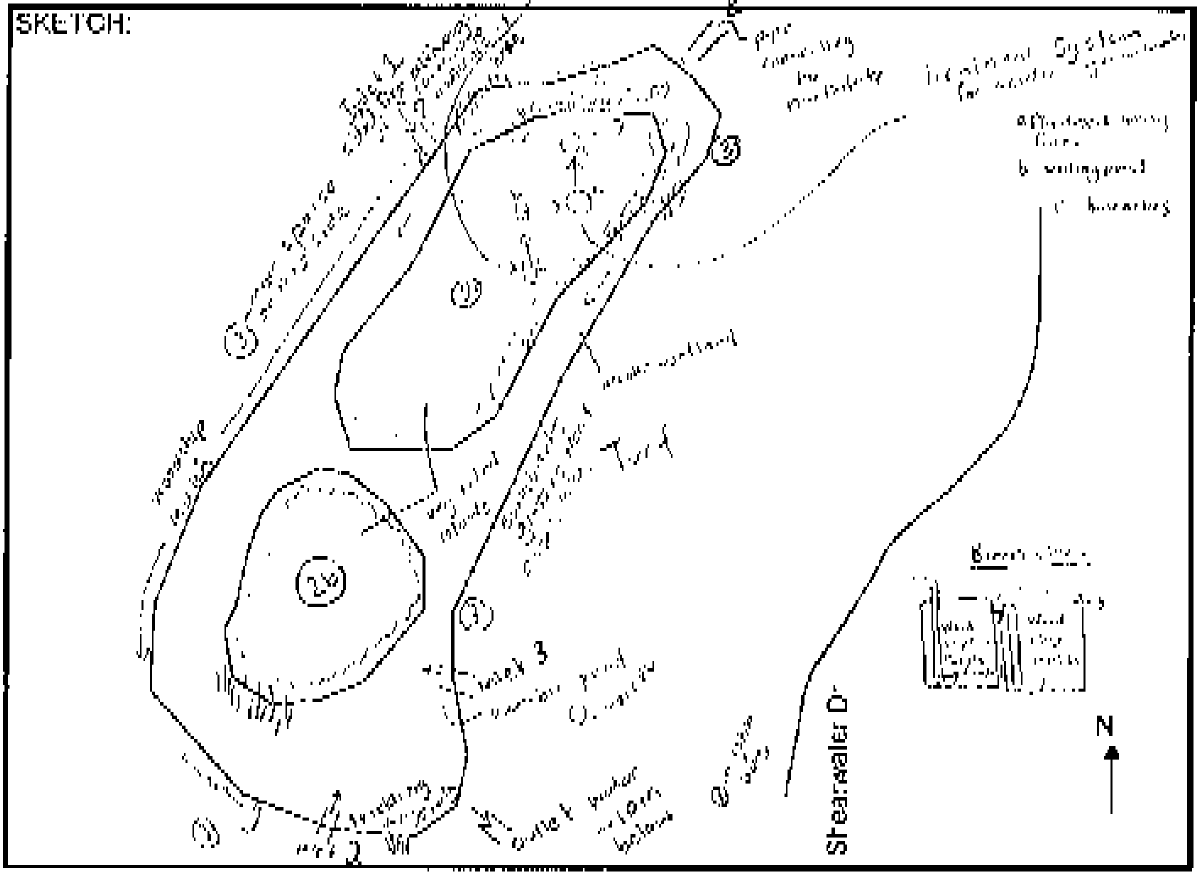


Water Level (mark location of staff gauges): no gauge located

Estimated Depth of Water: 1m max

Lake Edge	%	Notes
Walled	0	
Vegetated	20	Reeds poor condition [illegible] - most planted & [illegible] lake edge [illegible]
Grassed	0	
Earth	80	[illegible] of grass close to lake. [illegible]

Water quality: (scums, water clarity, algae, mosquitoes, pH, EC?) Clear [illegible] water [illegible] floating on surface

pH= 8.44 EC = [illegible] TDS = 0.51 ppt Temp = 18.1 °C

Fauna: [illegible] Low number of ducks.

Vegetation Type(s) adjacent to lake - (annotate with numbers) ① [illegible] ② [illegible] paperbarks [illegible]

③ Sparse Fringing veg of paperbarks, Eucalyptus, shrubs

Other Comments: [illegible] groundwater [illegible] lakes. [illegible] is pumped into a [illegible] the [illegible] groundwater. It then goes into a settling pond to settle the [illegible] and clarify the water. After this the water flows through 3 [illegible] [illegible] compared to [illegible] the lake. The [illegible] wetland [illegible]

eny

Shearwater Spoonbill Lakes - Photographic Plates

PLATE 1 – Dead vegetation and iron staining related to acidity in the lakes.

PLATE 2– Health warning signs and a diagram of the bioremediation project informs the public of the lakes' acidity problems.

City of Swan

- Emu Lake
- Lake Fresca
- Mornington Park Lake
- Sacromento Park Lake
- Sandown Park Lake
- Woodlake

Emu Lake – Summary Report

Emu Lake is located in the City of Swan with the suburb of Ballajura. The lake was constructed from a natural swamp in 1980 is approximately 12.8 hectares in area with an estimated maximum depth of up to 2.2 m (ATA, 1998). It is fed by stormwater runoff and groundwater from the Gnangara mound (Tan, 2006a).

The lake is highly valued by surrounding residents for its scenic view and has been a valuable marketing tool for the housing market since residential development began in the area in the 1980s. The lake provides other benefits such as a space for recreational activities and a refuge for wildlife such as ducks and turtles.

In recent years the aesthetic and environmental value of the lake has been compromised by unsightly algal blooms dominated by potentially toxic species of cyanobacteria. The first incidents of algal blooms in the lake were reported between 1997 and 1998 (Tan, 2006a). A subsequent bloom occurred following a sewer leak into the lake in September 2002 (Grant MacKinnon, City of Swan pers. comm.).

Following the recommendations of an Environmental Management Plan prepared for the lake by ATA in 1998 the City of Swan implemented several management actions including installing gross pollution traps, review of frequency and timing of street sweeping, netting of koi carp and revegetation using native species in an attempt to restore the water quality and ecological condition of Emu Lake. However to date cyanobacteria blooms have persisted, with the dominant species changing from the non-nitrogen fixing *Microcystis* species to the nitrogen fixing *Cylindrospermopsis raciborskii* (Tan, 2006a).

A water and nutrient balance conducted by ENV (2008) determined that the algal blooms are caused by excessive nutrient concentrations in particular phosphorus which is the limiting nutrient driving the blooms. The nutrient sources are mainly from the groundwater and stormwater runoff discharging in the lake.

Application of Phoslock to the lake in 2007 did not have a large impact on reducing algal concentrations in the lake because most of the phosphorus in Emu Lake is bound in algae cells and is not available to be bound by Phoslock. It is also suspected that only a small amount of phosphorus is being released from the sediment.

Based on the findings of the water and nutrient balance community catchment management (largely educating the public about fertiliser use), retrofitting of the stormwater drainage system with water-sensitive urban design measures such as vegetated nutrient-stripping zones at stormwater entry points to the lake and groundwater remediation were presented as possible management options for the lake (ENV, 2008).

Emu Lake – Summary Report

Previous Studies/Monitoring:

ATA (1998). *Environmental Management Plan, Emu Lake, Ballajura, Western Australia.* Alan Tingay & Associates, Perth, Western Australia.

Department of Environment (DoE) (2005). *Emu Lake, Ballajura.* Phytoplankton Ecology Unit, Aquatic Sciences Branch, Department of Environment, Western Australia.

ENV (2008), *Environmental Management Plan: Emu Lake, Ballajura*, Draft report prepared for the City of Swan.

JDA (2006). *Emu Lake Monitoring Results*. Jim Davies & Associates Pty Ltd Subiaco, Western Australia.

Rockwater Pty Ltd (2004). Surface Water Sediment Sampling at Emu Lakes. Rockwater Pty Ltd, Jolimont, Western Australia

Tan, C.K. (2006) *Emu Lake Water Quality 1986-2006.* Perth, Western Australia.

UWA (1998) *Environmental Management Plan – Remediation and Restoration of Emu Lake*, University of Western Australia.

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Emu Lake**

1. Basic Details	
Location (street and suburb)	Summerlakes Parade, Ballajura
Location (coordinates)	394193.8 E, 6476780.3 N
2007 Streetsmart page number	283, C7 & C8
Local Government	City of Swan
Owner	City of Swan
Function*	A, D
Age (years)	27
2. Physical Features	
Lining (y/n)	N
Area (ha)	12.8
Shape (eg. linear, round, irregular)	Irregular
Depth range (estimate) (m)	2.2 m maximum (ATA, 1998)
"Naturalness" rating (1 to 5)*	2.5
Social amenity value (High, Medium, Low)	High
Edging (eg. wall, trees, reeds, sloping banks, turf)	sloping banks
Vegetation type adjacent to lake*	Mix of N and X - mature *Eucalyptus rudis* remnant, planted *Eucalyptus rudis, Baumea articulata, Juncus pallidus, Melaleuca raphiophylla*, sheoak, non endemic *Eucalyptus*, pine tree, willow, plane trees, ash trees
Vegetation condition adjacent to lake*	G
Potential acid sulfate soil (ASS) risk (according to ASS risk map)	High to moderate risk of ASS occurring within 3 m of natural soil surface

* Notes:

Function
D - Drainage
C - Conservation
A - Aesthetic (and recreational)
I - Irrigation Storage

Naturalness rating
1 - Highly ornamental
2 - Mostly ornamental with some natural features
3 - Some ornamenatal and some natural features
4 - Natural or natural like with some ornamental features
5 - Natural or natural like

Vegetation type
N - Native
X - Exotic

Vegetation condition
P - Poor
F- Fair
G - Good
E - Excellent

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Emu Lake**

3. Catchment and Hydrology	
Catchment type (eg. industrial, residential)	Residential.
Prior land use	Natural swamp surrounded by grazing land
Catchment size (ha)	302
Geology (unit)	Bassendean Sand (Qpb), remnants of Swamp deposits (Qhw)
(description)	S_8 - SAND - white to pale grey at surface, yellow at depth, fine to medium grained, moderately sorted, subangular to subrounded, minor heavy minerals, of aeolian origin and remnants of Cps - PEATY CLAY - dark grey and black with variable sand content of lacustrine origin
No. inlets	11
Inlet volume/size	ND
No. outlets	0
Outlet volume/size	NA
Drainage connection flow through (FT) or End Point (EP) or No Drainage (NDr)	EP
Approximate volume of water extracted for irrigation	0
Water level top up (y/n)?	N
Estimated residence time	82 days
Water or nutrient balance undertaken (y/n)?	Y (ENV, 2007)
4. Management	
Aeration/agitation present/absent?	Present
Aeration type if present* How many?	1F (in lake recirculation basin off south western corner of lake)
Fertiliser application adjacent to lake (y/n)?	Y
Irrigation adjacent to lake (y/n)?	Y
Lawn mowing/ weed control	ND
Management problems*	5 (toxic cyanobacteria first recorded in 1997, persistent since 2002), 11 (carp - considered a pest by council however valued by some of the surrounding residents)
Maintenance and effectiveness	1999-2000 – Typha removal, planting of 30 000 rushes and sedges, the removal by netting of 300 koi carp, and installation of gross pollutant traps on eight of 11 stormwater outlets. No algal blooms until 2002 following sewage spill in the lake. Koi also eventually returned to original numbers. 2007 – trialled Phoslock in autumn 2007 to reduce algae levels. Successful in bunded section over 2 month period. Applied Phoslock to entire lake in December 2007. Algal levels initially fell than increased in January 2008. Considering applying Rotenone to get rid of carp.
Monitoring frequency	Monitored for parameters including pH, TDS, nutrients and chlorophyll *a* since 1986 to present but not every year. Monitored by ENV on a regular basis since autumn 2007. Algae speciation conducted on several occasions since 1997. Sediment and groundwater inflow quality also tested.

* Notes:

Aeration Features
F - Fountain
R - Rocks/waterfall
C - Circulation by pumping
A - Submerged Aerator

Management Problems (cont.)
1. Flooding
2. Drying Out
3. Slow infiltration
4. Odour
5. Nuisance algal growth
6. Fish deaths
7. Bird deaths
8. Mosquitos or midges
9. Acid Sulfate Soils
10. Iron Monosulfides
11. Feral Fish
12. Other (describe)

ND - Data not available within timeframe of study

NA - Not applicable

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Emu Lake**

5. Water Quality (if known)	
Total Nitrogen (µg/L)	200 - 17000**
Total Phosphorus (µg/L)	17 - 190**
Chlorophyll a (µg/L)	0.49 - 340**
pH	8.73* (5.7-9.92**)
EC (mS)	0.179*
TDS (ppt)	0.1* (0.2-3.5**)
Temperature (°C)	20.00* (21.26-30.72**)
Algae/ aquatic plants, water clarity	Water green and turbid with green flocs (*Microcystis*). No scums.* In recent years algal concentration has been typically dominated by *Microcystis* and *Cylindrospermopsis raciborskii*.
6.Fauna	
Macroinvertebrates eg. midges and mosquitos	Rich in zooplankton at time of site visit
Macrofauna	Pacific Black duck, Eurasian coot.

Notes:

* Mean field pH, EC, TDS and temperature measured during site visit on 24/9/07. Observations of algae also recorded on this day.

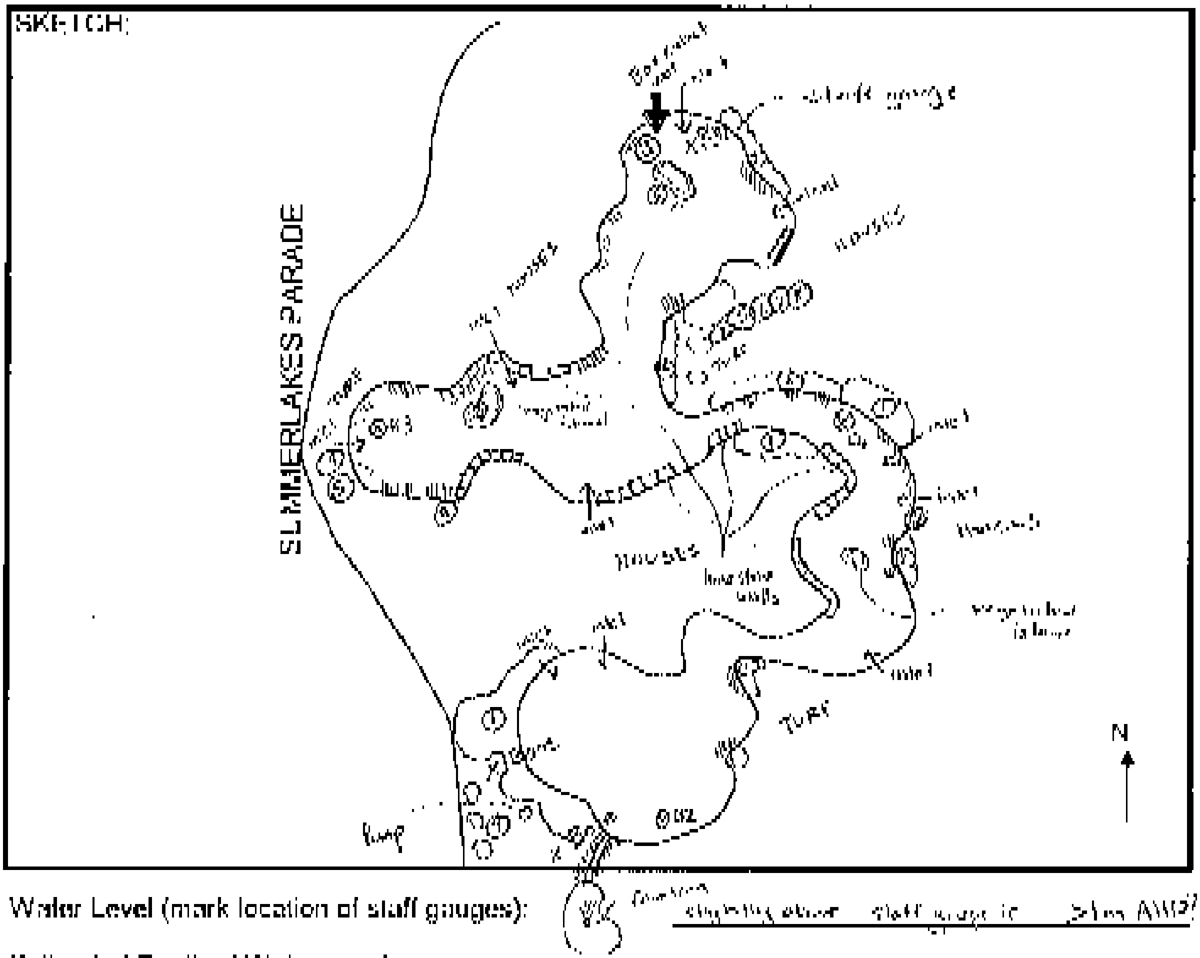
** Range of values recorded between 21 July 1986 and 13 April 2007 from Tan (2006) and ENV (2008)

Constructed Lake Study
Field Survey Form

Lake Name and Location: Emu Lake, Ballajura

Date: 21/11/97 Recorded By: Bronwyn Woodward

SKETCH:



Water Level (mark location of staff gauges): [illegible] staff gauge [illegible] AWP?

Estimated Depth of Water: ~4m max

Lake Edge	%	Notes
Walled	8	limestone blocks - part of residential properties
Vegetated	60	sedges, rushes (some natural, some planted)
Grassed	32	Turf (couch grass)
Earth	0	

Water quality: (scums, water clarity, algae, mosquitoes, pH, EC?) Water green and turbid. No scums. [illegible]

pH (range 8.1-8.4) = 8.73 SpC (mS/cm) (range [illegible]) = 0.179 Turb (g/L) (range [illegible]) = 0.1 Temp (range [illegible]) = 20.00

Fauna: ducks including Pacific Black, Australian coot, [illegible] fish in [illegible]

Vegetation Type(s) adjacent to lake - (annotate with numbers) (1) Mature Eucalypts (remnant) (2) planted rushes
(3) Baumea articulata, Juncus pallidus (4) Melaleuca raphiophylla (5) Shrubs
(6) Non endemic Eucalypts (7) Pine tree (8) Willow (9) Plane and Ash trees

Other Comments:

Emu Lake - Photographic Plates

PLATE 1 – Residential housing surrounding the lake. Subsoil drainage from residential lawns discharges directly into the lake.

PLATE 2 – Areas of fringing vegetation that were planted around the lake c. 2000.

Emu Lake - Photographic Plates

PLATE 3 – *Microcystis* bloom in August 2006 (ENV, 2008). This algae forms bright green scum in still water.

PLATE 4 – Applying Phoslock to the lake in April 2007 (ENV, 2008).

Lake Fresca – Summary Report

Lake Fresca was built at the site of a former pine plantation in Ellen Brook approximately 9 years ago. The lake intercepts groundwater and experienced problems with low water levels within two years of it being built. Some of the surrounding residents have expressed dissatisfaction that the lake is over a metre below its design level as this compromises its visual amenity.

To address community discontent the City of Swan is considering partially lining the lake. Pumping bore water into stormwater inlets to maintain water levels in the lake has been previously trialed however there were problems with the water turning milky due to the death of anaerobic bacteria. No other water quality problems have been recorded at the lake aside from oil slicks and rubbish from stormwater flow.

Previous Studies/ Monitoring:

No previous studies or monitoring records were located.

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Lake Fresca**

1. Basic Details	
Location (street and suburb)	Ponte Vecchio Boulevard, Ellenbrook
Location (coordinates)	401588 E, 6482316.9 N
2007 Streetsmart page number	255, B6
Local Government	City of Swan
Owner	City of Swan
Function*	D, A
Age (years)	9
2. Physical Features	
Lining (y/n)	N
Area (ha)	~ 2.88
Shape (eg. linear, round, irregular)	Irregular, 1 island
Depth range (estimate) (m)	<1
"Naturalness" rating (1 to 5)*	1
Social amenity value (High, Medium, Low)	High
Edging (eg. wall, trees, reeds, sloping banks, turf)	100% limestone wall then turf. Houses built within a few metres of lake on northern side.
Vegetation type adjacent to lake*	X - Pine trees (remnant from plantation), paperbarks, some patches of reeds, plane trees, poplars
Vegetation condition adjacent to lake*	G although very low density, mostly turf
Potential acid sulfate soil (ASS) risk (according to ASS risk map)	moderate to low risk of ASS occurring within 3 m of natural soil surface

* Notes:

Function
D - Drainage
C - Conservation
A - Aesthetic (and recreational)
I - Irrigation Storage

Naturalness rating
1 - Highly ornamental
2 - Mostly ornamental with some natural features
3 - Some ornamenatal and some natural features
4 - Natural or natural like with some ornamental features
5 - Natural or natural like

Vegetation type
N - Native
X - Exotic

Vegetation condition
P - Poor
F- Fair
G - Good
E - Excellent

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Lake Fresca**

3. Catchment and Hydrology	
Catchment type (eg. industrial, residential)	Residential
Prior land use	Pine plantation
Catchment size (ha)	ND
Geology (unit)	Bassendean Sand (Qpb)
(description)	S_8 - SAND - white to pale grey at surface, yellow at depth, fine to medium grained, moderately sorted, subangular to subrounded, minor heavy minerals, of aeolian origin
No. inlets	6 to 8
Inlet volume/size	ND
No. outlets	1
Outlet volume/size	ND
Drainage connection flow through (FT) or End Point (EP) or No Drainage (NDr)	FT, although hasn't overflowed in ~8 years so has been funtioning as a drainage end point
Approximate volume of water extracted for irrigation	0
Water level top up (y/n)?	N
Estimated residence time	ND
Water or nutrient balance undertaken (y/n)?	N
4. Management	
Aeration/agitation present/absent?	Absent
Aeration type if present* How many?	NA
Fertiliser application adjacent to lake (y/n)?	ND
Irrigation adjacent to lake (y/n)?	Y with bore water
Lawn mowing/ weed control	ND
Management problems*	2 - Residential concern due to low water levels, 12 - oil slicks and rubbish from stormwater
Maintenance and effectiveness	Tried pumping bore water into stormwater pipe to maintain water levels however had problems with water turning milky due to death of anaerobic bacteria. Proposal to partially line lake - would cost over $300,000.
Monitoring frequency	Not monitored

* Notes:

Aeration Features
F - Fountain
R - Rocks/waterfall
C - Circulation by pumping
A - Submerged aerator

ND - Data not available within timeframe of study
NA - Not applicable

Management Problems
1. Flooding
2. Drying Out
3. Slow infiltration
4. Odour
5. Nuisance algal growth
6. Fish deaths
7. Bird deaths
8. Mosquitos or midges
9. Acid Sulfate Soils
10. Iron Monosulfides
11. Feral Fish
12. Other (describe)

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Lake Fresca**

5. Water Quality (if known)	
Total Nitrogen (µ/L)	NT
Total Phosphorus (µ/L)	NT
Chlorophyll *a* (µg/L)	NT
pH	6.93*
EC (mS)	0.24*
TDS (ppt)	0.12*
Temperature (°C)	21.5*
Algae/ aquatic plants, water clarity	None observed.* No records of algal blooms.
6.Fauna	
Macroinvertebrates eg. midges and mosquitos	None observed during site visit. No recorded problems with mosquitoes or midges.
Macrofauna	Koi carp, ducks, banjo frogs

Notes:

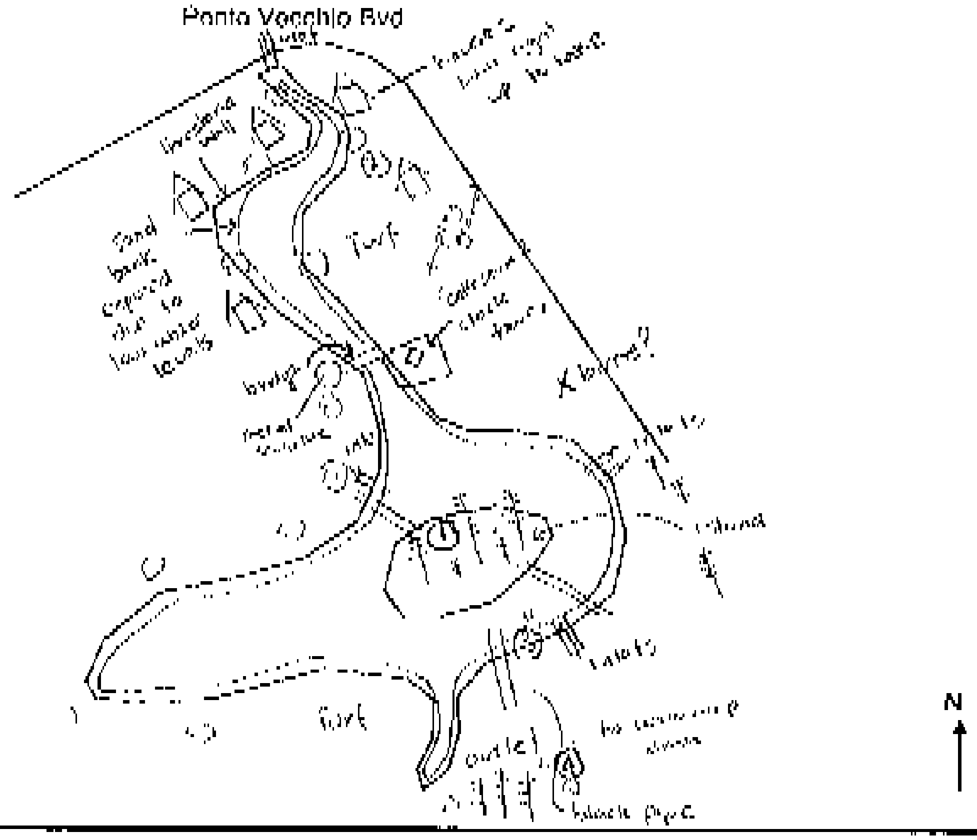
* Field pH, EC, TDS and temperature measured during site visit on 5/9/07. Observations of algae also recorded on this day.
NT = Not tested

Constructed Lake Study
Field Survey Form

Lake Name and Location: Lake Fresca, Ellenbrook

Date: 5/09/2007 Recorded By: Bronwyn Woodward

SKETCH:



Water Level (mark location of staff gauges): None located

Estimated Depth of Water: < 1m

Lake Edge	%	Notes
Walled	100	Limestone
Vegetated	0	some veg. in parkland around lake (on lawn)
Grassed	0	surrounding parkland consists mostly of turf
Earth	0	

Water quality: (scums, water clarity, algae, mosquitoes, pH, EC?) clear

pH 7.93 EC = 0.24 mS TDS = 0.12 ppt Temp = 21.5

Fauna: 2 large carp, ducks, water bird, bugs

Vegetation Type(s) adjacent to lake (annotate with numbers) ① Pine trees, ... planted

② planted trees mostly paperbarks ③ small patches of reeds around lake

④ Plane trees, pine trees, paperbarks

Other Comments: Wooden pipe have gone on them

Lake Fresca - Photographic Plates

PLATE 1 – At the beginning of Spring 2007, the water levels were well below the design level (the walls of the lake).

PLATE 2 – Remnant trees from the pine plantation have been retained on an island in the southern part of the lake.

Mornington Park Lake – Summary Report

Mornington Park Lake was created approximately eight years ago by excavating a natural ephemeral wetland to below the groundwater table. Some areas of natural banksia bushland around the lake have been retained and other areas have been landscaped with Australian species of paperbark, sedges and bottle brush, although these are not necessarily native to the area.

Water is recirculated through the lake over a waterfall. The lake does not receive stormwater and has no outlet. Drainage percolates to groundwater from a nearby bubbleup pit to the south of the lake but does not discharge directly into the lake.

Although the lake appeared quite green at the time of the site visit on the 5th September 2007 indicating the presence of high levels of microalgae, no water quality problems have been reported. There were complaints from a resident about weeds in the landscaped areas however these have now been removed.

Previous Studies/ Monitoring:

No previous studies or monitoring records were located.

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Mornington Park Lake**

1. Basic Details	
Location (street and suburb)	Mornington Parkway, Ellenbrook
Location (coordinates)	402939.9 E, 6483568.1 N
2007 Streetsmart page number	255, D4
Local Government	City of Swan
Owner	City of Swan
Function*	A
Age (years)	9
2. Physical Features	
Lining (y/n)	ND
Area (ha)	~ 0.1279
Shape (eg. linear, round, irregular)	Irregular
Depth range (estimate) (m)	<1
"Naturalness" rating (1 to 5)*	2
Social amenity value (High, Medium, Low)	Medium
Edging (eg. wall, trees, reeds, sloping banks, turf)	100% limestone wall
Vegetation type adjacent to lake*	Landscaping with mostly Australian species but not necessarily endemic to area (paperbark, bottlebrush), native remnant banksia bushland and *Melaleuca* , *Typha* and sedges
Vegetation condition adjacent to lake*	G
Potential acid sulfate soil (ASS) risk (according to ASS risk map)	high to moderate risk of ASS occurring within 3 m of natural soil surface

* Notes:

Function
D - Drainage
C - Conservation
A - Aesthetic (and recreational)
I - Irrigation Storage

Naturalness rating
1 - Highly ornamental
2 - Mostly ornamental with some natural features
3 - Some ornamenatal and some natural features
4 - Natural or natural like with some ornamental features
5 - Natural or natural like

ND - Data not available within timeframe of study

Vegetation type
N - Native
X - Exotic

Vegetation condition
P - Poor
F- Fair
G - Good
E - Excellent

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Mornington Park Lake**

3. Catchment and Hydrology	
Catchment type (eg. industrial, residential)	Residential
Prior land use	Bushland
Catchment size (ha)	NA - does not receive stormwater.
Geology (unit)	Bassendean Sand (Qpb)
(description)	S_8 - SAND - white to pale grey at surface, yellow at depth, fine to medium grained, moderately sorted, subangular to subrounded, minor heavy minerals, of aeolian origin
No. inlets	0, nearby bubbleup pit to the south but does not flow directly into lake
Inlet volume/size	NA
No. outlets	0
Outlet volume/size	NA
Drainage connection flow through (FT) or End Point (EP) or No Drainage (NDr)	NDr
Approximate volume of water extracted for irrigation	0
Water level top up (y/n)?	Possibly topped up with bore water
Estimated residence time	ND
Water or nutrient balance undertaken (y/n)?	N
4. Management	
Aeration/agitation present/absent?	Present
Aeration type if present* How many?	1R, C
Fertiliser application adjacent to lake (y/n)?	ND
Irrigation adjacent to lake (y/n)?	ND
Lawn mowing/ weed control	ND
Management problems*	Complaints from local resident about weeds in landscaped areas. No reported water quality problems.
Maintenance and effectiveness	Weeding - resident is now satisfied.
Monitoring frequency	Not monitored.

* Notes:

Aeration Features
F - Fountain
R - Rocks/waterfall
C - Circulation by pumping
A - Submerged aerator

ND - Data not available within timeframe of study
NA - Not applicable

Management Problems
1. Flooding
2. Drying Out
3. Slow infiltration
4. Odour
5. Nuisance algal growth
6. Fish deaths
7. Bird deaths
8. Mosquitos or midges
9. Acid Sulfate Soils
10. Iron Monosulfides
11. Feral Fish
12. Other (describe)

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Mornington Park Lake**

5. Water Quality (if known)	
Total Nitrogen (µg/L)	NT
Total Phosphorus (µg/L)	NT
Chlorophyll *a* (µg/L)	NT
pH	8.52*
EC (mS)	0.52*
TDS (ppt)	0.26*
Temperature (°C)	19.2*
Algae/ aquatic plants, water clarity	Green tinge indicating moderate levels of phytoplankton. Filamentous green algae floating on the surface in stagnant areas.*
6.Fauna	
Macroinvertebrates eg. midges and mosquitos	No visible macroinvertebrates at time of site visit. No records of problems with mosquitoes/midges.
Macrofauna	Birds, banjo frogs, juvenile *Gambusia* , dead perch/carp

* Notes:

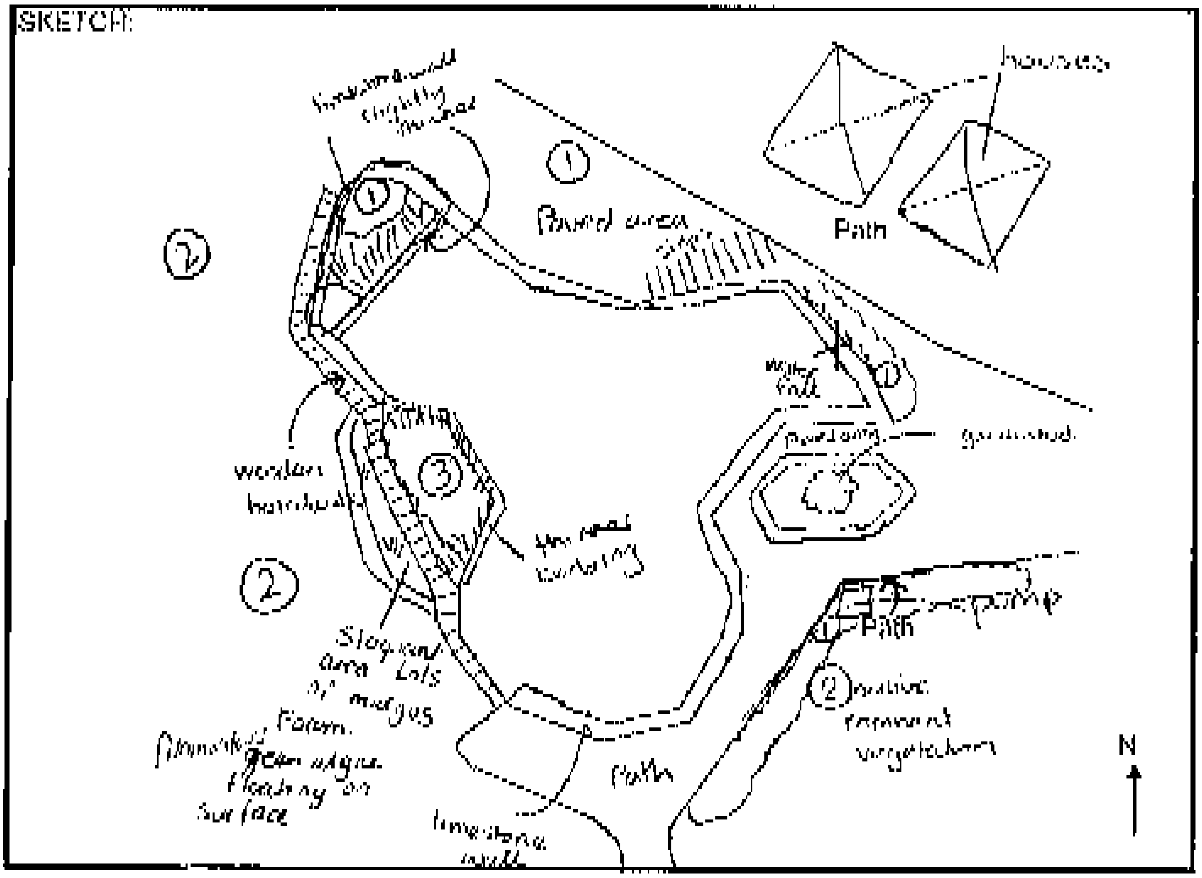
Field pH, EC, TDS and temperature measured during site visit on 5/9/07. Observations of algae also recorded on this day.
NT = Not tested

Constructed Lake Study
Field Survey Form

Lake Name and Location: Mornington Park Lake, Ellenbrook

Date: 5/09/2007 Recorded By: Bronwyn Woodward

SKETCH:



Water Level (mark location of staff gauges): None located

Estimated Depth of Water: < 1m

Lake Edge	%	Notes
Walled	100	limestone wall + timber decking in some areas
Vegetated		trees & reeds planted close to lake where vegetated
Grassed	0	
Earth	0	

Water quality: (scums, water clarity, algae, mosquitoes, pH, EC?) green tinge indicating presence of phytoplankton although water still relatively transparent.
pH = 8.52 EC = 0.52 TDS = 0.26 ppt Temp = 19.2 °C + filamentous green algae?

Fauna: birds, coots, frogs, juvenile gambusia. Dead parakeet.

Vegetation Type(s) adjacent to lake - (annotate with numbers) ① landscaping = native species but missing not necessarily endemic – paperbark, sedges, melaleuca

② Native remnant veg (banksia ② Native remnant melaleuca.
understorey of reeds & some Typha.

Other Comments:

Mornington Park Lake - Photographic Plates

PLATE 1 – Water is recirculated through the lake over a waterfall. The water appeared green in September 2007 indicating high levels of microalgae was present.

PLATE 2 – Remnant of native vegetation to the south of the lake

Sacromento Park Lake – Summary Report

Sacromento Park Lake is an approximately 0.66 hectare water body constructed approximately 22 years ago within the suburb of Beechboro in the City of Swan. The lake receives stormwater drainage and also serves an aesthetic function. Overflow from xthe lake flows to the lakes in Thorburn Park to the north east of Sacromento Park Lake which then overflows into the Bennett Brook.

Despite its age, the lake has not experienced any major water quality problems apart from minor amounts of rubbish collecting in the lake. The entire lake is surrounded by reeds and they are in reasonable condition apart from being invaded by exotic grasses.

Previous Studies/ Monitoring:

No previous studies or monitoring records were located.

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Sacromento Park Lake**

1. Basic Details	
Location (street and suburb)	Sacromento Avenue, Beechboro
Location (coordinates)	399963.4 E, 6473948.2 N
2007 Streetsmart page number	314, E3
Local Government	City of Swan
Owner	City of Swan
Function*	D, A
Age (years)	22
2. Physical Features	
Lining (y/n)	N
Area (ha)	~ 0.6605
Shape (eg. linear, round, irregular)	Oval, 1 island
Depth range (estimate) (m)	1-2
"Naturalness" rating (1 to 5)*	3
Social amenity value (High, Medium, Low)	High
Edging (eg. wall, trees, reeds, sloping banks, turf)	100% vegetated with sedges
Vegetation type adjacent to lake*	Sedges invaded with rye grass and kikuyu, sheoak, *Melaleuca* , bottlebrush
Vegetation condition adjacent to lake*	F due to invasion by grass
Potential acid sulfate soil (ASS) risk (according to ASS risk map)	Moderate to low risk of ASS occurring within 3 m of natural soil surface

* Notes:

Function
D - Drainage
C - Conservation
A - Aesthetic (and recreational)
I - Irrigation Storage

Naturalness rating
1 - Highly ornamental
2 - Mostly ornamental with some natural features
3 - Some ornamenatal and some natural features
4 - Natural or natural like with some ornamental features
5 - Natural or natural like

Vegetation type
N - Native
X - Exotic

Vegetation condition
P - Poor
F- Fair
G - Good
E - Excellent

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Sacromento Park Lake**

3. Catchment and Hydrology	
Catchment type (eg. industrial, residential)	Residential
Prior land use	ND
Catchment size (ha)	ND
Geology (unit)	Thin Bassendean Sand over Guildford Formation (Qpb/Qpa)/ Bassendean Sand (Qpb)
(description)	S_8 - SAND - white to pale grey at surface, yellow at depth, fine to medium grained, moderately sorted, subangular to subrounded, minor heavy minerals, of aeolian origin over SANDY CLAY (Sc) to CLAYEY SAND (Cs) of the Guildford Formation, of aeolian origin
No. inlets	1
Inlet volume/size	ND
No. outlets	1
Outlet volume/size	ND
Drainage connection flow through (FT) or End Point (EP) or No Drainage (NDr)	FT
Approximate volume of water extracted for irrigation	0
Water level top up (y/n)?	N
Estimated residence time	ND
Water or nutrient balance undertaken (y/n)?	N
4. Management	
Aeration/agitation present/absent?	Absent
Aeration type if present* How many?	NA
Fertiliser application adjacent to lake (y/n)?	Surrounding park land fertilised 2 x per year
Irrigation adjacent to lake (y/n)?	ND
Lawn mowing/ weed control	ND
Management problems*	No management problems recorded to date.
Maintenance and effectiveness	No special maintenance has been required.
Monitoring frequency	Not monitored

* Notes:

Aeration Features
F - Fountain
R - Rocks/waterfall
C - Circulation by pumping
A - Submerged aerator

ND - Data not available within timeframe of study
NA - Not applicable

Management Problems
1. Flooding
2. Drying Out
3. Slow infiltration
4. Odour
5. Nuisance algal growth
6. Fish deaths
7. Bird deaths
8. Mosquitos or midges
9. Acid Sulfate Soils
10. Iron Monosulfides
11. Feral Fish
12. Other (describe)

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Sacromento Park Lake**

5. Water Quality (if known)	
Total Nitrogen (µg/L)	NT
Total Phosphorus (µg/L)	NT
Chlorophyll *a* (µg/L)	NT
pH	6.23*
EC (mS)	0.58*
TDS (ppt)	0.29*
Temperature (°C)	17.6*
Algae/ aquatic plants, water clarity	Minor amounts of benthic filamentous green algae growing attached to sticks etc. No records of algal blooms.*
6.Fauna	
Macroinvertebrates eg. midges and mosquitos	No visible macroinvertebrates at time of site visit. No records of problems with mosquitoes/midges.
Macrofauna	Feral ducks, used to be geese.

Notes:

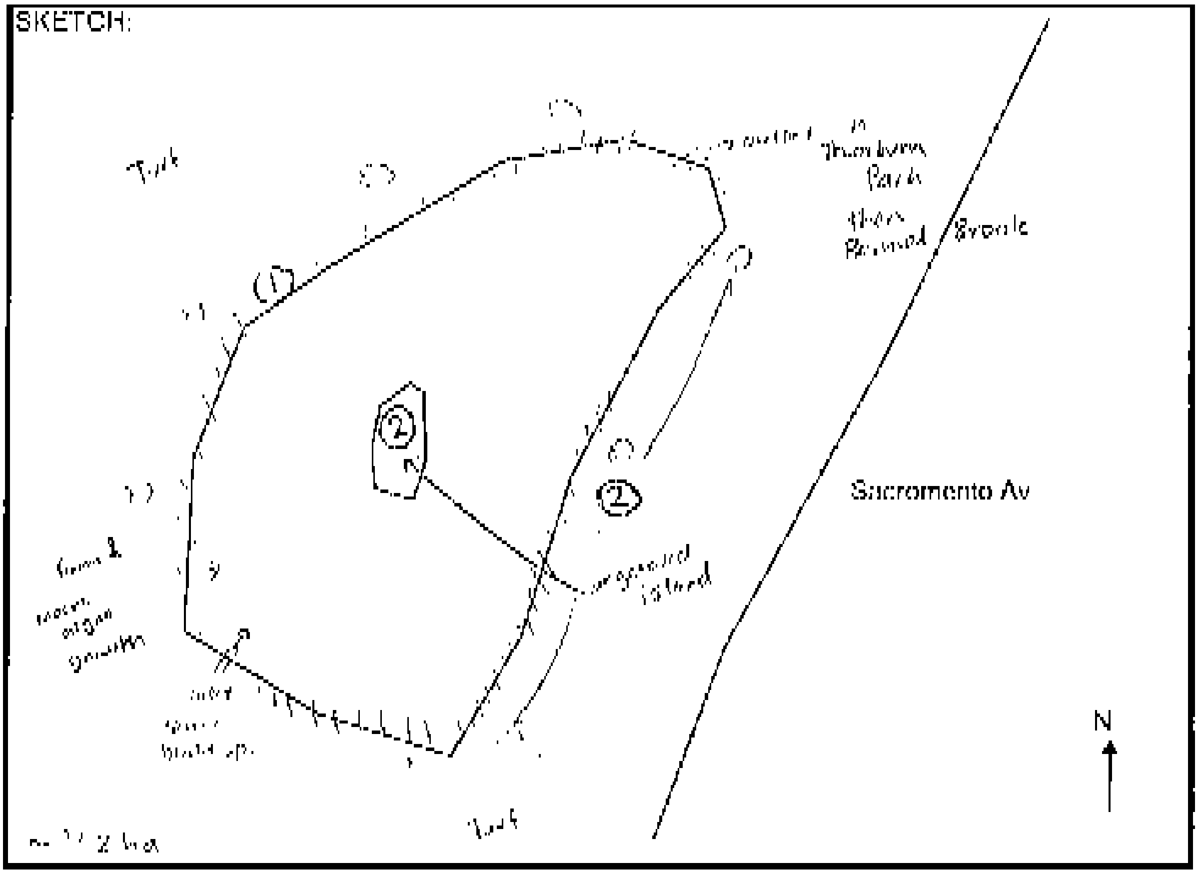
* Field pH, EC, TDS and temperature measured during site visit on 5/9/07. Observations of algae also recorded on this day.
NT = Not tested

Constructed Lake Study
Field Survey Form

Lake Name and Location: **Sacromento Park Lake, Beechboro**

Date: 5/09/2007 Recorded By: Bronwyn Woodward

SKETCH:



Water Level (mark location of staff gauges): Not located

Estimated Depth of Water: ~ 1-2 m

Lake Edge	%	Notes
Walled	0	
Vegetated	100	Sedges invaded with grass
Grassed	0	
Earth	0	

Water quality: (scums, water clarity, algae, mosquitoes, pH, EC?)

pH 6.23 EC 0.94 mS, TDS 0.49 ppt, Temp 17.6

Fauna: feral ducks, geese

Vegetation Type(s) adjacent to lake: (1) grass, sedge
(annotate with numbers)

(2) Sheoak, melaleuca, bottle brush

Other Comments:

Sacromento Park Lake - Photographic Plates

PLATE 1 – Northern section of lake.

PLATE 2 – The inlet of the single stormwater drain that discharges into the lake.

Sandown Park Lake – Summary Report

This lake consists of four connected sections located within residential development at a former horse agistment site in Ellenbrook. The lake was constructed four years ago and has a total area of approximately 4 ha. The eastern section of the lake intercepts groundwater and receives stormwater and is used for irrigation. The smaller western sections serve a purely aesthetic function. Water is circulated through the lake by pumping from the eastern section to the most western section and gravity flow towards from west to east over riffles installed between each of the sections.

Landscaping surrounding the lake consists mainly of introduced species such as lavender and willows which according to the council are expensive to maintain and have low habitat value. Some benthic algae was observed at the lake on the site visit on 5 September 2007 however no algal blooms have been reported. Attempts were made to stock native fish in the lake such as minnows, night gobies and yabbies. Establishment of the fish may have been compromised by the subsequent illegal release of koi carp which have since been removed by electrofishing.

Previous Studies/ Monitoring:

No previous studies or monitoring records were located.

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Sandown Park Lake**

1. Basic Details	
Location (street and suburb)	Sandown Circuit, Henley Brook
Location (coordinates)	402985 E, 6481343 N
2007 Streetsmart page number	255, D8
Local Government	City of Swan
Owner	City of Swan
Function*	D, I, A
Age (years)	5.5
2. Physical Features	
Lining (y/n)	Y - two western sections are lined
Area (ha)	4.05
Shape (eg. linear, round, irregular)	Irregular
Depth range (estimate) (m)	0.3 - 2
"Naturalness" rating (1 to 5)*	1
Social amenity value (High, Medium, Low)	High
Edging (eg. wall, trees, reeds, sloping banks, turf)	~60% stone and concrete walls, 36% vegetated, 2% turf, 2% sand beach
Vegetation type adjacent to lake*	Sedges, *Eucalyptus rudis* , paperpark, landscaping with introduced species eg. lavender and willows
Vegetation condition adjacent to lake*	F
Potential acid sulfate soil (ASS) risk (according to ASS risk map)	Moderate to low risk of ASS occurring within 3 m of natural soil surface

* Notes:

Function
D - Drainage
C - Conservation
A - Aesthetic (and recreational)
I - Irrigation Storage

Naturalness rating
1 - Highly ornamental
2 - Mostly ornamental with some natural features
3 - Some ornamenatal and some natural features
4 - Natural or natural like with some ornamental features
5 - Natural or natural like

Vegetation type
N - Native
X - Exotic

Vegetation condition
P - Poor
F- Fair
G - Good
E - Excellent

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Sandown Park Lake**

3. Catchment and Hydrology	
Catchment type (eg. industrial, residential)	Residential
Prior land use	Horse agistment
Catchment size (ha)	ND
Geology (unit)	Thin Bassendean Sand over Guildford Formation (Qpb/Qpa)/ Bassendean Sand (Qpb)
(description)	S8 - SAND - white to pale grey at surface, yellow at depth, fine to medium grained, moderately sorted, subangular to subrounded, minor heavy minerals, of aeolian origin over SANDY CLAY (Sc) to CLAYEY SAND (Cs) of the Guildford Formation, of aeolian origin
No. inlets	3
Inlet volume/size	ND
No. outlets	0
Outlet volume/size	NA
Drainage connection flow through (FT) or End Point (EP) or No Drainage (NDr)	EP
Approximate volume of water extracted for irrigation	ND
Water level top up (y/n)?	Possibly topped up with bore water.
Estimated residence time	ND
Water or nutrient balance undertaken (y/n)?	N
4. Management	
Aeration/agitation present/absent?	Present
Aeration type if present* How many?	2R, C
Fertiliser application adjacent to lake (y/n)?	Probably fertilised 2 x per year
Irrigation adjacent to lake (y/n)?	ND
Lawn mowing/ weed control	Mowed, lawn clippings left to mulch back in
Management problems*	11 - koi
Maintenance and effectiveness	Electrofishing of koi - appears to have worked in the short term
Monitoring frequency	Not monitored

* Notes:

Aeration Features
F - Fountain
R - Rocks/waterfall
C - Circulation by pumping
A - Submerged aerator

ND - Data not available within timeframe of study
NA - Not applicable

Management Problems
1. Flooding
2. Drying Out
3. Slow inflitration
4. Odour
5. Nuisance algal growth
6. Fish deaths
7. Bird deaths
8. Mosquitos or midges
9. Acid Sulfate Soils
10. Iron Monosulfides
11. Feral Fish
12. Other (describe)

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Sandown Park Lake**

5. Water Quality (if known)	**Section A**	**Section B**	**Section C**
Total Nitrogen (µ/L)		NT	
Total Phosphorus (µ/L)		NT	
Chlorophyll *a* (µg/L)		NT	
pH	6.89	7.47	6.94
EC (mS)	0.43	0.43	0.42
TDS (ppt)	0.21	0.21	0.21
Temperature (°C)	19.9	20.8	20.0
Algae/ aquatic plants, water clarity	Green/brown filamentous algae (possibly filamentous cyanobacteria), some detached and floating on surface. Benthic water plant, possibly *Potamogeton pectinus* - coated in microalgae.*		
6.Fauna			
Macroinvertebrates eg. midges and mosquitos	None observed during site visit.		
Macrofauna	Juvenile gambusia, a few Pacific Black ducks, Eurasian coot.		

* Notes:

Field pH, EC, TDS and temperature measured during site visit on 5/9/07. Observations of algae also recorded on this day.
NT = Not tested

Constructed Lake Study
Field Survey Form

Lake Name and Location: Sandown Park Lakes, Henley Brook

Date: 5/09/2007 Recorded By: Bronwyn Woodward

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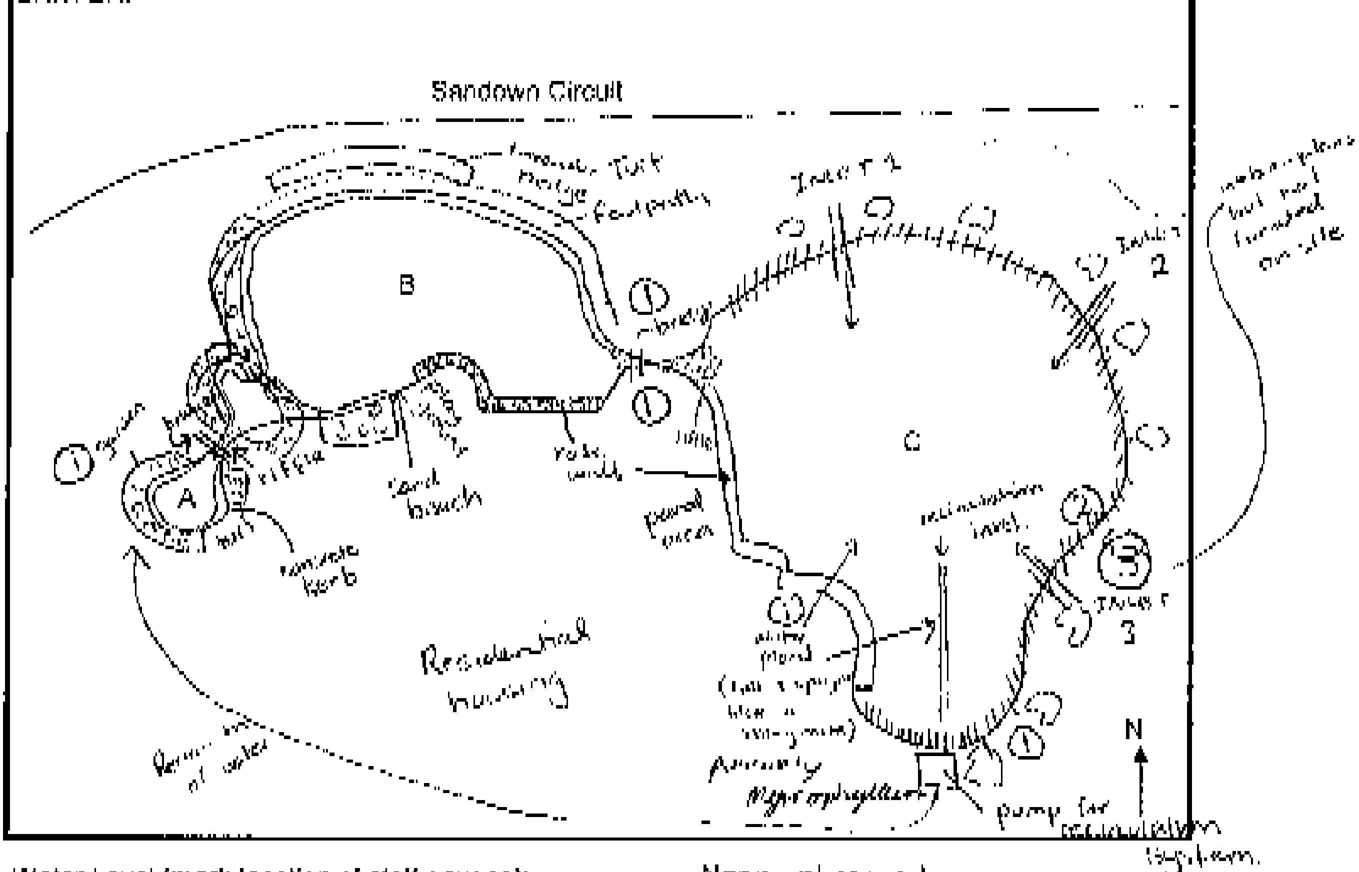

Water Level (mark location of staff gauges): None observed.

Estimated Depth of Water: A. 0.3m B. ? 1-2 C ? ~2

Lake Edge %	A	B	C	whole lake	Notes A	B	C
Walled	100	95	35	~60	Concrete edging	concrete / [illegible]	
Vegetated	(85)	(75)	75	~56	landscaping dominated by introduced species	some / sand sedges	sedges + trees
Grassed	(15)	0	0	~2	turf		
Earth	0	5	0	~2		sand beach	

Water quality: (scums, water clarity, algae, mosquitoes, pH, EC?) Clear Filamentous green algae? – possibly filamentous [illegible] [illegible] on [illegible] lake. [illegible] [illegible] water plant – (long [illegible] brown [illegible]) growing [illegible] [illegible] [illegible]

Fauna: [illegible] ducks, Eurasian Coot

Vegetation Type(s) adjacent to lake - (annotate with numbers) (1) Landscaping in gardens mostly introduced species eg. [illegible] willows (low habitat value). (2) Sedges (3) Larger more established trees eg. Eucalyptus, paperbark – [illegible] [illegible] [illegible] strip on southern side

Other Comments:

*	A	B	C
pH	6.89	7.47	6.94
EC (mS)	0.43	0.43	0.42
TDS (ppt)	0.21	0.21	0.21
Temp	19.9	20.8	20.0

env

Sandown Park Lake - Photographic Plates

PLATE 1 – The western sections of the lake are highly ornamental with intricately landscaped surrounds.

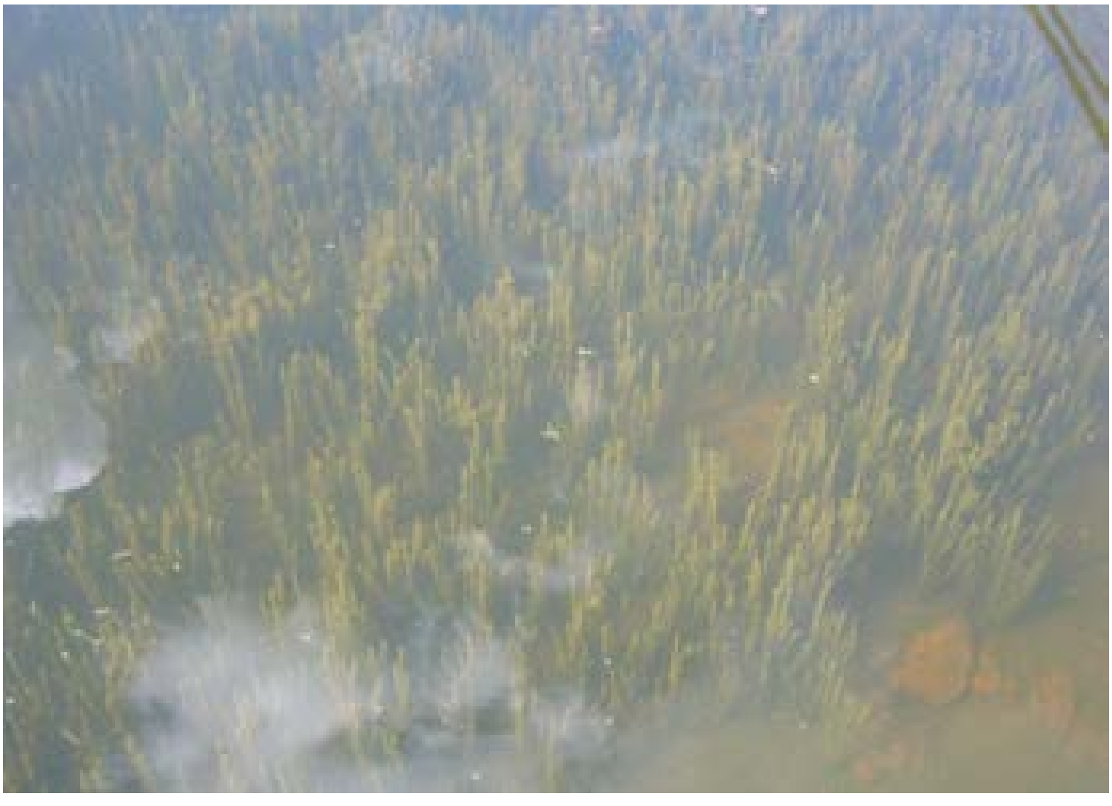

PLATE 2 – Benthic water plant, possibly *Potamogeton pectinus*, in the eastern section of the lake.

Woodlake – Summary Report

Woodlake is a highly ornamental water body constructed at the site of a former pine plantation within Ellenbrook approximately twelve years ago. The surrounding subdivision was marketed around the lake and houses on the eastern side have been built right up to the banks.

Water from the lake is circulated by pumping to a small lined artificial lake which overflows over a waterfall back into the main lake. The main lake intercepts groundwater and receives drainage. It is also used for irrigation of a substantial area of nearby parkland within Ellenbrook including that around Lake Fresca.

Last summer the irrigation system had to be shut down as the lake was pumped dry. Below average rainfall and the high water requirements of the mostly none native landscaping in the area also contributed to the lake being unable to sustain irrigation requirements and it is possible this problem may reoccur in the future. In recent years the lake also experienced a blue green algal bloom following a sewage spill from a nearby pump station.

Previous Studies/ Monitoring:

No previous studies or monitoring records were located.

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Woodlake** (Main Lake)

1. Basic Details	
Location (street and suburb)	Bronzewing Avenue, Ellenbrook
Location (coordinates)	402991.2 E, 6482456.2 N
2007 Streetsmart page number	255, D6
Local Government	City of Swan
Owner	City of Swan
Function*	A, I, D
Age (years)	12
2. Physical Features	
Lining (y/n)	N
Area (ha)	~ 5.7095
Shape (eg. linear, round, irregular)	Irregular C Shape
Depth range (estimate) (m)	1.5
"Naturalness" rating (1 to 5)*	2
Social amenity value (High, Medium, Low)	High
Edging (eg. wall, trees, reeds, sloping banks, turf)	35% walled, 65% vegetated
Vegetation type adjacent to lake*	Landscaping using mostly introduced species including Eastern states sheoak (*Casuarina equestifolia*), bottlebrush, willow, poplars, paperbark (*Melaleuca*), reeds, pine trees.
Vegetation condition adjacent to lake*	G
Potential acid sulfate soil (ASS) risk (according to ASS risk map)	moderate to low risk of ASS occurring within 3 m of natural soil surface

* Notes:

Function
D - Drainage
C - Conservation
A - Aesthetic (and recreational)
I - Irrigation Storage

Naturalness rating
1 - Highly ornamental
2 - Mostly ornamental with some natural features
3 - Some ornamenatal and some natural features
4 - Natural or natural like with some ornamental features
5 - Natural or natural like with some ornamental features

Vegetation type
N - Native
X - Exotic

Vegetation condition
P - Poor
F- Fair
G - Good
E - Excellent

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Woodlake** (Main Lake)

3. Catchment and Hydrology	
Catchment type (eg. industrial, residential)	Residential
Prior land use	Pine plantation
Catchment size (ha)	ND
Geology (unit)	Thin Bassendean Sand over Guildford Formation (Qpb/Qpa)/ Bassendean Sand (Qpb)
(description)	S_8 - SAND - white to pale grey at surface, yellow at depth, fine to medium grained, moderately sorted, subangular to subrounded, minor heavy minerals, of aeolian origin over SANDY CLAY (Sc) to CLAYEY SAND (Cs) of the Guildford Formation, of aeolian origin
No. inlets	5
Inlet volume/size	ND
No. outlets	2
Outlet volume/size	ND
Drainage connection flow through (FT) or End Point (EP) or No Drainage (NDr)	FT
Approximate volume of water extracted for irrigation	ND
Water level top up (y/n)?	Possibly topped up with borewater
Estimated residence time	ND
Water or nutrient balance undertaken (y/n)?	N
4. Management	
Aeration/agitation present/absent?	Present
Aeration type if present* How many?	1R, C
Fertiliser application adjacent to lake (y/n)?	Developer fertilised with large amounts of urea. Current council practices are not available.
Irrigation adjacent to lake (y/n)?	Y - using lake water.
Lawn mowing/ weed control	ND
Management problems*	2 (due to over extraction for irrigation), 5 (cyanobacteria bloom following sewage spill)
Maintenance and effectiveness	GPTs on stormwater inlets?
Monitoring frequency	Not monitored

* Notes:

Aeration Features
F - Fountain
R - Rocks/waterfall
C - Circulation by pumping
A - Submerged aerator

ND - Data not available within timeframe of study
NA - Not applicable

Management Problems
1. Flooding
2. Drying Out
3. Slow infiltration
4. Odour
5. Nuisance algal growth
6. Fish deaths
7. Bird deaths
8. Mosquitos or midges
9. Acid Sulfate Soils
10. Iron Monosulfides
11. Feral Fish
12. Other (describe)

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Woodlake** (Main Lake)

5. Water Quality (if known)	
Total Nitrogen (µ/L)	NT
Total Phosphorus (µ/L)	NT
Chlorophyll *a* (µg/L)	NT
pH	7.59*
EC (mS)	0.29*
TDS (ppt)	0.14*
Temperature (°C)	21.2*
Algae/ aquatic plants, water clarity	Some filamentous green algae - attached and floating.*
6.Fauna	
Macroinvertebrates eg. midges and mosquitos	None observed during site visit
Macrofauna	Pacific Black duck, Eurasian coot, banjo frogs, juvenile *Gambusia*

Notes:

* Field pH, EC, TDS and temperature measured during site visit on 5/9/07. Observations of algae also recorded on this day.
NT = Not tested

Constructed Lake Study
Field Survey Form

Lake Name and Location: **Wood Lake (Main Lake), Ellenbrook**

Date: 5/09/2007 Recorded By: Bronwyn Woodward

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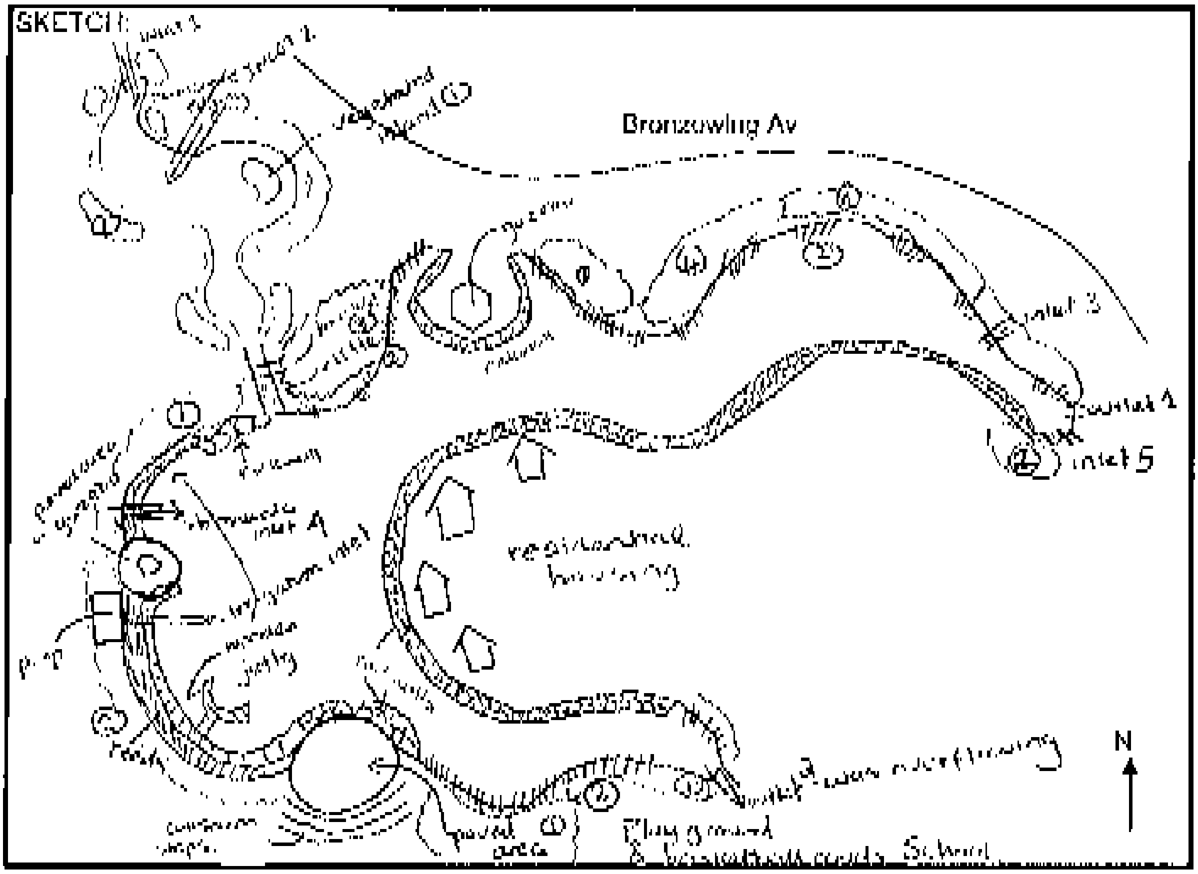

Water Level (mark location of staff gauges): None located

Estimated Depth of Water: ~1.5m

Lake Edge	%	Notes
Walled	35	rockwalls
Vegetated	65	artificial landscaping and reeds
Grassed	0	
Earth	0	

Water quality: (scums, water clarity, algae, mosquitoes, pH, EC?) clear [illegible]
[illegible] algae [illegible] to plants pH = 7.59 EC = 0.29 mS TDS: 0.14 ppt Temp = 21.2

Fauna: [illegible] Eurasian coot

Vegetation Type(s) adjacent to lake - (annotate with numbers) [illegible] bottlebrush [illegible]
Melaleuca, willows, poplars [illegible] Casuarina equisetifolia?

(2) Reeds (3) [illegible] (4) Melaleuca [illegible]

Other Comments:

Woodlake - Photographic Plates

PLATE 1 – Houses on the water's edge on the western side of the lake.

PLATE 2 – Irrigation pump station on western side of lake.

City of Wanneroo

- Carramar Golf Course Lake
- Ridgewood Park Lake
- The Duck Pond

Carramar Golf Course Lake – Summary Report

This constructed lake is located within the Carramar public golf course on Links Drive. The lake is used for irrigation of the golf course and is owned and managed by the City of Wanneroo. It is plastic lined and filled with bore water.

Although there is a high level of fertiliser application adjacent to the lake to maintain golf course mainly on putting greens and fairways no known management problems have been recorded at the lake to date. The water in the lake appeared quite clear at the time of the site visit on 28 August 2007. Most of the lake is surrounded by reeds and native vegetation which is in good condition.

Previous Studies/ Monitoring:

No previous studies or monitoring records were located.

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Carramar Golf Course Lake**

1. Basic Details	
Location (street and suburb)	Links Drive, Carramar
Location (coordinates)	384750.2 E, 6491885.8 N
2007 Streetsmart page number	191 A7
Local Government	City of Wanneroo
Owner	City of Wanneroo
Function*	I
Age (years)	16
2. Physical Features	
Lining (y/n)	Y - plastic
Area (ha)	~2.053
Shape (eg. linear, round, irregular)	Round
Depth range (estimate) (m)	2-3 (maximum)
"Naturalness" rating (1 to 5)*	3
Social amenity value (High, Medium, Low)	Medium
Edging (eg. wall, trees, reeds, sloping banks, turf)	~20% turf, ~80% reeds/native vegetation
Vegetation type adjacent to lake*	mostly N, some X
Vegetation condition adjacent to lake*	G
Potential acid sulfate soil (ASS) risk (according to ASS risk map)	No known ASS risk.

* Notes:

Function
D - Drainage
C - Conservation
A - Aesthetic (and recreational)
I - Irrigation Storage

Naturalness rating
1 - Highly ornamental
2 - Mostly ornamental with some natural features
3 - Some ornamenatal and some natural features
4 - Natural or natural like with some ornamental features
5 - Natural or natural like with some ornamental features

Vegetation type
N - Native
X - Exotic

Vegetation condition
P - Poor
F- Fair
G - Good
E - Excellent

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Carramar Golf Course Lake**

3. Catchment and Hydrology	
Catchment type (eg. industrial, residential)	Golf Course
Prior land use	ND
Catchment size (ha)	NA. Bore water fed.
Geology (unit)	Sand derived from Tamala Limestone (Qts)
(description)	S_7 - SAND - pale and olive yellow, medium to coarse grained, sub-angular to sub-rounded quartz, trace of feldspar, moderately sorted, of residual origin
No. inlets	0
Inlet volume/size	NA
No. outlets	0
Outlet volume/size	NA
Drainage connection flow through (FT) or End Point (EP) or No Drainage (NDr)	NDr
Approximate volume of water extracted for irrigation	ND
Water level top up (y/n)?	Y - topped up with bore water
Estimated residence time	ND
Water or nutrient balance undertaken (y/n)?	N
4. Management	
Aeration/agitation present/absent?	Absent
Aeration type if present* How many?	NA
Fertiliser application adjacent to lake (y/n)?	Y - high fertiliser application to maintain golf course mainly on putting greens and fairways
Irrigation adjacent to lake (y/n)?	Y - on golf course
Lawn mowing/ weed control	ND
Management problems*	No known history of problems
Maintenance and effectiveness	No special maintenance has been required
Monitoring frequency	Not monitored

* Notes:

Aeration Features
F - Fountain
R - Rocks/waterfall
C - Circulation by pumping
A - Submerged aerator

ND - Data not available within timeframe of study
NA - Not applicable

Management Problems
1. Flooding
2. Drying Out
3. Slow infiltration
4. Odour
5. Nuisance algal growth
6. Fish deaths
7. Bird deaths
8. Mosquitos or midges
9. Acid Sulfate Soils
10. Iron Monosulfides
11. Feral Fish
12. Other (describe)

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Carramar Golf Course Lake**

5. Water Quality (if known)	
Total Nitrogen (µg/L)	NT
Total Phosphorus (µg/L)	NT
Chlorophyll *a* (µg/L)	NT
pH	8.39*
EC (mS)	0.51*
TDS (ppt)	0.25*
Temperature (°C)	20.4*
Algae/ aquatic plants, water clarity	Water appeared fairly clear at time of site visit. No algae observed.*
6.Fauna	
Macroinvertebrates eg. midges and mosquitos	Macroinvertebrates observed in water during site visit. No known mosquito/midge problems.
Macrofauna	Carp, ducks.

Notes:

* Field pH, EC, TDS and temperature measured during site visit on 28/8/07. Observations of algae also recorded on this day.
NT = Not tested.

Constructed Lake Study
Field Survey Form

Lake Name and Location: **Carramar Golf Course Lake, Carramar**

Date: 28/8/07

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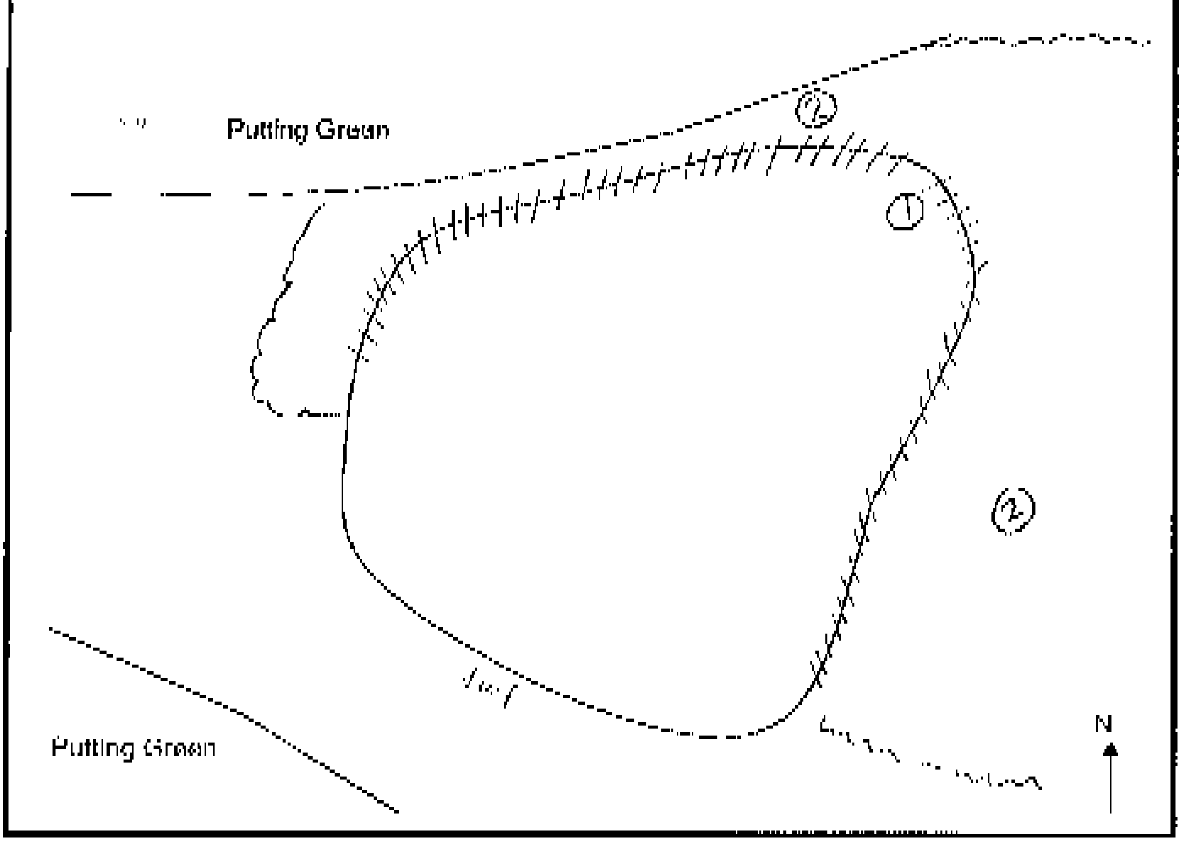


Water Level (mark location of staff gauges): No gauge

Estimated Depth of Water: fairly shallowed [illegible] max. depth

Lake Edge	%	Notes
Walled	0 %	
Vegetated	60%	native good condition original remnant?
Grassed	20%	has been golf course
Earth	0 %	

Water quality: (scums, water clarity, algae, mosquitoes, pH, EC?) fairly clear

pH 8.31 EC 0.51 mS TDS 0.25 ppt temp 20°

quite a few [illegible] in water, carp

Vegetation Type(s) adjacent to lake (annotate with numbers): (1) Reeds - [illegible] native [illegible]

possibly [illegible] (2) Native vegetation to north and west of

lake is in good condition

Other Comments:

Carramar Golf Course Lake - Photographic Plates

PLATE 1 – View of lake from northern bank facing south with fairway in the background.

PLATE 2 – Natural fringing vegetation on the eastern side of the lake.

Ridgewood Park Lake – Summary Report

This constructed lake is located in Ridgewood Park within the City of Wanneroo. It is an ornamental lake which also serves a drainage and irrigation function. The entire lake is surrounded by a concrete wall and coliseum steps on the eastern side of the lake and European style landscaping consisting mostly turf and a few exotic trees including willows, conifers and plane trees.

A large number of mature carp inhabit the lake however these are not viewed by the council to be a problem in the lake. Management problems recorded at the lake include sand build up at the drainage inlets clogging the irrigation system and build up of litter and gross pollutants. When lake level becomes high the surrounding turf is damaged from waterlogging and attack by ducks.

The lake requires regular pumping when water levels flood turf areas and is regularly skimmed for litter and the surrounds cleaned to prevent rubbish build up. Gross pollutant traps were also installed in 2002/2003 to manage litter problems however wind blown and dumped rubbish continues to be a problem.

Previous Studies/ Monitoring:

PPK (2002) *Ridgewood Lake Drainage Investigation*. Letter report to T Quinn, Coordinator Civil Design dated 1 July 2002.

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Ridgewood Park Lake**

1. Basic Details	
Location (street and suburb)	Ridgewood Avenue, Ridgewood
Location (coordinates)	378988.6 E, 6495594.7 N
2007 Streetsmart page number	159, D10
Local Government	City of Wanneroo
Owner	City of Wanneroo
Function*	D, A, I
Age (years)	15
2. Physical Features	
Lining (y/n)	Y - plastic
Area (ha)	~0.1936
Shape (eg. linear, round, irregular)	oval, slightly elongated
Depth range (estimate) (m)	<2
"Naturalness" rating (1 to 5)*	1
Social amenity value (High, Medium, Low)	High
Edging (eg. wall, trees, reeds, sloping banks, turf)	100% concrete walled, surrounded by turf
Vegetation type adjacent to lake*	X - willows, conifers, plane trees
Vegetation condition adjacent to lake*	G
Potential acid sulfate soils (ASS) risk (according to ASS risk map)	No known ASS.

* Notes:

Function
D - Drainage
C - Conservation
A - Aesthetic (and recreational)
I - Irrigation Storage

Naturalness rating
1 - Highly ornamental
2 - Mostly ornamental with some natural features
3 - Some ornamenatal and some natural features
4 - Natural or natural like with some ornamental features
5 - Natural or natural like with some ornamental features

Vegetation type
N - Native
X - Exotic

Vegetation condition
P - Poor
F- Fair
G - Good
E - Excellent

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Ridgewood Park Lake**

3. Catchment and Hydrology	
Catchment type (eg. industrial, residential)	Residential
Prior land use	ND
Catchment size (ha)	ND
Geology (unit)	Sand derived from Tamala Limestone (Qts)/ Tamala Limestone (Qtl)
(description)	S_7 - SAND - pale and olive yellow, medium to coarse grained, sub-angular to sub-rounded quartz, trace of feldspar, moderately sorted, of residual origin/ LS_1 - LIMESTONE - light yellowish brown, fine to coarse grained, sub-angular to well rounded quartz, trace of feldspar, shell debris, variably lithified, surface kankar, of aeolian origin
No. inlets	3
Inlet volume/size	ND
No. outlets	1 - however has never overflowed
Outlet volume/size	ND
Drainage connection flow through (FT) or End Point (EP) or No Drainage (NDr)	EP - given that hasn't overflowed before
Approximate volume of water extracted for irrigation	ND
Water level top up (y/n)?	Y - topped up with borewater in dry season
Estimated residence time	ND
Water or nutrient balance undertaken (y/n)?	N
4. Management	
Aeration/agitation present/absent?	Absent
Aeration type if present* How many?	NA
Fertiliser application adjacent to lake (y/n)?	Nearby playing field fertilised but not turf surrounding lake
Irrigation adjacent to lake (y/n)?	ND
Lawn mowing/ weed control	Mower crews attempt to minimise the amount of clippings that end up in the water by operating the machines in such a way that the clippings are directed away from the lake.
Management problems*	1 - when lake level becomes high the surrounding turf is damaged from waterlogging and attack by ducks, 5 - however only one occasion, 12 - sand build up resulting in irrigation system clogging, litter and gross pollutants
Maintenance and effectiveness	Lake is regularly pumped out when water levels get high. Lake is regularly skimmed for litter and the surrounds cleaned. Gross pollutant traps installed in 2002/2003 wind blown and dumped rubbish continues to be a problem.
Monitoring frequency	Not monitored

* Notes:

Aeration Features
F - Fountain
R - Rocks/waterfall
C - Circulation by pumping
A - Submerged aerator

ND - Data not available within timeframe of study
NA - Not applicable

Management Problems
1. Flooding
2. Drying Out
3. Slow infiltration
4. Odour
5. Nuisance algal growth
6. Fish deaths
7. Bird deaths
8. Mosquitos or midges
9. Acid Sulfate Soils
10. Iron Monosulfides
11. Feral Fish
12. Other (describe)

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Ridgewood Park Lake**

5. Water Quality (if known)	
Total Nitrogen (μ/L)	NT
Total Phosphorus (μ/L)	NT
Chlorophyll *a* (μg/L)	NT
pH	9.21*
EC (mS)	0.17*
TDS (ppt)	0.08*
Temperature (°C)	21.2*
Algae/ aquatic plants, water clarity	Fairly turbid and dark green indicating elevated levels of phytoplankton.*
6.Fauna	
Macroinvertebrates eg. midges and mosquitos	None observed during site visit (28/8/07). No records of mosquito/midge problems.
Macrofauna	Carp, ducks.

Notes:

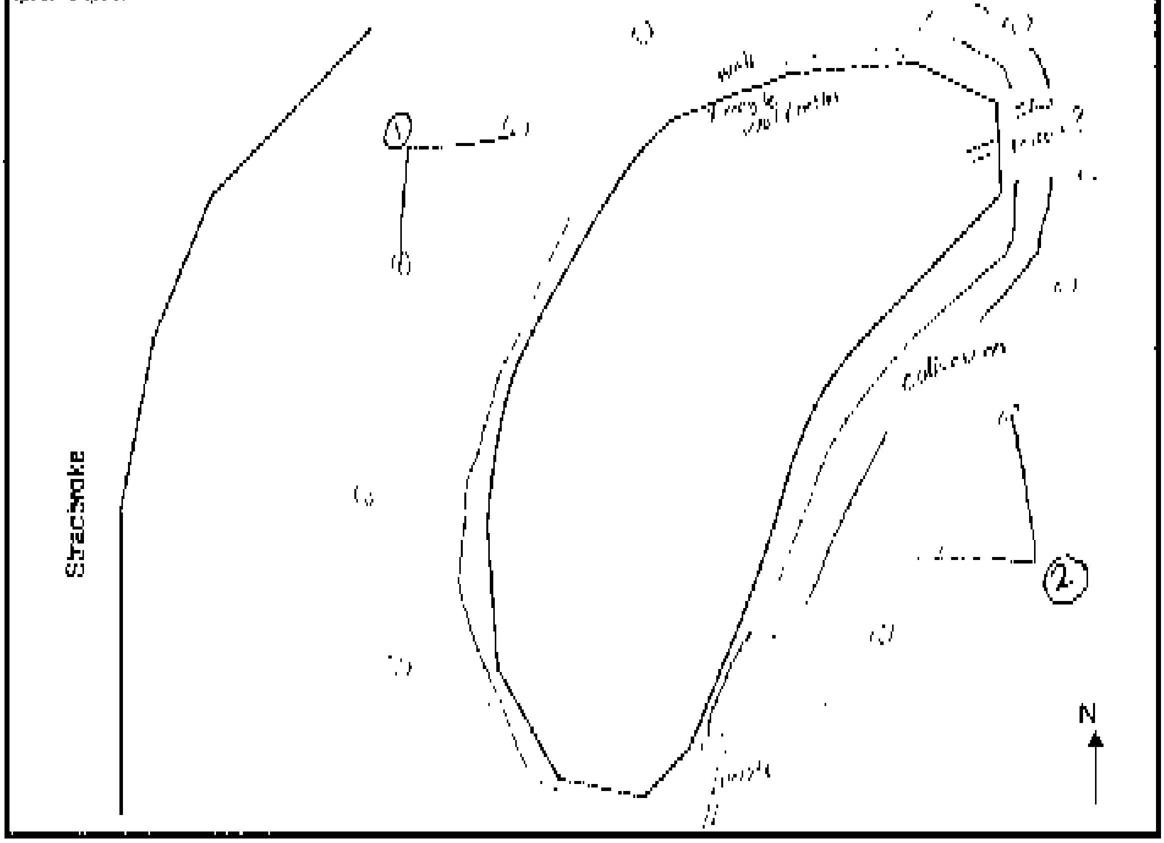
* Field pH, EC, TDS and temperature measured during site visit on 28/8/07. Observations of algae also recorded on this day.
NT = Not tested.

Constructed Lake Study
Field Survey Form

Lake Name and Location: **Ridgewood Park, Ridgewood**

Date: 28/3/07 Recorded By: [illegible]

SKETCH:



Water Level (mark location of staff gauges): No gauge

Estimated Depth of Water: Fairly shallow <1m

Lake Edge	%	Notes
Walled	100	concrete. Coliseum steps on eastern side
Vegetated	-	
Grassed		
Earth	-	

Water quality: (scums, water clarity, algae, mosquitoes, pH, EC?) [illegible]

EC : 0.17 mS pH: 9.20 TDS: 0.08 ppt Temp: 21.2 °C
fairly turbid, dark green. Ducks, carp

Vegetation Type(s) adjacent to lake (annotate with numbers) (1) [illegible] (2) [illegible]

Other Comments:

Ridgewood Park Lake - Photographic Plates

PLATE 1 – Southern side of lake. The turf is damaged due to high water levels.

PLATE 2 – Coliseum steps on eastern side of lake.

The Duck Pond – Summary Report

The Duck Pond is an ornamental plastic and concrete lined 0.175 ha lake located on Bayport Circuit in Mindarie within the City of Wanneroo. It was originally constructed as a temporary entry lake for the surrounding housing development. When the lake was due to be decommissioned, residents lobbied for it to remain. The council has only recently taken over responsibility for the lake.

The lake is filled with bore water and used to irrigate surrounding road verges. There is a high expectation from local residents to maintain green grass and landscaping within the verges previously maintained by the developer. The lake has experienced problems with algal blooms.

An aeration and recirculation system was installed c. 2004 to treat algal blooms in the lake. Water is pumped into settling tank to remove nutrients bound particulate matter then oxygenated via an ozone treatment and flow over a waterfall back into the lake. It is claimed that water quality improved following installation of the aeration/recirculation system (Aquatic Solutions and Mirvac, 2006) however when the site was visited on 28 August 2007 the water appeared fairly turbid and green indicating elevated levels of phytoplankton.

Previous Studies/ Monitoring:

Aquatic Solutions and Mirvac (2006) *Mindarie Duck Pond – Water Treatment Facility, 35 Bayport Circuit Mindarie – Operation and Management Plan.* Report produced for City of Wanneroo.

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **The Duck Pond**

1. Basic Details	
Location (street and suburb)	Bayport Cct, Mindarie
Location (coordinates)	377340 E, 6492881.9 N
2007 Streetsmart page number	189, B5
Local Government	City of Wanneroo
Owner	City of Wanneroo
Function*	A, I
Age (years)	ND
2. Physical Features	
Lining (y/n)	Y - plastic sheeting and concrete.
Area (ha)	~ 0.175
Shape (eg. linear, round, irregular)	Kidney bean.
Depth range (estimate) (m)	<2-3
"Naturalness" rating (1 to 5)*	1
Social amenity value (High, Medium, Low)	High - originally temporary but residents wanted it to remain. No recreational structures.
Edging (eg. wall, trees, reeds, sloping banks, turf)	concrete edging all the way around. 95% turf, 5% vegetated.
Vegetation type adjacent to lake*	N (50%), X (50%) - palms, native reeds, some native trees.
Vegetation condition adjacent to lake*	G
Potential acid sulfate soil (ASS) risk (according to ASS risk map)	No known ASS

* Notes:

Function
D - Drainage
C - Conservation
A - Aesthetic (and recreational)
I - Irrigation Storage

Naturalness rating
1 - Highly ornamental
2 - Mostly ornamental with some natural features
3 - Some ornamenatal and some natural features
4 - Natural or natural like with some ornamental features
5 - Natural or natural like with some ornamental features

Vegetation type
N - Native
X - Exotic

Vegetation condition
P - Poor
F- Fair
G - Good
E - Excellent

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **The Duck Pond**

3. Catchment and Hydrology	
Catchment type (eg. industrial, residential)	Residential.
Prior land use	ND
Catchment size (ha)	NA. Bore water fed.
Geology (unit)	Safety Bay Sand (Qhs)/ Tamala Limestone (Qtl)
(description)	S2 - CALCAREOUS SAND - white fine to medium grained, sub rounded quartz and shell debris, of aeolian origin/ LS_1 - LIMESTONE - light yellowish brown, fine to coarse grained, sub-angular to well rounded quartz, trace of feldspar, shell debris, variably lithified, surface kankar, of aeolian origin
No. inlets	0
Inlet volume/size	NA
No. outlets	0
Outlet volume/size	NA
Drainage connection flow through (FT) or End Point (EP) or No Drainage (NDr)	NDr
Approximate volume of water extracted for irrigation	ND
Water level top up (y/n)?	Y - topped up with bore water.
Estimated residence time	ND
Water or nutrient balance undertaken (y/n)?	N
4. Management	
Aeration/agitation present/absent?	Present.
Aeration type if present* How many?	1R, C
Fertiliser application adjacent to lake (y/n)?	N
Irrigation adjacent to lake (y/n)?	Y - nearby road verges
Lawn mowing/ weed control	Mower crews attempt to minimise the amount of clippings that end up in the water by operating the machines in such a way that the clippings are directed away from the lake.
Management problems*	4 - odour, 5 - elevated algal growth in 2004/2005, showed signs of improvement in late 2005 following implementation of management measures, 12 - Problems when bore broke down April/May 2007. Surface detritus (possibly algae formed).
Maintenance and effectiveness	An aeration and recirculation system was installed c. 2004 to treat algal blooms. Water is pumped into a settling tank to remove nutrients bound particulate matter, then oxygenated via an ozone treatment and finally flows over a waterfall back into the lake. It is claimed that water quality improved following installation of the aeration/recirculation system (Aquatic Solutions and Mirvac, 2006) however when the site was visited on the 28/8/07 the water appeared fairly turbid and green indicating elevated levels of phytoplankton.
Monitoring frequency	Field water quality parameters and visible water quality monitored between January 2005 and December 2006 by Aquatic Solutions and Mirvac.

* Notes:

Aeration Features
F - Fountain
R - Rocks/waterfall
C - Circulation by pumping
A - Submerged aerator

ND - Data not available within timeframe of study
NA - Not applicable

Management Problems
1. Flooding
2. Drying Out
3. Slow inflitration
4. Odour
5. Nuisance algal growth
6. Fish deaths
7. Bird deaths
8. Mosquitos or midges
9. Acid Sulfate Soils
10. Iron Monosulfides
11. Feral Fish
12. Other (describe)

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **The Duck Pond**

5. Water Quality (if known)	
Total Nitrogen (µ/L)	NT
Total Phosphorus (µ/L)	NT
Chlorophyll *a* (µg/L)	NT
pH	8.56* (7.7 - 8.9**)
EC (mS)	4.80*
TDS (ppt)	NT
Temperature (°C)	(16.0 - 27.7**)
Algae/ aquatic plants, water clarity	Fairly turbid and green indicating elevated levels of phytoplankton.*
6.Fauna	
Macroinvertebrates eg. midges and mosquitos	No visible macroinvertebrates at time of site visit (28 August 2007). No records of problems with mosquitoes/midges.
Macrofauna	Ducks.

Notes:

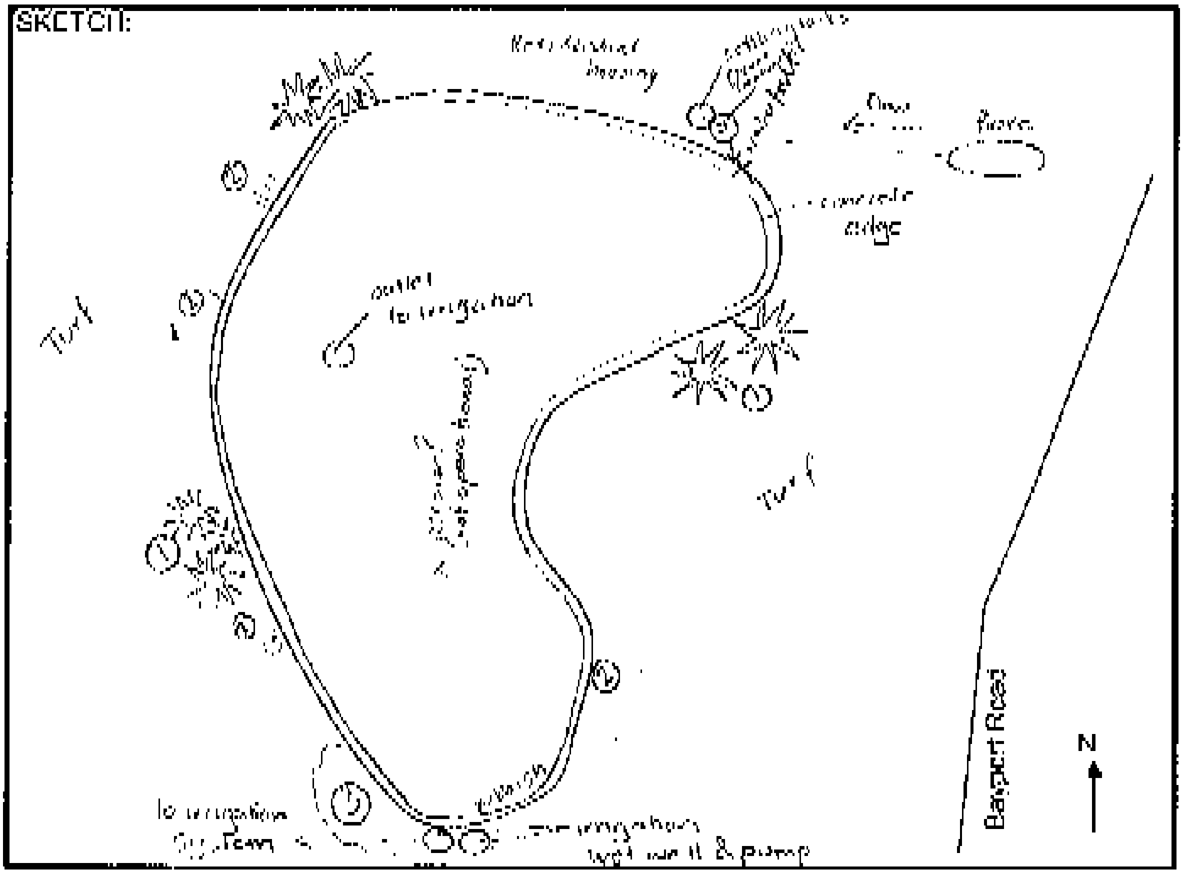
* Field pH and EC measured during site visit on 28/8/07. Observations of algae also recorded on this day.
** Range of values recorded between January 2005 and December 2006 by Aquatic Solutions and Mirvac (2006)
NT = Not tested.

Constructed Lake Study
Field Survey Form

Lake Name and Location: The Duck Pond, Mindarie

Date: 2/8/07 Recorded by: [illegible]

SKETCH:



Water Level (mark location of staff gauges): No gauge.

Estimated Depth of Water: Fairly shallow <2-3m

Lake Edge	%	Notes
Walled	100%	Concrete edging
Vegetated	<5%	a few reeds
Grassed	95%	
Earth	0%	

Water quality: (scums, water clarity, algae, mosquitoes, pH, EC?) Fairly turbid, green

pH = 8.86 EC = [illegible] mS

Ducks [illegible]

Vegetation Type(s) adjacent to lake - (annotate with numbers) (1) Palm trees (2) native reeds in [illegible] areas (3) a few native trees

Other Comments:

The Duck Pond - Photographic Plates

PLATE 1 – Western edge of lake facing south.

PLATE 2 – Waterfall.

The Duck Pond - Photographic Plates

PLATE 3 – Aerator (not operational).

PLATE 4 – View of lake facing west to east with warning sign not to feed ducks.

The Duck Pond - Photographic Plates

PLATE 5 – View of lake from south to north.

PLATE 6 – Wet well and pump used to extract water for irrigation from the lake.

Murray River Country Estate

- Murray River Country Estate South Lake
- Murray River Country Estate Central Lake

Murray River Country Estate Lakes – Summary Report

The first two lakes (South and Central Lakes) in the chain of 13 connected lakes within the Murray River Country Estate development in Pinjarra were examined in this study. Both lakes collect sub-soil drainage in addition to surface run off from the housing area to the west. The most southern lake also collects drainage from the public golf course to the west and is possibly connected to the lakes within the golf course. Further residential development is proposed around the lakes.

Water is extracted from the southern lake throughout most of the year apart from the wetter winter months, for irrigation of a golf course, public open space and landscaping within the estate. To replace the water extracted for irrigation the Central Lake is topped up with bore water extracted from the Leederville aquifer. The lakes have experienced problems with dead reeds blocking up channel between south and central lake and erosion of limestone weir systems.

Previous Studies/ Monitoring:

Douglas Partners (2005) *Report on Strategic Acid Sulphate Soils Investigation*: *Murray River Country Estate*

ENV (2007) *Murray River Country Estate Wetland Management Category Reclassification*

Ecoscape (2006) *Murray River Country Estate Outline Development Report Environmental Section*

Ecoscape (2006) *Murray River Country Estate Wetland Assessment*

Hydroplan (2008) *Aquifer Review Report July 2006 to June 2007 for Murray River Country Estate*

JDA Consulting Hydrologists (2006) *Murray River Country Estate Groundwater Assessment*

Le Provost Dames and Moore (1995) *Ravenswood Sanctuary Environmental Design and Management Study*

Le Provost Dames and Moore (1995) *Ravenswood Sanctuary Resort Nutrient and Irrigation Management Plan*

Le Provost Dames and Moore (1998) *Ravenswood Sanctuary Foreshore Management Plan*

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Murray River Country Estate South Lake**

1. Basic Details	
Location (street and suburb)	Sutton St, Pinjarra
Location (coordinates)	6391138.5 N, 393479.1 E
2007 Streetsmart page number	793, A8
Local Government	Shire of Murray
Owner	Murray Riverside
Function*	D, I, A
Age (years)	~12
2. Physical Features	
Lining (y/n)	N
Area (ha)	~ 2.17
Shape (eg. linear, round, irregular)	Linear (wider to the south)
Depth range (estimate) (m)	> 1m
"Naturalness" rating (1 to 5)*	3
Social amenity value (High, Medium, Low)	Low (most likely increase when residents move into the development)
Edging (eg. wall, trees, reeds, sloping banks, turf)	Vegetated (70%) sedged, grassed (30%), sloping grass banks
Vegetation type adjacent to lake*	N. Sedges - *Juncus krausii* and several other species, *Typha* , *Casuarina* , (sparse) paperbacks/*Eucalyptus* - flooded gum (some planted some appear to be natural remnant), planted shrubs (landscaping) e.g. bottlebrush
Vegetation condition adjacent to lake*	P-F
Potential acid sulfate soil (ASS) risk (according to ASS risk map)	Moderate to low risk of ASS occuring within 3 m of the natural soil surface

* Notes:

Function
D - Drainage
C - Conservation
A - Aesthetic (and recreational)
I - Irrigation Storage

Naturalness rating
1 - Highly ornamental
2 - Mostly ornamental with some natural features
3 - Some ornamenatal and some natural features
4 - Natural or natural like with some ornamental features
5 - Natural or natural like with some ornamental features

Vegetation type
N - Native
X - Exotic

Vegetation condition
P - Poor
F- Fair
G - Good
E - Excellent

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Murray River Country Estate South Lake**

3. Catchment and Hydrology	
Catchment type (eg. industrial, residential)	Residential
Prior land use	Farmland
Catchment size (ha)	ND
Geology (unit)	Thin Bassendean Sand over Guildford Formation (Qpb/Qpa)/ Bassendean Sand (Qpb)
(Description)	S8 - SAND - white to pale grey at surface, yellow at depth, fine to medium grained, moderately sorted, subangular to subrounded, minor heavy minerals, of aeolian origin over SANDY CLAY (Sc) to CLAYEY SAND (Cs) of the Guildford Formation, of aeolian origin
No. Inlets	3
Inlet Volume/ Size	ND
No. Outlets	1 (to central lake)
Outlet Volume/ Size	ND
Drainage Connection Flow through (FT) or End Point (EP) or No Drainage (NDr)	FT
Approximate volume of water extracted for irrigation	229,256 kL between June 2006 and July 2007
Water level top up (y/n)?	N - Central Lake to north is topped up with bore water
Estimated residence time	ND
Water or nutrient balance undertaken (y/n)?	N
4. Management	
Aeration/agitation present/absent?	Present
Aeration type if present* How many?	2 (possible fountains) - not operating at time of site visit
Fertiliser application adjacent to lake (y/n)?	Y - Bailey's blended variety, no phosphate, trace elements, low nitrogen levels
Irrigation adjacent to lake (y/n)?	Y - lake water
Lawn mowing/ weed control	ND
Management problems*	12 - Dead reeds (*Juncus krausii*) blocking up channel between south and central lake, weir systems eroding - water corrodes limestone
Maintenance and effectiveness	Removal of dead reeds, propose to rebuild weirs
Monitoring frequency	Not monitored

* Notes:

Aeration Features
F - Fountain
R - Rocks/waterfall
C - Circulation by pumping
A - Submerged Aerator

ND - Data not available within timeframe of study
NA - Not applicable

Management Problems
1. Flooding
2. Drying Out
3. Slow inflitration
4. Odour
5. Nuisance algal growth
6. Fish deaths
7. Bird deaths
8. Mosquitos or midges
9. Acid Sulfate Soils
10. Iron Monosulfides
11. Feral Fish
12. Other (describe)

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Murray River Country Estate South Lake**

5. Water Quality (if known)	
Total Nitrogen (µ/L)	ND
Total Phosphorus (µ/L)	ND
Chlorophyll *a* (µg/L)	ND
pH	7.58*
EC (mS)	1.27*
TDS (ppt)	0.63*
Temperature (°C)	19.3*
Algae/ aquatic plants, water clarity	Fairly clear although tannin stained - gives water a dark appearance.*
6.Fauna	
Macroinvertebrates eg. midges and mosquitos	None observed during site visit.
Macrofauna	A few ducks (Pacific Black), muskovy duck, could hear occasional frog calls of clicking froglets and quacking frogs

Notes:

* Field pH, EC, TDS and temperature measured during site visit on 9/10/07. Observations of algae also recorded on this day.
ND - Data not available within timeframe of study

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Murray River Country Estate Central Lake**

1. Basic Details	
Location (street and suburb)	Sutton St, Pinjarra
Location (coordinates)	6391311.5 N, 393667.1 E
2007 Streetsmart page number	793, A8
Local Government	Shire of Murray
Owner	Murray Riverside
Function*	D, A
Age (years)	~12
2. Physical Features	
Lining (y/n)	N
Area (ha)	~ 0.82
Shape (eg. linear, round, irregular)	Linear/round
Depth range (estimate) (m)	> 1m
"Naturalness" rating (1 to 5)*	3
Social amenity value (High, Medium, Low)	Low (most likely increase when residents move into the development)
Edging (eg. wall, trees, reeds, sloping banks, turf)	Vegetated (70%) sedged, grassed (30%) sloping grass banks
Vegetation type adjacent to lake*	N. Sedges - *Juncus krausii* and several other species, *Typha* , *Casuarina* , (sparse) paperbacks/*Eucalyptus* - flooded gum (some planted some appear to be natural remnant), planted shrubs (landscaping) e.g. bottlebrush
Vegetation condition adjacent to lake*	P-F
Potential acid sulfate soil (ASS) risk (according to ASS risk map)	Moderate to low risk of ASS occurring within 3 m of the natural soil surface

* Notes:

Function
D - Drainage
C - Conservation
A - Aesthetic (and recreational)
I - Irrigation Storage

Naturalness rating
1 - Highly ornamental
2 - Mostly ornamental with some natural features
3 - Some ornamenatal and some natural features
4 - Natural or natural like with some ornamental features
5 - Natural or natural like with some ornamental features

Vegetation type
N - Native
X - Exotic

Vegetation condition
P - Poor
F- Fair
G - Good
E - Excellent

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Murray River Country Estate Central Lake**

3. Catchment and Hydrology	
Catchment type (eg. industrial, residential)	Residential
Prior land use	Farmland
Catchment size (ha)	ND
Geology (unit)	Thin Bassendean Sand over Guildford Formation (Qpb/Qpa)/ Bassendean Sand (Qpb)
(description)	S8 - SAND - white to pale grey at surface, yellow at depth, fine to medium grained, moderately sorted, subangular to subrounded, minor heavy minerals, of aeolian origin over SANDY CLAY (Sc) to CLAYEY SAND (Cs) of the Guildford Formation, of aeolian origin
No. inlets	3 - 2 stormwater inlets plus overflow through from southern lake
Inlet volume/size	ND
No. outlets	1 (to northern lake)
Outlet volume/size	ND
Drainage connection flow through (FT) or End Point (EP) or No Drainage (NDr)	FT
Approximate volume of water extracted for irrigation	0
Water level top up (y/n)?	Y - topped up with borewater from Leederville aquifer to replace water taken from southern lake (180, 792 kL between June 2006 and July 2007)
Estimated residence time	ND
Water or nutrient balance undertaken (y/n)?	N
4. Management	
Aeration/agitation present/absent?	Present
Aeration type if present* How many?	2 (possible fountains) - not operating at time of site visit
Fertiliser application adjacent to lake (y/n)?	Y - Bailey's blended variety, no phosphate, trace elements, low nitrogen levels
Irrigation adjacent to lake (y/n)?	Y - using water from South Lake
Lawn mowing/ weed control	ND
Management problems*	12 - Dead reeds (*Juncus krausii*) blocking up channel between south and central lake, weir systems eroding - water corrodes limestone
Maintenance and effectiveness	Removal of dead reeds, propose to rebuild weirs
Monitoring frequency	Not monitored

* Notes:

Aeration Features
F - Fountain
R - Rocks/waterfall
C - Circulation by pumping
A - Submerged Aerator

Management Problems
1. Flooding
2. Drying Out
3. Slow infiltration
4. Odour
5. Nuisance algal growth
6. Fish deaths
7. Bird deaths
8. Mosquitos or midges
9. Acid Sulfate Soils
10. Iron Monosulfides
11. Feral Fish
12. Other (describe)

ND - Data not available within timeframe of study
NA - Not applicable

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Murray River Country Estate Central Lake**

5. Water Quality (if known)	
Total Nitrogen (µ/L)	NT
Total Phosphorus (µ/L)	NT
Chlorophyll *a* (µg/L)	NT
pH	7.67*
EC (mS)	1.12*
TDS (ppt)	0.56*
Temperature (°C)	19.2*
Algae/ aquatic plants, water clarity	Fairly clear although tannin stained - gives water a dark appearance*
6.Fauna	
Macroinvertebrates eg. midges and mosquitos	None observed during site visit.
Macrofauna	A few ducks (Pacific Black), muskovy duck, could hear occasional frog calls, clicking froglets, quacking frog.

Notes:

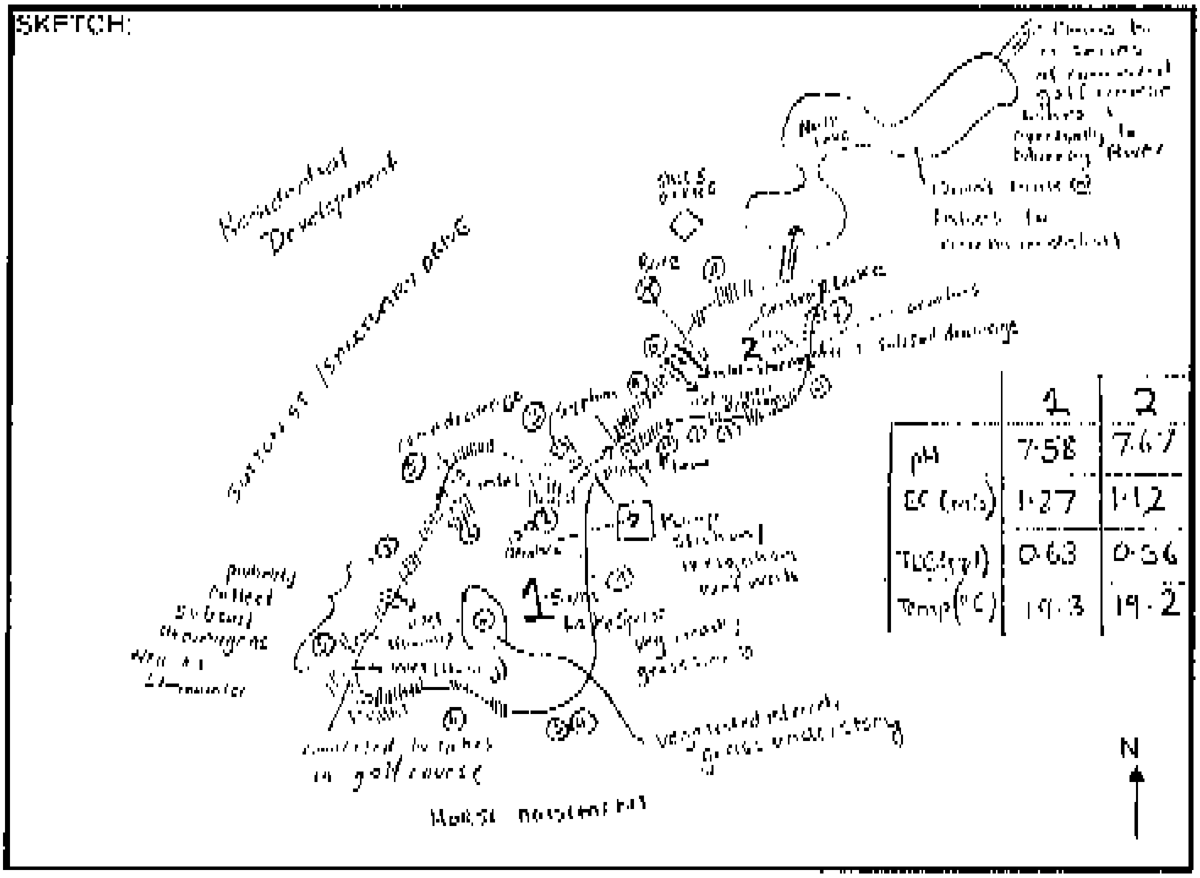
* Field pH, EC, TDS and temperature measured during site visit on 9/10/07. Observations of algae also recorded on this day.

Constructed Lake Study
Field Survey Form

Lake Name and Location: **Murray River Country Estate, Pinjarra** (South and Central Lake)

Date: 9/10/2007 Recorded By: Bronwyn Woodward

SKETCH:



	1	2
pH	7.58	7.67
EC (mS)	1.27	1.12
TDS (g/l)	0.63	0.56
Temp (°C)	19.3	19.2

Water Level (mark location of staff gauges): None Located

Estimated Depth of Water: ? >1m

Lake Edge % Notes

Walled

Vegetated 70 Sedges (see notes)

Grassed 30 Sloping grass borders

Earth

Water quality: (scums, water clarity, algae, mosquitoes, pH, EC?) Fairly clear although

tannin stained groundwater - a dark appearance

Fauna: A few ducks (mainly black), musk duck sound heard in reeds (Chicken Frogs?)

Vegetation Type(s) adjacent to lake - (annotate with numbers) ① Sedges + Juncus kraussii & several other species

② Typha ③ Casuarina ④ (Spanish) paperbark / Melaleuca - (planted gum?)

Some planted grass species - below - dominant

⑤ Planted shrubs (landscaping) eg bottlebrush

Other Comments:

Murray River Country Estate Lakes - Photographic Plates

PLATE 1 – Suspected sub-soil drainage flowing into the South Lake.

PLATE 2 – Connection between South Lake and Central Lake.

Satterley

- Brighton Central Lake
- Dalyellup Central Park North Lake
- Dalyellup Fountain Lake

Brighton Central Lake – Summary Report

The Brighton Central Lake was constructed c. 2000 by Satterley within a beach side residential development in the City of Wanneroo. The lake has a highly ornamental appearance and is valued by the community for is scenic and recreational value. Many members of the public also feed the large numbers of birds the lake attracts.

The lake manager was not certain if the lake receives drainage however it is used for irrigation of surrounding park land and topped up with bore water. Recently the lake water has turned turbid, and a greenish brown colour, indicating algal blooms are present. Short-lived algal problems have been reported in the lake in the past. The lake has also experienced problems with calcium from bore water top up clogging the irrigation system and rubbish build up.

Previous Studies/ Monitoring:

No previous studies or monitoring records were located.

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Brighton Central Lake**

1. Basic Details	**Section A**	**Section B**	**Section C**
Location (street and suburb)	Kingsbridge Bvd, Brighton		
Location (coordinates)	6497831.7 N, 376800.2 E		
2007 Streetsmart page number	159, A5		
Local Government	City of Wanneroo		
Owner	City of Wanneroo		
Function*	A, possibly D	A, possibly D	A, I, possibly D
Age (years)	6 to 7 years		
2. Physical Features	**Section A**	**Section B**	**Section C**
Lining (y/n)	Yes PVC liner with sand cover		
Area (ha)	~0.6824	~0.74282	~0.2181
Shape (eg. linear, round, irregular)	Round	Linear/round	Round
Depth range (estimate) (m)	~ 0.3	> 1m	> 1m
"Naturalness" rating (1 to 5)*	1-2		
Social amenity value (High, Medium, Low)	High		
Edging (eg. wall, trees, reeds, sloping banks, turf)	Walled (100%) limestone blocks	Walled (20%) limestone blocks, vegetated (25%) broadleaf rush, grassed (55%) sloping grass banks	Walled (25%) limestone blocks, vegetated (5%) shrubs, grassed (70%) sloping grass banks
Vegetation type adjacent to lake*	Artificial landscaping -ornamental trees (mainly European deciduous species), shrubs, conifers, *Allocasuarina* , broadleaved rush, bottlebrush, *Eucalyptus* , palm trees, native sedges - possibly *Baumea* , *Typha* at outlet		
Vegetation condition adjacent to lake*	G		
Potential acid sulfate soil (ASS) risk (according to ASS risk map)	No known risk of ASS occurring within 3 m of the natural soil surface (or deeper)		

* Notes:

Function
D - Drainage
C - Conservation
A - Aesthetic (and Recreational)
I - Irrigation Storage

Naturalness rating
1 - Highly ornamental
2 - Mostly ornamental with some natural features
3 - Some ornamenatal and some natural features
4 - Natural or natural like with some ornamental features
5 - Natural or natural like with some ornamental features

Vegetation Condition
P - Poor
F- Fair
G - Good
E - Excellent

Lake manager was not sure if the lake was connected to drainage

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Brighton Central Lake**

3. Catchment and Hydrology	**Section A**	**Section B**	**Section C**
Catchment type (eg. industrial, residential)	Residential		
Prior land use	ND		
Catchment size (ha)	ND		
Geology (unit)	Safety Bay Sand (Qhs)/ Tamala Limestone (Qtl)		
(Description)	S2 - CALCAREOUS SAND - white fine to medium grained, sub rounded quartz and shell debris, of aeolian origin/ LS_1 - LIMESTONE - light yellowish brown, fine to coarse grained, sub-angular to well rounded quartz, trace of feldspar, shell debris, variably lithified, surface kankar, of aeolian origin		
No. Inlets	ND	at least 1 (overflow from section A)	at least 1 (overflow from section B)
Inlet Volume/ Size	ND	ND	ND
No. Outlets	1 (to section B)	1 (to section C)	2
Outlet Volume/ Size	ND	ND	ND
Drainage Connection Flow through (FT) or End Point (EP) or No Drainage (NDr)	FT		
Approximate volume of water extracted for irrigation	0	0	1.8 ML per night during summer period
Water level top up (y/n)?	Y (topped up with bore water from the superficial aquifer)		
Estimated residence time	ND	ND	ND
Water or nutrient balance undertaken (y/n)?	N		
4. Management	**Section A**	**Section B**	**Section C**
Aeration/agitation present/absent?	Present	Present	Absent
Aeration type if present* How many?	2F, C	1F, 1A	NA
Fertiliser application adjacent to lake (y/n)?	ND		
Irrigation adjacent to lake (y/n)?	Y (extracted from section C)		
Lawn mowing/ weed control	Grass appears to be mowed regularly - clippings were not being collected and were going into lake (10/10/07)		
Management problems*	5. Algal problems in ~2003 and an algal bloom in section C in 2005. Calcium clogging in in the irrigation system, rubbish blowing/being thrown into the lake		
Maintenance and effectiveness	A recirculation system and submerged aerator were installed at Brighton Central Lake to oxygenate the water to treat algal problems however recently the water has been fairly turbid and green/brown in colour. The algal bloom in 2005 was treated with bore clean.		
Monitoring frequency	The water was tested for algal concentrations in spring 2007 however the results were not available.		

* Notes:

Aeration Features
F - Fountain
R - Rocks/waterfall
C - Circulation by pumping
A - Submerged Aerator

Management Problems
1. Flooding
2. Drying Out
3. Slow infiltration
4. Odour
5. Nuisance algal growth
6. Fish deaths
7. Bird deaths
8. Mosquitos or midges
9. Acid Sulfate Soils
10. Iron Monosulfides
11. Feral Fish
12. Other (describe)

ND - Data not available within timeframe of study
NA - Not applicable

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Brighton Central Lake**

5. Water Quality (if known)	**Section A**	**Section B**	**Section C**
Total Nitrogen (µ/L)	NT	NT	NT
Total Phosphorus (µ/L)	NT	NT	NT
Chlorophyll *a* (µg/L)	NT	NT	NT
pH	8.27*	8.48*	8.59*
EC (mS)	0.83*	0.81*	0.79*
TDS (ppt)	0.41*	0.4*	0.39*
Temperature (°C)	19.5*	19.7*	20*
Algae/ aquatic plants, water clarity	Green/brown and turbid indicating high phytoplankton levels, possibly *Cylindrospermopsis raciborskii* .*		
6.Fauna			
Macroinvertebrates eg. midges and mosquitos	None observed.		
Macrofauna	Numerous well fed Pacific Black Ducks and ducklings (population growth appears high), other ducks, white goose with red beak, seagulls		

Notes:

* Field pH, EC, TDS and temperature measured during site visit on 10/10/07. Observations of algae also recorded on this day.
NT = Not tested

Constructed Lake Study
Field Survey Form

Lake Name and Location: Central Lake, Brighton

Date: 10/10/2007 Recorded By: Bronwyn Woodward

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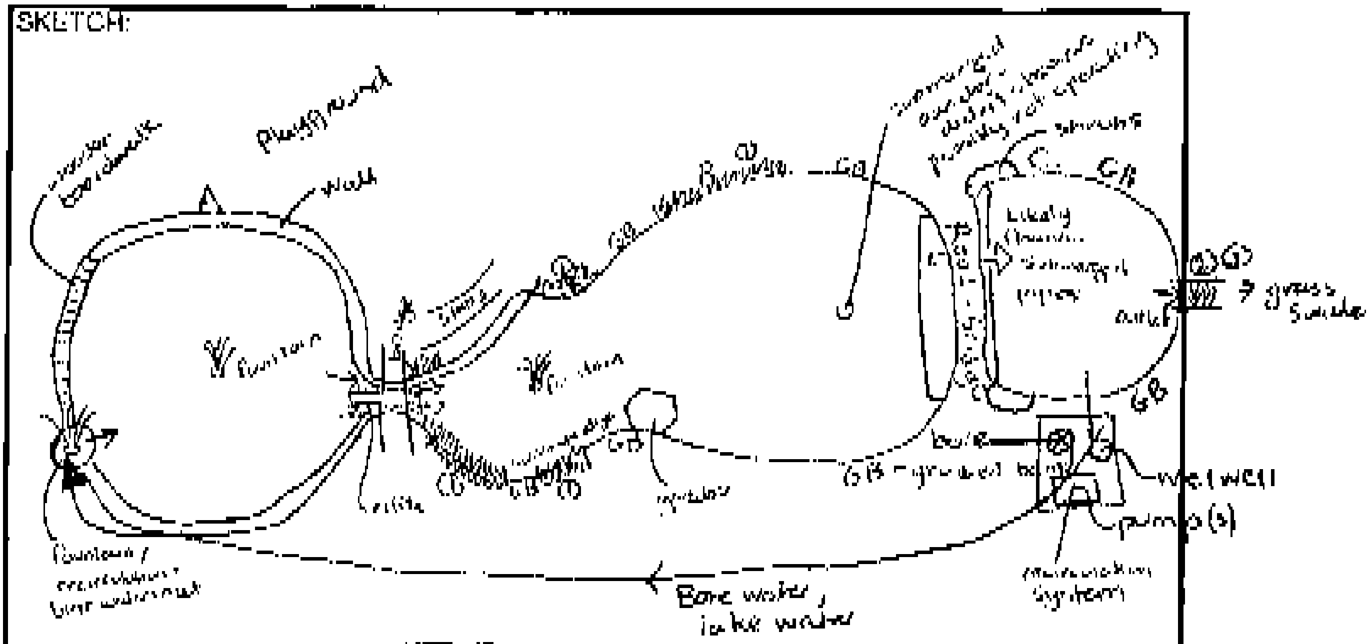

	A	B	C
pH	8.27	8.48	8.59
EC (mS)	0.63	0.81	0.79
TDS (ppt)	0.41	0.40	0.39
Temp (°C)	19.5	19.7	20.0

Water Level (mark location of staff gauges): None located

Estimated Depth of Water: A shallower ~0.3m B&C deeper than A [illegible]

Lake Edge	A %	B %	C %	overall	Notes
Walled	100	20	25		limestone blocks
Vegetated	0	25	5	~10	broadleaf rush (B), shrubs (C)
Grassed	0	55	70		sloping grass banks
Earth	0	0	0		

Water quality: (scums, water clarity, algae, mosquitoes, pH, EC?) green coloured + turbid indicating high phytoplankton levels possibly Cylindrospermopsis [illegible]

Fauna: numerous (Wild) Pacific Black Ducks, [illegible]

Vegetation Type(s) adjacent to lake - (annotate with numbers) ornamental landscaping - [illegible]

shrubs, [illegible], casuarina, broadleaf rush (1), [illegible], palm trees

(2) native sedge - baumea? (3) typha (cattail)

Other Comments:

Brighton Central Lake - Photographic Plates

PLATE 1 – Bore water and lake water is recirculated from the eastern side of the lake and discharges through a fountain on the western side.

PLATE 2 – Middle section of the lake facing west.

Brighton Central Lake - Photographic Plates

PLATE 3 – Birds gathering on the southern bank of the lake.

PLATE 4 – Greenish brown water observed in the lake in October 2007.

Dalyellup Lakes – Summary Report

The entry lake (Fountain Lake) and the most northern lake (Central Park North Lake) in a chain of three lakes in Satterley's Dalyellup Beach Estate were examined in this study. Fountain Lake receives road drainage from the estate as well as overflow from the northern lake and irrigates a small surrounding landscaped area. It has not recorded any management problems.

Central Park North Lake is an unlined irrigation lake that is topped up with bore water. The lake has experienced problems with the precipitation of iron and calcium from the bore water top up. Bore water is now directed through a bubbleup/rip rap system designed to strip iron prior to entering the lake.

Previous Studies/ Monitoring:

JDA Consultant Hydrologists completed some studies relating to water management at the Dalyellup Beach Estate however the reports were not made available within the timeframe of the study.

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Dalyellup Beach Central Park North Lake**

1. Basic Details	
Location (street and suburb)	near Bussell Highway
Location (coordinates)	6303776.3 N, 371053.9 E
2007 Streetsmart page number	Map 35
Local Government	Shire of Capel
Owner	Satterley
Function*	I & A
Age (years)	~ 7
2. Physical Features	
Lining (y/n)	N
Area (ha)	2.5 (@ average level)
Shape (eg. linear, round, irregular)	linear, irregular
Depth range (estimate) (m)	~3.5-4 (max)
"Naturalness" rating (1 to 5)*	3
Social amenity value (High, Medium, Low)	Medium to High
Edging (eg. wall, trees, reeds, sloping banks, turf)	95% vegetated, 5% earth (a few bare patches between vegetation)
Vegetation type adjacent to lake*	N - Natural remnant of tuart forest and mature paperbarks to west of lake, sedges (appear dominated by one species), X - *Typha* , planted plane trees and *Eucalypts*
Vegetation condition adjacent to lake*	G
Potential acid sulfate soil (ASS) risk (according to ASS risk map)	High to moderate/moderate to low risk of ASS occurring within 3 m of the natural soil surface

* Notes:

Function
D - Drainage
C - Conservation
A - Aesthetic (and Recreational)
I - Irrigation Storage

Naturalness rating
1 - Highly ornamental
2 - Mostly ornamental with some natural features
3 - Some ornamenatal and some natural features
4 - Natural or natural like with some ornamental features
5 - Natural or natural like with some ornamental features

Vegetation Type
N - Native
X - Exotic

Vegetation Condition
P - Poor
F- Fair
G - Good
E - Excellent

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Dalyellup Beach Central Park North Lake**

3. Catchment and Hydrology	
Catchment type (eg. industrial, residential)	Residential
Prior land use	Vegetated sand dunes
Catchment size (ha)	ND
Geology (unit)	Safety Bay Sand (Qhs)/ Swamp Deposits (Qhw)
(Description)	Calcareous quartz sand dunes/ peaty sand
No. Inlets	4
Inlet Volume/ Size	Stormwater inlet ~ 0.5m diameter
No. Outlets	1
Outlet Volume/ Size	ND
Drainage Connection Flow through (FT) or End Point (EP) or No Drainage (NDr)	ND
Approximate volume of water extracted for irrigation	110,000 kL/yr (currently) ~180,000kL/yr (expected at full development of Dalyellup Beach)
Water level top up (y/n)?	Y - topped up with bore water (50 to 100% water extracted for irrigation depending on rainfall)
Estimated residence time	ND
Water or nutrient balance undertaken (y/n)?	ND
4. Management	
Aeration/agitation present/absent?	Present
Aeration type if present* How many?	1R - Bore water directed through bubbleup/ rip rap system (see below)
Fertiliser application adjacent to lake (y/n)?	Y. Grassed areas are fertilised with Bailey's 411 and Brilliance (phosphate free) in spring summer and autumn. A couple of applications of urea in winter.
Irrigation adjacent to lake (y/n)?	Y - irrigated with lake water
Lawn mowing/ weed control	Spraying of weeds within turf areas
Management problems*	None recorded apart from bore water being rich in iron and calcium
Maintenance and effectiveness	No special maintenance has been require apart from directing bore water through bubbleup/rip rap system designed to strip iron
Monitoring frequency	Possibly monitored by JDA

* Notes:

Aeration Features
F - Fountain
R - Rocks/waterfall
C - Circulation by pumping
A - Submerged Aerator

ND - Data not available within timeframe of study
NA - Not applicable

Management Problems
1. Flooding
2. Drying Out
3. Slow infiltration
4. Odour
5. Nuisance algal growth
6. Fish deaths
7. Bird deaths
8. Mosquitos or midges
9. Acid Sulfate Soils
10. Iron Monosulfides
11. Feral Fish
12. Other (describe)

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Dalyellup Beach Central Park North Lake**

5. Water Quality (if known)	
Total Nitrogen (μ/L)	ND
Total Phosphorus (μ/L)	ND
Chlorophyll *a* (μg/L)	ND
pH	A = 8.20, B = 8.25*
EC (mS)	A = 1.17, B = 1.17*
TDS (ppt)	A = 0.59, B = 0.58*
Temperature (°C)	A = 25.3, B = 24.2*
Algae/ aquatic plants, water clarity	Fairly clear, slight green/brown tinge. Sand at the bottom has a very slight orange tinge. Looks slightly yellow in cup. Filamentous green algae present in the southern end of the lake.*
6.Fauna	
Macroinvertebrates eg. midges and mosquitos	Mosquitos breeding in flooded area
Macrofauna	Clicking froglets (could hear calls), moaning frog and other species that couldn't be identified, a few Eurasian coot, one grey duck with a dark head and smooth feathers, black ibis, large long beaked white bird black tipped tail, thousands of juvenile *Gambusia* observed

Notes:

* Field pH, EC, TDS and temperature measured at two locations (A and B) during site visit on 16/10/07. Observations of algae also recorded on this day.

ND - Data not available within timeframe of study

Constructed Lake Study
Field Survey Form

Lake Name and Location: Dalyellup Beach Central Park Lake 1

Date: 16/10/2007 Recorded By: Bronwyn Woodward

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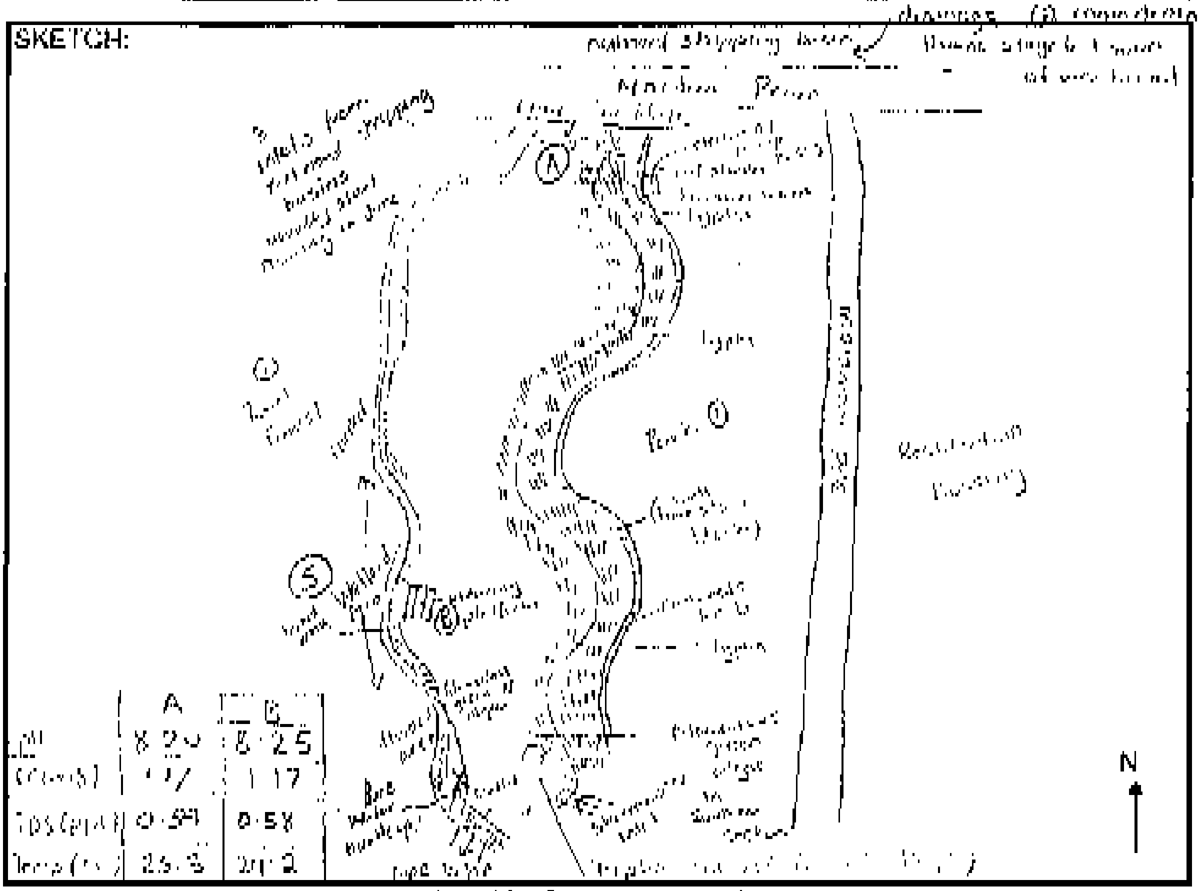

	A	B
pH	8.20	8.25
(Cond.)	1.17	1.17
TDS (ppt)	0.59	0.58
Temp (°C)	23.8	24.2

Water Level (mark location of staff gauges): None located

Estimated Depth of Water: [illegible] 20 [illegible], Max depth ~2-3m

Lake Edge	%	Notes
Walled		[illegible]
Vegetated	95	see below
Grassed		
Earth	5	a few bare earth patches

Water quality: (scums, water clarity, algae, mosquitoes, pH, EC?) [illegible]

[illegible]

Fauna: [illegible]

Vegetation Type(s) adjacent to lake - (annotate with numbers) (1) [illegible]

(2) [illegible]

[illegible]

Other Comments: [illegible]

[illegible]

[illegible]

[illegible]

[illegible] Sedges

[illegible]

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Dalyellup Beach Fountain Lake**

1. Basic Details	
Location (street and suburb)	cnr Dalyellup Boulevard and Norton Promenade, Dalyellup
Location (coordinates)	6303679.7 N, 372211.8 E
2007 Streetsmart page number	Map 35
Local Government	Shire of Capel
Owner	Satterley
Function*	I, A, D
Age (years)	~ 8
2. Physical Features	
Lining (y/n)	Y
Area (ha)	~0.1153
Shape (eg. linear, round, irregular)	Round
Depth range (estimate) (m)	~ 0.3 @ shore, ~ 1 max
"Naturalness" rating (1 to 5)*	1
Social amenity value (High, Medium, Low)	High (entry statement to housing estate)
Edging (eg. wall, trees, reeds, sloping banks, turf)	100% brick/concrete wall
Vegetation type adjacent to lake*	mix of X and N. Planted rushes and sedges, shrubs including young planted paperbarks, *Eucalypts*
Vegetation condition adjacent to lake*	F - sedges are dry and in poor condition
Potential acid sulfate soil (ASS) risk (according to ASS risk map	High to moderate/Moderate to low risk of ASS occurring within 3 m of the natural soil surface

* Notes:

Function
D - Drainage
C - Conservation
A - Aesthetic (and Recreational)
I - Irrigation Storage

Naturalness rating
1 - Highly ornamental
2 - Mostly ornamental with some natural features
3 - Some ornamenatal and some natural features
4 - Natural or natural like with some ornamental features
5 - Natural or natural like with some ornamental features

Vegetation Type
N - Native
X - Exotic

Vegetation Condition
P - Poor
F- Fair
G - Good
E - Excellent

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Dalyellup Beach Fountain Lake**

3. Catchment and Hydrology	
Catchment type (eg. industrial, residential)	Residential
Prior land use	Vegetated sand dunes
Catchment size (ha)	ND
Geology (unit)	Sand associated with Tamala Limestone (Qts)
(Description)	High dunes.
No. Inlets	2 - water from Central Park Lake 1 and one stormwater inlet
Inlet Volume/ Size	~ 0.5m x 0.4m rectangular bubble up
No. Outlets	0
Outlet Volume/ Size	NA
Drainage Connection Flow through (FT) or End Point (EP) or No Drainage (NDr)	EP
Approximate volume of water extracted for irrigation	ND
Water level top up (y/n)?	Y - currently topped up with water from Dalyellup Central Park Lake 1
Estimated residence time	ND
Water or nutrient balance undertaken (y/n)?	N
4. Management	
Aeration/agitation present/absent?	Present
Aeration type if present* How many?	2R
Fertiliser application adjacent to lake (y/n)?	Y. Grassed areas are fertilised with Bailey's 411 and Brilliance (phosphate free) in spring summer and autumn. A couple of applications of urea in winter
Irrigation adjacent to lake (y/n)?	Y - lake water
Lawn mowing/ weed control	Spraying of weeds within turf areas
Management problems*	None recorded
Maintenance and effectiveness	No special maintenance required
Monitoring frequency	Possibly monitored by JDA

* Notes:

Aeration Features
F - Fountain
R - Rocks/waterfall
C - Circulation by pumping
A - Submerged aerator

ND - Data not available within timeframe of study
NA - Not applicable

Management Problems
1. Flooding
2. Drying Out
3. Slow infiltration
4. Odour
5. Nuisance algal growth
6. Fish deaths
7. Bird deaths
8. Mosquitos or midges
9. Acid Sulfate Soils
10. Iron Monosulfides
11. Feral Fish
12. Other (describe)

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Dalyellup Beach Fountain Lake**

5. Water Quality (if known)	
Total Nitrogen (µ/L)	ND
Total Phosphorus (µ/L)	ND
Chlorophyll *a* (µg/L)	ND
pH	8.88*
EC (mS)	0.72*
TDS (ppt)	0.36*
Temperature (°C)	23.5*
Algae/ aquatic plants, water clarity	Green/brown scum/foam on eastern (downwind) side of lake. Rest of water very clear. Benthic water plant (*Myriophyllum*) growing on bed of lake, some benthic filamentous green algae attached to it.*
6.Fauna	
Macroinvertebrates eg. midges and mosquitos	None observed during site visit.
Macrofauna	A few ducks, juvenile *Gambusia*

Notes:

* Field pH, EC, TDS and temperature measured during site visit on 16/10/07. Observations of algae also recorded on this day.
ND - Data not available within timeframe of study

Constructed Lake Study
Field Survey Form

Lake Name and Location: **Dalyellup Beach** Fountain Lake

Date: 16/10/2007 Recorded By: Branwyn Woodward

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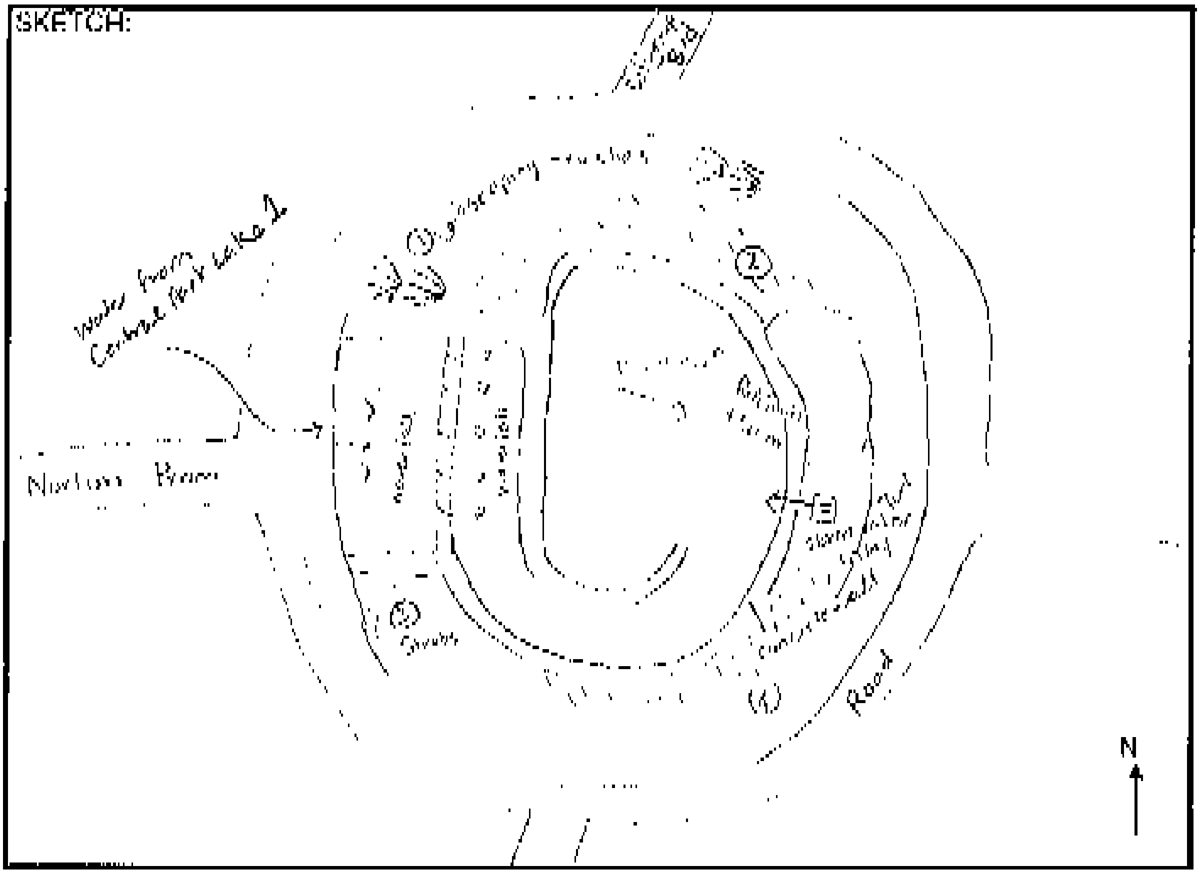

Water Level (mark location of staff gauges): None located

Estimated Depth of Water:

Lake Edge	%	Notes
Walled	100	concrete / brick
Vegetated		
Grassed		
Earth		

Water quality: (scums, water clarity, algae, mosquitoes, pH, EC?)

pH = 8.88 EC = 0.72 mS TDS = 0.36ppt Temp = 21.5°C

Fauna:

Vegetation Type(s) adjacent to lake - (annotate with numbers) (1) Planted rush (2) Planted sedges (3) Shrubs (4) Constructed lawns

Other Comments:

Dalyellup Lakes - Photographic Plates

PLATE 1 – View of Central Park North Lake facing north. Park visible to the east and natural remnants of paperbark wetland and tuart forest to the west.

PLATE 2 – Fountain Lake. Overflow from Central Park North Lake overflows via a water fall. The lake also receives drainage via the inlet visible in the foreground.

Vasse Felix

- Vasse Felix Winery Lake

Vasse Felix Winery Lake – Summary Report

The lake in the Vasse Felix Winery, Cowaramup was the only rural lake examined within this study. Other rural winery lakes in the south west were considered however permission was not granted by the owners to include them. The lake has been created by damming off a natural stream and is used to irrigate vineyards and turf. It also serves as an entry statement to the winery, which attracts a large number of tourists.

The lake has not experienced any major management problems although recently its water levels have been low in summer due to lower rainfall. The lake has still been able to supply sufficient water for irrigation even in the driest years. The drains flowing into the lakes from a car park and nearby paddocks have been blocked at times with overgrown kikuyu grass however this is managed by spraying.

Previous Studies/ Monitoring:

No previous studies or monitoring records were located.

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Vasse Felix Winery Lake**

1. Basic Details	
Location (street and suburb)	Corner Caves Road and Harmans South, Cowaramup
Location (coordinates)	6255789.7 N, 318958.1 E
2007 Streetsmart page number	Map 26, B4/C4
Local Government	Shire of Augusta-Margaret River
Owner	Holmes a Court Family
Function*	I, D
Age (years)	Old (~20)
2. Physical Features	
Lining (y/n)	N
Area (ha)	~ 1.5
Shape (eg. linear, round, irregular)	Triangular
Depth range (estimate) (m)	3.5 - 4 m
"Naturalness" rating (1 to 5)*	3-4
Social amenity value (High, Medium, Low)	Medium
Edging (eg. wall, trees, reeds, sloping banks, turf)	25% road, 25% vegetated (reeds), 40% grassed, 10% earth
Vegetation type adjacent to lake*	Trees (planted white gums, red gum and peppermint trees), tubular green reeds, young planted broadleaf paperbark
Vegetation condition adjacent to lake*	G
Potential acid sulfate soil (ASS) risk (according to ASS risk map)	Moderate to low risk/no known risk of ASS occurring within 3 m of the natural soil surface

* Notes:

Function
D - Drainage
C - Conservation
A - Aesthetic (and recreational)
I - Irrigation Storage

Naturalness rating
1 - Highly ornamental
2 - Mostly ornamental with some natural features
3 - Some ornamenatal and some natural features
4 - Natural or natural like with some ornamental features
5 - Natural or natural like with some ornamental features

Vegetation type
N - Native
X - Exotic

Vegetation condition
P - Poor
F- Fair
G - Good
E - Excellent

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Vasse Felix Winery Lake**

3. Catchment and Hydrology	
Catchment type (eg. industrial, residential)	Vineyard
Prior land use	ND
Catchment size (ha)	50 - 100
Geology (unit)	ND
(description)	ND
No. inlets	2
Inlet volume/size	ND
No. outlets	1 (to natural creek)
Outlet volume/size	ND
Drainage connection flow through (FT) or End Point (EP) or No Drainage (NDr)	FT
Approximate volume of water extracted for irrigation	~ 8 ML/yr
Water level top up (y/n)?	N
Estimated residence time	ND
Water or nutrient balance undertaken (y/n)?	N
4. Management	
Aeration/agitation present/absent?	Absent
Aeration type if present* How many?	NA
Fertiliser application adjacent to lake (y/n)?	Y, mineral fertiliser (to crops), sometimes folia fertiliser, have tried to minimise
Irrigation adjacent to lake (y/n)?	Y, irrigated vineyard
Lawn mowing/ weed control	spray kikuyu grass
Management problems*	12 some clogging/blocking of drains from dead kikuyu grass
Maintenance and effectiveness	Spraying of grass seems to be effective
Monitoring frequency	Not monitored

* Notes:

Aeration Features
F - Fountain
R - Rocks/waterfall
C - Circulation by pumping
A - Submerged aerator

ND - Data not available within timeframe of study
NA - Not applicable

Management Problems
1. Flooding
2. Drying Out
3. Slow infiltration
4. Odour
5. Nuisance algal growth
6. Fish deaths
7. Bird deaths
8. Mosquitos or midges
9. Acid Sulfate Soils
10. Iron Monosulfides
11. Feral Fish
12. Other (describe)

Constructed Lake Study
Summary of Lake Characteristics

Lake Name: **Vasse Felix Winery Lake**

5. Water Quality (if known)	
Total Nitrogen (µ/L)	NT
Total Phosphorus (µ/L)	NT
Chlorophyll *a* (µg/L)	NT
pH	7.80*
EC (mS)	0.67*
TDS (ppt)	0.33*
Temperature (°C)	20.6*
Algae/ aquatic plants, water clarity	Very clear water.*
6.Fauna	
Macroinvertebrates eg. midges and mosquitos	None observed during site visit.
Macrofauna	M. geese, Pacific Black ducks, Eurasian coot, could hear calls of clicking froglet

Notes:

* Field pH, EC, TDS and temperature measured during site visit on 18/10/07. Observations of algae also recorded on this day.
NT = Not tested

Constructed Lake Study
Field Survey Form

Lake Name and Location: Vasse Felix Winery Lake, Cowaramup

Date: 18/10/2007 Recorded By: Bronwyn Woodward

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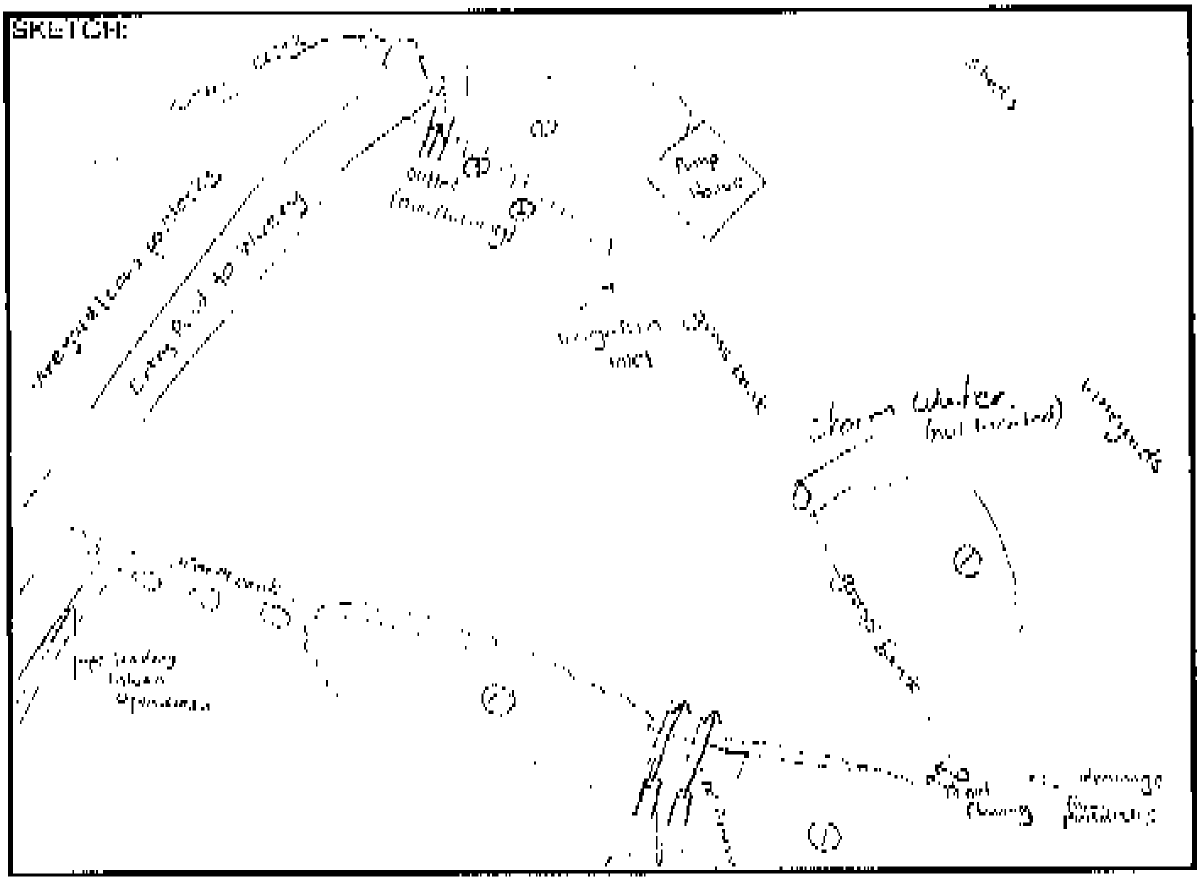


Water Level (mark location of staff gauges): Not located [illegible] max water level.

Estimated Depth of Water: 3.5-4 m [illegible]

Lake Edge	%	Notes
Walled	~ 25%	Sand
Vegetated	~ 25%	reeds etc. (see below)
Grassed	~ 40%	
Earth	~10%	

Water quality: (scums, water clarity, algae, mosquitoes, pH, EC?) [illegible] pH 7.80

EC = 0.67 mS TDS: 0.33 Temp: 20.6°C

Fauna: M[illegible] [illegible], Pacific Black Ducks, [illegible] [illegible] [illegible]

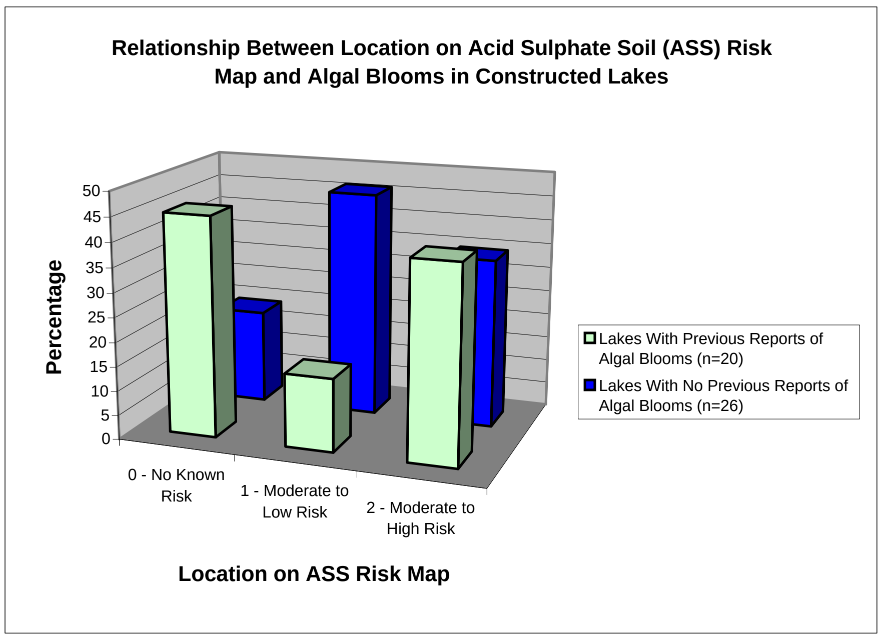
Vegetation Type(s) adjacent to lake - (annotate with numbers) (1) [illegible]

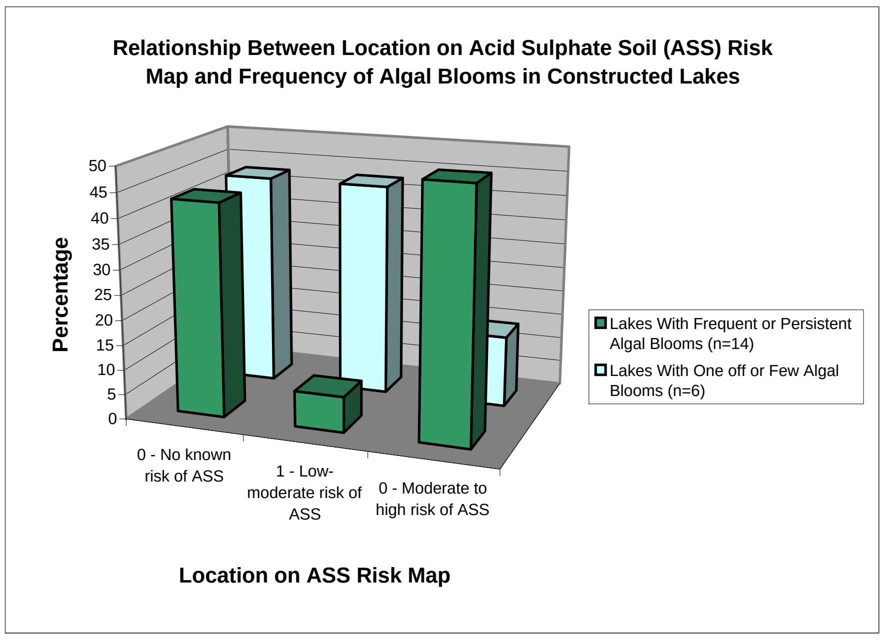
(2) Typha/ [illegible] reeds (3) Young planted broadleaf paperbark

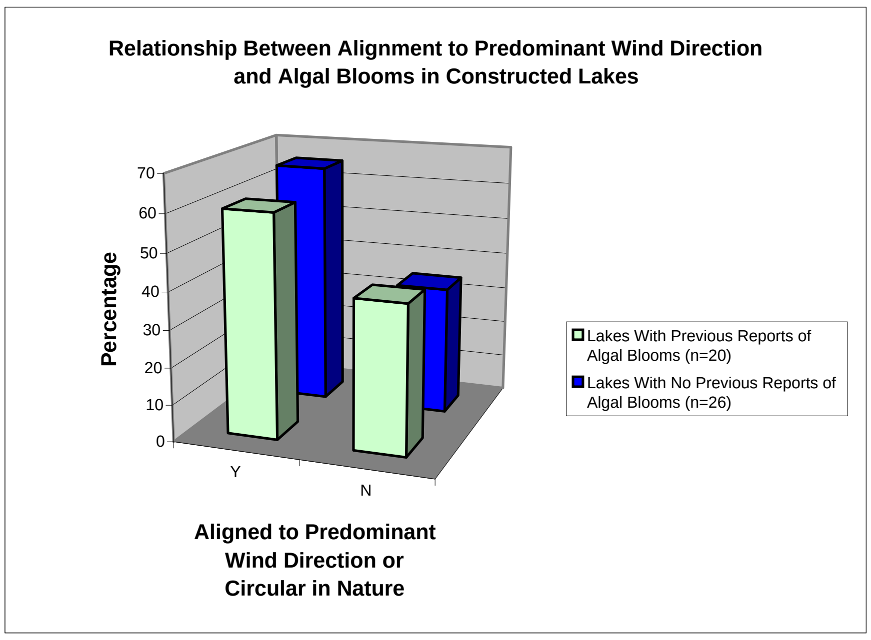
Other Comments: [illegible] [illegible] ML capacity

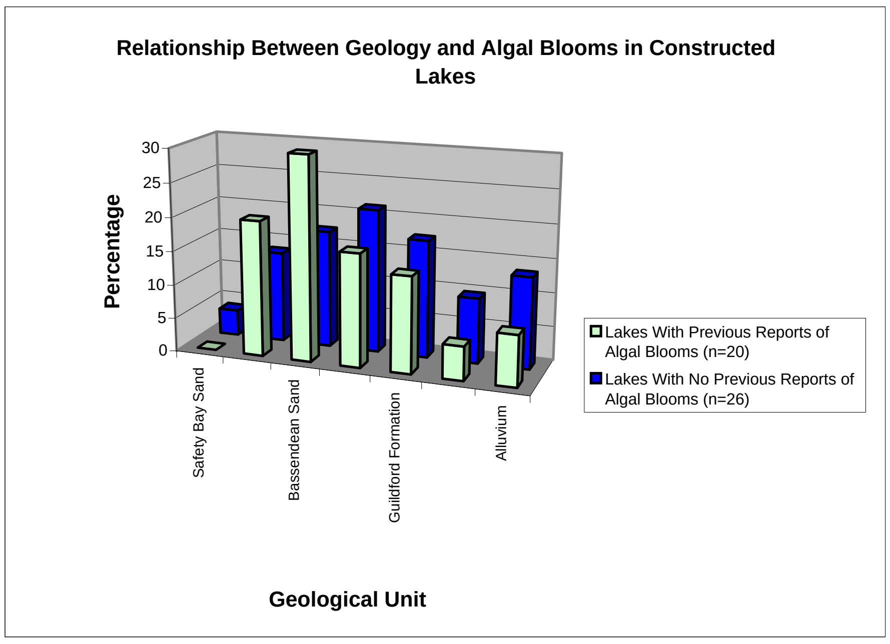
APPENDIX B

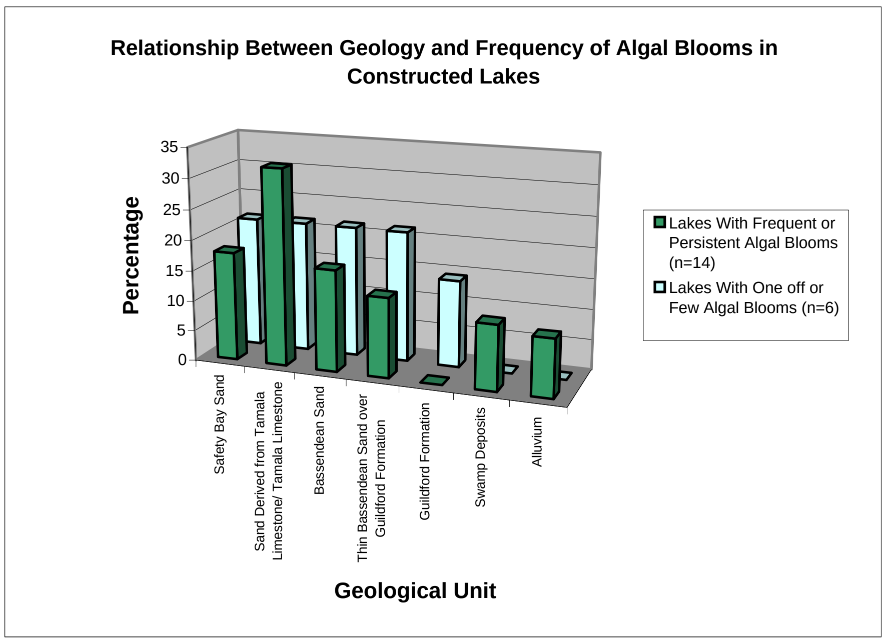
DATA ON LINK BETWEEN ALGAL BLOOMS, MIDGES AND MOSQUITOES AND LAKE DESIGN CHARACTERISTICS

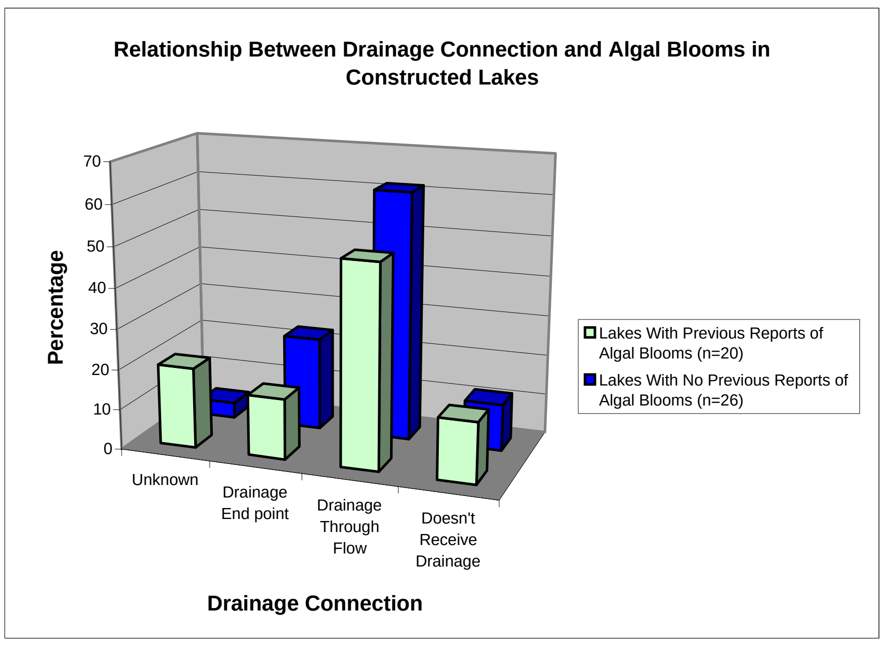

Relationship Between Location on Acid Sulphate Soil (ASS) Risk
Map and Algal Blooms in Constructed Lakes
Percentage
0
5
10
15
20
25
30
35
40
45
50
0 - No Known Risk
1 - Moderate to Low Risk
2 - Moderate to High Risk
Location on ASS Risk Map
Lakes With Previous Reports of Algal Blooms (n=20)
Lakes With No Previous Reports of Algal Blooms (n=26)

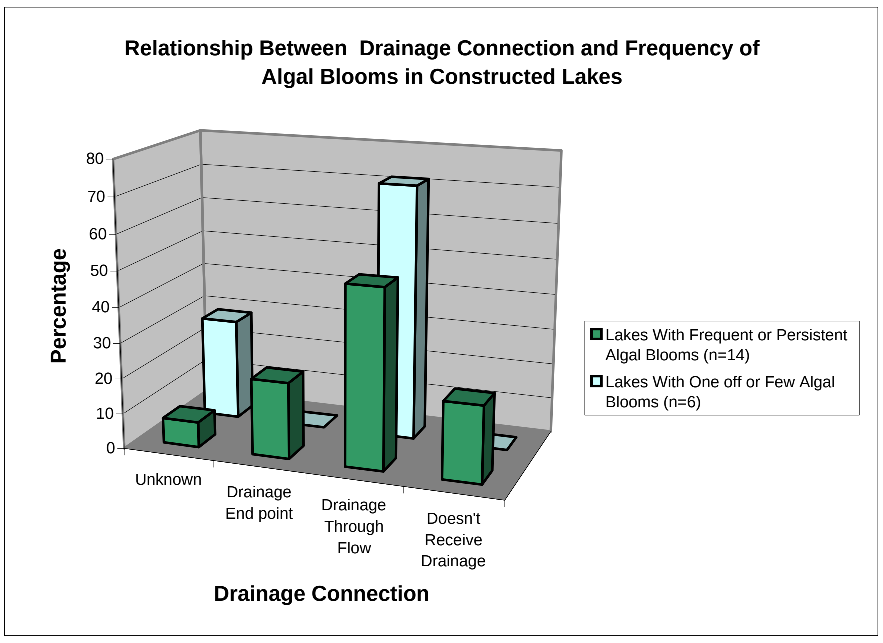

Relationship Between Location on Acid Sulphate Soil (ASS) Risk
Map and Frequency of Algal Blooms in Constructed Lakes
Percentage
0
5
10
15
20
25
30
35
40
45
50
0 - No known risk of ASS
1 - Low-moderate risk of ASS
0 - Moderate to high risk of ASS
Location on ASS Risk Map
Lakes With Frequent or Persistent Algal Blooms (n=14)
Lakes With One off or Few Algal Blooms (n=6)

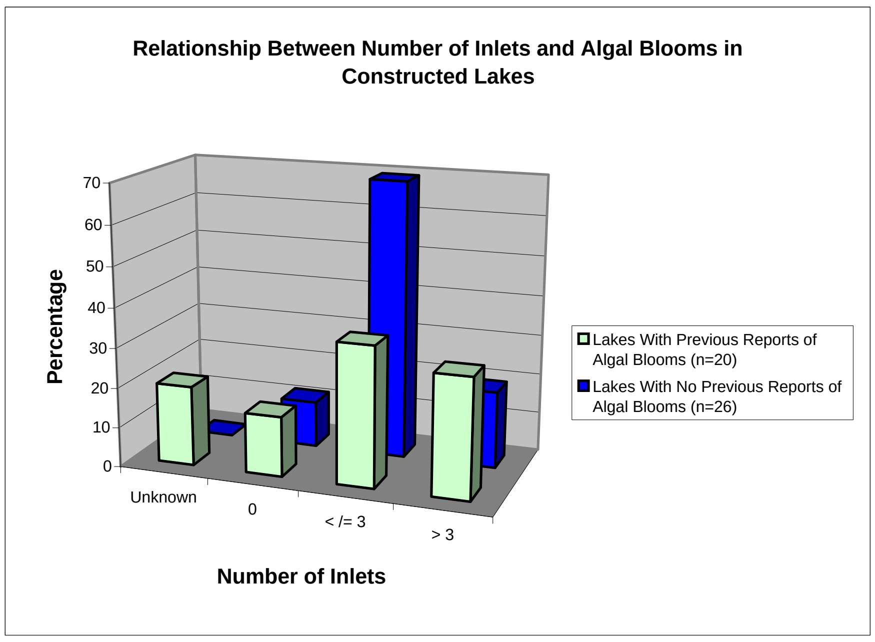

Relationship Between Alignment to Predominant Wind Direction
and Algal Blooms in Constructed Lakes
Percentage
0
10
20
30
40
50
60
70
Y
N
Aligned to Predominant
Wind Direction or
Circular in Nature
Lakes With Previous Reports of Algal Blooms (n=20)
Lakes With No Previous Reports of Algal Blooms (n=26)

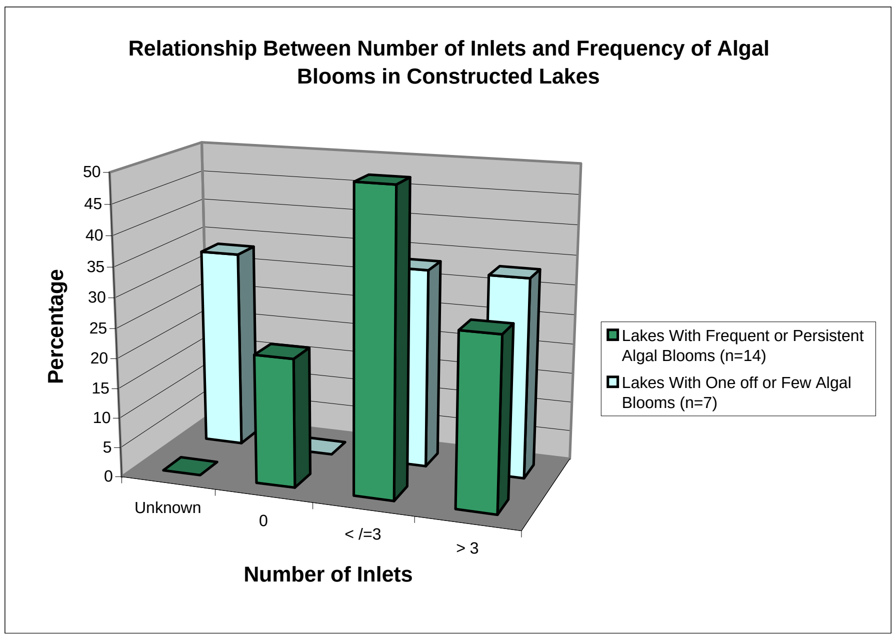

Relationship Between Geology and Algal Blooms in Constructed
Lakes
Percentage
0
5
10
15
20
25
30
Safety Bay Sand
Bassendean Sand
Guildford Formation
Alluvium
Geological Unit
Lakes With Previous Reports of Algal Blooms (n=20)
Lakes With No Previous Reports of Algal Blooms (n=26)

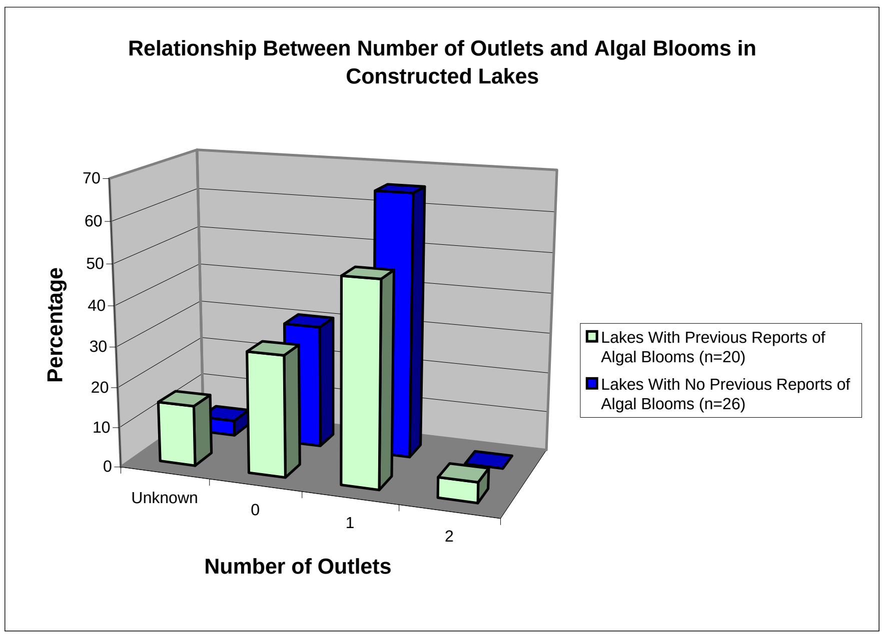

Relationship Between Geology and Frequency of Algal Blooms in
Constructed Lakes
Percentage
0
5
10
15
20
25
30
35
Safety Bay Sand
Sand Derived from Tamala Limestone/ Tamala Limestone
Bassendean Sand
Thin Bassendean Sand over Guildford Formation
Guildford Formation
Swamp Deposits
Alluvium
Geological Unit
Lakes With Frequent or Persistent Algal Blooms (n=14)
Lakes With One off or Few Algal Blooms (n=6)

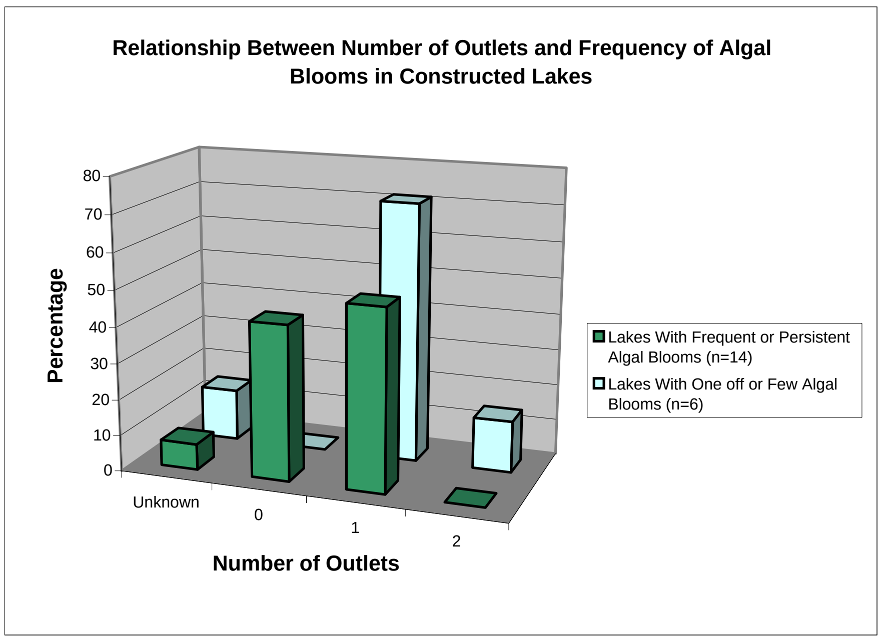

Relationship Between Drainage Connection and Algal Blooms in
Constructed Lakes
Percentage
0
10
20
30
40
50
60
70
Unknown
Drainage End point
Drainage Through Flow
Doesn't Receive Drainage
Drainage Connection
Lakes With Previous Reports of Algal Blooms (n=20)
Lakes With No Previous Reports of Algal Blooms (n=26)

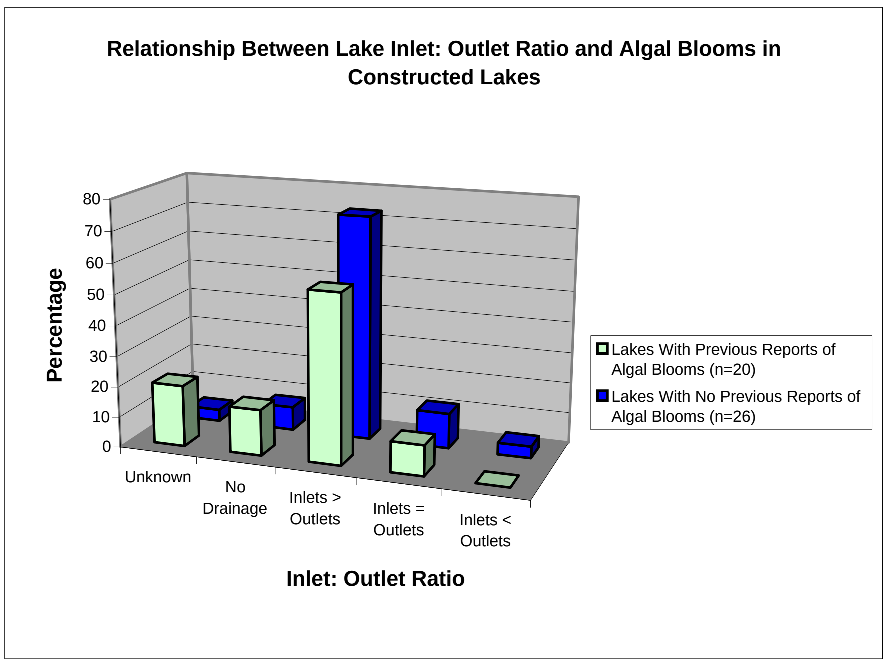

Relationship Between Drainage Connection and Frequency of
Algal Blooms in Constructed Lakes
Percentage
0
10
20
30
40
50
60
70
80
Unknown
Drainage End point
Drainage Through Flow
Doesn't Receive Drainage
Drainage Connection
Lakes With Frequent or Persistent Algal Blooms (n=14)
Lakes With One off or Few Algal Blooms (n=6)

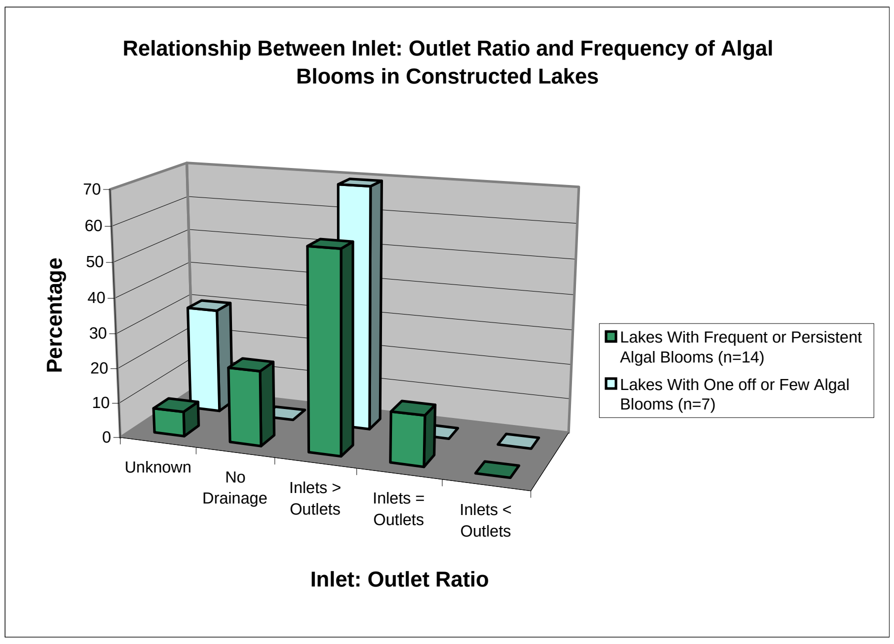

Relationship Between Number of Inlets and Algal Blooms in Constructed Lakes
Percentage
70
60
50
40
30
20
10
0
Unknown
0
< /= 3
> 3
Number of Inlets
Lakes With Previous Reports of Algal Blooms (n=20)
Lakes With No Previous Reports of Algal Blooms (n=26)

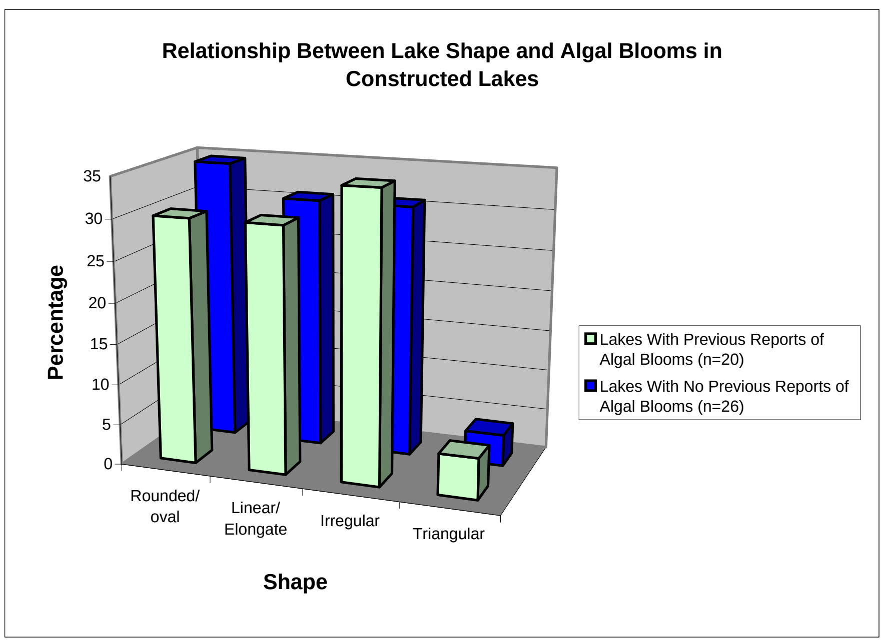

Relationship Between Number of Inlets and Frequency of Algal Blooms in Constructed Lakes
Percentage
50
45
40
35
30
25
20
15
10
5
0
Unknown
0
< /=3
> 3
Number of Inlets
Lakes With Frequent or Persistent Algal Blooms (n=14)
Lakes With One off or Few Algal Blooms (n=7)

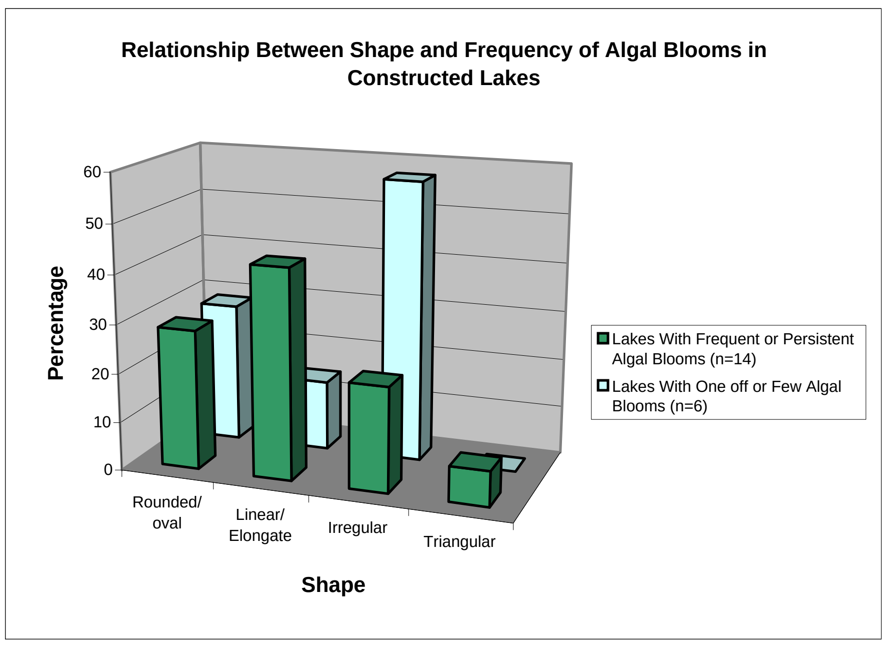

Relationship Between Number of Outlets and Algal Blooms in Constructed Lakes
Percentage
70
60
50
40
30
20
10
0
Unknown
0
1
2
Number of Outlets
Lakes With Previous Reports of Algal Blooms (n=20)
Lakes With No Previous Reports of Algal Blooms (n=26)

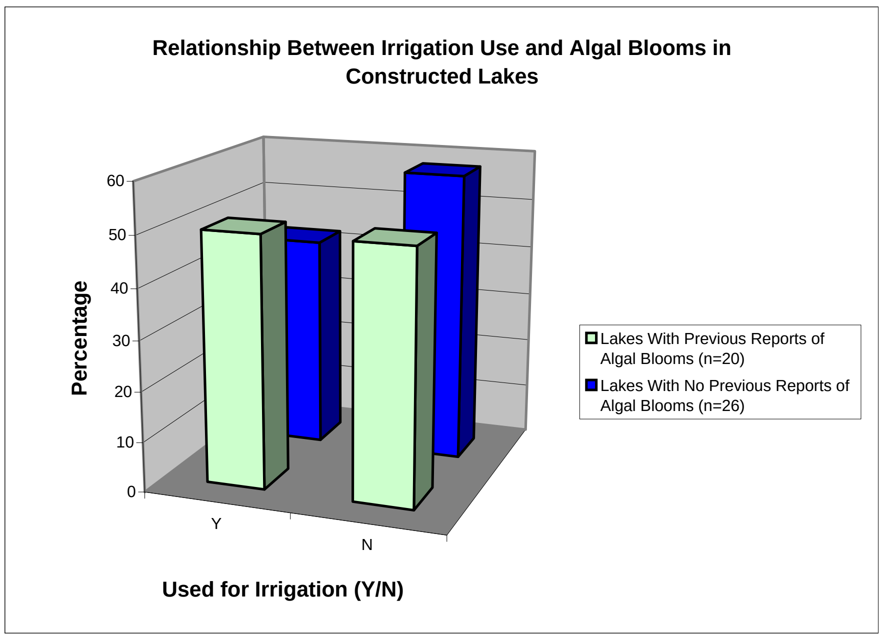

Relationship Between Number of Outlets and Frequency of Algal Blooms in Constructed Lakes
Percentage
80
70
60
50
40
30
20
10
0
Unknown
0
1
2
Number of Outlets
Lakes With Frequent or Persistent Algal Blooms (n=14)
Lakes With One off or Few Algal Blooms (n=6)

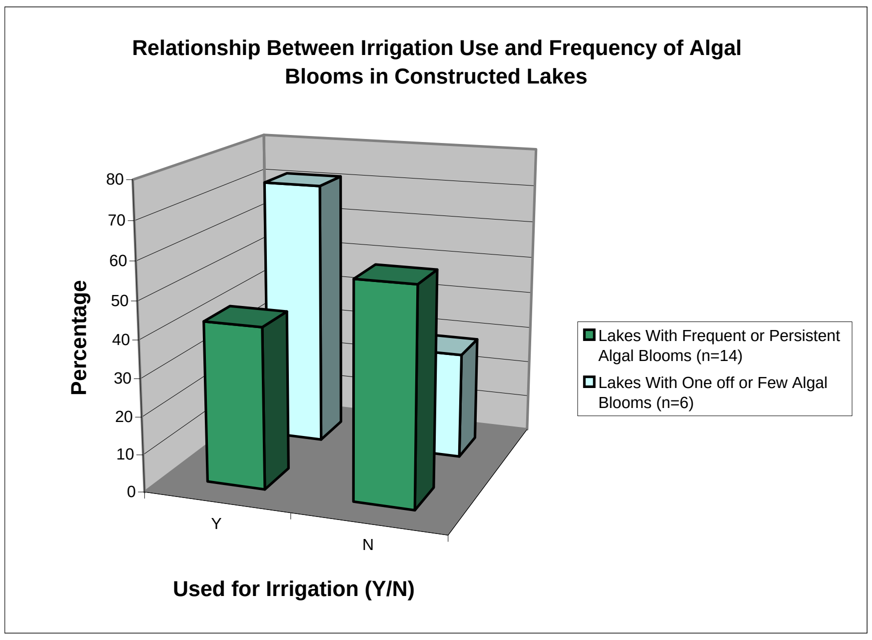

Relationship Between Lake Inlet: Outlet Ratio and Algal Blooms in Constructed Lakes
Percentage
80
70
60
50
40
30
20
10
0
Unknown
No Drainage
Inlets > Outlets
Inlets = Outlets
Inlets < Outlets
Inlet: Outlet Ratio
Lakes With Previous Reports of Algal Blooms (n=20)
Lakes With No Previous Reports of Algal Blooms (n=26)

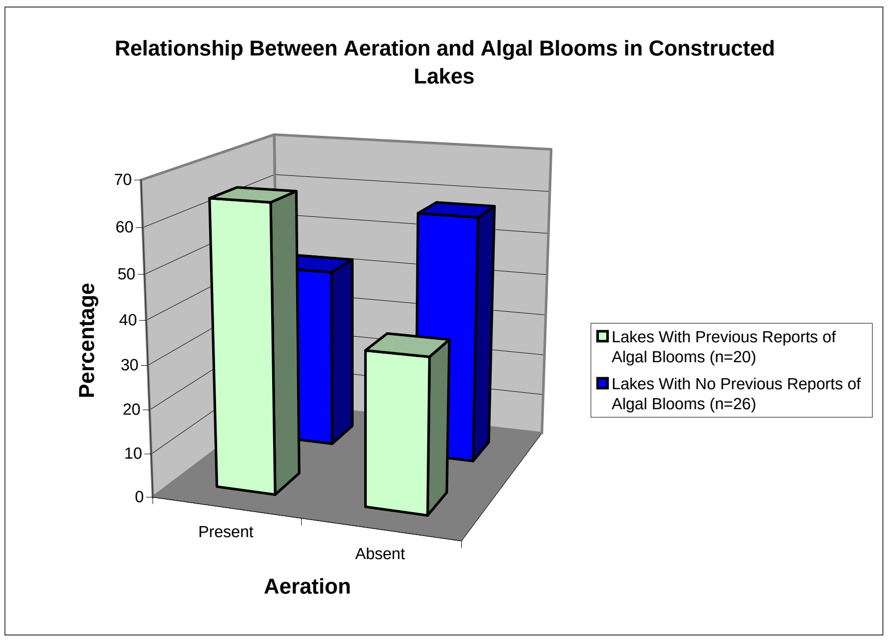

Relationship Between Inlet: Outlet Ratio and Frequency of Algal Blooms in Constructed Lakes
Percentage
70
60
50
40
30
20
10
0
Unknown
No Drainage
Inlets > Outlets
Inlets = Outlets
Inlets < Outlets
Inlet: Outlet Ratio
Lakes With Frequent or Persistent Algal Blooms (n=14)
Lakes With One off or Few Algal Blooms (n=7)

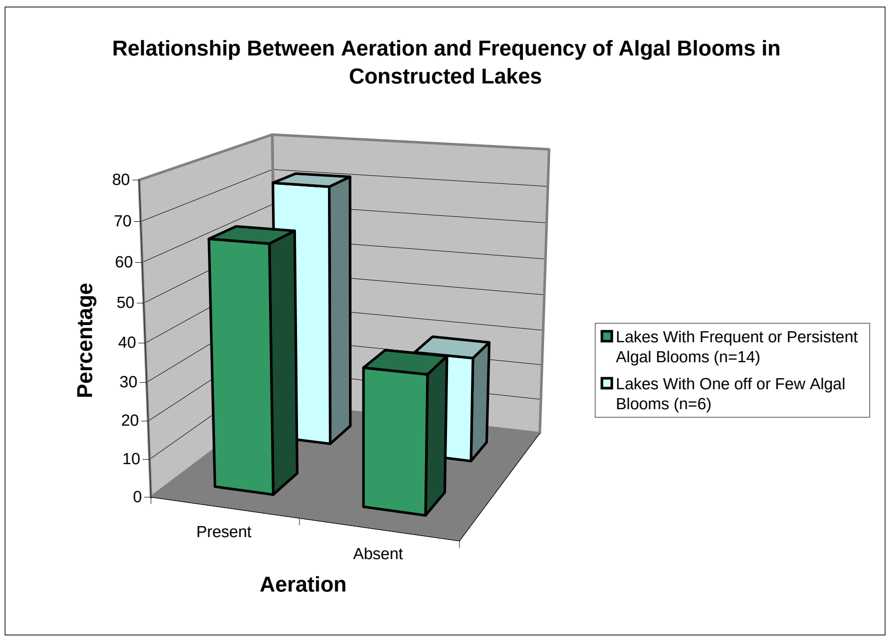

Relationship Between Lake Shape and Algal Blooms in Constructed Lakes
Percentage
35
30
25
20
15
10
5
0
Rounded/ oval
Linear/ Elongate
Irregular
Triangular
Shape
Lakes With Previous Reports of Algal Blooms (n=20)
Lakes With No Previous Reports of Algal Blooms (n=26)

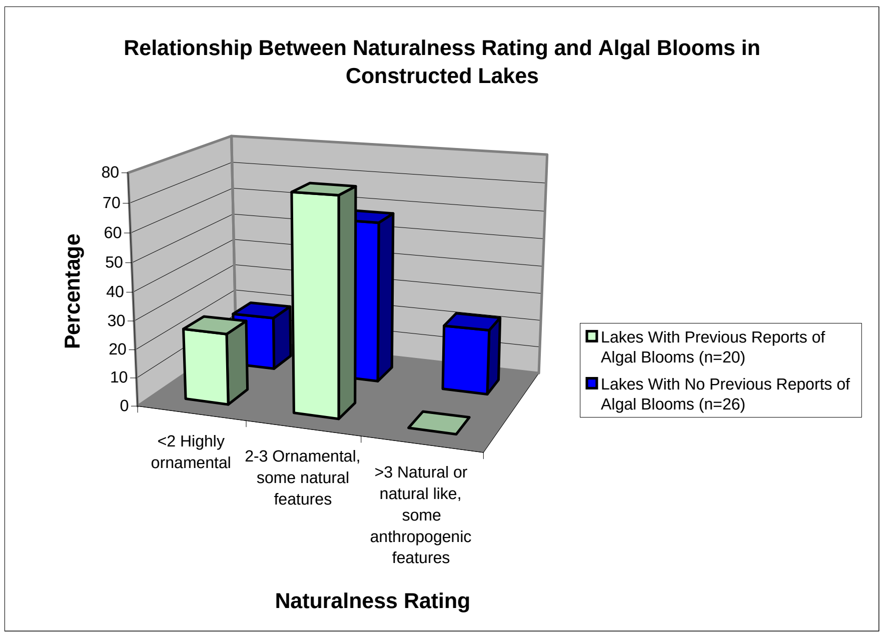

Relationship Between Shape and Frequency of Algal Blooms in Constructed Lakes
Percentage
60
50
40
30
20
10
0
Rounded/ oval
Linear/ Elongate
Irregular
Triangular
Shape
Lakes With Frequent or Persistent Algal Blooms (n=14)
Lakes With One off or Few Algal Blooms (n=6)

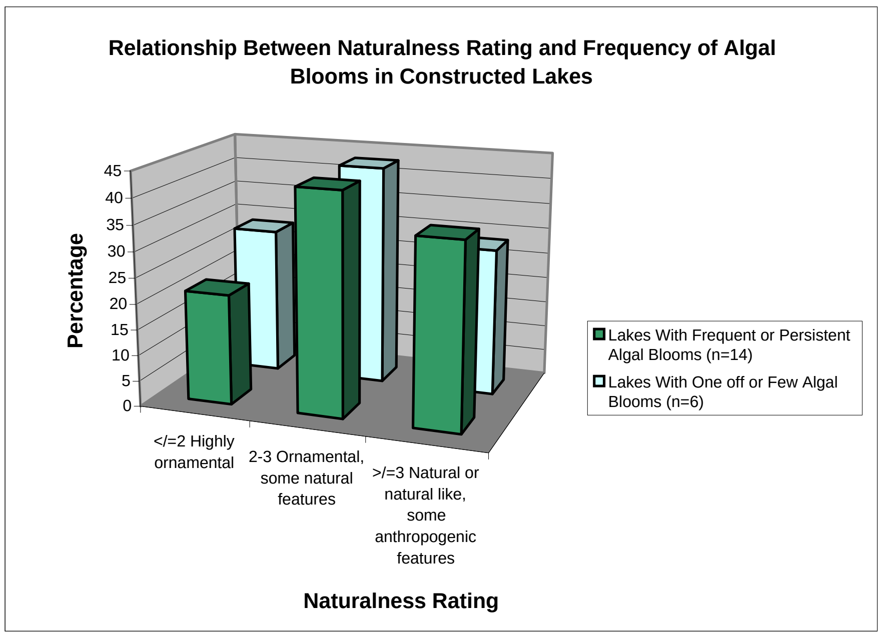

Relationship Between Irrigation Use and Algal Blooms in Constructed Lakes
Percentage
0 10 20 30 40 50 60
Y
N
Used for Irrigation (Y/N)
Lakes With Previous Reports of Algal Blooms (n=20)
Lakes With No Previous Reports of Algal Blooms (n=26)

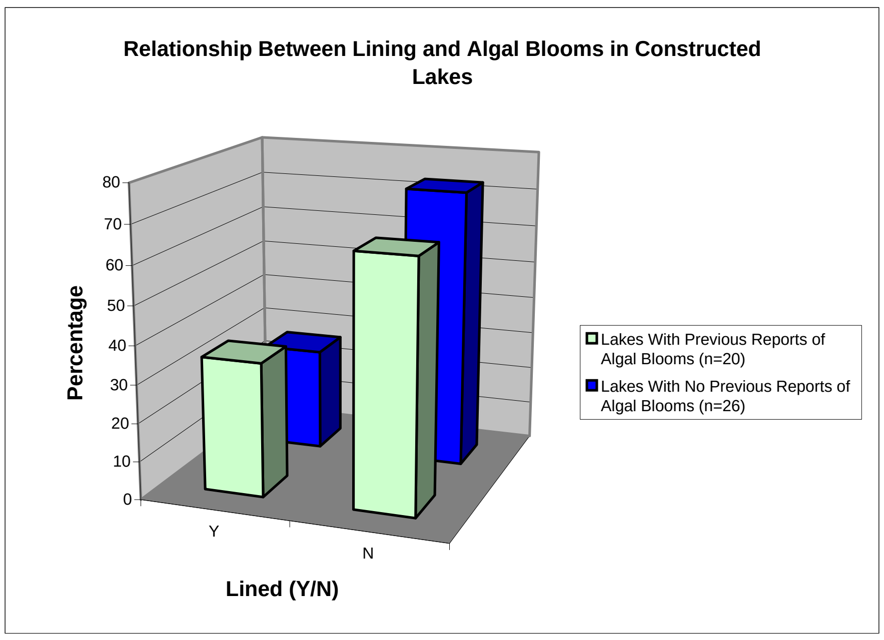

Relationship Between Irrigation Use and Frequency of Algal Blooms in Constructed Lakes
Percentage
0 10 20 30 40 50 60 70 80
Y
N
Used for Irrigation (Y/N)
Lakes With Frequent or Persistent Algal Blooms (n=14)
Lakes With One off or Few Algal Blooms (n=6)

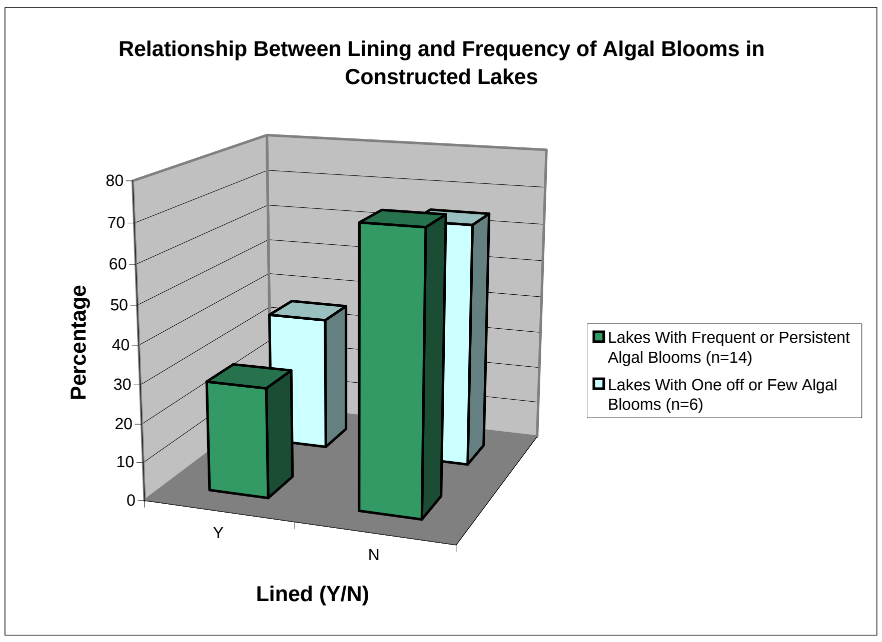

Relationship Between Aeration and Algal Blooms in Constructed Lakes
Percentage
0 10 20 30 40 50 60 70
Present
Absent
Aeration
Lakes With Previous Reports of Algal Blooms (n=20)
Lakes With No Previous Reports of Algal Blooms (n=26)

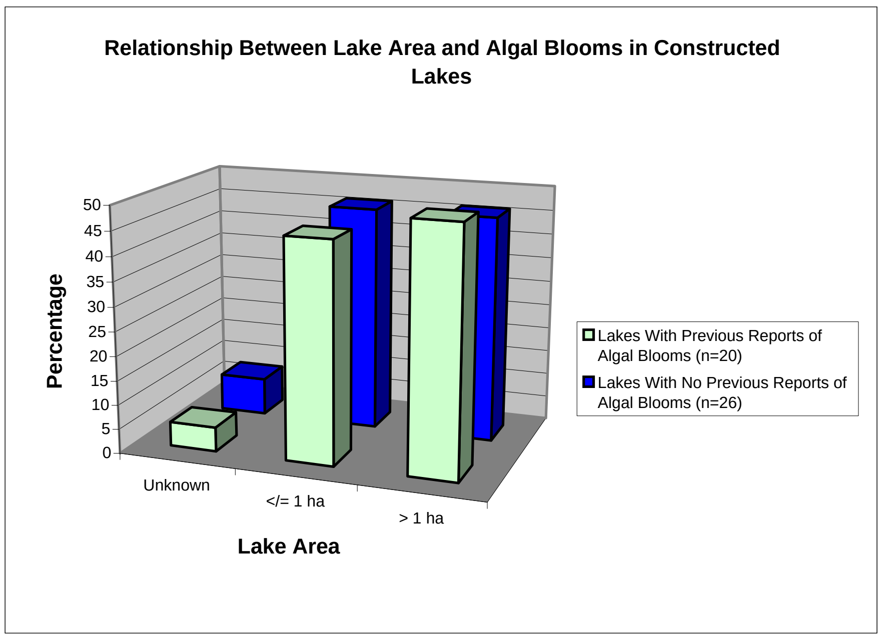

Relationship Between Aeration and Frequency of Algal Blooms in Constructed Lakes
Percentage
0 10 20 30 40 50 60 70 80
Present
Absent
Aeration
Lakes With Frequent or Persistent Algal Blooms (n=14)
Lakes With One off or Few Algal Blooms (n=6)

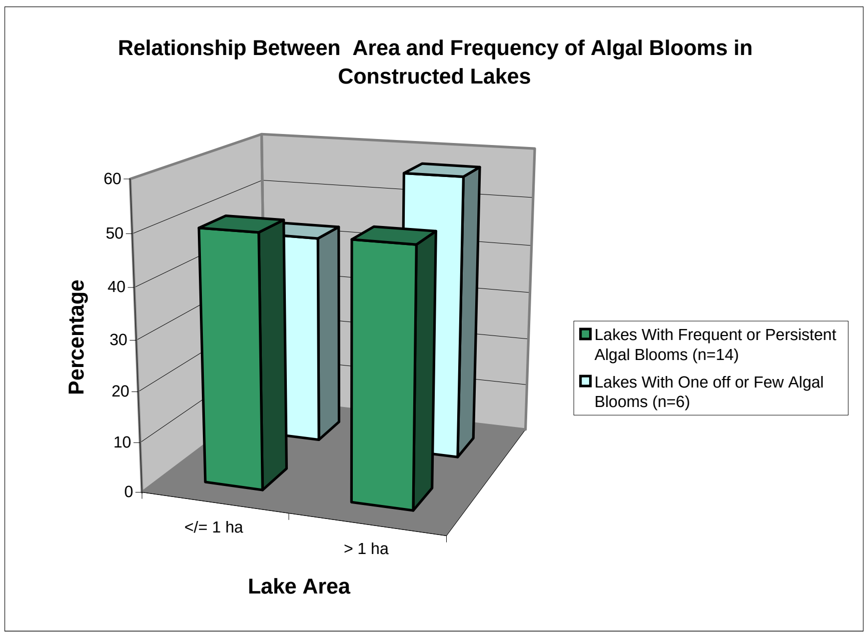

Relationship Between Naturalness Rating and Algal Blooms in Constructed Lakes
Percentage
0 10 20 30 40 50 60 70 80
<2 Highly ornamental
2-3 Ornamental, some natural features
>3 Natural or natural like, some anthropogenic features
Naturalness Rating
Lakes With Previous Reports of Algal Blooms (n=20)
Lakes With No Previous Reports of Algal Blooms (n=26)

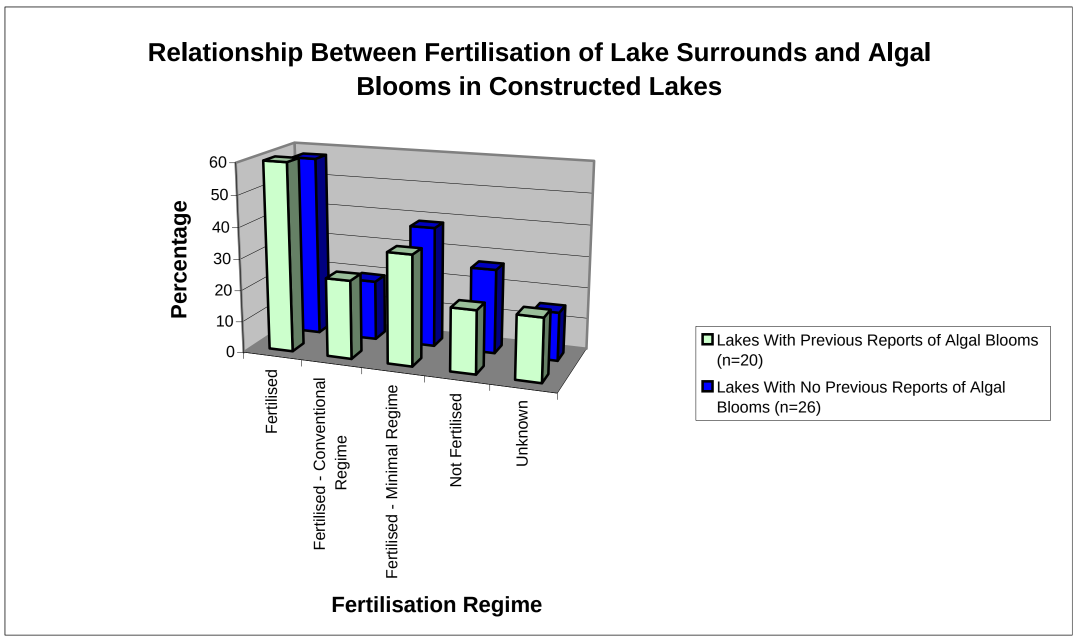

Relationship Between Naturalness Rating and Frequency of Algal Blooms in Constructed Lakes
Percentage
0 5 10 15 20 25 30 35 40 45
</=2 Highly ornamental
2-3 Ornamental, some natural features
>/=3 Natural or natural like, some anthropogenic features
Naturalness Rating
Lakes With Frequent or Persistent Algal Blooms (n=14)
Lakes With One off or Few Algal Blooms (n=6)


Relationship Between Lining and Algal Blooms in Constructed Lakes
Percentage
0 10 20 30 40 50 60 70 80
Y
N
Lined (Y/N)
Lakes With Previous Reports of Algal Blooms (n=20)
Lakes With No Previous Reports of Algal Blooms (n=26)


Relationship Between Lining and Frequency of Algal Blooms in Constructed Lakes
Percentage
0 10 20 30 40 50 60 70 80
Y
N
Lined (Y/N)
Lakes With Frequent or Persistent Algal Blooms (n=14)
Lakes With One off or Few Algal Blooms (n=6)


Relationship Between Lake Area and Algal Blooms in Constructed Lakes
Percentage
50
45
40
35
30
25
20
15
10
5
0
Unknown
</= 1 ha
> 1 ha
Lake Area
Lakes With Previous Reports of Algal Blooms (n=20)
Lakes With No Previous Reports of Algal Blooms (n=26)


Relationship Between Area and Frequency of Algal Blooms in Constructed Lakes
Percentage
60
50
40
30
20
10
0
</= 1 ha
> 1 ha
Lake Area
Lakes With Frequent or Persistent Algal Blooms (n=14)
Lakes With One off or Few Algal Blooms (n=6)


Relationship Between Fertilisation of Lake Surrounds and Algal Blooms in Constructed Lakes
Percentage
60
50
40
30
20
10
0
Fertilised
Fertilised - Conventional Regime
Fertilised - Minimal Regime
Not Fertilised
Unknown
Fertilisation Regime
Lakes With Previous Reports of Algal Blooms (n=20)
Lakes With No Previous Reports of Algal Blooms (n=26)

Hydrology of the Water Body:

Lake ID		Water level fluctuates and water body dries out.	Water body does not dry out but water level remains constant.	Water body does not dry out and water level fluctuates.	Midges/Mosquitoes (Y/N)
Jackadder Lake	St1		X		Y
Prior Close Reserve Lake	Go2		X		Y
Alexandria Bvd Reserve Lake	Go3		X		Y
Christmas Tree Park Lake East	Co1		X		Y
Christmas Tree Park Lake West	Co2		X		Y
Harvest Lakes South	Co3		X		Y
Centenary Park Lake	Ro1		X		Y
Pelican Point Lake	Bu1		X		Y
West Road Lake	Bu3		X		Y - anecdotal
Ridgewood Park Lake	Wa1			X	N
Carramar Golf Course Lake	Wa2		X		N
The Duck Pond	Wa3		X		N
Brighton Central Lake	Sa1		X		N
Joondalup Central Park Lake	Jo1		X		N
Broadbeach Lake North	Jo2			X	N
Broadbeach Lake Central	Jo3			X	N
Emu Lake	Sw1			X	N
Lake Fresca	Sw2			X	N
Mornington Park Lake	Sw3		X		N
Sandown Park Lake	Sw4		X		N
Sacromento Park	Sw5			X	N
Woodlake (Main Lake)	Sw6		X		N
Shearwater Spoonbill North	St2		X		N
Shearwater Spoonbill South	St3		X		N
Bradford St Lake	St4		X		N
Lake Bungana	Ba1		X		N
Lake Bungana Irrigation Lake	Ba2		X		N
Lake Brearley	Ba3		X		N
Whaleback Golf Course Lake	Ca1			X	N
Sandringham Prom Reserve 2	Go1		X		N
The Bridgeway Lake	Go4		X		N
Chinchilla	Ro2			X	N
Lagoon Park Lake	Ro3		X		N
Hermitage Lake North	Ma1			X	N
Hermitage Lake South	Ma2			X	N
Bridgewater Northern Lake	Ma3			X	N
Meadow Springs Lake North	Ma4			X	N
Meadow Springs Lake South	Ma5			X	N
Murray River Country Estate Central Lake	Mu1		X		N
Murray River Country Estate South Lake	Mu2		X		N
Queens Gardens Lake	Bu2			X	N
Fenian Park Lake	Bu4			X	N
Dalyellup Beach Central Park North Lake	Sa1		X		N*
Dalyellup Beach Fountain Lake	Sa2		X		N
Dunsborough Lakes Main Storage Lake	As1		X		N
Vasse Felix Winery Dam	Va1		X		N

Location of the Water Body to Residential Areas:

Lake ID		Nearest resident is located at least 200m from waters edge.	Nearest resident is located between 100m and 200m from waters edge.	Nearest resident is located between 50m and 100m from waters edge.	Nearest resident is located less than 50m from waters edge.	Midges/ Mosquitoes (Y/N)
Jackadder Lake	St1			X		Y
Prior Close Reserve Lake	Go2				X	Y
Alexandria Bvd Reserve Lake	Go3				X	Y
Christmas Tree Park Lake East	Co1			X		Y
Christmas Tree Park Lake West	Co2			X		Y
Harvest Lakes South	Co3			X		Y
Centenary Park Lake	Ro1			X		Y
Pelican Point Lake	Bu1				X	Y
West Road Lake	Bu3				X	Y - anecdotal
Ridgewood Park Lake	Wa1			X		N
Carramar Golf Course Lake	Wa2	X				N
The Duck Pond	Wa3				X	N
Brighton Central Lake	Sa1				X	N
Joondalup Central Park Lake	Jo1	X				N
Broadbeach Lake North	Jo2			X		N
Broadbeach Lake Central	Jo3				X	N
Emu Lake	Sw1				X	N
Lake Fresca	Sw2				X	N
Mornington Park Lake	Sw3				X	N
Sandown Park Lake	Sw4				X	N
Sacromento Park	Sw5			X		N
Woodlake (Main Lake)	Sw6				X	N
Shearwater Spoonbill North	St2			X		N
Shearwater Spoonbill South	St3			X		N
Bradford St Lake	St4			X		N
Lake Bungana	Ba1				X	N
Lake Bungana Irrigation Lake	Ba2				X	N
Lake Brearley	Ba3				X	N
Whaleback Golf Course Lake	Ca1		X			N
Sandringham Prom Reserve 2	Go1				X	N
The Bridgeway Lake	Go4				X	N
Chinchilla	Ro2			X		N
Lagoon Park Lake	Ro3		X			N
Hermitage Lake North	Ma1			X		N
Hermitage Lake South	Ma2		X			N
Bridgewater Northern Lake	Ma3				X	N
Meadow Springs Lake North	Ma4				X	N
Meadow Springs Lake South	Ma5				X	N
Murray River Country Estate Central Lake	Mu1	X				N
Murray River Country Estate South Lake	Mu2		X			N
Queens Gardens Lake	Bu2				X	N
Fenian Park Lake	Bu4				X	N
Dalyellup Beach Central Park North Lake	Sa1				X	N*
Dalyellup Beach Fountain Lake	Sa2				X	N
Dunsborough Lakes Main Storage Lake	As1				X	N
Vasse Felix Winery Dam	Va1				X	N

Form of the Water Body

		Part 1				Part 2		
Lake ID		80-100% of the water body's edge is hard vertical edge thereby maximising the effect of wave action	50-80% of the waterbody's edge is hard vertical edge and located across prevailing wind axis	50-80% of the water body's edge is hard vertical edge but is randomly located.	Less than 50% of the water body's edge is hard vertical edge	Shape of the water body is simple in order to facilitate good water circulation.	Shape of the water body is intricate or includes angles which may restrict water circulation.	Midges/ Mosquitoes (Y/N)
Jackadder Lake	St1				X		X	Y
Prior Close Reserve Lake	Go2		X			X		Y
Alexandria Bvd Reserve Lake	Go3				X		X	Y
Christmas Tree Park Lake East	Co1				X	X		Y
Christmas Tree Park Lake West	Co2				X	X		Y
Harvest Lakes South	Co3	X				X		Y
Centenary Park Lake	Ro1			X				Y
Pelican Point Lake	Bu1	X					X	Y
West Road Lake	Bu3	X				X		Y - anecdotal
Ridgewood Park Lake	Wa1	X				X		N
Carramar Golf Course Lake	Wa2				X	X		N
The Duck Pond	Wa3	X						N
Brighton Central Lake	Sa1				X		X	N
Joondalup Central Park Lake	Jo1		X				X	N
Broadbeach Lake North	Jo2				X			N
Broadbeach Lake Central	Jo3				X			N
Emu Lake	Sw1				X		X	N
Lake Fresca	Sw2	X					X	N
Mornington Park Lake	Sw3	X				X		N
Sandown Park Lake	Sw4			X			X	N
Sacromento Park	Sw5				X	X		N
Woodlake (Main Lake)	Sw6				X		X	N
Shearwater Spoonbill North	St2				X			N
Shearwater Spoonbill South	St3				X			N
Bradford St Lake	St4				X		X	N
Lake Bungana	Ba1				X		X	N
Lake Bungana Irrigation Lake	Ba2			X		X		N
Lake Brearley	Ba3			X			X	N
Whaleback Golf Course Lake	Ca1				X		X	N
Sandringham Prom Reserve 2	Go1		X			X		N
The Bridgeway Lake	Go4				X		X	N
Chinchilla	Ro2			X			X	N
Lagoon Park Lake	Ro3				X			N
Hermitage Lake North	Ma1				X	X		N
Hermitage Lake South	Ma2				X	X		N
Bridgewater Northern Lake	Ma3				X		X	N
Meadow Springs Lake North	Ma4				X		X	N
Meadow Springs Lake South	Ma5				X		X	N
Murray River Country Estate Central Lake	Mu1				X	X		N
Murray River Country Estate South Lake	Mu2				X	X		N
Queens Gardens Lake	Bu2				X		X	N
Fenian Park Lake	Bu4						X	N
Dalyellup Beach Central Park North Lake	Sa1				X		X	N*
Dalyellup Beach Fountain Lake	Sa2	X				X		N
Dunsborough Lakes Main Storage Lake	As1	X					X	N
Vasse Felix Winery Dam	Va1	X					X	N

Wind Related Parameters

Lake ID		The long axis of the water body is in line with known prevailing wind directions or is of a circular nature.	The long axis of the water body is perpendicular to known prevailing wind directions.	Surrounding land level with water body preventing surface runoff entering and maximising potential wind action.	Constructed wetland located in a depression so that surrounding land slopes down to the waters edge.	Midges/ Mosquitoes (Y/N)
Jackadder Lake	St1	X			X	Y
Prior Close Reserve Lake	Go2		X		X	Y
Alexandria Bvd Reserve Lake	Go3	X			X	Y
Christmas Tree Park Lake East	Co1		X	X		Y
Christmas Tree Park Lake West	Co2	X		X		Y
Harvest Lakes South	Co3		X		X	Y
Centenary Park Lake	Ro1		X			Y
Pelican Point Lake	Bu1	X		X		Y
West Road Lake	Bu3	X			X	Y - anecdotal
Ridgewood Park Lake	Wa1	X			X	N
Carramar Golf Course Lake	Wa2	X			X	N
The Duck Pond	Wa3		X	X		N
Brighton Central Lake	Sa1	X			X	N
Joondalup Central Park Lake	Jo1	X		X		N
Broadbeach Lake North	Jo2	X			X	N
Broadbeach Lake Central	Jo3	X			X	N
Emu Lake	Sw1		X		X	N
Lake Fresca	Sw2		X	X		N
Mornington Park Lake	Sw3	X			X	N
Sandown Park Lake	Sw4	X			X	N
Sacromento Park	Sw5	X			X	N
Woodlake (Main Lake)	Sw6	X			X	N
Shearwater Spoonbill North	St2	X			X	N
Shearwater Spoonbill South	St3	X			X	N
Bradford St Lake	St4	X			X	N
Lake Bungana	Ba1		X	X		N
Lake Bungana Irrigation Lake	Ba2		X	X		N
Lake Brearley	Ba3	X		X		N
Whaleback Golf Course Lake	Ca1	X			X	N
Sandringham Prom Reserve 2	Go1		X	X		N
The Bridgeway Lake	Go4	1		X		N
Chinchilla	Ro2	1				N
Lagoon Park Lake	Ro3		X		X	N
Hermitage Lake North	Ma1	X			X	N
Hermitage Lake South	Ma2	X			X	N
Bridgewater Northern Lake	Ma3	X		X		N
Meadow Springs Lake North	Ma4		X		X	N
Meadow Springs Lake South	Ma5		X		X	N
Murray River Country Estate Central Lake	Mu1	X				N
Murray River Country Estate South Lake	Mu2	X				N
Queens Gardens Lake	Bu2	X			X	N
Fenian Park Lake	Bu4		X		X	N
Dalyellup Beach Central Park North Lake	Sa1		X		X	N*
Dalyellup Beach Fountain Lake	Sa2	X			X	N
Dunsborough Lakes Main Storage Lake	As1		X	X		N
Vasse Felix Winery Dam	Va1		X		X	N

Depth of the Water Body

Lake ID		Seasonal water bodies which dry out.	Between 60cm and 2m	Between 30cm and 60cm	Greater than 2m	Less than 30cm	Midges/ Mosquitoes (Y/N)
		NB: Depth is to be the average predominant depth typical for the month of November with the exception of seasonal water bodies which dry out.					
Jackadder Lake	St1				?		Y
Prior Close Reserve Lake	Go2				X		Y
Alexandria Bvd Reserve Lake	Go3				X		Y
Christmas Tree Park Lake East	Co1		?				Y
Christmas Tree Park Lake West	Co2		?				Y
Harvest Lakes South	Co3		?				Y
Centenary Park Lake	Ro1				X		Y
Pelican Point Lake	Bu1				X		Y
West Road Lake	Bu3		X				Y - anecdotal
Ridgewood Park Lake	Wa1		X				N
Carramar Golf Course Lake	Wa2		X				N
The Duck Pond	Wa3		X				N
Brighton Central Lake	Sa1		X				N
Joondalup Central Park Lake	Jo1		X				N
Broadbeach Lake North	Jo2		X				N
Broadbeach Lake Central	Jo3		X				N
Emu Lake	Sw1		X				N
Lake Fresca	Sw2			X			N
Mornington Park Lake	Sw3		X				N
Sandown Park Lake	Sw4		X				N
Sacromento Park	Sw5		X				N
Woodlake (Main Lake)	Sw6		X				N
Shearwater Spoonbill North	St2		X				N
Shearwater Spoonbill South	St3		X				N
Bradford St Lake	St4		X				N
Lake Bungana	Ba1				X		N
Lake Bungana Irrigation Lake	Ba2				X		N
Lake Brearley	Ba3				X		N
Whaleback Golf Course Lake	Ca1		X				N
Sandringham Prom Reserve 2	Go1				X		N
The Bridgeway Lake	Go4				X		N
Chinchilla	Ro2				X		N
Lagoon Park Lake	Ro3		X				N
Hermitage Lake North	Ma1		X				N
Hermitage Lake South	Ma2		X				N
Bridgewater Northern Lake	Ma3		X				N
Meadow Springs Lake North	Ma4		X				N
Meadow Springs Lake South	Ma5		X				N
Murray River Country Estate Central Lake	Mu1				?		N
Murray River Country Estate South Lake	Mu2				?		N
Queens Gardens Lake	Bu2		X				N
Fenian Park Lake	Bu4				X		N
Dalyellup Beach Central Park North Lake	Sa1				X		N*
Dalyellup Beach Fountain Lake	Sa2		X				N
Dunsborough Lakes Main Storage Lake	As1		X				N
Vasse Felix Winery Dam	Va1				X		N

Mechanical Aeration

Lake ID		Aeration Y/N	Midges/Mosquitoes (Y/N)
Jackadder Lake	St1	N	Y
Prior Close Reserve Lake	Go2	Y	Y
Alexandria Bvd Reserve Lake	Go3	Y	Y
Christmas Tree Park Lake East	Co1	N	Y
Christmas Tree Park Lake West	Co2	Y	Y
Harvest Lakes South	Co3	Y	Y
Centenary Park Lake	Ro1	Y	Y
Pelican Point Lake	Bu1	Y	Y
West Road Lake	Bu3	N	Y - anecdotal
Ridgewood Park Lake	Wa1	N	N
Carramar Golf Course Lake	Wa2	N	N
The Duck Pond	Wa3	Y	N
Brighton Central Lake	Sa1	Y	N
Joondalup Central Park Lake	Jo1	Y	N
Broadbeach Lake North	Jo2	N	N
Broadbeach Lake Central	Jo3	Y	N
Emu Lake	Sw1	Y	N
Lake Fresca	Sw2	N	N
Mornington Park Lake	Sw3	Y	N
Sandown Park Lake	Sw4	Y	N
Sacromento Park	Sw5	N	N
Woodlake (Main Lake)	Sw6	Y	N
Shearwater Spoonbill North	St2	Y	N
Shearwater Spoonbill South	St3	Y	N
Bradford St Lake	St4	N	N
Lake Bungana	Ba1	Y	N
Lake Bungana Irrigation Lake	Ba2	Y	N
Lake Brearley	Ba3	N	N
Whaleback Golf Course Lake	Ca1	N	N
Sandringham Prom Reserve 2	Go1	Y	N
The Bridgeway Lake	Go4	Y	N
Chinchilla	Ro2	Y	N
Lagoon Park Lake	Ro3	Y	N
Hermitage Lake North	Ma1	N	N
Hermitage Lake South	Ma2	N	N
Bridgewater Northern Lake	Ma3	Y	N
Meadow Springs Lake North	Ma4	N	N
Meadow Springs Lake South	Ma5	N	N
Murray River Country Estate Central Lake	Mu1	Y	N
Murray River Country Estate South Lake	Mu2	Y	N
Queens Gardens Lake	Bu2	N	N
Fenian Park Lake	Bu4	N	N
Dalyellup Beach Central Park North Lake	Sa1	Y	N*
Dalyellup Beach Fountain Lake	Sa2	Y	N
Dunsborough Lakes Main Storage Lake	As1	N	N
Vasse Felix Winery Dam	Va1	N	N

Aquatic Vegetation

Lake ID		Emergent vegetation in small stands parallel to predominant wind direction. Measures taken to reduce vegetation colonisation of remaining water body.	Emergent vegetation in small stands parallel to predominant wind direction.	Aquatic vegetation planted in large dense stands randomly and in a manner so it is not restrained from colonising other parts of the water body	No aquatic vegetation.	Midges/ Mosquitoes (Y/N)
Jackadder Lake	St1	X				Y
Prior Close Reserve Lake	Go2	X				Y
Alexandria Bvd Reserve Lake	Go3	X				Y
Christmas Tree Park Lake East	Co1			X		Y
Christmas Tree Park Lake West	Co2	X				Y
Harvest Lakes South	Co3	X				Y
Centenary Park Lake	Ro1			X		Y
Pelican Point Lake	Bu1				4	Y
West Road Lake	Bu3			X		Y - anecdotal
Ridgewood Park Lake	Wa1				4	N
Carramar Golf Course Lake	Wa2				4	N
The Duck Pond	Wa3				4	N
Brighton Central Lake	Sa1				4	N
Joondalup Central Park Lake	Jo1	X				N
Broadbeach Lake North	Jo2			X		N
Broadbeach Lake Central	Jo3			X		N
Emu Lake	Sw1	X				N
Lake Fresca	Sw2	X				N
Mornington Park Lake	Sw3	X				N
Sandown Park Lake	Sw4	X				N
Sacromento Park	Sw5			X		N
Woodlake (Main Lake)	Sw6			X		N
Shearwater Spoonbill North	St2	X				N
Shearwater Spoonbill South	St3	X				N
Bradford St Lake	St4	X				N
Lake Bungana	Ba1	X				N
Lake Bungana Irrigation Lake	Ba2	X				N
Lake Brearley	Ba3	X				N
Whaleback Golf Course Lake	Ca1	X				N
Sandringham Prom Reserve 2	Go1	X				N
The Bridgeway Lake	Go4	X				N
Chinchilla	Ro2			X		N
Lagoon Park Lake	Ro3			X		N
Hermitage Lake North	Ma1	X				N
Hermitage Lake South	Ma2	X				N
Bridgewater Northern Lake	Ma3	X				N
Meadow Springs Lake North	Ma4			X		N
Meadow Springs Lake South	Ma5			X		N
Murray River Country Estate Central Lake	Mu1	X				N
Murray River Country Estate South Lake	Mu2	X				N
Queens Gardens Lake	Bu2			X		N
Fenian Park Lake	Bu4			X		N
Dalyellup Beach Central Park North Lake	Sa1	X				N*
Dalyellup Beach Fountain Lake	Sa2				X	N
Dunsborough Lakes Main Storage Lake	As1		X			N
Vasse Felix Winery Dam	Va1		X			N

Terrestrial Vegetation

Lake ID		Buffer vegetation mainly planted down wind of the water body or surrounding entire water body. Clear open space provide between buffer vegetation and nearest residence.	Buffer vegetation mainly planted down wind of the water body. Vegetation grows right up to nearest residence and may act as a dispersal corridor.	Vegetation randomly planted or in insufficient quantity to provide an effective buffer.	Midges/ Mosquitoes (Y/N)
Jackadder Lake	St1			X	Y
Prior Close Reserve Lake	Go2			X	Y
Alexandria Bvd Reserve Lake	Go3			X	Y
Christmas Tree Park Lake East	Co1	X			Y
Christmas Tree Park Lake West	Co2			X	Y
Harvest Lakes South	Co3			X	Y
Centenary Park Lake	Ro1			X	Y
Pelican Point Lake	Bu1			X	Y
West Road Lake	Bu3			X	Y - anecdotal
Ridgewood Park Lake	Wa1			X	N
Carramar Golf Course Lake	Wa2	X			N
The Duck Pond	Wa3			X	N
Brighton Central Lake	Sa1			X	N
Joondalup Central Park Lake	Jo1			X	N
Broadbeach Lake North	Jo2				N
Broadbeach Lake Central	Jo3				N
Emu Lake	Sw1			X	N
Lake Fresca	Sw2			X	N
Mornington Park Lake	Sw3			X	N
Sandown Park Lake	Sw4			X	N
Sacromento Park	Sw5			X	N
Woodlake (Main Lake)	Sw6			X	N
Shearwater Spoonbill North	St2			X	N
Shearwater Spoonbill South	St3			X	N
Bradford St Lake	St4			X	N
Lake Bungana	Ba1			X	N
Lake Bungana Irrigation Lake	Ba2			X	N
Lake Brearley	Ba3			X	N
Whaleback Golf Course Lake	Ca1			X	N
Sandringham Prom Reserve 2	Go1			X	N
The Bridgeway Lake	Go4			X	N
Chinchilla	Ro2			X	N
Lagoon Park Lake	Ro3			X	N
Hermitage Lake North	Ma1			X	N
Hermitage Lake South	Ma2			X	N
Bridgewater Northern Lake	Ma3			X	N
Meadow Springs Lake North	Ma4			X	N
Meadow Springs Lake South	Ma5			X	N
Murray River Country Estate Central Lake	Mu1			X	N
Murray River Country Estate South Lake	Mu2			X	N
Queens Gardens Lake	Bu2			X	N
Fenian Park Lake	Bu4			X	N
Dalyellup Beach Central Park North Lake	Sa1			X	N*
Dalyellup Beach Fountain Lake	Sa2			X	N
Dunsborough Lakes Main Storage Lake	As1			X	N
Vasse Felix Winery Dam	Va1			X	N

Other Characteristics

Lake ID			TP conc (maximum)	Chl a. conc (maximum)	Naturalness Rating	%Fringing Veg	Approximate Area (ha)	Lined (Y/N)	Midges/Mosquitoes (Y/N)	Algal Blooms Reported (Y/N)	
Jackadder Lake	St1	1	7580	-	3.5	50	7.43	N	Y	Y	
Prior Close Reserve Lake	Go2	1	985	170	2	25	1.69	N	Y	Y	
Alexandria Bvd Reserve Lake	Go3	1	160	5.04	2	70	6.44	N	Y	Y	
Christmas Tree Park Lake East	Co1	1	-	-	3.5	100	0.18	N	Y	N	
Christmas Tree Park Lake West	Co2	1	1700	14	2.5	95	0.31	Y	Y	N	
Harvest Lakes South	Co3	1	70	45	2	0	1.47	Y	Y	Y	
Centenary Park Lake	Ro1	1	-	-	1.5	50	0.30	N	Y	Y	
Pelican Point Lake	Bu1	1	-	-	1	0	1.65	Y	Y	Y	
West Road Lake	Bu3	1	-	-	2	7	0.05	N	Y - anecdotal	N	
Ridgewood Park Lake	Wa1		-	-	1	0	0.19	Y	N	Y	
Carramar Golf Course Lake	Wa2	1	-	-	3	80	2.05	Y	N	N	
The Duck Pond	Wa3	1	-	-	1	5	0.18	Y	N	Y	
Brighton Central Lake	Sa1	1	-	-	1.5	10	1.64	Y	N	Y	
Joondalup Central Park Lake	Jo1	1	-	-	2	0	0.75	Y	N	Y	
Broadbeach Lake North	Jo2	1	-	-	3	35	0.52	N	N	Y	
Broadbeach Lake Central	Jo3	1	-	-	3	60	0.26	N	N	Y	
Emu Lake	Sw1	1	190	340	2.5	60	12.80	N	N	Y	
Lake Fresca	Sw2	1	-	-	1	0	2.88	Y	N	N	
Mornington Park Lake	Sw3	1	-	-	2	0	0.13	N	N	N	
Sandown Park Lake	Sw4	1	-	-	1	36	4.05	Y	N	N	
Sacromento Park	Sw5	1	-	-	3	100	0.66	N	N	N	
Woodlake (Main Lake)	Sw6	1	-	-	2	65	5.71	N	N	Y	
Shearwater Spoonbill North	St2	1	-	-	3.5	20	0.90	N	N	N	
Shearwater Spoonbill South	St3	1	-	-	3.5	20	1.30	N	N	N	
Bradford St Lake	St4	1	-	-	2	5	0.36	Y	N	Y	
Lake Bungana	Ba1	1	-	-	3	65	-	N	N	N	
Lake Bungana Irrigation Lake	Ba2	1	-	-	3	55	-	N	N	Y	
Lake Brearley	Ba3	1	-	-	3	35	9.02	N	N	N	
Whaleback Golf Course Lake	Ca1	1	410	-	3	85	1.15	N	N	N	
Sandringham Prom Reserve 2	Go1	1	180	3.5	1	8	0. 868	Y	N	N	
The Bridgeway Lake	Go4	1	220	24	2	30	1.63	N	N	Y	
Chinchilla	Ro2	1	-	-	1	8	0.08	N	N	N	
Lagoon Park Lake	Ro3	1	-	-	3.5	95	1.05	N	N	N	
Hermitage Lake North	Ma1	1	-	-	3	30	0.74	N	N	N	
Hermitage Lake South	Ma2	1	-	-	3	40	0.59	N	N	N	
Bridgewater Northern Lake	Ma3	1	150	19	3	50	1.25	N	N	Y	
Meadow Springs Lake North	Ma4	1	-	-	3	50	0.78	N	N	Y	
Meadow Springs Lake South	Ma5	1	-	-	3	50	0.70	N	N	Y	
Murray River Country Estate Central Lake	Mu1	1	-	-	3	70	0.57	N	N	N	
Murray River Country Estate South Lake	Mu2	1	-	-	3	70	1.71	N	N	N	
Queens Gardens Lake	Bu2	1	-	-	3	0	-	N	N	N	
Fenian Park Lake	Bu4	1	-	-	3	0	2.37	N	N	N	
Dalyellup Beach Central Park North Lake	Sa1	1	-	-	3	95	2.50	N	N*	N	*larvae were observed during site visit
Dalyellup Beach Fountain Lake	Sa2	1	-	-	1	0	0.12	Y	N	N	
Dunsborough Lakes Main Storage Lake	As1	1	-	-	3	10	3.07	Y	N	N	
Vasse Felix Winery Dam	Va1	1	-	-	3-4	25	1.50	N	N	N	
Average Max (midges and mosquitos)			2099	58.51							
Average Max (no midges and mosquitos)			230	96.625							