Australian Government

National Capital Authority

WATER QUALITY MANAGEMENT PLAN

LAKE BURLEY GRIFFIN

2011

The Commonwealth is committed to a National Capital which symbolises Australia's heritage, values and aspirations, is internationally recognised, and worthy of pride by Australians.

THE NATIONAL CAPITAL AUTHORITY MANAGES THE AUSTRALIAN GOVERNMENT'S ONGOING INTEREST IN THE PLANNING AND DEVELOPMENT OF CANBERRA AS AUSTRALIA'S NATIONAL CAPITAL.

About this Document

The National Capital Authority is responsible for the management of Lake Burley Griffin in Canberra.

As part of the water quality management of the Lake, the National Capital Authority has produced this document for the sustainable use of the Lake and protection of water quality.

This document comprises:

- **Part 1: Explanatory Paper**
- **Part 2: Management Response.**

The document was first released in 2004.

The document has been reviewed by CQUniversity between 2010 and 2011 and a revised version of the document released in November 2011.

A copy of this document can be obtained from:

National Capital Authority
GPO Box 373
Canberra ACT 2601

Or:

www.nationalcapital.gov.au

THE NATIONAL CAPITAL AUTHORITY IS RESPONSIBLE FOR THE MANAGEMENT OF LAKE BURLEY GRIFFIN.

FOREWORD

The Lake Burley Griffin Water Quality Management Plan is prepared by the NCA to help manage lake water quality and to inform interested parties about matters affecting the quality of water in the lake.

This Plan will be used by the NCA, which has statutory responsibility for the Lake, to undertake specific management functions related to the protection of water quality.

The management objective is to protect the Lake as an important visual, recreational and environmental feature of the National Capital for current and future generations.

The Plan documents the current water quality status of the Lake, benchmark values for future monitoring, and management responses to address events that may affect water quality.

The Plan adopts the policies and directions of ANZECC/ARMCANZ *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (2000), prepared under the National Water Quality Management Strategy.

In June 2004, the first version of the Plan was published, following a consultation process involving a range of water quality professionals, government agencies and user groups. This process supported the need for continued water quality monitoring, robust water quality guidelines, additional scientific studies, and dissemination of information.

In 2010 and 2011 the Plan was reviewed by Central Queensland University to ensure the use of current data and compliance with current water quality guidelines and legislation.

This Plan includes an Explanatory Paper and a Management Response. A copy of the Plan is available in the NCA's website www.nationalcapital.gov.au

CONTENTS

About this Document 4

Foreword 5

Abbreviations and Units 8

Acknowledgments 9

Study Team (2004 report) 9

Review Team (2010 and 2011) 9

Executive Summary 10

1 Introduction 12

1.1 Background 12

1.2 Need for a Plan 12

1.3 Structure of the Document 12

2 Objectives 13

3 Process of the Plan 14

PART 1: EXPLANATORY PAPER 15

4 Context 15

4.1 Statutory and Management Plans 15

4.2 National Water Quality Guidelines 17

4.3 Existing Management Practices 18

4.4 Recent Incidences of Elevated Bacterial Levels 19

5 Past Water Quality Trends 20

5.1 Overview of Trends 20

5.2 General 21

5.3 Turbidity and Suspended Material 21

5.4 Phosphorus 24

5.5 Nitrogen 26

5.6 Algae and Chlorophyll-a 30

5.7 Conductivity and pH 33

5.8 Bacteria 36

5.9 Metals 40

5.10 Dissolved Oxygen 40

5.11 Water Column Depth Profiles 44

6 Development of Benchmark Levels for Water Quality 49

6.1 General 49

6.2 Methodology 50

6.3 Turbidity and Suspended Material 50

6.4 Phosphorus 51

6.5 Nitrogen 51
6.6 Algae and Chlorophyll-a 51
6.7 Conductivity and pH 51
6.8 Bacteria 52
6.9 Metals 52

PART 2: MANAGEMENT RESPONSE 53

7 Management Response 53
7.1 Introduction 53
7.2 Recommended Benchmark Values for Key Water Quality Indicators 54

8 Overview of Water Quality Monitoring Programs 55
8.1 Routine Testing of Midstream Samples 55
8.2 Microbiological Monitoring of Designated Recreational Sites 55
8.3 Algal Monitoring Program 56
8.4 Other Tests 56
8.5 Testing Method 56
8.6 General Management Response 56
8.7 General Catchment Management Issues 57

9 Actions Arising from the Management of Pollutants 58
9.1 Managing Stormwater Pollution 58
9.2 Managing Accidental Sewer Overflow 59
9.3 Managing Unacceptable Water Quality Conditions at Designated Recreational Sites 60
9.4 Managing Elevated Bacterial Levels 61
9.5 Managing Algal Blooms 61
9.6 Managing Chemical Spills and Industrial Waste 62
9.7 Communications 63
9.8 Use of Legislation 64
9.9 Roles and Responsibilities 65

10 Conclusion 66

11 References 67

Appendix A. Water Quality Testing Methods 69

Appendix B. Lake Map with water quality sampling sites 71

ABBREVIATIONS AND UNITS

ANZECC	Australian and New Zealand Environment and Conservation Council
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
cells/mL	cells per millilitre
CFU	Colony Forming Unit
CRC	Cooperative Research Centre
µm	micrometre (micron)
mg/L	milligrams per litre
LBGMP1995	*Lake Burley Griffin Management Plan 1995*
NATA	National Association of Testing Authorities
NCA	National Capital Authority
NCOSS	National Capital Open Space System
NCP	National Capital Plan
NHMRC	National Health and Medical Research Council
NTU	Nephelometric Turbidity Unit
NWQMS	National Water Quality Management Strategy
WQMP	Water Quality Management Plan

ACKNOWLEDGMENTS

The National Capital Authority would like to acknowledge the support of personnel from a wide range of organisations who provided comments and feedback on this updated report.

In particular, the NCA would like to thank:

- **The NCA's Publication Committee**
- **ACT Environment and Sustainable Development Directorate**
- **ACT Health Protection Service**
- **Dr David Bagnall.**

The NCA would also like to thank the staff of ECOWISE Australia Pty Ltd, trading as ALS Water Resources Group for providing the water quality monitoring information on Lake Burley Griffin.

STUDY TEAM (2004 REPORT)

- **Dr Laslo Nagy, Atech Group**
- **Professor Bill Maher, University of Canberra, CRC Freshwater Ecology**
- **Mr Simon Foster, University of Canberra**
- **Mr Steve Hure, ECOWISE Environmental**
- **Mr Barry Horsburgh, ECOWISE Environmental**
- **Mr T. Sritharan (Sri), NCA**

REVIEW TEAM (2010 AND 2011)

- **Associate Professor Larelle Fabbro, CQUniversity**
- **Mr Les Unwin, CQUniversity**
- **Dr Claire Sellens, CQUniversity**
- **Ms Catherine Jones, CQUniversity**

EXECUTIVE SUMMARY

THE PRESERVATION AND ENHANCEMENT OF LAKE BURLEY GRIFFIN AS A CENTRAL LANDSCAPE FEATURE, ESSENTIAL TO THE CHARACTER AND SETTING OF THE NATIONAL CAPITAL, IS A MATTER OF NATIONAL SIGNIFICANCE IN THE PLANNING AND DEVELOPMENT OF CANBERRA.

Lake Burley Griffin is an integral part of the tributary system within the Murray-Darling Basin, Australia's most significant drainage basin. Water management within the Basin is also a matter of national significance with Lake Burley Griffin acting as a retention pond for downstream parts of the system.

Lake Burley Griffin is also an important inland water resource that supports a variety of water-based commercial and recreational uses for Canberra's residents and visitors. This means that there is increasing pressure to provide better water quality outcomes to support these functions and to protect the health and safety of users.

The National Capital Authority is responsible for the management of the Lake. Sustainable use of the Lake is promoted whilst protecting and enhancing its water quality and allowing for a greater and more diverse range of uses.

Water quality is usually determined by reference to a number of factors, particularly turbidity and suspended material, phosphorus, nitrogen, algae and chlorophyll-a, conductivity and pH, bacteria, metals, and dissolved oxygen. At any point in time the water quality will vary within areas of the Lake. These water quality factors and variations across the Lake are influenced by a range of natural and man-made trends and activities, including:

- **Climate – rainfall, temperature and wind conditions. For example, the ten year extreme drought conditions between 1999-2009 saw near zero catchment inflows to the Lake and a changing physical and chemical environment conducive to increases in blue-green algae.[1]**
- **Lake geography – water depth, slope of lake bed, aquatic plants, bank treatments, exposure to prevailing winds and inflows.**
- **Urban growth – since the Lake was formed some 48 years ago, the ACT population has increased from 70,000 in 1963 to 365,000 in 2011 (Australian Bureau of Statistics, 2011), resulting in an increase in urban stormwater and other discharges of nutrients and organic material.**
- **Activities in the catchment – water treatment plants, water abstraction, operation of dams, agriculture, horticulture, mining land uses, plant and animal populations, lake use.**

[1] The *Lake Burley Griffin Water Quality Monitoring Report July 2010 – June 2011* (Australian Laboratory Services Water Resources Group Canberra, 2011) noted that conditions in the Lake appear to have improved over the preceding drought period with blue-green algal counts at beach sites showing a considerable decrease compared to 2009.

Parameters set out in the ANZECC/ARMCANZ *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (2000), *Guidelines for Managing Risks in Recreational Water* (Australian Government, 2008), local guidelines and water-quality data collected over the past 28 years have been used to develop the benchmarks for the Water Quality Management Plan (WQMP) contained in this document.

The ANZECC/ARMCANZ (2000) guidelines are generic for south-east Australian waterways and include guidelines for all uses—including drinking, recreational, irrigational and environmental uses. ANZECC/ARMCANZ (2000) also states that its generic guidelines can be modified to suit local conditions, if detailed local information is available.

In summary, the general water quality trends for Lake Burley Griffin over the period 1981-2009 indicate:

- ➔ The overall environmental health of the Lake is generally good.
- ➔ Turbidity has decreased and now remains in a consistently lower range. Drought conditions have probably been a factor in producing these low levels.
- ➔ Phosphorus concentrations have gradually decreased in the Lake, probably because of improved catchment management including improvements to sewage treatment plant discharge from the Queanbeyan Wastewater facility, and low inflows because of drought since 2002.
- ➔ Nitrogen concentrations have also decreased gradually, but not as markedly as phosphorus. The decrease in both nutrients has probably been due to the same factors.
- ➔ Total algal cell concentrations have remained within the same general range, with cyanobacterial cell concentrations generally below the high alert level for recreational exposure according to the Australian Government (2008) and ACT Government (2010). However, the intensity of late summer cyanobacterial blooms has increased in recent years.
- ➔ Chlorophyll-a values have decreased and all primary water contact areas are now generally below the benchmark values for other ACT waters (ACT Government, 2011).
- ➔ Conductivity had remained relatively consistent prior to 2003. However, since December 2002, there has been an upward trend. This is likely to be due to drought conditions.
- ➔ pH values have remained in the same general range, and within an acceptable limit for this type of water body.
- ➔ Bacterial counts have generally remained within the guideline values but have had some significant exceedences of undetermined cause.
- ➔ The Lake contains high levels of some metals, particularly in the sediments.
- ➔ Averaged dissolved oxygen concentrations were at their maximum during the late winter months, and at their minimum during the late summer months.

There is a considerable amount of local information available on Lake Burley Griffin water quality. This has been invaluable in setting appropriate benchmarks for the WQMP and in setting management practices to achieve those benchmarks. The WQMP lists commonly occurring events that can reduce water quality and outlines management measures to protect public health and the environment.

The WQMP is designed to be a practical guide to actions required for the effective management of the Lake's water quality. It fits within the overarching direction of the Lake Burley Griffin Management Plan. This WQMP will be revised and updated regularly as new information becomes available.

1 INTRODUCTION

1.1 BACKGROUND

Lake Burley Griffin is an integral part of Walter Burley Griffin's design for Canberra and is a vital and key element in the plan for the National Capital (National Capital Development Commission, 1981 and 1988). The Lake (which was created in 1964) is not only one of the centrepieces of Canberra's plan in its own right but also forms the immediate foreground of the Parliamentary Zone.

Lying within the National Capital Open Space System (NCOSS), the Lake is part of the nationally significant open space framework, visual backdrop and landscape setting for the National Capital, and contributes to the system that protects the environmental quality of the city.

The Lake's overall management is guided by the principles and policies of the *National Capital Plan*, the *Lake Burley Griffin Management Plan 1995*, the *Lake Burley Griffin and Adjacent Lands Heritage Management Plan*, and the *Lake Burley Griffin Recreation Policy 2010*. The *Lake Burley Griffin Management Plan 1995* (LBGMP1995) acknowledges a range of uses for the Lake, consistent with the policies of the NCP.

The above policies direct that the water quality and hydraulic operation of the Lake be maintained in a manner that protects the Lake and its foreshores, as well as their visual and symbolic roles. Should the water quality of the Lake not be managed effectively, these functions and values could be compromised, leading to stakeholder and community dissatisfaction.

1.2 NEED FOR A PLAN

The NCA manages comprehensive water quality programs to monitor the water quality conditions against parameters set out in ANZECC/ARMCANZ *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (2000), prepared under the National Water Quality Management Strategy.

One of the key outcomes of the ANZECC/ARMCANZ (2000) guidelines is to develop site-specific water quality guidelines and management plans, tailored to local conditions.

It is therefore critical that the Lake management strategies include the development of a Water Quality Management Plan (WQMP) to address those issues.

1.3 STRUCTURE OF THE DOCUMENT

The document contains the following:

Introductory Sections

Part 1: Explanatory Paper

The Explanatory Paper provides the background information for the development of the Water Quality Management Plan and outlines:

- ➔ the context for which the Water Quality Management Plan has been formulated, including the functions and uses of the Lake;
- ➔ the summary of Lake Burley Griffin's water quality, using the results of a monitoring program from 1981 to 2009; and
- ➔ the process used in the development of benchmark values.

Part 2: Management Response

The Water Quality Management Plan summarises the benchmark values, which then help to detect possible threats to water quality in terms of public health and environmental management. The Water Quality Management Plan provides details of:

- recommended benchmark water quality values for key water quality indicators;
- an overview of the water quality monitoring programs;
- actions arising from the management of pollutants;
- communications;
- use of legislation; and
- roles and responsibilities.

Conclusions

References

Appendices

2 OBJECTIVES

The objectives of the Explanatory Paper are to:

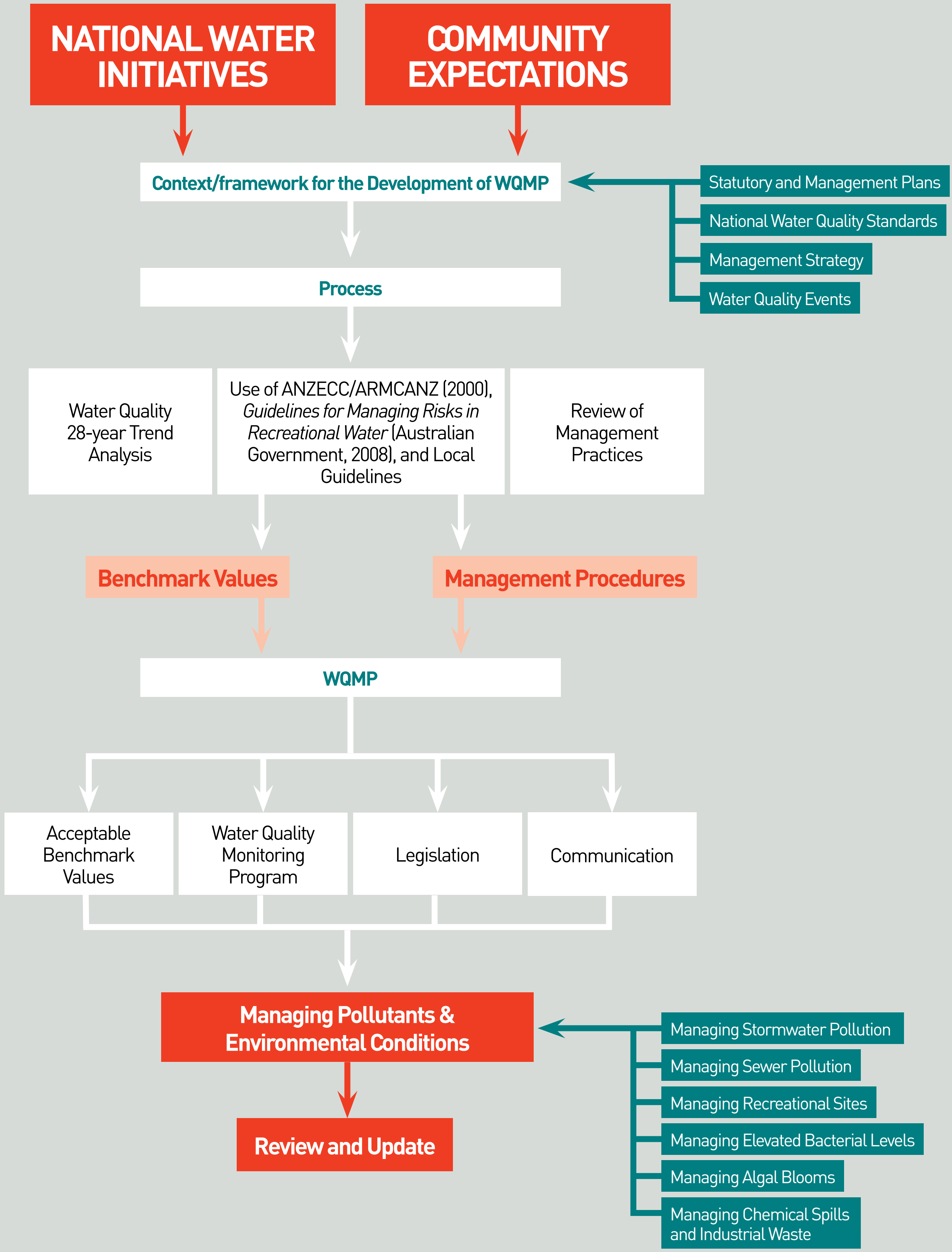
- Outline the drivers for the development of this plan and context for which the plan is to be developed.
- Provide sufficient background information and disseminate the findings on the current water quality condition of the Lake.
- Outline how the benchmark values for the water quality parameters were developed.

The objectives of the Management Response are to:

- Outline benchmark values for the water quality parameters against which the monitoring and reporting will be carried out.
- List commonly occurring events that may cause harmful changes to water quality, and provide management measures that minimise the risks to public health and to the aquatic environment.
- Outline the current water quality program, reporting and assessment.
- Outline communications on water quality matters.

3 PROCESS OF THE PLAN

The process adopted for developing the Water Quality Management Plan is shown below.



PART 1 EXPLANATORY PAPER

4 CONTEXT

The context in which the Water Quality Management Plan (WQMP) has been prepared includes:

- **requirements to manage the water quality of the Lake with the aspirations of the statutory plans such as the National Capital Plan and the Lake Burley Griffin Management Plan relating to the Lake and to water quality generally;**
- **compliance under the National Water Quality Management Strategy (NWQMS), and ANZECC/ARMCANZ (2000), for establishing quality standards, monitoring water quality and reporting pollution incidents;**
- **existing Lake management practices; and**
- **recent reported incidences of elevated levels of bacterial activity in the Lake and concern about the health consequences and impacts on Lake-based recreational events.**

4.1 STATUTORY AND MANAGEMENT PLANS

4.1.1 National Capital Plan

Water quality management is identified as an important management issue in the National Capital Plan (NCP). Broader water quality objectives of the NCP are generally consistent with the National Water Quality Management Strategy guidelines, and they are covered in Section 1.2 of the NCP, a copy of which can be obtained from the NCA's website at www.nationalcapital.gov.au

The object of the NCP is to ensure 'that Canberra and the Territory are planned and developed in accordance with their national significance'. Lake Burley Griffin is defined in the NCP as part of the Central National Area. It is a Designated Area under the provisions of the *Australian Capital Territory (Planning and Land Management) Act 1988*, being an area having the special characteristics of the National Capital.

A most significant aspect of the NCP is the National Capital Open Space System (NCOSS), which exists to protect the nationally significant open-space framework, visual backdrop, and landscape setting for the National Capital. The management of water resources as a part of NCOSS comes under two categories:

a. **The Murrumbidgee and Molonglo River Corridors; and**

b. **Lake Burley Griffin**

The land use policies associated with the above water resources allow certain functions, such as nature conservation and recreation, along the foreshores and river corridors (ie places where water quality is an important management issue).

4.1.2 The Lake Burley Griffin Management Plan 1995

In relation to the management of the Lake, the NCP recommended the preparation of a management plan for the Lake (Appendix J of the NCP).

The Lake Burley Griffin Management Plan was developed in 1995 (LBGMP1995) through extensive public consultation. The broader objectives of the water quality management of the Lake were derived from this plan which specifically identified the following key requirements:

- **Promoting the ornamental and visual values of the Lake as intended by the NCP.**
- **Maintaining the Lake as a viable and stable ecosystem, which encourages the development of plant and animal species in order to protect the ecological, aesthetic and scientific values of the Lake and its foreshores.**
- **Having an acceptable 'quality of flow' regime that enables the Lake to be utilised as a water quality control pond to maintain, as far as practicable, downstream water quality and flow.**
- **Maintaining acceptable water quality to support the recreational and commercial functions of the Lake.**

Broader aspects of the management issues are covered in the LBGMP1995, many of which can be related to this Water Quality Management Plan. This WQMP should consequently be read in conjunction with the LBGMP1995.

In terms of water quality monitoring, the LBGMP1995 recommends the following:

Types of Water Quality Programs

The LBGMP1995 identified the types of water quality programs necessary to address water quality issues as:

- **Monitoring for baseline performance to determine how the water quality of the Lake is performing against management objectives or guidelines, and establishing long term goals.**
- **Monitoring for specific periods at specific sites from a public health and safety viewpoint, particularly in relation to primary and secondary contact recreation.**
- **Intense monitoring for specific events or specific parts of the Lake with a view to improving the understanding of Lake process.**

The Zoning of the Lake for Activities

The LBGMP1995 directs the management of water quality to be based on a 'best practicable means' approach aimed at satisfactory water quality objectives for different parts of the Lake in accordance with designated water use. The designated uses of different parts of the Lake have been derived from the water quality considerations and they limit the nature of the recreational activities permitted in a particular area.

Based on water quality considerations, the Lake is divided into five regions:

- **Molonglo Reach. This is the section of the Molonglo River from Dairy Road to East Basin Pavilion (The Boathouse Restaurant). Zoned for primary contact water recreation activities.**
- **East Basin. This extends from Molonglo Reach to Kings Avenue Bridge. Secondary contact water sports only are permitted here. This section of the Lake is relatively shallow, so it is subject to high turbidity in windy conditions and has poorer water quality than other parts of the Lake. Wall structures are in place around much of this area to discourage incidental primary contact with the water.**
- **Central Basin. This is the section between Kings Avenue and Commonwealth Avenue. It is a secondary contact area, and normally reserved for water activities where the emphasis is on passive recreational use.**
- **West Lake and Tarcoola Reach. This is the area from Commonwealth Avenue to Kurrajong Point, and is the principal recreational area of the Lake, supporting both primary and secondary contact water sports.**
- **Yarramundi Reach. This section supports rowing events and other water spectator sports and is zoned for secondary contact but primary contact is also permitted.**

The above framework forms the basis of the NCA's current Water Quality Program with the necessary enhancements added over the period since the LBGMP1995 was prepared. The monitoring programs are designed to support the Lake's activities, including public health and environmental management considerations as well as the monitoring of the on-going performance of water quality.

4.2 NATIONAL WATER QUALITY GUIDELINES

This updated Water Quality Management Plan is based on the National Water Quality Management Strategy guidelines, entitled *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (2000) (ANZECC/ARMCANZ, 2000), the *Guidelines for Managing Risks in Recreational Water* (Australian Government, 2008), the *ACT Guidelines for Recreational Water Quality* (ACT Government, 2010), the *ACT Water Report 2009-2010* (ACT Government, 2011), and the *Environment Protection Regulation 2005* (ACT).

The Guidelines provide an authoritative template for setting up water quality objectives and limiting values for all Australian waters.

These Guidelines were prepared according to the National Water Quality Management Strategy (NWQMS) and are aimed at helping the community, catchment managers, and water authorities protect water quality.

The Lake Burley Griffin Management Plan 1995 identified a number of broader principal values for the Lake to reflect management objectives of that plan. From those values, several environmental values have been derived for the purpose of this WQMP.

The applications of ANZECC/ARMCANZ (2000), the *Guidelines for Managing Risks in Recreational Water* (Australian Government, 2008) and Local Guidelines for each of these environmental values are shown below:

ENVIRONMENTAL VALUES	Application of ANZECC/ARMCANZ (2000)
National Capital Values	Visual and ornamental values. Passive recreation based on Chapter 5 of ANZECC/ARMCANZ (2000) and the *Guidelines for Managing Risks in Recreational Water* (Australian Government, 2008).
Ecological Values	Protection of the aquatic ecosystem based on Chapter 3 of ANZECC/ ARMCANZ (2000), the *ACT Water Report 2009-2010* (ACT Government, 2011), and Part 4.7 of the *Environment Protection Regulation 2005* (ACT).
Water Resources	Irrigation water quality based on Chapter 4 of ANZECC/ARMCANZ (2000) and Part 4.6 of the *Environment Protection Regulation 2005* (ACT); and *Guidelines for Managing Risks in Recreational Water* (Australian Government, 2008). The allocation of water is based on the *Environmental Flow Guidelines* (ACT Government, 2006) and the ACT Water Resources Management Plan *Think Water Act Water* (ACT Government, 2004).
Recreational Values	Primary and secondary contact recreational activities based on Chapter 5 of ANZECC/ARMCANZ (2000) and the *Guidelines for Managing Risks in Recreational Water* (Australian Government 2008), the *ACT Guidelines for Recreational Water Quality* (ACT Government, 2010), the *ACT Water Report 2009-2010* (ACT Government, 2011), and Part 4.3 of the *Environment Protection Regulation 2005* (ACT).

Recreational Water Quality Criteria

The philosophical approach of ANZECC/ARMCANZ (2000) generally recommends a risk-based assessment for decision-making for water quality objectives, depending on local environmental conditions.

The *Guidelines for Managing Risks in Recreational Water* (Australian Government, 2008) incorporates the outcomes of the review of recreational water quality health criteria by the National Health and Medical Research Council. The new guidelines are risk based and include a preventative management approach based on understanding local impacts and management of hazards that impact on local water quality.

Consequently the updated WQMP was developed consistent with the direction from ANZECC/ARMCANZ (2000) and the *Guidelines for Managing Risks in Recreational Water* (Australian Government, 2008).

The *Guidelines for Recreational Use of Water* ANZECC/ARMCANZ (2000) take into account the assessment of risk to public health in the use of recreational water, an assessment of the indicators of pollution, the level of exposure associated with the recreational activity and a number of other factors.

This risk-based approach provides an effective set of management guidelines as set out on the summary of Lake Programs below.

4.3 EXISTING MANAGEMENT PRACTICES

The Lake is managed by several programs that are structured according to a series of functions and operations requiring different skills and experience. Depending on those requirements, functions are managed by different programs contracted to external agencies.

A brief summary of Lake Programs are outlined below. The various aspects of water quality criteria relating to those functions are also outlined.

MANAGEMENT FUNCTIONS	SCOPE OF PROGRAM	RELATING TO WATER QUALITY OBJECTIVES
Water Quality Management	This program includes water quality management for environmental conditions in the overall body of the Lake through monitoring representative sample locations and monitoring of designated recreational sites covering indicators eg. turbidity, nutrients, inorganic and organic parameters.	Based on ANZECC/ ARMCANZ (2000) and *Guidelines for Managing Risks in Recreational Water* (Australian Government, 2008).
General Lake Maintenance	This program includes routine cleaning of beaches, water areas and Lake structures. This program helps to ensure that the lake water is maintained in a manner that aesthetically enhances the National Capital values and meets the requirements for ornamental waters as an important symbolic element. Control and cutting of aquatic plants is also covered in this program. Whilst the removal of aquatic plant material each year improves the amenity value of the Lake, they should not be completely removed.	Based on ANZECC/ ARMCANZ (2000).
Algal Monitoring	This program covers routine visual inspection of the Lake areas for algal scums and conducting algal testing of water samples.	In accordance with *ACT Guidelines for Recreational Water Quality* (ACT Government, 2010) and *Guidelines for Managing Risks in Recreational Water* (Australian Government, 2008).
Management of Water Resources Allocations	The water resources of the Lake will form part of the ACT's allocation (once such allocations are finalised) for the water resources of the Murray-Darling Basin.	Allocation of water from the Lake includes environmental flows and abstractions, based on the ACT Water Resources Management Plan, *Think Water Act Water* (ACT Government, 2004).
Scrivener Dam Facility Management	This program includes operation and maintenance of the Dam and Flood Management	Based on Scrivener Dam flood operating procedures.

The functions identified above contribute to the maintenance of an acceptable quality of water in the Lake. The operation and maintenance of the Lake and Dam can significantly influence the quality of water in the Lake. The regular cleaning of decaying or green debris and pollutants in the water body and along the foreshores minimises undesirable water quality conditions.

The NCA manages comprehensive water quality programs to test and report on a range of physical, biological and chemical properties. The quality of the water is measured against the parameters for the protection of aquatic ecosystems and recreational water quality as set out by ANZECC/ARMCANZ (2000) and *Guidelines for Managing Risks in Recreational Water* (Australian Government, 2008).

4.4 RECENT INCIDENCES OF ELEVATED BACTERIAL LEVELS

A concern in the past has been elevated bacterial levels at certain times of the year. These events tend to happen in late summer and early autumn periods with bacterial levels reaching a bloom condition for a short time (typically ten to fifteen days) before counts return to normal levels. The occurrence of such events has been sporadic in the past. However, the frequency of such events has probably increased in the last decade (Lawrence, 2001).

These conditions necessitated the closure of recreational beaches and, in some cases, closure of the whole Lake where faecal pollution was the proven cause. Warnings about the risks of using the Lake were also issued.

Unexpected changes in water quality can severely disrupt lake-based recreational and commercial activities and cause inconvenience to prospective attendees. Effective management of bacterial problems is imperative to support aquatic sports all year around, including nationally significant events that are important to the National Capital.

4.4.1 Responses During Elevated Bacterial Counts

During periods of elevated bacterial counts, the initial responses have primarily focused on protecting the public from health risks associated with possible faecal contamination. Sanitary surveys, additional confirmation testing, and assessment of alternate indicators have also been carried out.

Where faecal contamination has been confirmed, the appropriate management measure has been Lake closure, despite inconvenience to the users of the Lake and particular inconvenience to commercial operations. In recognising the concerns, in the past the NCA has also:

- **Invited the Cooperative Research Centre for Freshwater Ecology of the University of Canberra to undertake a study of the bacterial problems to ascertain whether or not they represented actual faecal pollution in the Lake (Lawrence, 2001). The study included a review of the appropriateness of the management responses.**
- **Commenced research works to identify causes of or environmental conditions responsible for the growth of bacteria including whether or not these bacteria were likely to pose a risk to human health.**
- **Developed management strategies to address water quality problems to protect public health and minimise adverse impacts on users resulting from Lake closures.**

5 PAST WATER QUALITY TRENDS

5.1 OVERVIEW OF TRENDS

The results of the monitoring program from 1981 to 2009 indicate that:

- The overall environmental health of the Lake is generally good.
- Turbidity has decreased and now remains in a consistently lower range. Drought conditions have probably been a factor in producing these low levels.
- Phosphorus concentrations have gradually decreased in the Lake, probably because of improved catchment management including improvements to sewage treatment plant discharge from the Queanbeyan Wastewater facility, and low inflows because of drought since 2002.
- Nitrogen concentrations have also decreased gradually, but not as markedly as phosphorus. The decrease in both nutrients has probably been due to the same factors.
- Total algal cell concentrations have remained within the same general range, with cyanobacterial cell concentrations generally below the high alert level for recreational exposure according to the Australian Government (2008) and ACT Government (2010). However, the intensity of late summer cyanobacterial blooms has increased in recent years.
- Chlorophyll-a values have decreased and all primary water contact areas are now generally below the benchmark values for other ACT waters (ACT Government, 2011).
- Conductivity had remained relatively consistent prior to 2003. However, since December 2002, there has been an upward trend. This is likely to be due to drought conditions.
- pH values have remained in the same general range, and within an acceptable limit for this type of water body.
- Bacterial counts have generally remained within the guideline values but have had some significant exceedences of undetermined cause.
- The Lake contains high levels of some metals, particularly in the sediments.
- Averaged dissolved oxygen concentrations were at their maximum during the late winter months, and at their minimum during the late summer months.

Generally, observed values for the above mentioned water quality characteristics were:

- Turbidity, generally below 40 NTU in East Basin and generally below 20 NTU in West Lake (since 2000).
- Suspended solids, usually below 50 mg/L in East Basin and below 25 mg/L in West Lake.
- Total phosphorus concentrations, usually below 0.08 mg/L in East Basin and below 0.06 mg/L in West Lake (although concentrations in the past were generally 2–3 times higher).
- Total nitrogen concentrations, usually below 1.4 mg/L in East Basin and usually below 1.0 mg/L in West Lake (although concentrations in the past were generally 20–30% higher).
- Ammonia concentrations, usually below 0.1 mg/L for both East Basin and West Lake.
- Cell concentrations of cyanobacteria have increased to levels in excess of 10,000 cells/mL since 2005.
- Chlorophyll-a, usually below 10 µg/L for West Lake (although higher in the past), and usually below 30 µg/L for East Basin.
- Conductivity in West Lake and East Basin generally below 400 µS/cm.
- pH in the range of 7.0 to 9.0, with a mean Lake value of 7.8 (±0.4).
- Bacterial counts, (faecal coliforms) usually below 150 CFU/100mL in West Lake and usually below 1000 CFU/100mL in East Basin.
- Averaged dissolved oxygen concentrations for Central Basin, West Lake and Scrivener Dam ranging with depth from 1.4-8.5 mg/L in the warmer months and from 6.6-11.1 mg/L in the cooler months.

5.2 GENERAL

Routine water quality monitoring in Lake Burley Griffin started in December 1981 and with some minor modifications has been continued to the present day by ECOWISE Australia Pty Ltd, trading as ALS Water Resources Group. Public health monitoring is undertaken by ACT Health Protection Service. Intensive monitoring of specific events or at specific locations is undertaken by a wide range of organisations (including government agencies, research organisations and community groups).

The results of various monitoring programs and research projects are summarised in a number of previous reports (ACT Electricity and Water, 1988; ACT Parks and Conservation Service, 1988a and b; Burgess and Olive, 1975; Cullen, Rosich and Bek, 1978; Department of Housing and Construction, 1982 and 1984; EcoChemistry Laboratory, 2003; Ecowise Scientific and Aquatech, 1995; Gutteridge, Haskins and Davey, 1982; Hillman, 1980; Maher et al. 1992; Nagy and Butters, 1987 and 1988; Nazer, 1986; Norris, 1983; Office of ACT Administration, 1987; Scientific Services and Aquatech, 1994). Collectively, these research and monitoring programs contain a considerable amount of valuable information on Lake Burley Griffin water quality.

Most of the monitoring effort has used the following four main sites, and generally a monthly sampling frequency:

- **East Basin (site 529).**
- **Central Basin (site 530).**
- **West Lake (site 504).**
- **Scrivener Dam (site 507).**

A fifth site was added in April 2009:

- **West Lake (2) (site 505).**

Refer to Appendixes A and B for location of sites.

At each site, both surface and tube samples have been collected. Surface samples (taken at 0.3 m below the surface) were generally used for bacteriological analysis. Tube samples, which consisted of a composite of the top 5 m of the water column, were used for chemical and algal analyses. The only exception to this was East Basin (site 529), where only surface samples were taken, because the site is relatively shallow.

The remainder of this section provides an overall assessment of the results from the past 28 years of monitoring focusing on:

- **Turbidity and suspended material.**
- **Phosphorus.**
- **Nitrogen.**
- **Algae and chlorophyll-a.**
- **Conductivity and pH.**
- **Bacteria.**
- **Metals.**
- **Dissolved oxygen.**

Also included are water column depth profiles taken in 2009 and 2010 in order to better understand and manage blue-green algal blooms within Lake Burley Griffin.

5.3 TURBIDITY AND SUSPENDED MATERIAL

5.3.1 Background

Turbidity is used as an indication of the amount of suspended material in the water, and is important for environmental, public health and aesthetic reasons.

Turbidity is important environmentally, as it reduces the clarity of the water and thus the amount of sunlight available for algae and aquatic plants. Also, nutrients such as phosphorus and nitrogen are often attached to the surface of suspended material.

Turbidity is also important in terms of public health, as bacteria and pollutants (such as heavy metals) are often attached to the surface of suspended material.

Furthermore, turbidity is an important aesthetic measure, particularly for recreational areas, as it is an indication of water clarity.

Suspended material and turbidity can come from the surrounding catchment (as part of rainfall runoff during storm events), or it can be resuspended Lake sediment (due to wind mixing in shallow areas).

Like most lakes in south-east Australia, Lake Burley Griffin has always been a relatively turbid lake. The Lake's catchment contains:

- **Large areas of agricultural land (used primarily for grazing).**
- **Large areas of urban land (involving residential and light commercial uses).**

Such relatively high levels of turbidity can introduce significant amounts of nutrients into a lake, but can also reduce the ability of algae to use such nutrients (due to reduced light penetration into the water column). The relatively high turbidity can also serve to reduce the aesthetic value of the water for recreational activities (such as swimming or boating) and potential for growth of aquatic macrophytes.

The Lake also experiences a considerable amount of wind induced sediment resuspension. This is especially the case in East Basin, which is relatively shallow (less than 3 metres) over large parts of its area, and relatively exposed to strong westerly winds (Scientific Services and Aquatech, 1994).

5.3.2 General Trends

Turbidity is measured in nephelometric turbidity units (NTU), and its monitoring in Lake Burley Griffin commenced in 1981. Information is generally available from four sites (five sites from April 2009) in the Lake and usually at a monthly frequency.

From the collected information (EcoChemistry Laboratory, 2003; Ecowise Scientific and Aquatech, 1995; Office of ACT Administration, 1987) and more recent water quality data, it is possible to indicate the following general trends:

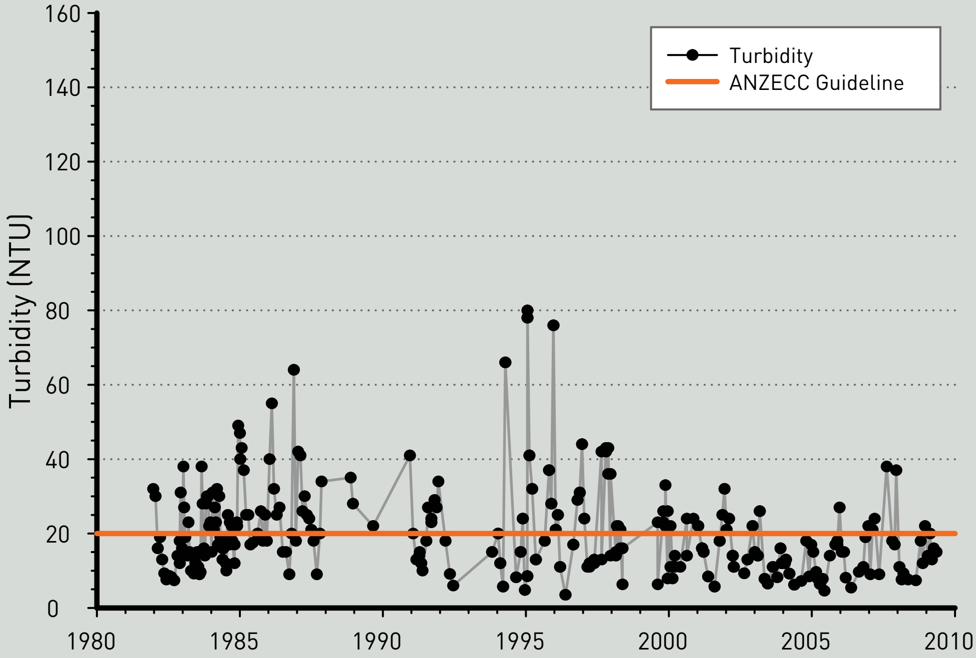
- **Turbidity is higher in the shallower eastern parts of the Lake than in the deeper western parts. This is to be expected, as suspended solids settle out on entering most lakes, and indeed one of the intended functions of the Lake was to serve as a settling basin for catchment runoff.**
- **Turbidity is higher just after stormwater inflow into the Lake. Once again, this is to be expected, as stormwater runoff contains higher levels of suspended material, resulting in higher turbidity values.**
- **Turbidity is higher just after strong windy periods, especially in the shallower eastern parts of the Lake. This is largely the result of wind resuspension of bottom sediments (Scientific Services and Aquatech, 1994).**
- **Turbidity values in East Basin are generally below 40 NTU, whereas in West Lake values are generally below 20 NTU.**
- **Suspended solids show very similar patterns to turbidity, with values in East Basin generally below 50 mg/L, whereas in West Lake values are generally below 25 mg/L.**

Turbidity values for East Basin (site 529 surface) and West Lake (site 504 tube) are shown in figures 1A and 1B respectively for the period from 1981 to 2009. The figures show that turbidity in East Basin has remained in the same general range over the 28 years of available monitoring data. However, the turbidity in West Lake has decreased since 2000. Turbidity values in East Basin are generally below 40 NTU, whereas in West Lake values are generally below 20 NTU. The turbidity value for undisturbed sites of 20 NTU cited in the ANZECC/ARMCANZ Guidelines (2000) is shown on the graph and has generally been achieved in more recent years. Given the lower comparative turbidity a revised water quality benchmark value for turbidity in East Basin could be 40 NTU, and for West Lake 20 NTU.

The water quality standards in other parts of the ACT for water based recreational swimming areas state that turbidity should not be objectionable. The standard for water based recreational boating areas states the same condition (ACT Government, 2011).

Corresponding values for suspended solids are 40 mg/L in East Basin and 20 mg/L in West Lake. These will be discussed in more detail in Chapter 6.

a. East Basin Turbidity 1981-2009



b. West Lake Turbidity 1981-2009

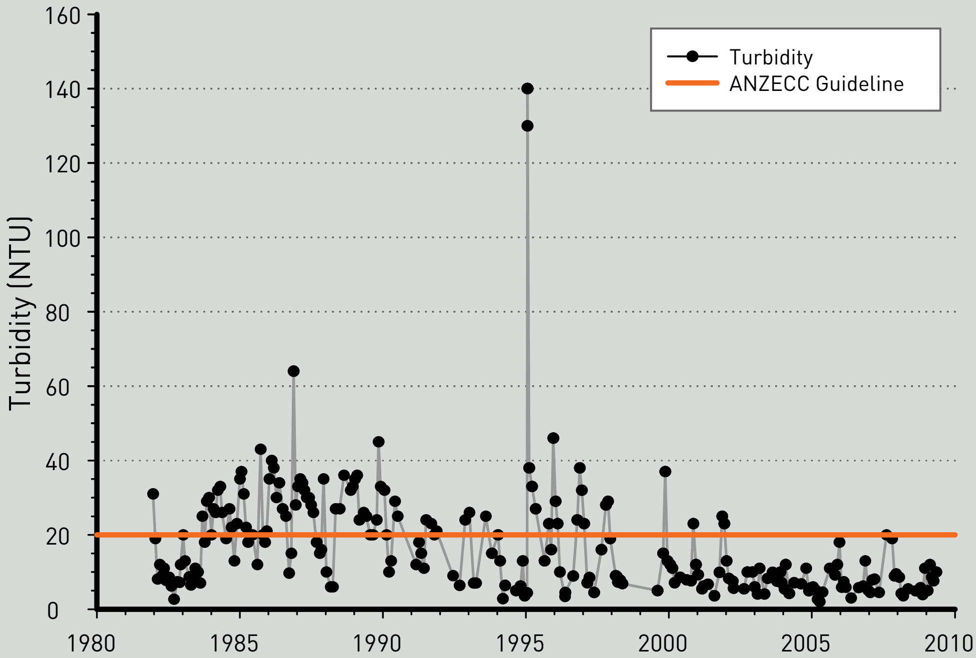


Figure 1. Turbidity (NTU) values in Lake Burley Griffin for 1981–2009
a. East Basin (site 529 surface)
b. West Lake (site 504 tube)

5.4 PHOSPHORUS

5.4.1 Background

Phosphorus is an essential nutrient in aquatic ecosystems, particularly to photosynthetic organisms such as algae and macrophytes. However, high concentrations of phosphorus increase the amount of biological activity. Consequently, phosphorus promotes algal activity and this in turn can result in serious water quality problems. During algal blooms, the water becomes unsuitable for a number of recreational activities, whereas after a large algal bloom, the decaying material can deplete the oxygen levels in the water column (and thus result in fish deaths).

Phosphorus originates from a number of sources including:

- **soils in the catchment;**
- **wastewater discharges;**
- **fertilizers applied to agricultural land or suburban gardens;**
- **waterbirds defecating into or near the water body; and**
- **releases from lake sediments if oxygen becomes depleted in the overlying waters.**

In environmental waters, both total phosphorus and filterable phosphorus concentrations are measured. Filterable phosphorus is generally regarded as the fraction that is biologically available in the short term. In Australian lakes and rivers, filterable phosphorus usually represents 30–60% of the total phosphorus in the water column.

5.4.2 General Trends

Total phosphorus and filterable phosphorus concentrations are both measured in terms of mg/L. Generally, both have been monitored in Lake Burley Griffin since 1981, at four sites (five sites from April 2009) and usually at a monthly frequency.

From the collected information (EcoChemistry Laboratory, 2003; Ecowise Scientific and Aquatech, 1995; Office of ACT Administration, 1987) and more recent water quality data, it is possible to indicate the following general trends:

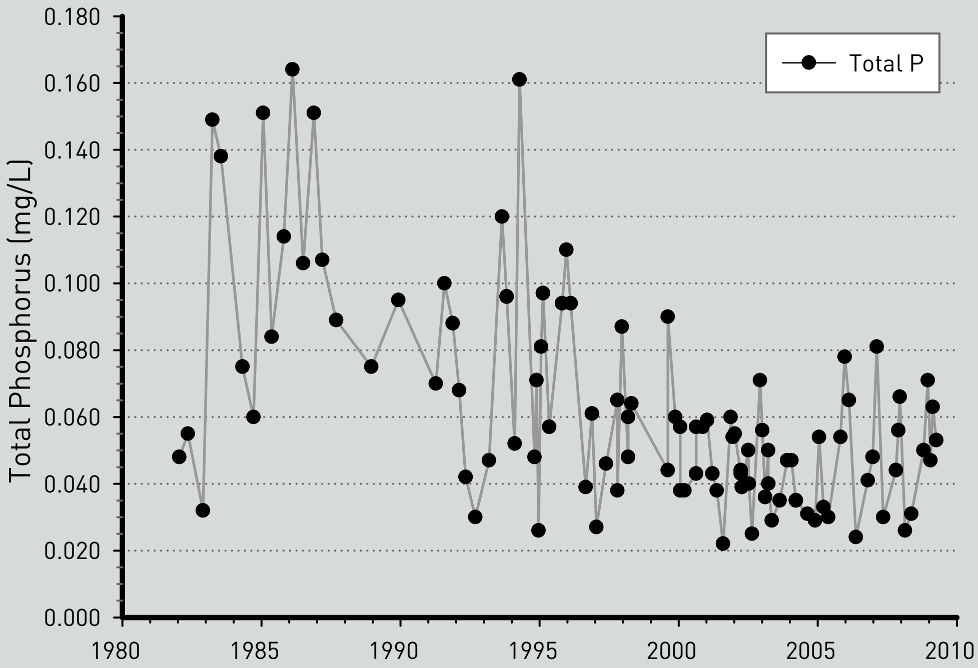
- **Both total phosphorus and filterable phosphorus concentrations have been gradually decreasing since the mid 1980s. The main reason for this decrease has been a reduction in the amount of phosphorus entering the Lake from the Queanbeyan Wastewater Treatment Plant. This plant was upgraded in the mid 1980s and its phosphorus discharges were reduced by over 90%. Other contributing factors have included a range of catchment management and lake management practices (such as the harvesting and removal of aquatic plants from some areas).**
- **Total phosphorus and filterable phosphorus concentrations are higher in the shallower eastern parts of the Lake, than in the deeper western parts. This is to be expected, as higher suspended solids concentrations (caused by stormwater runoff and wind resuspension of sediment) generally correlate with higher phosphorus and nitrogen values.**
- **Total phosphorus concentrations are higher just after stormwater inflows into the Lake.**
- **Total phosphorus concentrations are higher just after strong windy periods, especially in the shallower eastern parts of the Lake.**
- **Total phosphorus concentrations in East Basin are generally below 0.08 mg/L, whereas in West Basin values are generally below 0.06 mg/L.**
- **Filterable phosphorus concentrations in East Basin and West Basin are generally below 0.02 mg/L.**

Total phosphorus concentrations for East Basin (site 529 surface) and West Lake (site 504 tube) are shown in figures 2A and 2B respectively for the period from 1981 to 2009. The water quality standards in other parts of the ACT for water based recreational activities and for aquatic habitat indicate a value of <0.1 mg/L total phosphorus (ACT Government, 2011). The values observed for Lake Burley Griffin are generally below this level. Total phosphorus concentrations were consistently below 0.06 mg/L but well above the 0.05 mg/L suggested in the ANZECC/ARMCANZ (2000) for undisturbed sites. The benchmark concentration of 0.1 mg/L for total phosphorus should be lowered to 0.06 mg/L. This will be discussed in more detail in Chapter 6.

Filterable reactive phosphorus concentrations for East Basin (site 529 surface) and West Lake (site 504 tube) are shown in figures 3A and 3B respectively. Filterable reactive phosphorus concentrations have been generally below 0.01 mg/L in recent years. However, this is biologically available phosphorus and would be expected to decrease when it is taken up into algal biomass.

The figures show that total phosphorus concentrations in both basins have gradually decreased since the mid 1980s. As indicated previously, the main reason for this decrease has been the upgrading of the Queanbeyan Wastewater Treatment Plant (during the mid 1980s). Ongoing reductions since then have probably been due to a range of other catchment management practices.

a. East Basin Total Phosphorus 1981-2009



b. West Lake Total Phosphorus 1981-2009

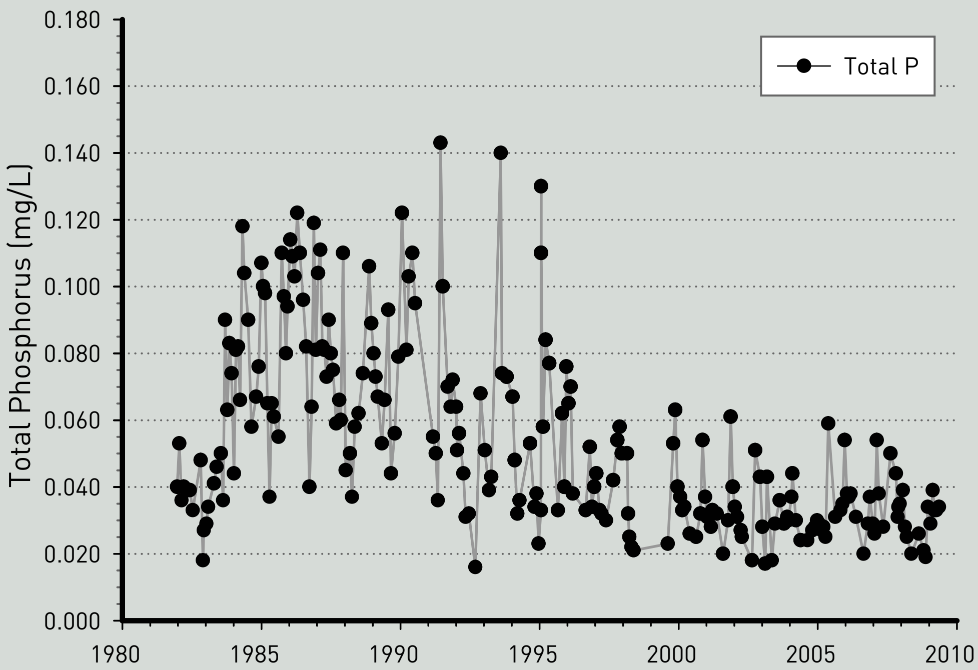
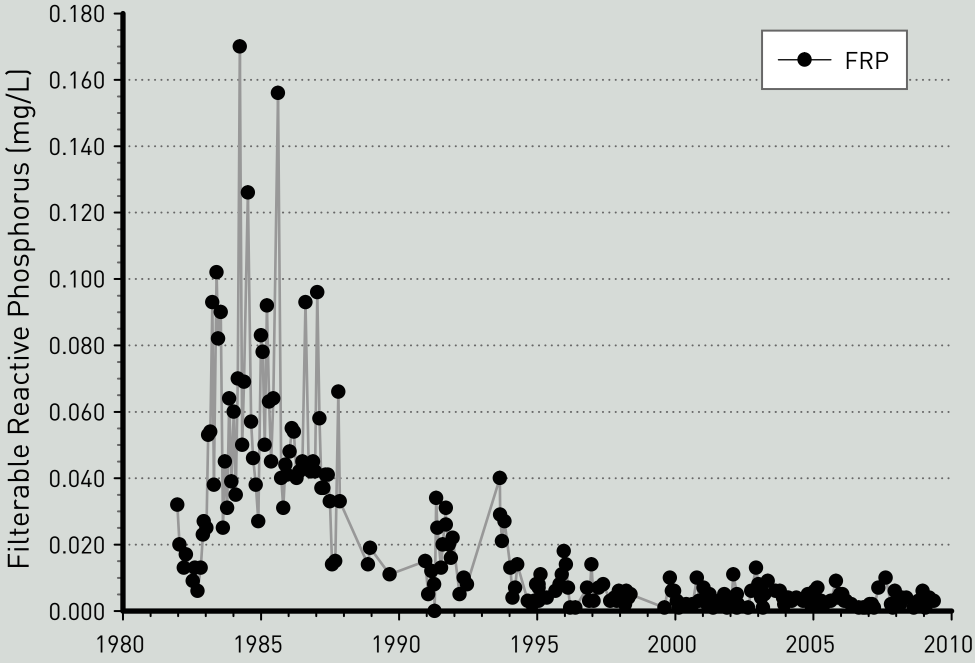


Figure 2. Total Phosphorus (mg/L) concentrations in Lake Burley Griffin for 1981–2009
a. East Basin (site 529 surface)
b. West Lake (site 504 tube)

a. East Basin Filterable Reactive Phosphorus 1981-2009



b. West Lake Filterable Reactive Phosphorus 1981-2009

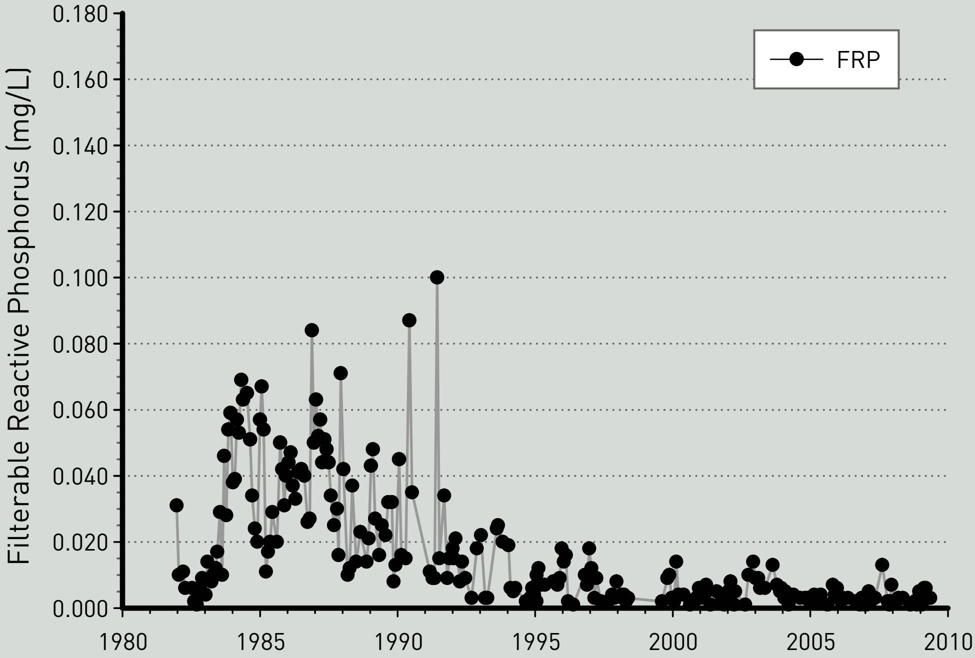


Figure 3. Filterable Reactive Phosphorus (mg/L) concentrations in Lake Burley Griffin for 1981–2009
a. East Basin (site 529 surface)
b. West Lake (site 504 tube)

5.5 NITROGEN

5.5.1 Background

Nitrogen is also an essential nutrient in aquatic ecosystems. High nitrogen concentrations can promote nuisance growths of algae and macrophytes, which in turn can result in eutrophication.

Nitrogen originates from the same general sources as phosphorus, including:

- **soils in the catchment;**
- **wastewater discharges;**
- **fertilizers applied to agricultural land, or suburban gardens;**
- **waterbirds defecating into or near the water body; and**
- **releases from lake sediments as ammonia, if oxygen becomes depleted in the overlying waters.**

In environmental waters, nitrogen is measured in a number of forms, including ammonia, nitrate, nitrite, total kjeldahl nitrogen, and total nitrogen. Of these, total nitrogen and ammonia are particularly important (especially for algal and fish activity). High concentrations of total nitrogen and ammonia can promote algal blooms, whereas high ammonia concentrations can interfere with the ability of fish gills to absorb oxygen (and can thus result in fish deaths).

5.5.2 General Trends

Total nitrogen and ammonia concentrations are both measured in terms of mg/L. Generally, both have been monitored in Lake Burley Griffin since 1981, at four sites (five sites from April 2009) and usually at a monthly frequency.

From the collected information (EcoChemistry Laboratory, 2003; Ecowise Scientific and Aquatech, 1995; Office of ACT Administration, 1987) and more recent water quality data, it is possible to indicate the following general trends:

- **Both total nitrogen and ammonia concentrations have decreased slightly over the past 28 years of monitoring (but not as dramatically as total phosphorus and filterable phosphorus). This decrease has probably been the result of a range of catchment and sewage management practices.**
- **Nitrogen concentrations are higher just after stormwater flows into the Lake.**
- **Nitrogen concentrations are higher just after strong windy periods, especially in the shallower eastern parts of the Lake.**
- **Total nitrogen concentrations in East Basin are generally below 1.4 mg/L, whereas in West Basin values are generally below 1.0 mg/L.**
- **Ammonia concentrations are generally below 0.1 mg/L.**

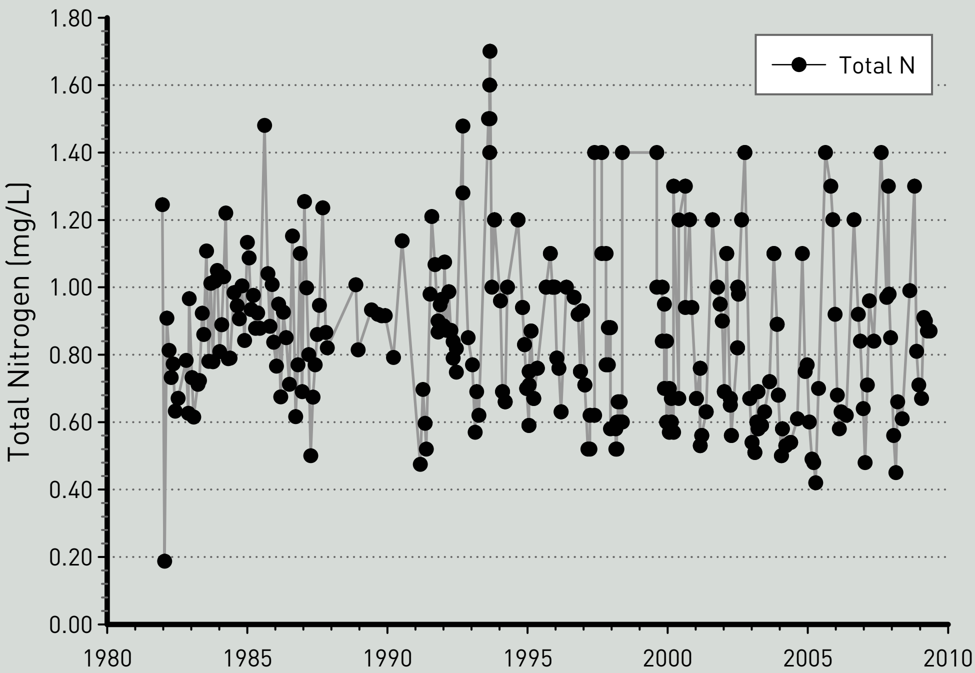
Total nitrogen concentrations for East Basin (site 529 surface) and West Lake (site 504 tube) are shown in figures 4A and 4B respectively for the period from 1981 to 2009. The figures show that total nitrogen in both basins has decreased slightly over the three decades of available monitoring data.

There are no total nitrogen water quality standards for other parts of the ACT for recreational waters or for aquatic habitat. Nitrogen is not regarded as a limiting factor for algal growth in regional waters and is non-toxic to other organisms (ACT Government, 2011). Furthermore, the availability of oxidized nitrogen will generally favour the growth of green algae as opposed to blue-green algae (which are less desirable from the recreational, ecological or aesthetic perspective). Consequently, the water quality benchmark proposed for total nitrogen concentrations is 1.4 mg/L in East Basin, and 1.0 mg/L in West Lake. This is discussed in more detail in Chapter 6.

Ammonia concentrations for East Basin (site 529 surface) and West Lake (site 504 tube) are shown in figures 5A and 5B respectively for the period from 1981 to 2009. The figures show that ammonia concentrations in both basins have decreased slightly over the 28 years of available monitoring data. However the presence of ammonia or ammonium nitrogen has the potential to select for the presence of blue-green algae, particularly *Microcystis*.

The water quality standard for ammonia in other parts of the ACT is calculated from ANZECC/ARMCANZ (2000), and is dependent on water pH and temperature at the time of sample collection. However, a concentration of 0.1 mg/L, as recommended in the previous version of this Water Quality Management Plan, has been retained as a benchmark. It is recommended that sampling of hypolimnetic concentrations of ammonium nitrogen is undertaken on all occasions when the water column is stratified. This will be discussed in more detail in Chapter 6.

a. East Basin Total Nitrogen 1981-2009



b. West Lake Total Nitrogen 1981-2009

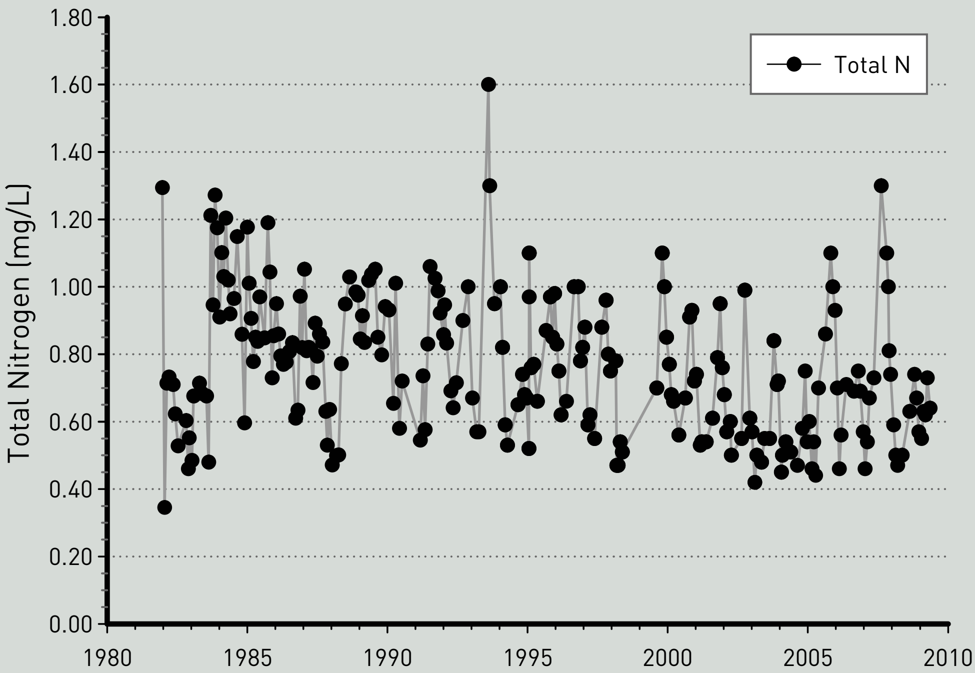
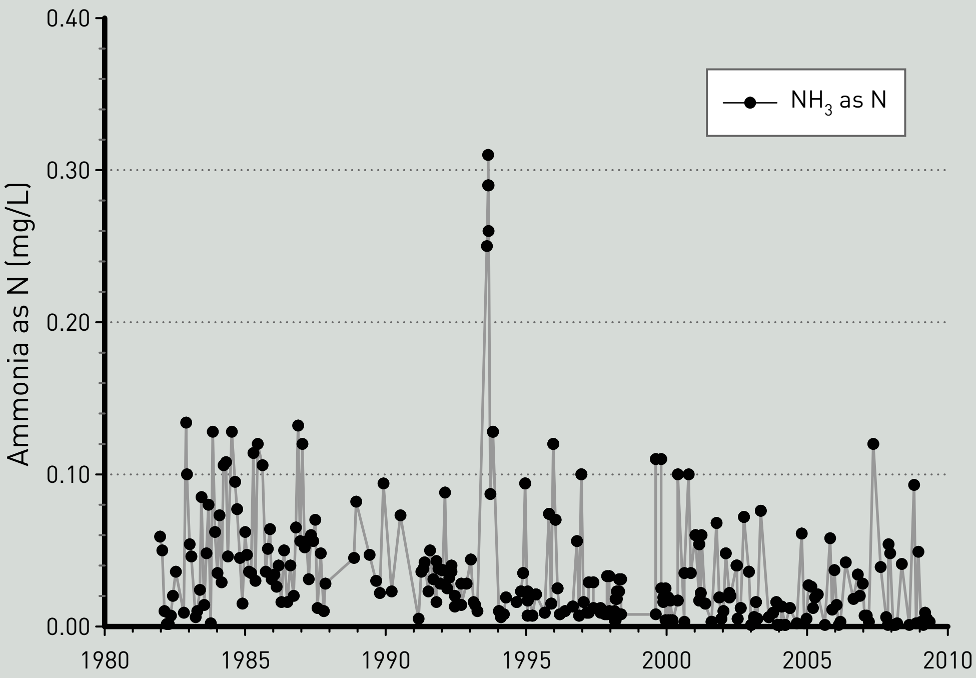


Figure 4. Total Nitrogen (mg/L) concentrations in Lake Burley Griffin for 1981–2009
a. East Basin (site 529 surface)
b. West Lake (site 504 tube)

a. East Basin Ammonia 1981-2009



b. West Lake Ammonia 1981-2009

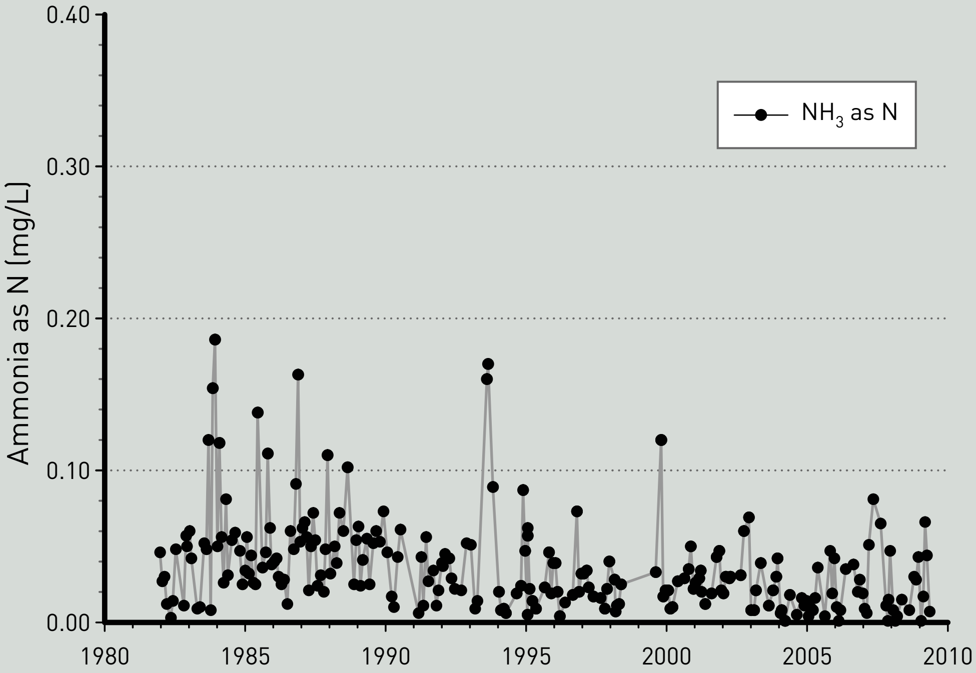


Figure 5. Ammonia as N (mg/L) concentrations in Lake Burley Griffin for 1981–2009
a. East Basin (site 529 surface)
b. West Lake (site 504 tube)

5.6 ALGAE AND CHLOROPHYLL-A

5.6.1 Background

Algae are aquatic plants that can range in size from microscopic to several metres long. Water quality problems can occur when some algae rapidly increase in numbers (during a bloom) and make the water unsuitable for a wide range of recreational uses (such as swimming, boating, or even passive recreation, such as sightseeing). Even more significant problems can occur when such blooms die and decompose. The decomposing algae use up the oxygen in the water column, which in turn often results in fish deaths.

5.6.2 General Trends

Algal cell concentration is measured in cells/mL. Classification then divides the algal assemblage into cyanobacteria (blue-green algae), green algae and the like. Further classification of problematic algae may occur to the level of genus and species. Cyanobacterial blooms may produce unsightly green powder like scums on the surface of water bodies, malodorous compounds and in some cases toxins which pose a health risk to humans and animals. Some cyanobacterial species do not produce surface scums but produce cells and toxin at depth. Biovolume may be used as a surrogate for the determination of the biomass of algae in a water body. Chlorophyll-a (µg/L) is also used as a measure of algal biomass.

Both total algal and cyanobacterial cell concentrations, and chlorophyll-a concentrations have been monitored in Lake Burley Griffin since 1981, at four sites (five sites from April 2009), and usually at a monthly frequency. As the monitoring program is time based, as opposed to event based, it is possible that the true peaks in algal activity have been under-reported.

From the collected information (EcoChemistry Laboratory, 2003; Ecowise Scientific and Aquatech, 1995; Office of ACT Administration, 1987) and more recent water quality data, it is possible to indicate the following trends:

- ➔ **Both total algal cell concentrations and chlorophyll-a concentrations have remained in the same general range. This is despite the previously mentioned reductions in the amount of phosphorus entering the Lake, and better flow management through the Lake during the key summer months (Nagy and Butters, 1988). However, the intensity of late summer cyanobacterial blooms has generally increased in recent years.**

Total algal and cyanobacterial cell concentrations for East Basin (site 529) and West Lake (site 504 tube) are shown in figure 6A and 6B respectively for the period from 1981 to 2009.

Water quality standards for cyanobacterial cell concentrations in other parts of the ACT provide a value of <5,000 cells per mL for water based recreation and for aquatic habitat (*Environment Protection Regulation 2005* (ACT)).

As shown in figure 6, cyanobacterial cell concentrations were usually below this level over the last 15 years, except for in late summer when blooms have generally increased in recent years. A cyanobacterial cell concentration of 20,000 cells/mL may be an appropriate water quality benchmark for Lake Burley Griffin. This will be discussed in more detail in Chapter 6.

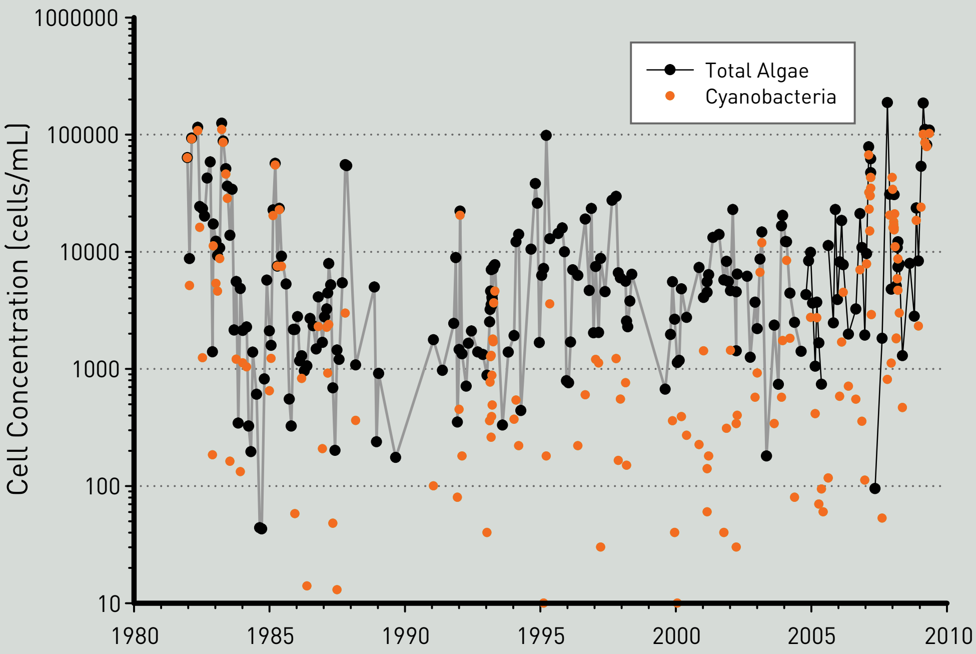
Chlorophyll-a concentrations for East Basin (site 529 surface) and West Lake (site 504 tube) are shown in figures 7A and 7B respectively for the period from 1981 to 2009.

It is possible to indicate the following trends:

- ➔ **Chlorophyll-a concentrations are generally the same over the period from 2004 to 2009 but far greater than the ANZECC/ARMCANZ (2000) guideline for undisturbed sites.**
- ➔ **The cell concentration of cyanobacteria has increased during the period 2004 to 2009.**

The water quality standards in other parts of the ACT indicate a chlorophyll-a concentration of <10 µg/L for water based recreation, and between <2-<10 µg/L for aquatic habitat (ACT Government, 2011). As shown in figure 7, chlorophyll-a concentrations have generally decreased at both sites. However East Basin (a secondary contact recreation area) was often above this level over the past 15 years. Consequently, a concentration of 20 µg/L chlorophyll-a may be an appropriate water quality benchmark for Lake Burley Griffin. This will be discussed in more detail in Chapter 6.

a. East Basin Total Algae and Cyanobacteria 1981-2009



b. West Lake Total Algae and Cyanobacteria 1981-2009

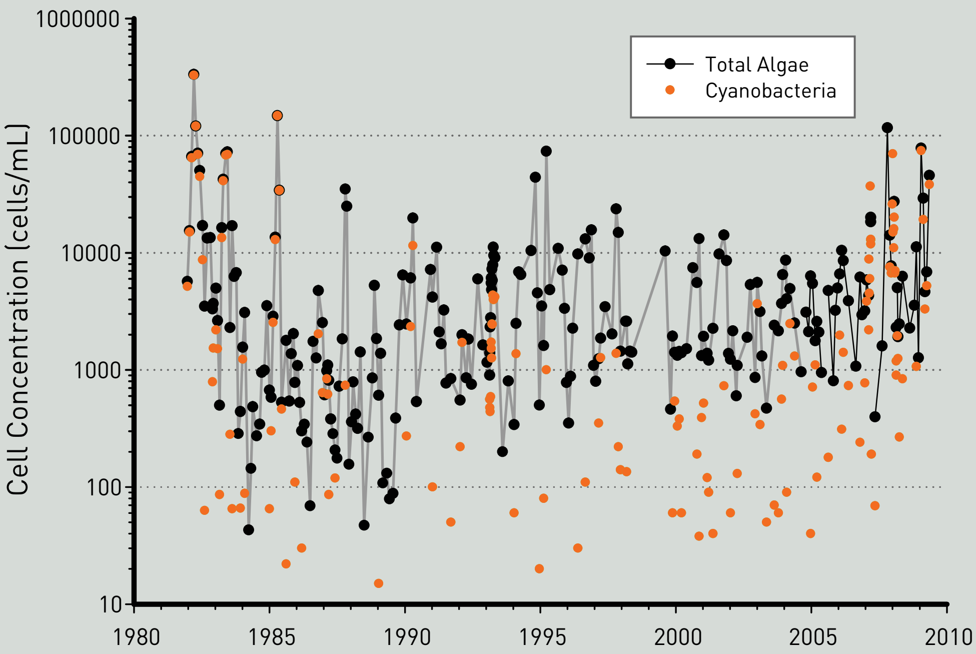
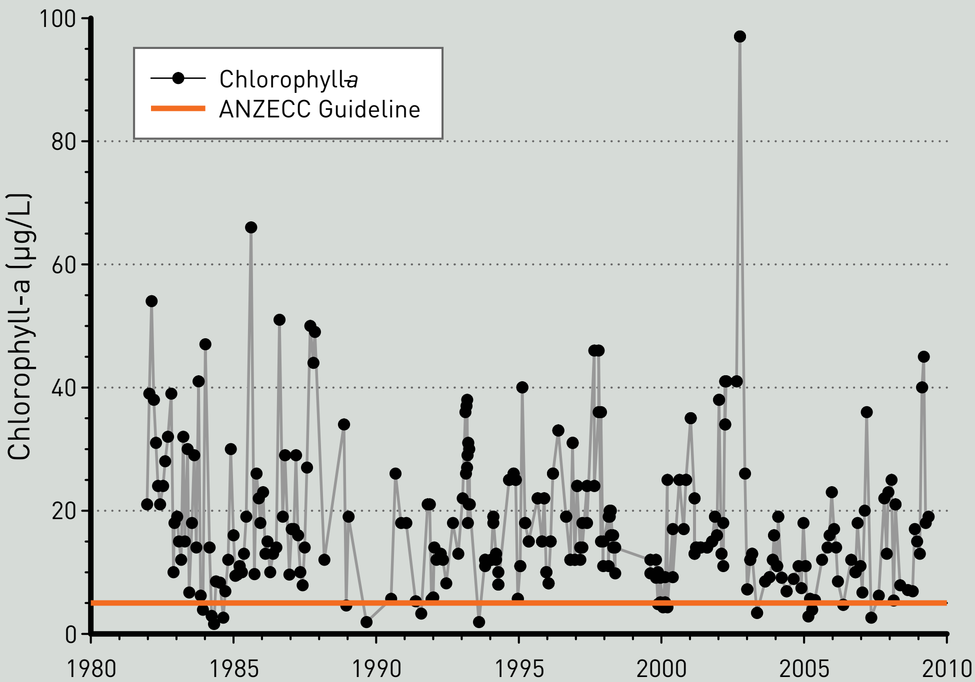


Figure 6. Total Algae and Cyanobacteria (cells/mL)

a. East Basin (site 529 surface)

b. West Lake (site 504 tube)

a. East Basin Chlorophyll 1981-2009



b. West Lake Chlorophyll 1981-2009

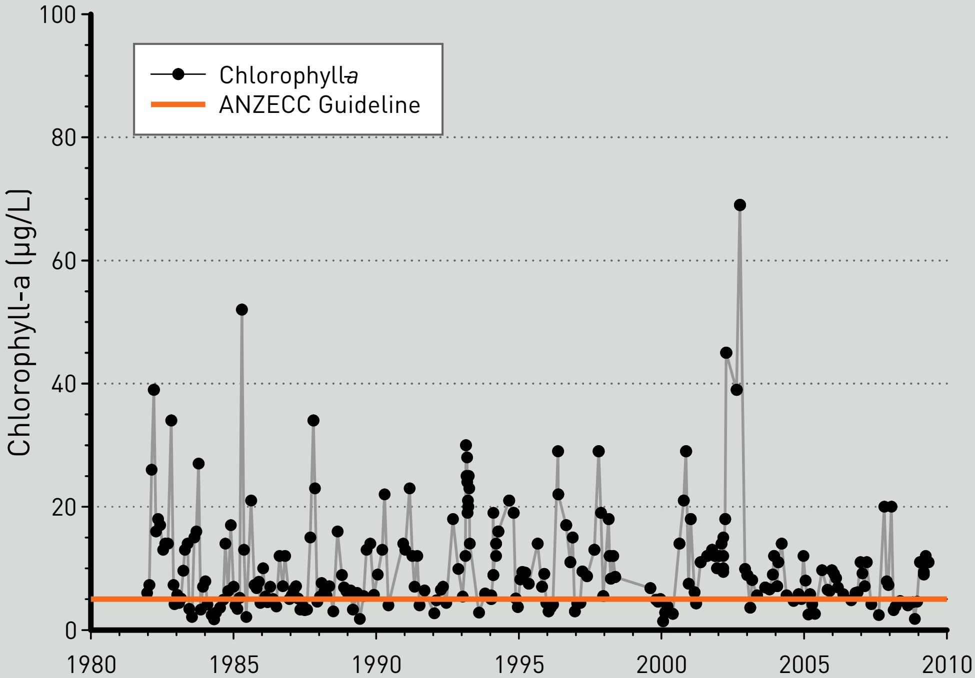


Figure 7. Chlorophyll-a concentrations in Lake Burley Griffin for 1981–2009
a. East Basin (site 529 surface)
b. West Lake (site 504 tube)

5.7 CONDUCTIVITY AND PH

5.7.1 Background

Conductivity measures the amount of inorganic ions (salts) in the water (in µS/cm). Catchment geology, land use and weather fluctuations (particularly rainfall) significantly impact upon the concentration of salts present. This concentration of dissolved salts subsequently impacts upon ecosystem processes and values.

pH is a measure of the concentration of hydrogen ions in the water. Neutral pH is 7, with waters becoming increasingly acidic as the scale decreases below 7, and increasingly alkaline as the scale increases above 7. Like conductivity, pH influences a wide range of ecological processes and values.

5.7.2 General Trends

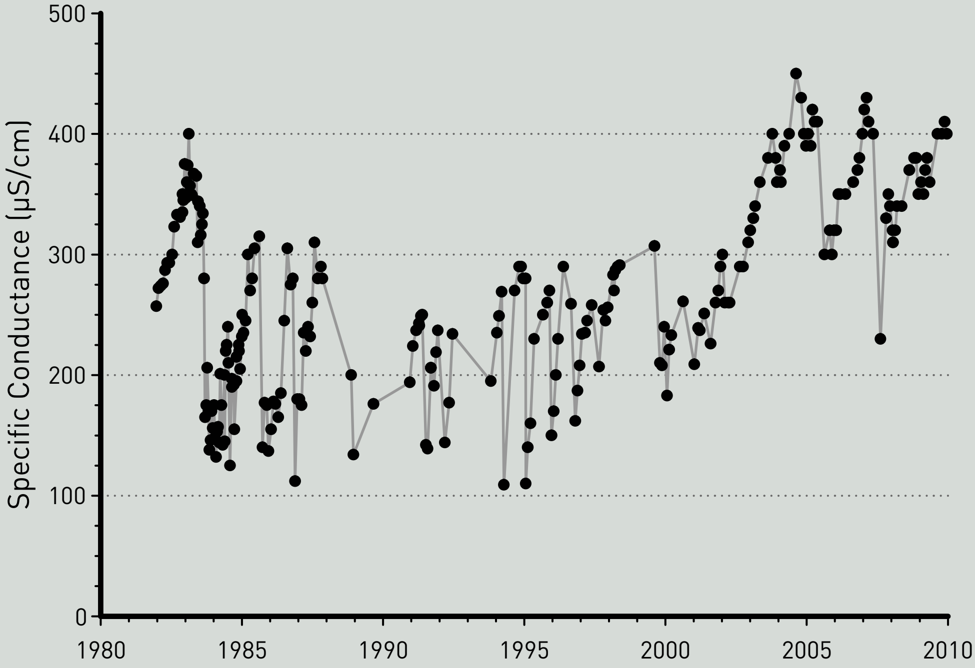
Conductivity and pH have been monitored in Lake Burley Griffin since 1981, at four sites (five sites from April 2009), and usually eight times a year.

Conductivity data recorded in East Basin (site 529 surface) and West Lake (site 504 tube) are shown in figures 8A and 8B respectively for the period from 1981 to 2009. East Basin (site 529 surface samples) and West Lake (site 504 tube samples) pH data are shown in figures 9A and 9B respectively for the period 1981 to 2009. From the collected information (EcoChemistry Laboratory, 2003; Ecowise Scientific and Aquatech, 1995; Office of ACT Administration, 1987), and more recent water quality data it is possible to indicate the following general trends:

- ➔ **Conductivity recorded in Lake Burley Griffin (and reported in terms of specific conductance) has remained relatively consistent prior to December 2002. However, during the period 2002 and December 2009 there has been an upward trend with values generally in excess of 300 µS/cm.**
- ➔ **pH values have remained in the same range over the past 28 years of monitoring.**

The water quality standard for pH in the ACT for recreational waters is 6.5-8.5 (ACT Government, 2011). This same range may be appropriate as a water quality benchmark for Lake Burley Griffin. Between 1981 and 2009, there were 2% of readings above 8.5 in West Lake and 6% of readings above 8.5 in East Basin. Therefore, the recommended benchmark for pH is between the range 6.5 to 8.5. This will be discussed in more detail in Chapter 6.

a. East Basin Conductivity 1981-2009



b. West Lake Conductivity 1981-2009

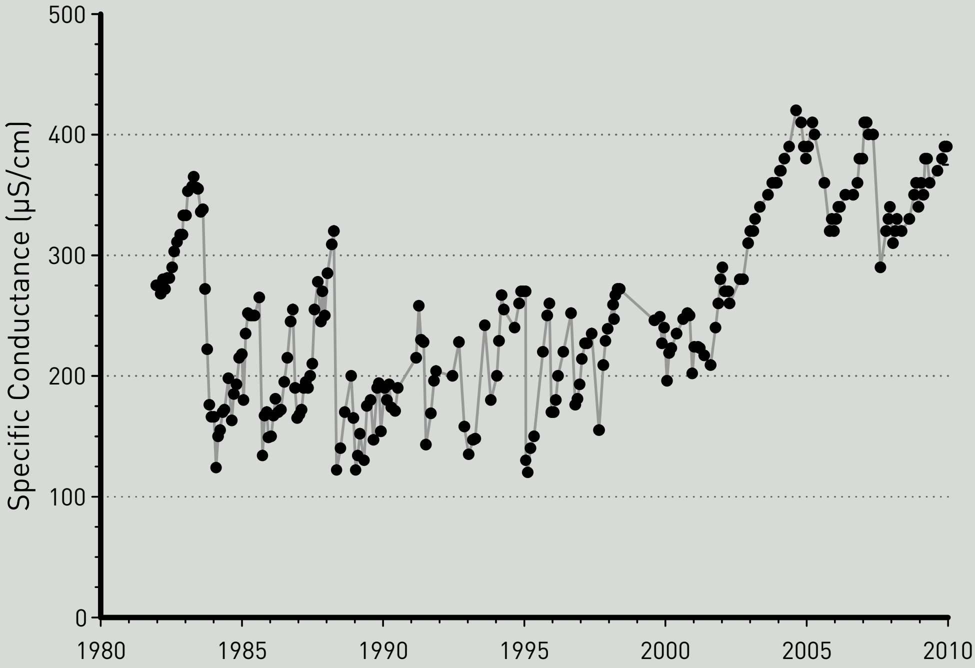
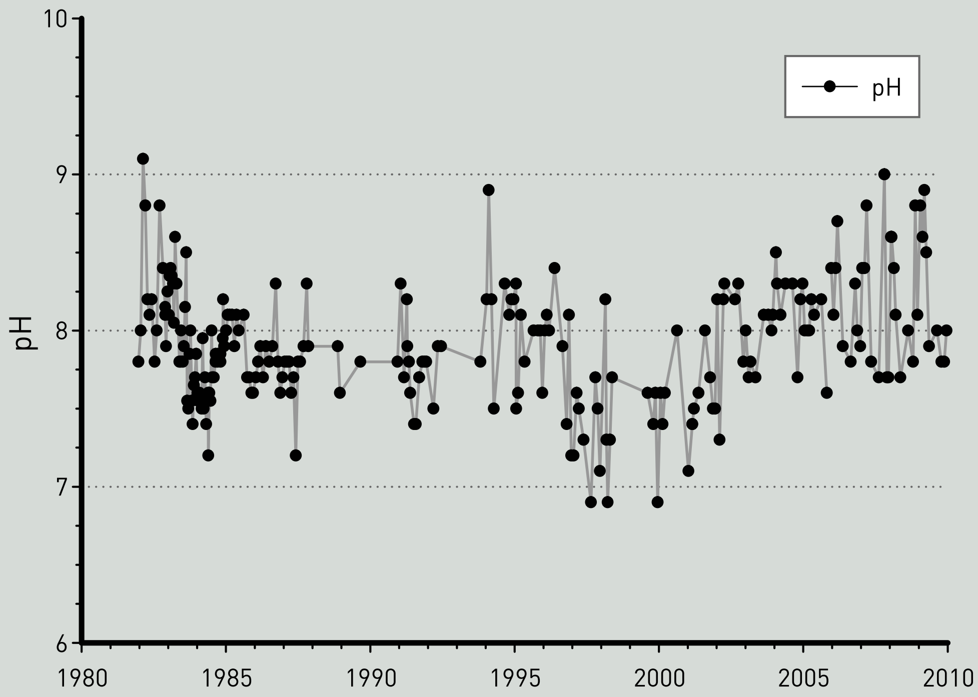


Figure 8. Conductivity (µS/cm) in Lake Burley Griffin for 1981–2009
a. East Basin (site 529 surface)
b. West Lake (site 504 tube)

a. East Basin pH 1981-2009



b. West Lake pH 1981-2009

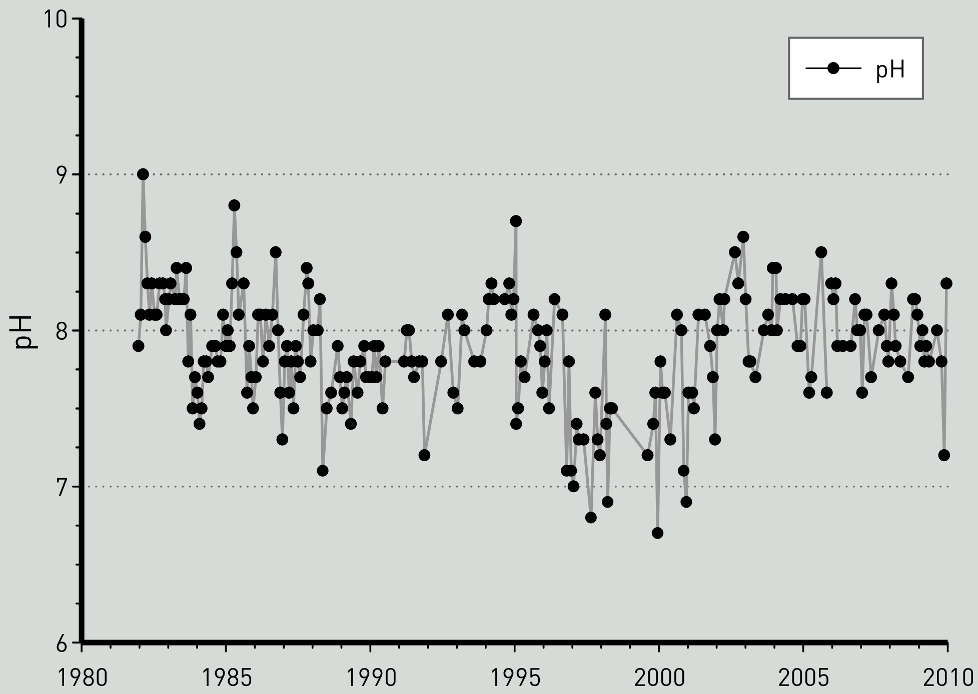


Figure 9. pH in Lake Burley Griffin for 1981–2009

a. East Basin (site 529 surface)

b. West Lake (site 504 tube)

5.8 BACTERIA

5.8.1 Background

Bacteria are microorganisms which are present in most environments, including aquatic environments such as Lake Burley Griffin. Some bacteria are pathogenic or harmful to humans, and their presence in lake water can make it unsuitable for some recreational uses (especially swimming). Indicator organisms are used to evaluate the human health risk associated with the presence of bacteria in a water body. As it is impossible to regularly monitor for the entire suite of potential pathogens, indicators have been developed which can be monitored and used as an assessment of the risk of human pathogens being present. Historically, faecal coliforms (which include *Escherichia coli* (*E.coli*)) were used as the indicator for faecal pollution in Lake Burley Griffin. The limitation of *E.coli* is that it is a non-specific indicator and it does not identify whether the source of contamination is animals, humans, or from plant decomposition. From 2002 onwards, intestinal enterococci (*Enterococci spp.*) have also been measured as an indicator of faecal contamination, as they are thought to be better correlated with human pathogens than *E.coli*. In December 2009, intestinal enterococci replaced faecal coliforms as the indicator used for faecal pollution in Lake Burley Griffin.

The *Guidelines for Managing Risks in Recreational Water* (Australian Government, 2008) recommend implementing a risk management procedure for managing bacteria in recreational waters, and provide appropriate management and monitoring responses for bacterial hazards (Chapter 5 *Guidelines for Managing Risks in Recreational Water* (Australian Government, 2008)). The benchmark provided in this Plan is based on these Guidelines. The NCA is now using intestinal enterococci as indicator organisms for bacteria in its risk management programme.

A concentration of <200 CFU/100mL for intestinal enterococci is recommended as a benchmark.

5.8.2 General Trends for the previous testing regime

Faecal coliforms are measured in colony forming units per 100 mL (CFU/100mL) of water. Faecal coliforms have been monitored in Lake Burley Griffin since the late 1980s until late 2009, at a number of swimming locations, particularly in the summer months.

From the collected information (EcoChemistry Laboratory, 2003; Ecowise Scientific and Aquatech, 1995; Lawrence, 2001; Office of ACT Administration, 1987) and more recent water quality data it is possible to indicate the following general trends:

- ➔ **Faecal coliforms counts have sometimes been above the guidelines for recreational water. This may be due to a number of reasons, including greater bacterial inputs from the catchment, as well as in-lake regrowth.**

Faecal coliform numbers are indicated for East Basin (site 529 surface) and West Lake (site 504 surface) in figures 10A and 10B respectively. Between January 2008 and December 2009 results from faecal coliform testing have indicated concentrations less than 150 CFU/100mL. This number of colony forming units is the water quality standard for other parts of the ACT for primary water based recreational activity (such as swimming) (ACT Government, 2011). The ACT water quality standard for secondary water based recreational activity (such as boating) is 1,000 CFU/100mL (ACT Government, 2011). East Basin is a secondary contact area and coliform numbers have generally been below 1,000 CFU/100mL. West Lake is a primary contact area and coliform numbers have generally been below 150 CFU/100mL.

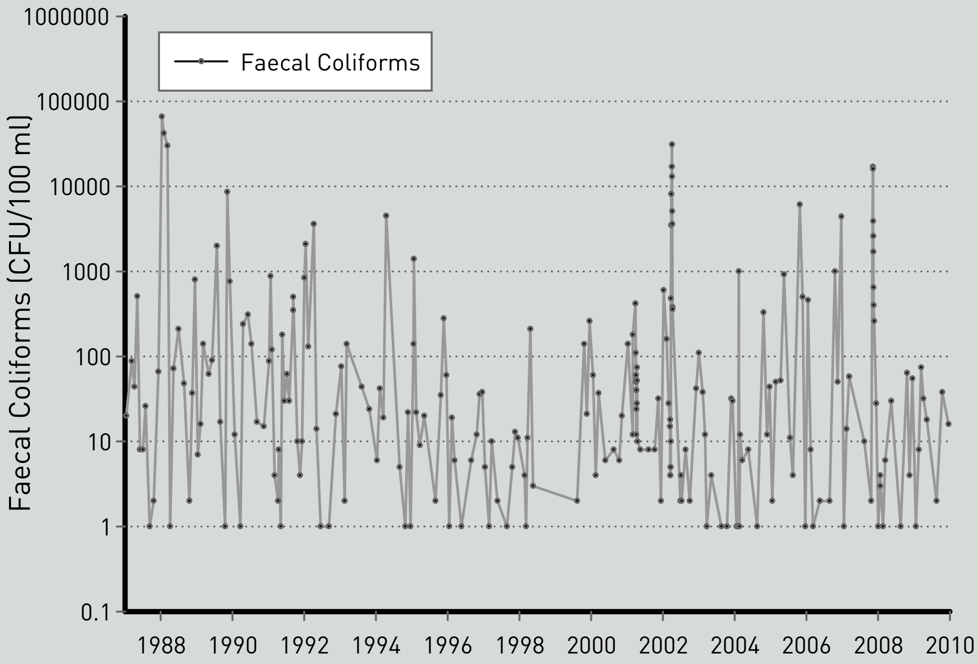
Although a number of water quality issues in the Lake have improved over the past 23 years of monitoring, faecal coliform numbers may have increased. There are several possible reasons for this, including:

- ➔ **Increased urbanisation of the catchments, with urban runoff resulting in greater bacterial levels in the runoff (from such things as food wastes, and animal and pet droppings).**
- ➔ **The possibility of sewage overflow during heavy rain periods (although this is relatively rare in Canberra, and does not explain the observed relationship between faecal coliform numbers and high water temperatures).**
- ➔ **In-lake regrowth of coliforms (Lawrence, 2001).**
- ➔ **Better and more accurate faecal coliform monitoring techniques. The accuracy and sensitivity of faecal coliform enumeration techniques has generally increased over the past 20 years, and this may give the appearance of an increase in faecal coliform levels.**
- ➔ **Some changes to the monitoring methodology for faecal coliforms.**
- ➔ **Increased abundance of waterbirds in and around the Lake. Waterbird faeces will contain large numbers of bacteria, including some faecal coliforms.**

It is not possible to indicate at this stage which of the above mentioned factors may be the most important in terms of managing bacterial pollution of the Lake. Indeed, it is not even possible to state conclusively if bacterial levels have generally increased in the Lake, even though the issue has been receiving research attention since the early 1970s (Burgess and Olive, 1975).

It is important to note that since December 2009, intestinal enterococci replaced *E.coli* as the alert measure of faecal contamination. Water bodies remain open when enterococci levels are ≤ 200 CFU/100mL, whereas a closed alert level for primary contact recreation and a series of management protocols apply when intestinal enterococci are > 200 CFU/100mL (ACT Government, 2010). Enterococci data available from the period between 2005 and 2009 are presented for East Basin (site 529 surface) and West Lake (site 504 surface) in figures 11A and 11B respectively.

a. East Basin Faecal Coliforms 1981-2009



b. West Lake Faecal Coliforms 1981-2009

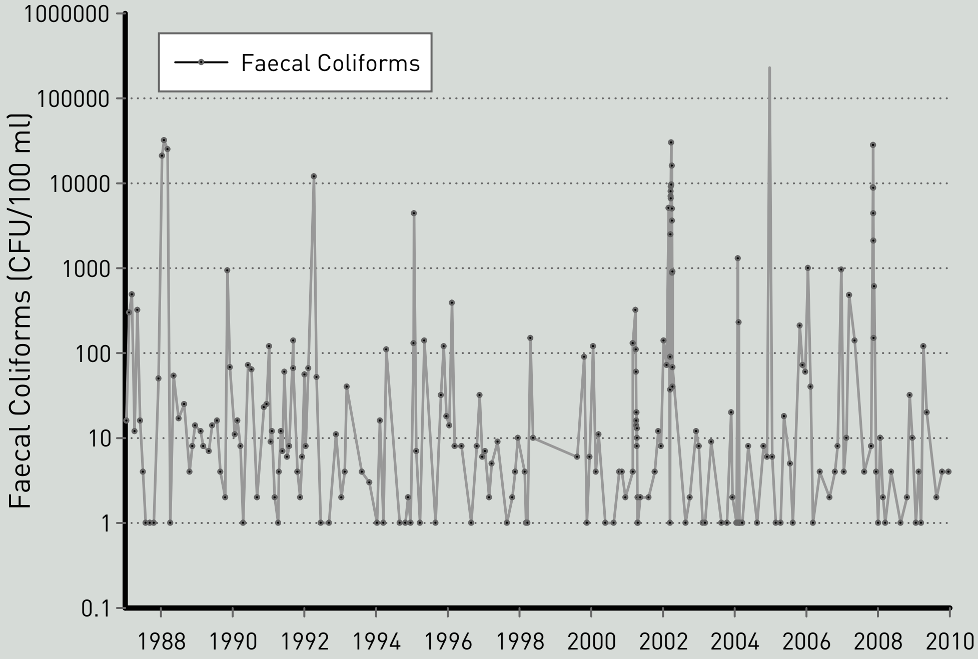
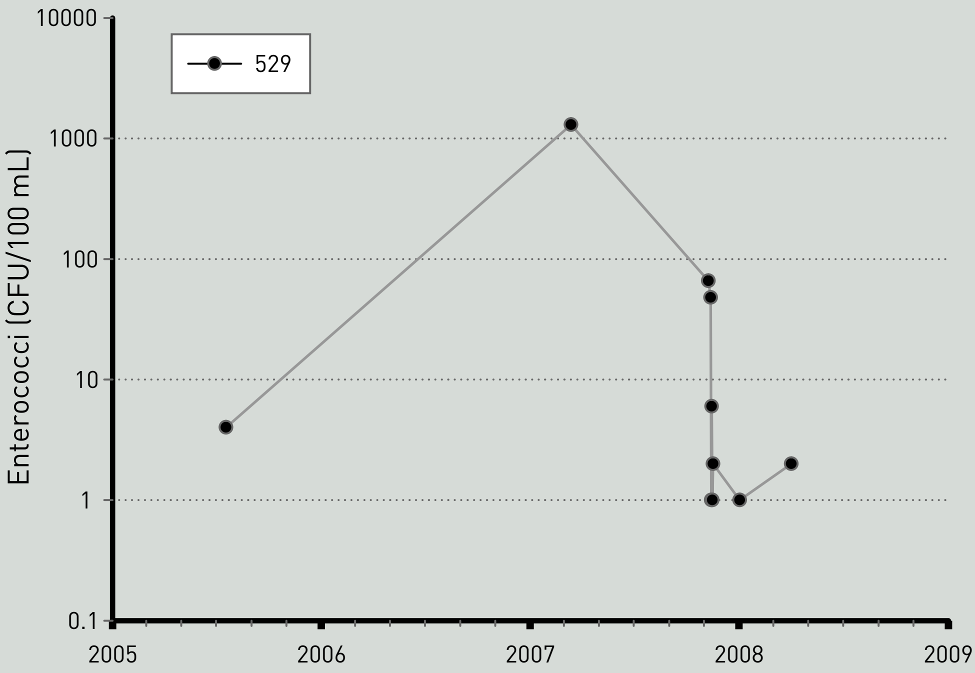


Figure 10. Faecal coliforms (CFU/100mL) in Lake Burley Griffin for 1981–2009
a. East Basin (site 529 surface)
b. West Lake (site 504 tube)

a. East Basin Enterococci 2005-2009



b. West Lake Enterococci 2005-2009

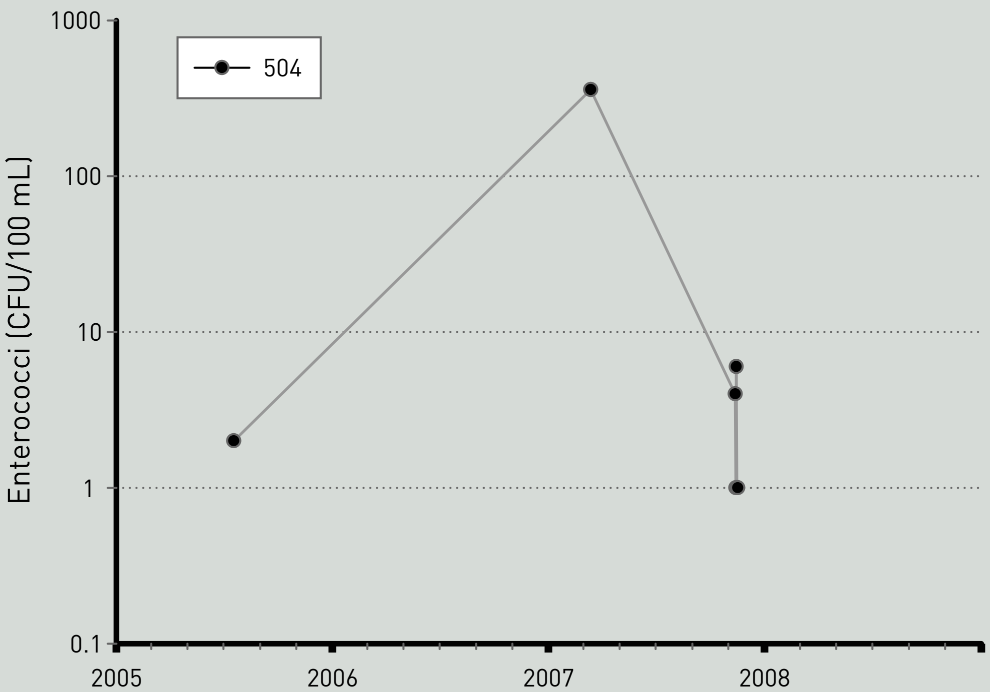


Figure 11. Intestinal Enterococci (CFU/100mL) in Lake Burley Griffin for 2005–2009
a. East Basin (site 529 surface)
b. West Lake (site 504 tube)

5.9 METALS

5.9.1 Background

Trace metal concentrations in Lake Burley Griffin used to be relatively high, due to runoff from abandoned zinc mining areas in the catchment, primarily in the Captains Flat area (Joint Government Technical Committee, 1974 and 1978). However, as a result of major remediation works in the 1970s, the abandoned mining areas were stabilised and metal concentrations in the subsequent runoff were significantly reduced (Hillman, 1980; National Capital Development Commission, 1981).

5.9.2 General Trends

Trace metal concentrations in Lake Burley Griffin waters, sediments and biota have been measured by several research projects (EcoChemistry Laboratory, 2003; Maher et al, 1992; Norris 1983), as well as by some ongoing monitoring programs (Ecowise Scientific and Aquatech, 1995). These research and monitoring programs, together with recent data, indicate that generally:

➔ **Metal concentrations in the Lake are still elevated, especially in lake sediments.**

5.10 DISSOLVED OXYGEN

5.10.1 Background

Dissolved oxygen is critical for Lake biodiversity, as many macroinvertebrates and most fish species require concentrations above 5mg/L. Low dissolved oxygen concentrations at the sediment-water interface can result in the anoxic release of bioavailable forms of nutrients and metals into the overlying water column. These nutrient releases may stimulate the growth of cyanobacteria (blue-green algae).

5.10.2 General Trends

Dissolved oxygen values (in mg/L) have been monitored in the Lake since 1981, at four sites (five sites from April 2009), and usually at least eight times a year.

From the collected information (Eco Chemistry Laboratory, 2003; Ecowise Scientific and Aquatech 1995; Office of ACT Administration, 1987) and more recent water quality data it is possible to indicate the following general trends:

➔ **Dissolved oxygen concentrations in East Basin are generally above 5mg/L, most likely due to wind mixing and its shallow profile.**

➔ **Dissolved oxygen values in Central Basin, West Lake, and Scrivener Dam are at their maximum during the late winter months and at their minimum during the late summer months. This is because during the winter months of the year, water temperatures are relatively homogeneous through the depth profile. However, during the warmer months of the year, the water column becomes stratified (with warmer water at the surface and colder water at the bottom). This layering and lack of mixing of the water column together with greater biological activity in the sediments during the warmer months of the year can deplete dissolved oxygen in the deeper parts of the Lake.**

Averaged dissolved oxygen concentrations for Central Basin (site 530), West Lake (site 504), and Scrivener Dam (site 507) are shown in figures 12A, 12B, and 12C respectively for the period from 1981 to 2009.

The figures show dissolved oxygen concentrations through the water column averaged for each quarter of the year (1st quarter – Jan to March; 2nd quarter – April to June; 3rd quarter – July to Sept; and 4th quarter – Oct to Dec).

As shown in the figures, dissolved oxygen concentrations at Central Basin range from about 8–11 mg/L at the water surface, and about 5–11 mg/L at the bottom (near the sediment).

At West Lake, dissolved oxygen concentrations range from about 8-11 mg/L at the water surface and from about 4-10 mg/L at the bottom (near the sediment).

Similarly, dissolved oxygen concentrations recorded at Scrivener Dam, range from about 7–11 mg/L at the water surface and from about 1–10 mg/L at the bottom (near the sediment). This is because West Lake and Scrivener Dam are deeper sites than Central Basin and consequently experience greater temperature and dissolved oxygen stratifications during the summer months.

No particular benchmark value is proposed at this stage for dissolved oxygen concentrations through the water profile at the various Lake Burley Griffin sites. However, as with other water quality characteristics, continuing monitoring will be an important component of the WQMP.

a. Central Basin – Dissolved Oxygen 1981-2009

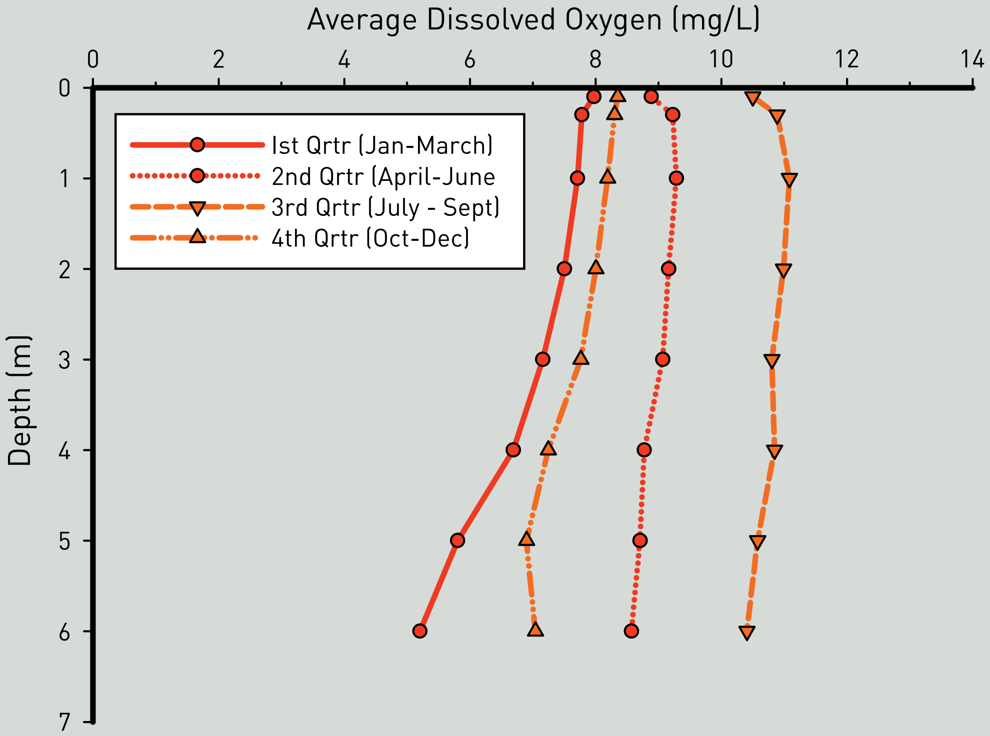


Figure 12. Dissolved Oxygen in Lake Burley Griffin for 1981–2009
a. Central Basin (site 530)

Note: Surface readings taken at 0.1m and 0.3m. No 0.1m readings after 1991; No 0.3m readings before 1989. Some depth readings have been rounded to the nearest metre. The number of samples (n) taken at each depth, in each quarter over the 28 year period, ranged in the following way:

- **1st Quarter** n=34-85;
- **2nd Quarter** n=26-47;
- **3rd Quarter** n=19-36;
- **4th Quarter** n=25-70.

b. West Lake – Dissolved Oxygen 1981-2009

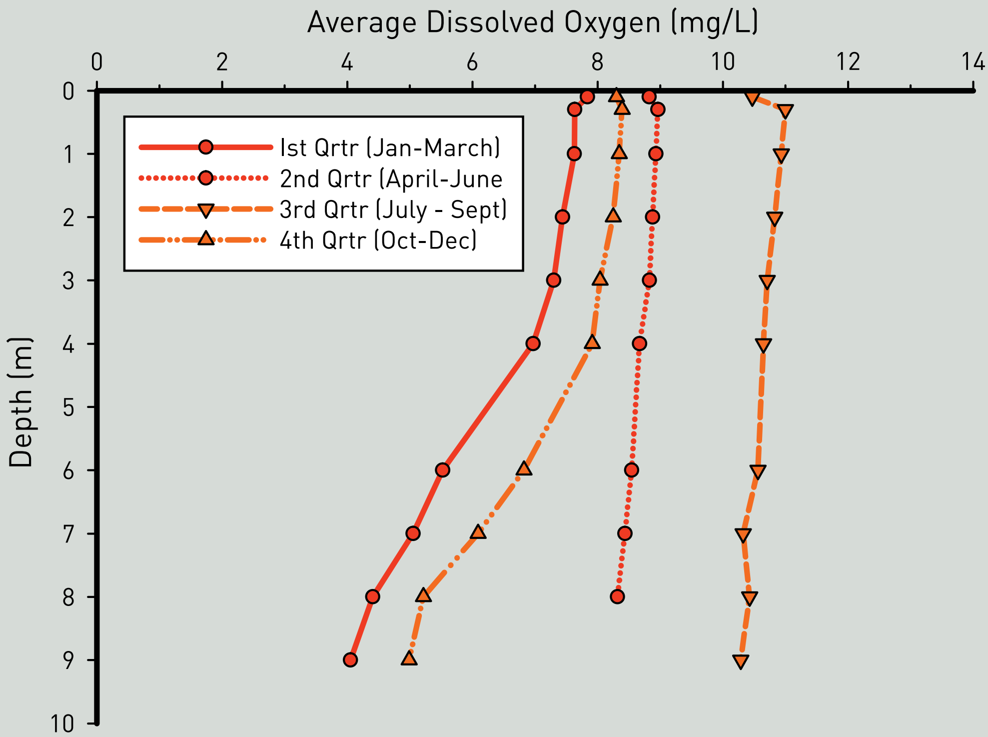


Figure 12. Dissolved Oxygen in Lake Burley Griffin for 1981–2009
b. West Lake (site 504)

Note: Surface readings taken at 0.1m and 0.3m. No 0.1m readings after 1992; No 0.3m prior to 1989. Some depth readings have been rounded to the nearest metre. The number of samples (n) taken at each depth, in each quarter over the 28 year period, ranged in the following way:

- **1st Quarter** n=31-76;
- **2nd Quarter** n=25-47;
- **3rd Quarter** n=18-36;
- **4th Quarter** n=26-67.

c. Scrivener Dam – Dissolved Oxygen 1981-2009

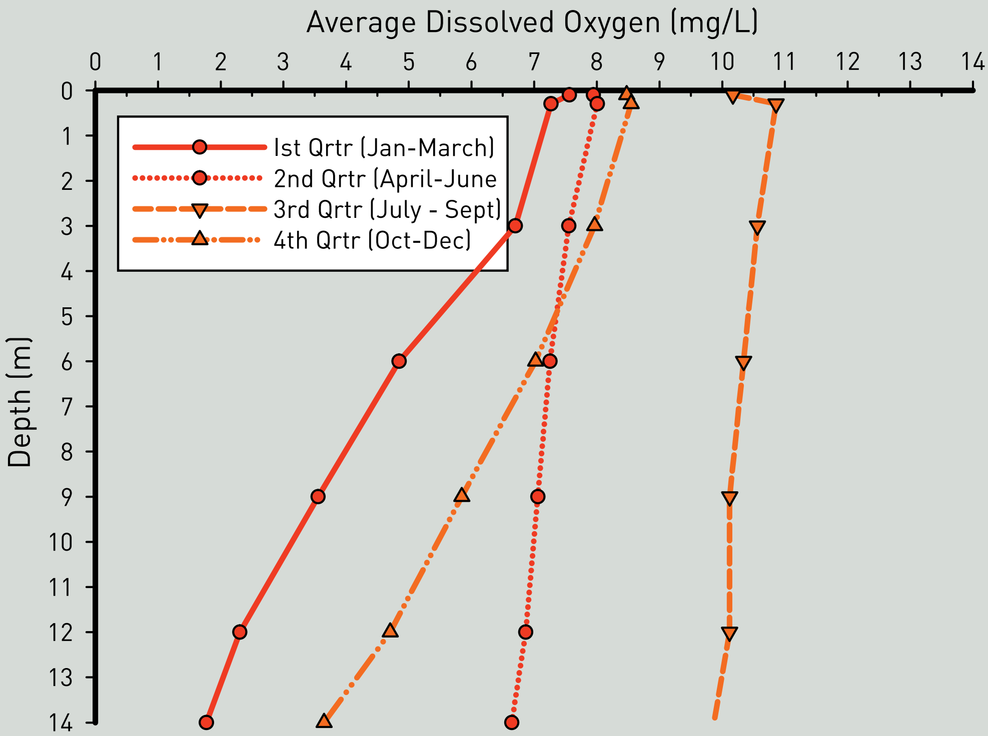


Figure 12. Dissolved Oxygen in Lake Burley Griffin for 1981–2009
c. Scrivener Dam (site 507)

Note: Surface readings taken at 0.1m and 0.3m. No 0.1m readings after 1992; No 0.3m prior to 1989. Some depth readings have been rounded to the nearest metre. The number of samples (n) taken at each depth, in each quarter over the 28 year period, ranged in the following way:

- **1st Quarter** n=30-82;
- **2nd Quarter** n=25-40;
- **3rd Quarter** n=18-37;
- **4th Quarter** n=27-70.

5.11 WATER COLUMN DEPTH PROFILES

In 2009 and 2010, water column depth profiles were taken along a Molonglo River transect and at midstream sites within Lake Burley Griffin in order to better understand and manage blue-green algal blooms within the Lake Burley Griffin.

Water column depth profiles of temperature, dissolved oxygen, specific conductance and pH were compiled for a selected transect upstream in the Molonglo River (Figure 13) between sites 1 and 5 (Figure 14), East Basin (site 529) (Figure 15), West Lake (site 504) (Figure 16) and Scrivener Dam (site 507) (Figure 17). Profiles from upstream in the Molonglo River (site 5) towards the entrance to Lake Burley Griffin at site 1 show a highly thermally and chemically stratified water column with an anoxic, and slightly acidic hypolimnion of lower conductivity. The waters carried by the Molonglo are of lower conductivity than those in the Lake itself. Such an anoxic and slightly acidic hypolimnion would facilitate the release of bound nutrients. Water samples for assessment of the possible presence of cyanobacterial toxins were taken at survey sites 6, 7 and 8 at the same time as the Molonglo transects. The toxicity testing was to determine if the bloom had become uncharacteristically toxic after construction dredging and digging behind the silt curtain of the Kingston harbour.

Cyanobacterial toxins were not detected in these samples.

Quite different mixing and stratification profiles occur in the Lake at sites of distinctly different depths. Profiles show a mixed water column in the comparatively shallow East Basin (site 529) with elevated pH in the summer months. East Basin is the warmest site in summer. Profiles for West Lake (site 504) show mid-summer stratification in temperature, dissolved oxygen, conductivity and pH with decreased oxygen concentrations in the hypolimnion. The profiles from the deeper site near Scrivener Dam (site 507) show a strongly stratified water column between January and April and the presence of an anoxic hypolimnion. Temperature profiles recorded in May 2009 suggest the probability of winter mixing.

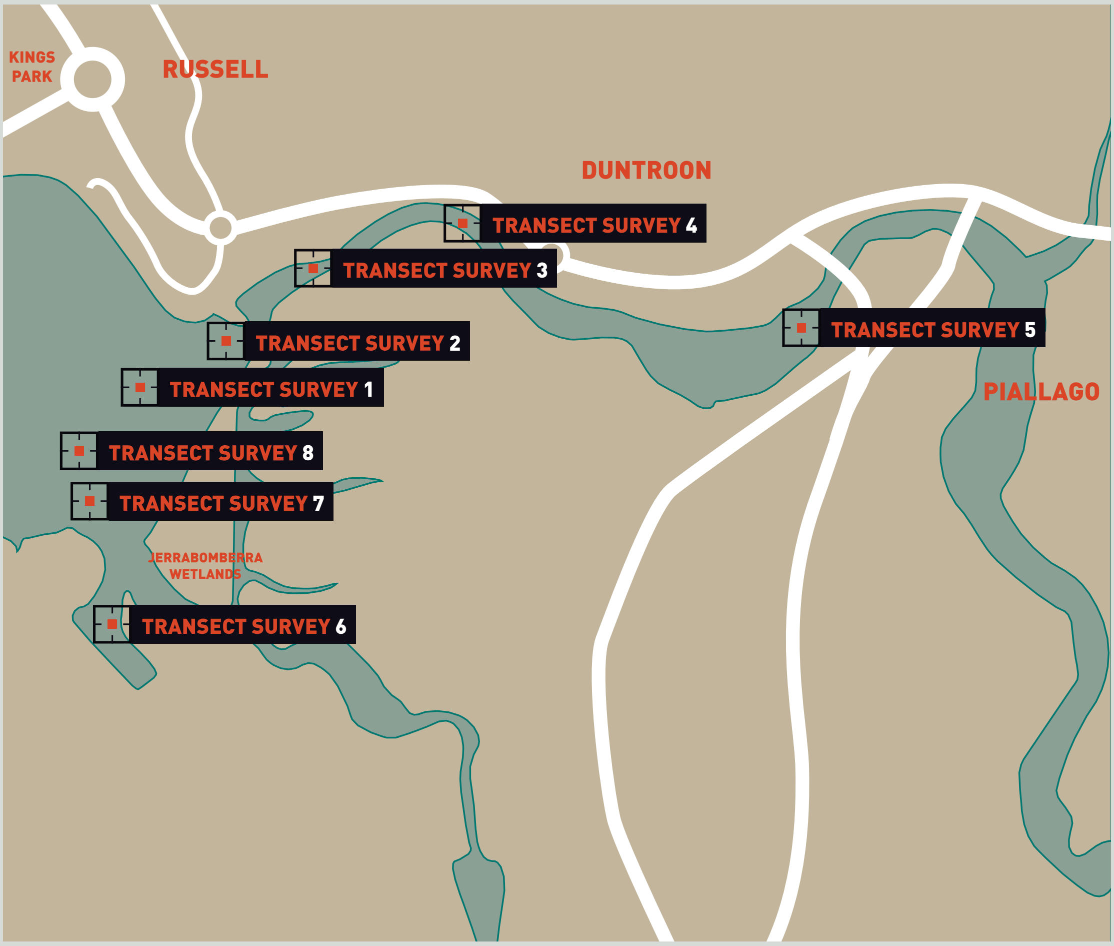


Figure 13. Map showing start of transect of sampling sites from Site 1 (Transect Survey 1) to Site 5 (Transect Survey 5) used for the construction of the contour plots in figure 14. Note that data for profiles were not recorded at transect sites 6, 7 and 8 within Lake Burley Griffin.

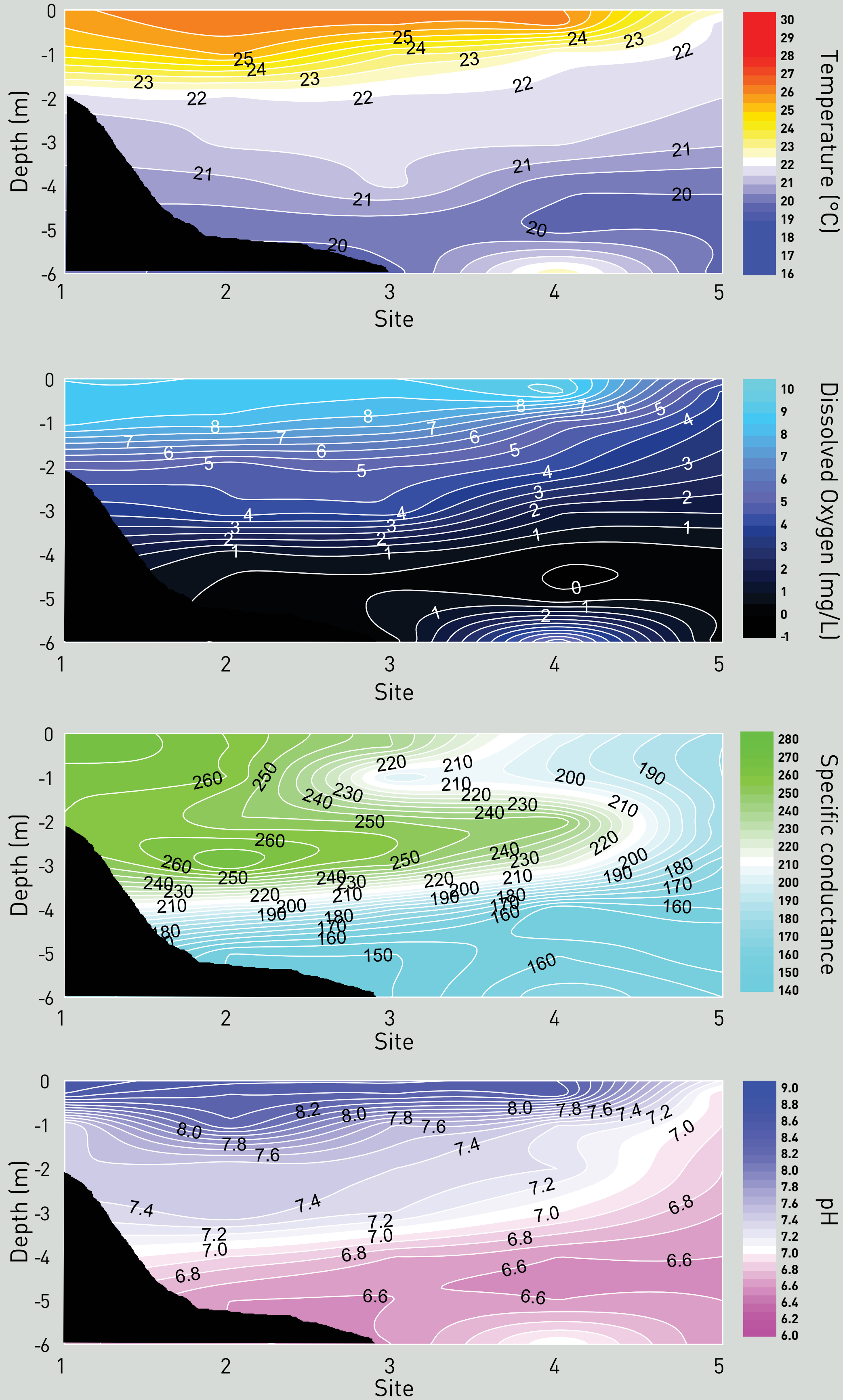


Figure 14. Vertical water column depth profiles for the series of sites along the Molonglo River transect starting at site 1 at the entrance of Lake Burley Griffin and heading in an upstream direction on 26 February 2010.

- **a.** Temperature (°C),
- **b.** Dissolved oxygen (mg/L),
- **c.** Specific Conductance (µS/cm at 25 °C) and
- **d.** pH

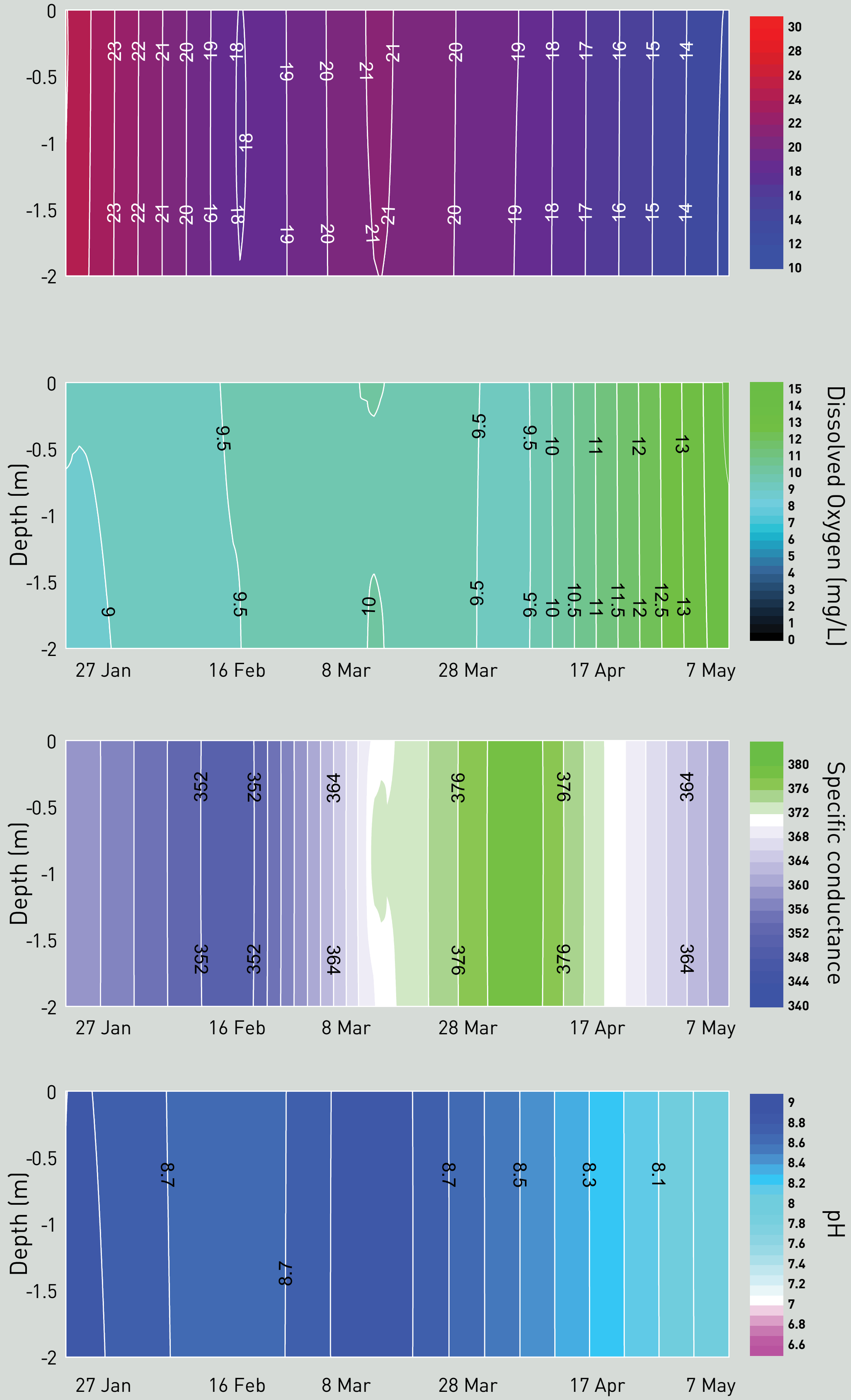


Figure 15. Vertical water column depth profiles for East Basin (site 529) between 20 January and 5 May 2009.

a. Temperature (°C),

b. Dissolved oxygen (mg/L),

c. Conductivity (μS/cm) and

d. pH

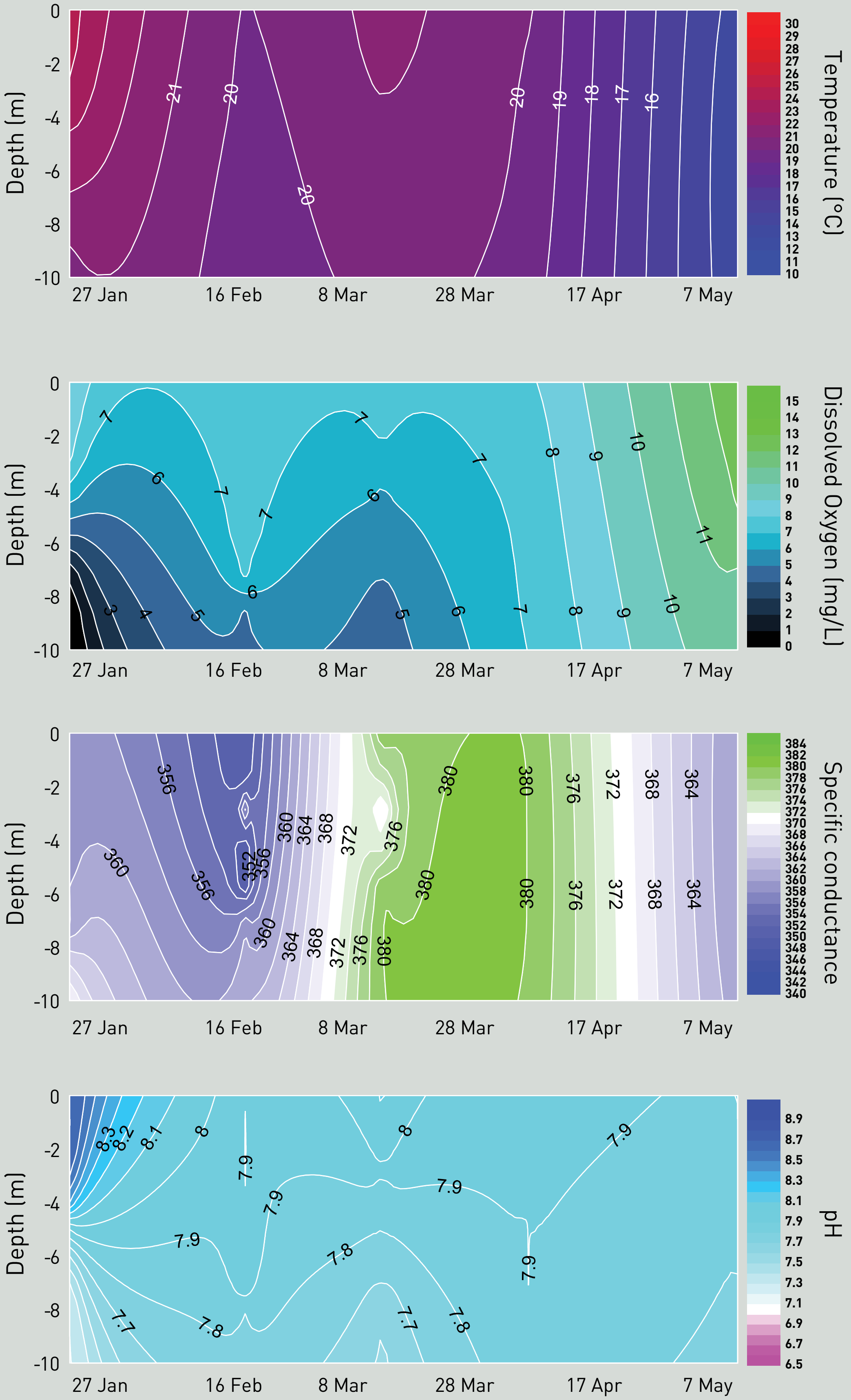


Figure 16. Vertical water column depth profiles for West Lake (site 504) between 20 January and 5 May 2009.

- **a.** Temperature (°C),
- **b.** Dissolved oxygen (mg/L),
- **c.** Conductivity (µS/cm) and
- **d.** pH

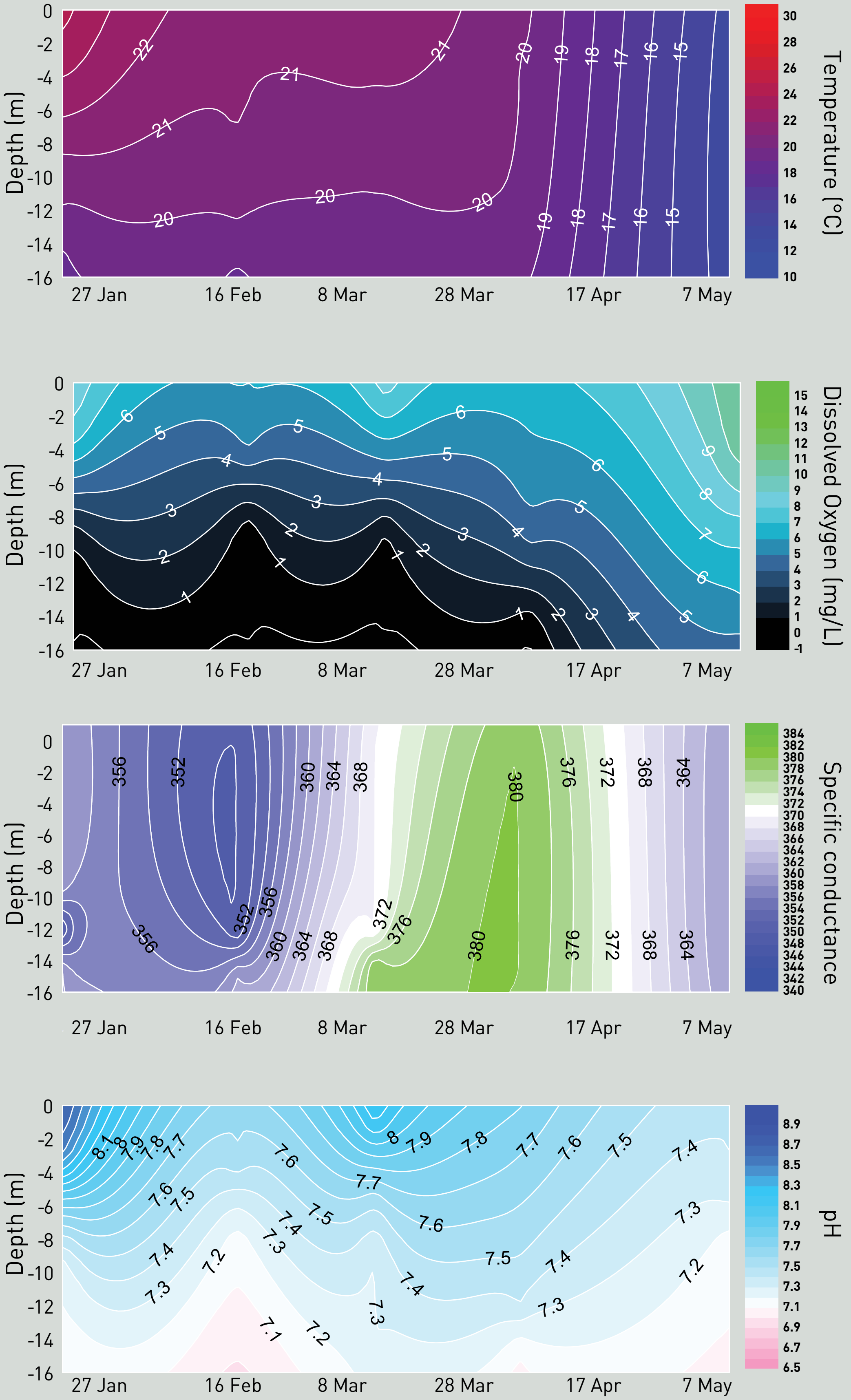


Figure 17. Vertical water column depth profiles for Scrivener Dam (site 507) between 20 January and **5 May 2009.**

a. Temperature (°C),
b. Dissolved oxygen (mg/L),
c. Conductivity (μS/cm) and
d. pH .

6 DEVELOPMENT OF BENCHMARK LEVELS FOR WATER QUALITY

6.1 GENERAL

The water quality of Lake Burley Griffin has been extensively monitored since about 1978, by a number of organisations, including:

- University of Canberra, CRC for Freshwater Ecology
- ECOWISE Environmental (now ECOWISE Australia Pty Ltd, trading as ALS Water Resources Group)
- ACT Environment and Sustainable Development Directorate
- ACT Health Protection Service.

Water quality in the Lake and its tributaries has also been the focus of a number of research studies (including Honours, Masters and Doctoral projects), from:

- Australian National University
- University of Canberra
- Australian Defence Force Academy.

Community groups, through Waterwatch ACT, have also collected water quality information on the Lake and its surrounding tributaries.

Collectively, these various efforts have provided a considerable amount of valuable information on water quality in the Lake, and have made the Lake one of the most studied lakes in Australia (Atech Group, 2002).

Consequently, it is possible to provide some good indications for benchmark water quality values within the Lake.

A summary of these benchmark values for the respective environmental values is provided below, with additional information in subsequent sections of the previous chapter:

Environmental value: Ornamental water

- Turbidity values of 40 NTU in East Basin, and 20 NTU in West Lake.
- Suspended solids values of 40 mg/L in East Basin, and 20 mg/L in West Lake.

Environmental value: Protection of freshwater aquatic system

- Turbidity values of 40 NTU in East Basin, and 20 NTU in West Lake.
- Suspended solids values of 40 mg/L in East Basin, and 20 mg/L in West Lake.
- Total phosphorus concentration of 0.06 mg/L.
- Total nitrogen concentrations of 1.4 mg/L in East Basin and 1.0 mg/L in West Lake.
- Ammonia concentration of 0.1 mg/L.
- Cyanobacteria cell concentration of 20,000 cells/mL
- Chlorophyll-a concentration of 20 µg/L.
- Conductivity of 400 µS/cm.
- pH range of 6.5–8.5.
- Metal concentrations as specified by ANZECC/ARMCANZ (2000).

Environmental value: Recreational water

- Recreational benchmark values are based on the *Guidelines for Managing Risks in Recreational Water* (Australian Government, 2008).

- **Bacterial quality as specified by Australian Government (2008) preferentially using intestinal enterococci as indicators of the potential presence of pathogens. A concentration of <200 CFU/100mL is recommended.**
- **Cyanobacterial toxin concentration of <4 μg/L (possible toxins include microcystins and cylindrospermopsins), or <20,000 cells/mL where known toxin producing species are dominant.**
- **pH 6.5-8.5**

Environmental value: Irrigation water for parks and gardens

- **Water quality as specified in *Guidelines for Managing Risks in Recreational Water* (Australian Government, 2008)**

6.2 METHODOLOGY

The National Water Quality Management Strategy (NWQMS), which has provided the ANZECC/AMRCANZ (2000) guidelines, has suggested that communities develop their own water quality objectives in their local environment, based on a number of factors, including:

- **ecological information (either of a general nature or specifically related to the water body of interest);**
- **economic affordability (and the willingness of the community to obtain a particular level of water quality).**

This Lake Burley Griffin WQMP generally follows the above-mentioned NWQMS procedures. However, instead of using water quality objectives (based on the 80th percentile values), this WQMP uses water quality benchmark values (which are close to, but not necessarily exactly, at the 80th percentile value for each data set). Revised benchmarks in this updated WQMP also consider values in the *Guidelines for Managing Risks in Recreational Water* (Australian Government, 2008).

Because the Lake has been extensively studied, it is possible to establish benchmark values for the key water quality characteristics at levels that in the past have shown no adverse effects (in terms of either ecology or human health).

This approach is suggested, as it is unlikely that the community would be interested in paying for and providing a more stringent benchmark than one that showed no adverse effects on the environment or on human health. For example, it is unlikely that the community would be willing to pay for increased phosphorus removal at the Queanbeyan Wastewater Treatment Plant (upstream of Lake Burley Griffin), if current phosphorus concentrations showed no adverse effects. Limited financial resources would then be allocated to other, more needy water quality issues (or indeed to a range of other general issues such as schools, hospitals, roads etc).

It is important to balance the above approach (using specific information on the Lake) with:

- **a more general Australia-wide approach (using information from a range of sources including values generic for south-east Australian waterways) as outlined in ANZECC/ARMCANZ (2000);**
- **a more general ACT-wide approach, using information from ACT Government (2011).**

Furthermore, once a benchmark is established, it is nevertheless important to continue with its ongoing assessment (and if necessary, with its ongoing adjustment).

6.3 TURBIDITY AND SUSPENDED MATERIAL

The ANZECC/ARMCANZ (2000) guideline value for turbidity is 20 NTU. The corresponding value for suspended material is 25mg/L.

Other ACT water bodies have no specific turbidity standard for recreational areas, other than the requirement that the turbidity should not be objectionable. The corresponding value for aquatic habitats is <10–<30 NTU (ACT Government, 2011).

The Lake often exceeds these values, particularly in the shallower areas such as East Basin. Most of this is due to wind mixing, with turbidity levels in East Basin often being well above those in the Molonglo Reach (just upstream of the Lake).

Lake Burley Griffin has always been a relatively turbid lake, but these levels have shown no adverse effects in terms of ecology or human health.

Consequently, based on past information on the Lake, it is proposed that the benchmark level for Lake Burley Griffin turbidity should be 40 NTU and 20 NTU in East Basin and West Lake respectively.

It is proposed that the benchmark suspended solids values should be 40 mg/L and 20 mg/L in East Basin and West Lake respectively.

6.4 PHOSPHORUS

The ANZECC/ARMCANZ (2000) guideline values for total phosphorus and filterable phosphorus are 0.1 mg/L and 0.05 mg/L respectively.

The corresponding value for other ACT waters is <0.1 mg/L total phosphorus. Filterable phosphorus concentrations are not specified, as total phosphorus concentrations appear to be the more important measure in terms of lake management (ACT Government, 2011).

Consequently, a 0.06 mg/L benchmark total phosphorus value is proposed for Lake Burley Griffin.

6.5 NITROGEN

The ANZECC/ARMCANZ (2000) guideline values for total nitrogen and ammonia are 0.35mg/L and 0.1mg/L respectively.

There is no particular value for other ACT waters (ACT Government, 2011).

The Lake has higher than usual nitrogen values, but this has had no adverse effects in terms of ecology or human health. Consequently, based on past information on the Lake, it is proposed that the benchmark concentrations for total nitrogen be 1.4 mg/L in East Basin and 1.0 mg/L in West Lake.

It is proposed that for ammonia, the benchmark level should be 0.1 mg/L, which is the ANZECC/ARMCANZ (2000) trigger value.

6.6 ALGAE AND CHLOROPHYLL-A

Total algal counts and chlorophyll-a concentrations have remained in the same general range, despite phosphorus reduction measures implemented at the Queanbeyan Wastewater Treatment Plant. However, the intensity of late summer cyanobacterial blooms has generally increased since 2005.

Based on past information on the Lake, and from other sources, it is proposed that the benchmark level for cyanobacterial cell concentration is 20,000 cells/mL. This is based on national and ACT algal water quality standards (Australian Government, 2008; ACT Government, 2010).

A benchmark value of 20 µg/L chlorophyll-a is proposed for the Lake.

6.7 CONDUCTIVITY AND PH

Based on monitoring information on the Lake over the past 28 years, a conductivity value of 400 µS/cm is proposed as a benchmark value.

Similarly, based on monitoring information a pH range of 6.5–8.5 is proposed for Lake Burley Griffin. This is also the same range as that specified for water based recreation in other ACT waters (ACT Government, 2011).

6.8 BACTERIA

Bacterial quality as specified by Australian Government (2008) preferentially using intestinal enterococci as indicators of the potential presence of pathogens. A concentration of <200 CFU/100mL is recommended. This testing regime has been undertaken since late 2009, therefore no trend information for intestinal enterococci is available for this updated Plan.

Prior to late 2009, faecal coliforms were used as the indicator for bacteria. Historically, bacterial counts in terms of faecal coliforms have been in the same general range, except in the late summer months, at which times they have increased.

The ANZECC/ARMCANZ (2000) faecal coliform guideline value is 150 CFU/100mL for primary contact recreation, and 1,000 CFU/100mL for secondary contact recreation. This is the same as water quality standards for other ACT waters (ACT Government, 2011). The *ACT Guidelines for Recreational Water Quality* (ACT Government, 2010) sets the intestinal enterococci guideline value for primary and secondary contact recreation at ≤200 CFU/100mL.

These are important health based guidelines, and are proposed as the Lake Burley Griffin benchmark values for primary and secondary contact recreational activities.

Based on previous faecal coliform levels in the Lake, it is likely that additional effort and resources will be required to ensure that the Lake meets these benchmark levels. Alternatively, if these levels are exceeded, appropriate action will be required to close the Lake (or parts of the Lake) to some types of recreational activities.

However, it will also be important to establish the cause of the increase in bacterial levels. Possible factors include:

- increased urbanisation in the catchment;
- possible sewage overflows;
- in-lake regrowth of coliforms;
- better and more accurate bacterial monitoring techniques;
- some changes to monitoring methodology for faecal coliforms;
- increased number of waterbirds using the Lake as their home.

6.9 METALS

Trace metal concentrations have generally decreased in the Lake since abandoned mining areas upstream of the Lake were rehabilitated in the 1970s.

Consequently, trace metal concentrations in the Lake are generally not regarded as an ecological or human health problem. This is further supported by results indicating that trace metal concentrations in fish caught from the Lake are either extremely low or below detection values specified by the Australian National Food Authority.

PART 2 MANAGEMENT RESPONSE

7 MANAGEMENT RESPONSE

7.1 INTRODUCTION

The NCA is responsible for the management of the National Capital's Lake Burley Griffin to ensure its sustainable use and to protect and enhance its water quality.

This section covers:

- Recommended benchmark values for key water quality indicators.
- Overview of the water quality monitoring programs.
- Actions arising from the management of pollutants.
- Communications.
- Use of legislation.
- Roles and responsibilities.

7.2 RECOMMENDED BENCHMARK VALUES FOR KEY WATER QUALITY INDICATORS

The recommended benchmarks for water quality in Lake Burley Griffin are as follows:

ENVIRONMENTAL VALUES	BENCHMARK VALUES
Ornamental water	Turbidity values of 40 NTU in East Basin, and 20 NTU in West Lake. Suspended solids values of 40 mg/L in East Basin, and 20 mg/L in West Lake
Protection of freshwater aquatic system	Turbidity values of 40 NTU in East Basin and 20 NTU in West Lake. Suspended solids values of 40 mg/L in East Basin and 20 mg/L in West Lake. Total phosphorus concentration of 0.06 mg/L. Total nitrogen concentrations of 1.4 mg/L in East Basin and 1.0 mg/L in West Lake. Ammonia concentration of 0.1 mg/L. Cyanobacterial cell concentration of 20,000 cells/mL. Chlorophyll-a concentration of 20 µg/L. Conductivity of 400 µS/cm. pH range of 6.5-8.5 Metal values as specified by ANZECC/ARMCANZ (2000).
Recreational water	Recreational benchmark values are based on the NHMRC *Guidelines for Managing Risks in Recreational Water* (Australian Government 2008) Bacterial quality as specified by Australian Government (2008) preferentially using intestinal enterococci as indicators of the potential presence of pathogens. A concentration of <200 CFU/100mL is recommended. Cyanobacterial toxin concentration of <4µg/L (possible toxins include microcystins and cylindrospermopsins), or <20,000 cell/mL where known toxin producing species are dominant. pH range of 6.5-8.5
Irrigation water for parks and gardens	Water quality based on the *Guidelines for Managing Risks in Recreational Water* (Australian Government, 2008)

Benchmark values are provided only as a guide. The values for East Basin can be used generally for the eastern sections of the Lake (i.e Central Basin) whereas the values for the West Basin can be used generally for the western sections of the Lake (i.e West Lake to Scrivener Dam).

Although the development of a benchmark value in this Water Quality Management Plan (WQMP) generally follows the Australia-wide National Water Quality Management Strategy procedures, it nevertheless includes some local adaptations.

Instead of defining water quality objectives based on 80th percentile values, this WQMP proposes water quality benchmark values. These benchmark values are close to, but not necessarily exactly, at the 80th percentile values for each data set. The benchmark values as used in this WQMP are based on a combination of statistical analysis and scientific judgement. The benchmark values in this updated WQMP also take into consideration the values of the *Guidelines for Managing Risks in Recreational Water* (Australian Government, 2008).

The benchmark values will be reviewed from time to time, as new information and research on water quality becomes available.

8 OVERVIEW OF WATER QUALITY MONITORING PROGRAMS

The NCA's water quality program comprises three sub-programs to monitor the overall environment of the Lake as well as the bacterial quality and algal conditions during specific periods at specific sites (to support the recreational use of the Lake).

These sub-programs are summarised below.

A brief summary of the testing program is also discussed below.

8.1 ROUTINE TESTING OF MIDSTREAM SAMPLES

This is a monitoring program to determine how the water quality of the Lake is performing against management benchmarks and established long-term trends, as well as to report on the overall environmental condition of the Lake.

Under this program, water quality conditions are assessed and reported (usually on a monthly basis excluding April, June, July and September), using midstream samples from four sites (five sites from April 2009) within the Lake. A wide range of physical, chemical, microbiological and biological analyses are carried out at these points to determine the overall water quality at these sites. These analyses then allow judgements to be made about overall water quality right across the Lake. The concentration of bioavailable nutrients at the end of the mixing period provides an indication of the potential for primary production the following summer. Where possible, inclusion of oxidation-reduction potential to the suite of temperature, dissolved oxygen, conductivity, pH and turbidity is recommended.

The results are analysed annually and compared with historical data and the benchmark values of this WQMP. Assessments of the trends of selected water quality indicators are also carried out to identify an improvement or a deterioration in water quality.

- ➔ **Routine lake monitoring by boat (eight sampling events, commencing August).**

Routine water quality testing, assessment and reporting is carried out by ECOWISE Australia Pty Ltd, trading as ALS Water Resources Group. The routine monitoring of Lake Burley Griffin water quality began in December 1981. It has been continued, with a few modifications, to the present day by ECOWISE Australia Pty Ltd, trading as ALS Water Resources Group (with the exception of the 1998–99 period when monitoring was undertaken by the University of Canberra).

8.2 MICROBIOLOGICAL MONITORING OF DESIGNATED RECREATIONAL SITES

This is a program carried out during a specific period at specific sites from a public health and safety viewpoint to support the recreational use of the Lake.

Under this program, bacterial quality of the water is tested in accordance with water quality guidelines. The sites are tested periodically (not more than seven days apart) for the levels of intestinal enterococci in the water.

- ➔ **Routine bacterial monitoring of beaches (weekly between the second week of October and the mid week in April).**

Beach sites are monitored routinely between the second week of October and the mid week in April for microbial indicators of water quality contamination. This part of the program is designed to keep lake users informed of the health risks associated with the primary or secondary contact water activities permitted in those areas.

The ACT Health Protection Service also undertakes some monitoring of the upper reaches of the Lake, again associated with establishing the health risks for users of those parts of the Lake. The outcomes of the monitoring programs are managed separately and are outside the scope of this program.

There is also a need for increased monitoring should sewage spills occur and reduction in potential health risks requires the collaborative efforts and notifications of all agencies. Testing should be for reliable indicators of the potential presence of pathogens. The use of intestinal enterococci as an indicator is recommended by the Australian Government (2008).

8.3 ALGAL MONITORING PROGRAM

This is also a program carried out from a public health and safety viewpoint to support the visual and recreational use of the Lake.

This activity is part of the ACT-wide program to test and report on algal levels. Visual observation and laboratory testing for algae are carried out routinely in selected locations and actions are taken in accordance with the *ACT Guidelines for Recreational Water Quality* (ACT Government, 2010). Reliance on visual observation for the presence of potential toxin-producing cyanobacteria, which normally form blooms below the surface, is not recommended. The testing for both cell and toxin concentrations is recommended as this is a more reliable assessment of human health risk.

8.4 OTHER TESTS

The NCA reserves the right to undertake or support ACT Government authorities in additional:

- **events based tests;**
- **stormwater monitoring, sampling variability investigation;**
- **pathogenic free-living protozoans survey (when water temperatures are high or following sewage spills or treatment plant malfunctions in summer);**
- **investigate sources of faecal contamination if the above is recorded;**
- **monitoring of hypolimnetic concentrations of nutrients, particularly the bioavailable forms of ammonia/ammonium nitrogen, oxidized nitrogen and soluble reactive phosphorus when the water column is stratified.**
- **additional monitoring as required by the NCA during the swimming season.**

The NCA undertakes to conduct periodic Sanitary Surveys to identify changes in source of faecal contamination.

8.5 TESTING METHOD

Routine water samples are collected from a tube sampler, being 5 metres in depth (where depth is sufficient). Bacterial samples are collected 0.3 m below the water surface by 'grab sampling' directly into the final sample bottle. Detailed information on the exact method of sampling is contained in Appendix A.

8.6 GENERAL MANAGEMENT RESPONSE

Decisions to issue warnings or close the Lake are based on a series of test results (five tests) taken over a period of time not exceeding 5 days. Management actions should be based on the *ACT Guidelines for Recreational Water Quality* (ACT Government, 2010).

The NCA's management response generally includes routine communications with regulatory agencies including the ACT Environment and Sustainable Development Directorate's Environment Protection Authority and ACT Health Protection Service, and also the transfer of data, consultation and formulation of management actions. In case of contamination, the NCA consults with the regulatory agencies to ensure an immediate response and appropriate regulatory action.

If a closure is recommended, this is coordinated with the ACT Water Police in consultation with commercial operators and event organisers, with warning signs informing the public erected at the affected sites.

Wherever necessary, the NCA's communication strategies include appropriate public announcements, media statements, interviews, Lake Closure notices, regular update of the NCA's website, and Lake signage of the current water quality condition.

Detailed discussions of the management responses are covered in the following sections.

8.7 GENERAL CATCHMENT MANAGEMENT ISSUES

The catchment of Lake Burley Griffin covers parts of NSW and the ACT. Consequently, there is a significant catchment management role played by:

- NSW state government agencies and departments such as the NSW Government Office of Water;
- NSW local governments such as the Queanbeyan City Council;
- ACT government agencies and departments such as the Environment and Sustainable Development Directorate and other sections of the Territory and Municipal Services Directorate; and
- Community organisations comprising Landcare and catchment management interest groups such as the Molonglo Catchment Coordination Group.

This Plan also supports good land management practices in catchments, adhering to relevant environmental policies aiming at nutrient reductions, sediment control and pollution removal. Management of stormwater quality is critical to the maintenance of lake water quality. In this respect, the catchment management roles played by the agencies stated above contribute to achieving good water quality in the Lake.

In terms of the above-mentioned organisations, the ACT Environment and Sustainable Development Directorate provides a key water management role and has produced a range of documents relevant to this WQMP, including:

- ACT Government (2011). *ACT Water Report 2009-2010*. Available at www.environment.act.gov.au
- ACT Government (2004). *Think water, act water, Volumes 1, 2, and 3*. Available at www.environment.act.gov.au
- ACT Government (2006) *Environmental Flow Guidelines*. Available at www.environment.act.gov.au

The ACT Health Protection Service has produced the local recreational water quality guidelines relevant to this WQMP:

- ACT Government (2010). *ACT Guidelines for Recreational Water Quality*. Available at www.health.act.gov.au

9 ACTIONS ARISING FROM THE MANAGEMENT OF POLLUTANTS

Waterways can be polluted from many sources (point or non-point) and through a variety of processes, including storm events and ground water seepage.

The characteristics of the catchment, land use practices, waste disposal methods, sewage treatment facilities and irrigation practices all contribute to pollution problems in a receiving water such as Lake Burley Griffin.

Controlling the pollutants entering the Lake is often difficult as it depends on the activities of a large number of individuals and agencies involved in the management of upstream catchments.

The Water Quality Management Plan focuses on early detection of pollutants entering the Lake, and on providing management actions where possible.

Health risks and environmental concerns can arise from elevated bacterial levels, toxic algal conditions and other undesirable events.

The monitoring of the benchmark values helps detect possible threats to water quality and provides a sound basis for actions to protect public health and environmental quality.

The water quality monitoring should also be able to identify events which make the water unsuitable for human recreational use.

A number of commonly occurring events can pollute Lake waters. Such events and associated changes identified in this Water Quality Management Plan include the management of:

- **stormwater pollution;**
- **accidental sewer overflow;**
- **unacceptable water quality conditions at designated recreational sites;**
- **elevated bacterial levels;**
- **algae blooms; and**
- **chemical spills and industrial waste.**

Management of water quality during the above events is outlined in the following sections. There may be other events that could be considered equally harmful to water bodies and have the potential to change the water quality characteristics. They will be identified and incorporated in this plan as the knowledge of their detrimental effect becomes available.

9.1 MANAGING STORMWATER POLLUTION

Understanding the Problems

Stormwater can contain nutrients, sediments, trace metals and micro-organisms.

Stormwater run-off can contribute significantly to the growth of microbes in a recreational water body, particularly at times of heavy rain when street gutters and stormwater systems that often contain decaying organic matter are flushed out by large volumes of water.

In some cases, sewer systems, which are connected to trunk sewers or treatment facilities, may overflow during heavy rains. Leaking sewers, which are difficult to detect, may also drain into the stormwater system and reach recreational water bodies.

Dry weather urban run-off may also contain high levels of contaminants, which may be of concern, particularly after a long dry period.

The land use patterns of the catchment can influence the quality of inflow to the Lake. The Lake's catchment comprises urban and rural lands. Where wildlife or domestic animals are found in dense populations, this may also add microbes in high densities in the run-off to the Lake.

Monitoring

- Monitor rainfall events that can cause significant surface water/stormwater run-off.
- Identify catchment characteristics and Lake sections to be influenced including surface and sub-surface flow.
- Carry out testing as required.
- Liaise and coordinate works as necessary to ensure regular clean-up of stormwater structures and flood mitigation structures to minimise pollutants entering into the Lake.

Management

- Conduct sanitary surveys, especially in areas where significant rainfall may result in urban run-off that enters recreational waters and beaches.
- Carry out clean-up as appropriate to remove floating debris (including submerged material), and other undesirable objects.
- Inspect for excessive weed growth, turbidity, bacterial quality.
- When excessive weed growth is treated, the trimmed material should be removed from the Lake.
- Improve the aesthetic quality of the water and conduct special cleaning as appropriate; in the event of public safety concerns, issue public notification.
- Develop a better understanding of the catchment land use practices impacting on receiving waters.
- Notify as required ACT Government agencies and Lake users likely to be affected.
- Ensure ongoing refinement of, and compliance with, the Water Quality Management Plan.

9.2 MANAGING ACCIDENTAL SEWER OVERFLOW

Understanding the Problems

Potential sources of microbiological contamination can occur from sewage resulting from system overloads or failures in sewage treatment facilities, leaking sewer lines, or heavy rainfall causing surface water run-off overflow.

When excessive rainfall occurs, some sewerage systems may not be able to process the subsequent volume of stormwater entering the system. This may result in releases of untreated or partially treated sewage into rivers and lakes. Flooding may also contribute to this problem.

Other sources of sewage release may include those from sewerage systems that are poorly maintained and through accidents, error, or deliberate action, from boat and recreational vessel holding tanks, sewer pump-out facilities, and portable toilets.

Septic systems, particularly when poorly maintained or during flooding, can introduce pollutants into receiving waters. This may occur in parts of the upstream catchment, but the risk from this source of contamination is very low.

Monitoring

- On-going assessment of routine bacterial quality testing, inspection from Lake foreshore maintenance and communication from users.

Management

- Respond quickly to reported events of sewer overflow and implement control measures.
- Liaise with relevant regulatory bodies to ensure adequate controls on treated sewer discharges into the river, and for compliance.
- Conduct appropriate assessment of the site—extent of the contamination, smell conditions, quantities of overflow, type of sewer, and any other details.

- ➔ Advise the affected users for immediate evacuation if necessary.
- ➔ Initiate water quality testing and monitoring of the affected sites.
- ➔ Initiate Lake closure/prohibition notice for the protection of users of the affected areas.
- ➔ Erect signage as required.
- ➔ Monitor the water quality conditions of the affected areas and arrange for reopening of the sites after confirmation of compliance.
- ➔ The NCA will ensure liaison with the ACT Environment Protection Authority and other ACT authorities with regard to sewage entering the catchment, and compliance with management standards within the catchment.
- ➔ Ensure ongoing refinement of, and compliance with, the Water Quality Management Plan.

9.3 MANAGING UNACCEPTABLE WATER QUALITY CONDITIONS AT DESIGNATED RECREATIONAL SITES

Understanding the Problems

A number of factors can contribute to the change in water quality conditions at designated recreational sites. As mentioned previously, surface water run-off can contribute significantly to growth of microbes in a recreational body of water, particularly after heavy rains.

Decaying green waste (water plants) usually found in the water body and foreshores, if not collected within a reasonable time, can contribute to the build-up of microbes. Excessive numbers of water birds, especially around sites with limited water circulation, may also contribute to the growth of microbes in the water.

Another source of microbiological contamination is the users themselves. At sites where high use is found, constituents of residual faecal matter may be washed off the body on contact with water, with most of it washed off within a relatively short time after submersion. Hence swimmers, bathers, waders, surfers, the fishing population, and others who may come into contact with water may all contribute to the contamination to which they are exposed.

Contamination due to accidental faecal releases or by intentional faecal releases are also possible, due to a lack of proper sanitary facilities near every potential recreational area.

Monitoring

- ➔ Monitor events that can change the water quality characteristics.
- ➔ Carry out routine and additional tests in accordance with the approved water quality monitoring programs.

Management

- ➔ Analyse and report water quality results.
- ➔ Ensure the communication of the most recent water quality information.
- ➔ Update regularly the water quality condition on website.
- ➔ In the event of non-compliance with the guidelines:
    - a. Instigate remedial action;
    - b. conduct sanitary surveys and checks for any sources of faecal pollution;
    - c. carry out additional sampling and assess the extent of affected areas;
    - d. issue prohibition / warning notice as appropriate;
    - e. erect signage;
    - f. monitor the sampling results; and
    - g. re-open the affected sites after compliance with the guidelines.
- ➔ Ensure ongoing refinement of, and compliance with, the Water Quality Management Plan.

9.4 MANAGING ELEVATED BACTERIAL LEVELS

Understanding the Problems

In the past, elevated bacterial levels at certain times of the year have been a concern. Such events were sporadic, occurring in the late summer and early autumn period. However, the number of such events has probably increased in the last decade.

From the investigations completed into the cause of the events, the in-lake growth of bacteria has been reported as the probable reason for such bacterial blooms. Other sources of pollution (such as birdlife, stormwater overflow, etc.) may also contribute to this problem. These blooms seem to occur in February/ March, when water temperatures are at their maximum.

To assess the public health risk, over the years the NCA has commissioned research into the cause of bacteria events, particularly to study the pathogenic nature of the organisms responsible for the elevated counts and the environmental conditions that trigger their growth.

The World Health Organisation advocates intestinal enterococci as preferred indicator of the potential presence of microbial pathogens, and this was subsequently adopted in the *Guidelines for Managing Risks in Recreational Water* (Australian Government, 2008). The NCA is now using intestinal enterococci as indicator organisms in its water quality monitoring program. Assessment on water quality conditions arising from elevated bacterial counts are currently based on the *ACT Guidelines for Recreational Water Quality* (ACT Government, 2010).

Monitoring

- Monitor events that can change water quality characteristics.
- Carry out routine and additional tests in accordance with the approved water quality monitoring programs.
- Identify unusual trends from routine testing.

Management

- Analyse and report water quality results.
- Ensure the communication of the most recent water quality information.
- Consult with regulatory agencies, in particular ACT Health Protection Service.
- Update regularly the water quality condition on the NCA's website.
- In the event of non-compliance with the guidelines:
    - a. conduct sanitary surveys and checks for any sources of faecal pollution;
    - b. carry out additional sampling and assess the extent of affected areas;
    - c. issue prohibition/warning notice or other compliance response as appropriate;
    - d. erect signage;
    - e. monitor the sampling results; and
    - f. re-open the affected sites after compliance with the guideline.
- Ensure ongoing refinement of, and compliance with, the Water Quality Management Plan.

9.5 MANAGING ALGAL BLOOMS

Understanding the Problems

During the warmer months of the year, algal blooms can occur in the Lake. High concentrations of nutrients, combined with low flows, warm temperatures and other suitable environmental factors determine the frequency and extent of such algal blooms. They can occur when the concentration of nutrients is fairly low, but blooms are more frequent when the concentration of nutrients is high.

While algae perform an important role within aquatic ecosystems, excessive concentrations can have a detrimental effect upon the aquatic environment. Blue-green algae are a major concern because they have the ability to out-compete most other algal species in marginal light conditions. Additionally, under bloom conditions they can produce toxins and seriously reduce the aesthetic, recreational and sometimes public health qualities of the water.

Monitoring

- Carry out routine visual inspection for algal scums at recreational sites and other parts of the Lake in general and carry out routine testing as required.
- Respond to public reporting in relation to algal conditions and undertake necessary visual inspection and testing of the reported sites.

Management

- Manage routine visual inspection, testing and reporting.
- Monitor events (drought, low flow conditions, storm events, etc) and identify unusual trends from routine testing (eg changes in temperature, flow, chlorophyll-a, nutrients, etc) that can support the growth of algal blooms.
- Consult with regulatory agencies, in particular ACT Health Protection Service.
- In the event of reported algal blooms, carry out actions in accordance with ACT Government (2010) *ACT Guidelines for Recreational Water Quality*, that will include additional testing, issue of prohibition/warning notice as appropriate; erect signage; monitor the test results, and re-open the affected sites after compliance with the guidelines.
- Advise and/or complete remedial work to minimise availability of nutrients and conditions supporting blue-green algal growth where feasible.
- Ensure information on the algal condition is made available to users.
- Ensure ongoing refinement of, and compliance with, the Water Quality Management Plan.

9.6 MANAGING CHEMICAL SPILLS AND INDUSTRIAL WASTE

Understanding the Problems

Inland waterways are susceptible to receiving contamination from chemical spillage and industrial wastes. The contamination may consist of industrial wastes that may be stored or transported in large quantities. This can lead to fire risk, toxicity, mechanical dangers and environmental threats.

These may occur due to deliberate dumping or accidental spillage from boats and land based activities. Generally, stormwater from industrial and urban catchments can also contribute to contaminants in the waterways.

Management of spillage requires an understanding of the type, volume and extent of the spillage. Such incidents of spillage are usually identified by the Lake maintenance crew, which has experience in managing such contamination. The crew also carries a spill response kit for immediate action (if necessary).

The crew undertakes a series of tasks to minimise damage to the ecology of the Lake with an assessment of any fire risk, toxicity, and environmental threats.

Monitoring

- Monitor rainfall events that can cause significant surface water/stormwater runoff from industrial and urban catchment.
- Monitor for such contaminants whilst undertaking Lake maintenance.

Management

- Where a confirmed chemical spill has occurred, the NCA will advise the ACT Government. If ACT Government are treating the event and a 'known incident', the NCA will rely on their control, containment and remediation measures. If not, the NCA will record control, containment and remediation.
- Respond quickly to reported events of spillage and implement control measures.
- Identify the sources of the spillage.

- Liaise with relevant regulatory agencies to ensure adequate controls are in place and all necessary action is taken.
- Carry out an assessment of the contamination.
- Advise affected users of water quality impacts on public safety.
- Initiate water quality testing and monitoring of the affected sites.
- Initiate lake closure/prohibition notice for the users of the affected section of the lake and erect signage.
- Monitor the water quality of the affected areas and arrange for re-opening of the sites after confirmation of compliance.
- Ensure ongoing refinement of, and compliance with, the Water Quality Management Plan.

9.7 COMMUNICATIONS

Continuing assessment of the water quality conditions, dissemination of appropriate information to event managers, the public and regulatory agencies, and initiating appropriate response plans are vital to the management of this Water Quality Management Plan. To address these management issues, the proposed communication strategy will include:

Current Water Quality Information

The current status of water quality conditions is to be made available to the public through the NCA's:

- website: www.nationalcapital.gov.au
- switch board: 02 6271 2888 (BH).
- after hours emergency number 02 6273 4458

Content of Public Information

The information to be made available will include:

- weekly water temperature;
- bacterial and algal condition of the water; and
- any restrictions applying.

Stakeholder Briefing

To disseminate water quality information, stakeholder briefings are recommended at appropriate times. Information on such briefings will be made available either through the NCA's website or through letters.

Liaison with ACT Government Agencies, Contractors, Lake Users

Where management measures require closures/prohibition of the use of the Lake, the NCA will advise the following agencies over the phone or by e-mail of the intended actions:

- Water Police
- ACT Health Protection Service
- ACT Environment Protection Authority
- the NCA's lake maintenance contractor
- the NCA's open space maintenance contractor
- the NCA's Scrivener Dam operations and maintenance contractor
- the NCA's water quality monitoring and recording contractor
- the NCA's Events Officer
- Lake users based in the affected areas
- Other personnel as appropriate.

9.8 USE OF LEGISLATION

9.8.1 Legislation Governing Management Actions

Legislation governing management of the Lake is the *National Land Ordinance 1989* and the applied provision of the *Lakes Ordinance 1976*.

Activities such as the erection of warning signs and the issuing of public notices prohibiting the use of the Lake are controlled by provisions of the *Lakes Ordinance 1976*.

Prohibition of the use of the Lake area or parts of the Lake for health-related concerns is provided for by the following sections of the *Lakes Ordinance 1976*:

21 (1) Subject to subsection (3), the Minister may, by notice published in a newspaper circulating in the Territory, prohibit entry to a lake area.

(2) Subject to subsection (3), the Minister may, by notice published in a newspaper circulating in the Territory, declare an area of a lake to be a prohibited area.

(3) The Minister shall not prohibit entry to a lake or declare an area of a lake to be a prohibited area unless—

(a) the condition of the waters of a lake or that area, as the case may be, is such as to constitute a threat to the health of a person entering those waters;

(b) the prohibition or declaration is reasonably necessary in connection with the maintenance or preservation of a lake or the maintenance, preservation or testing of an associated work;

(c) the Commissioner of Police has given to the Minister a certificate in writing stating that the prohibition or declaration, as the case may be, is reasonably necessary to enable members of the Police Force of the Territory to carry out their duties in a lake or in a lake area;

(d) by reason of an emergency in a lake or a lake area, it is necessary or desirable to do so; or

(e) to do so is otherwise in the public interest.

(4) The Minister may cause a boundary of a prohibited area to be defined by such means as he thinks necessary.

Section 15 of the *Lakes Ordinance 1976* provides for the erection of signs for warning against lake-based activities.

The NCA's role in managing the Lake derives from the functions of the NCA set out in Section 6 of the *Australian Capital Territory (Planning and Land Management) Act 1988*. Additional information about the statutory responsibilities of the NCA can be found on the NCA's website, at www.nationalcapital.gov.au

9.8.2 Other Relevant Legislation

In addition to provisions of the *Lakes Ordinance 1976*, there are several pieces of Commonwealth and ACT legislation which have implications for the Water Quality Management Plan. They include:

- *Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth)
- *Environmental Protection Act 1997* (ACT)
- *Australian Heritage Commission Act 1975* (Commonwealth)
- *Plant Disease Act 1934* (ACT)
- *Public Health Act 1928* (ACT)
- *Noxious Weeds Act 1921* (ACT)

9.9 ROLES AND RESPONSIBILITIES

Various agencies perform roles and exercise responsibilities in relation to water quality and associated activities in and around Lake Burley Griffin. They include:

- **National Capital Authority**, responsible for:
  - the overall management of the Lake;
  - on-going water quality monitoring and assessment and advice, including implementation of actions arising from this Water Quality Management Plan;
  - Collaboration between corporate bodies, authorities and local government;
  - Compilation of a single database for water quality data affecting the Lake; and
  - ensuring that the service delivery contracts are effectively managed to expedite the smooth operation of Lake functions.
- **Australian Federal Police**, responsible for:
  - enforcement (in consultation with the NCA) of actions arising from water quality management protocols;
  - any necessary evacuation of Lake users;
  - any necessary waterborne rescues; and
  - maintaining Lake closures as appropriate.
- **ACT Government and utilities bodies**, responsible for:
  - operation and maintenance of retarding basins, levee banks, major and minor drainage, and other permanent flood mitigation structures within urban areas of the ACT through a maintenance service, and to ensure that they are maintained to minimise pollutants entering the Lake.
- **ACT Environment Protection Authority**, responsible for:
  - monitoring the dumping of waste materials in the waterways;
  - conducting visual inspections of algal conditions in the Lake (under a contract arrangement);
  - taking necessary actions to control quality of stormwater draining into the Lake;
  - ensuring the effective operation of sewage treatment plants and managing treated effluent draining into the river to ensure compliance with environmental authorisations and agreements; and
  - taking necessary actions to prevent contamination from sewer overflow events and advising relevant agencies as soon as possible.
- **ACT Health Protection Service**, responsible for advising on public health issues, including:
  - infectious disease arising from illness-related bacterial levels in recreational waters;
  - public and community advice on the necessary measures to enable maintenance of personal and community health; and
  - water quality that has the potential to affect the health of recreational users of the Lake.

10 CONCLUSION

The management of the Lake is intended to achieve a healthy, sustainable and usable environment, while maintaining the water quality at a level acceptable to the community.

Water quality management is a critical aspect of Lake management. This is the second version of the Water Quality Management Plan for the Lake.

The Water Quality Management Plan is a practical guide to specific actions required for the effective management of the Lake's water quality. It fits within the overarching direction of the Lake Burley Griffin Management Plan. The Water Quality Management Plan outlines roles and responsibilities, monitoring regimes, response protocols and communication with regulatory agencies, stakeholders and the public.

The Water Quality Management Plan, to be implemented under the NCA's Environmental Management System, addresses issues that are not always well understood, and as such should be revised as further information becomes available.

The Water Quality Management Plan will be reviewed on an ongoing basis, to address issues such as elevated bacterial levels, nutrient management and benchmark water quality values. It is hoped that this will help to quickly detect threats to public health and the environment.

11 REFERENCES

ACT Electricity and Water (1988). ***Water quality baseline and performance monitoring***. Report to the National Capital Development Commission.

ACT Government (2004). ***Think water, act water***, Volumes 1, 2 and 3. Available at www.environment.act.gov.au.

ACT Government (2006) ***Environmental Flow Guidelines***. Available at www.environment.act.gov.au

ACT Government (2010). ***ACT Guidelines for Recreational Water Quality***. ACT Health. Available at www.health.act.gov.au

ACT Government (2011). ***ACT Water Report 2009–2010***. Department of the Environment, Climate Change, Energy and Water. Available at www.environment.act.gov.au.

ACT Parks and Conservation Service (1988a). ***The Lake Burley Griffin sediment study – interim report***.

ACT Parks and Conservation Service (1988b). ***The Lake Burley Griffin catchment protection scheme – a review***.

ANZECC/ARMCANZ (2000). ***Australian and New Zealand guidelines for fresh and marine water quality***. Paper no.4.

Atech Group (2002). ***Water monitoring in Australia***. Report to Environment Australia and the National Land and Water Resources Audit.

Australian Bureau of Statistics (2011), '1367.0 – State and Territory Statistical Indicators, 2011 – Estimated Resident Population – Australian Capital Territory' http://www.abs.gov.au/ausstats/abs@.nsf/Lookup/by+Subject/1367.0~2011~Main+Features~Estimated+Resident+Population~9.1. First Issue. Last Updated 30 September 2011. [Accessed on 31 October 2011]

Australian Government (2008). ***Guidelines for Managing Risks in Recreational Water***. Australian Government, National Health and Medical Research Council, Canberra.

Australian Laboratory Services Water Resources Group Canberra (2011). ***Lake Burley Griffin Water Quality Monitoring Report July 2010 – June 2011***. Report to the National Capital Authority.

Burgess J.S. and Olive L.J. (1975). 'Bacterial pollution of Lake Burley Griffin', ***Water*** 2(4): 17–20.

Cullen P., Rosich R. and Bek P. (1978). ***A phosphorus budget for Lake Burley Griffin and management implications for urban lakes***. Australian Water Resources Council Technical Paper no. 31. Report to the Department of National Development. Australian Government Publishing Service, Canberra.

Department of Housing and Construction (1982). ***Water quality monitoring—Lake Burley Griffin and Lake Ginninderra, December 1981 to June 1982***. Report to the National Capital Development Commission.

Department of Housing and Construction (1984). ***Water quality monitoring—Lake Burley Griffin and Lake Ginninderra, July 1982 to June 1983***. Report to the National Capital Development Commission.

EcoChemistry Laboratory (2003). ***Lake Burley Griffin Water Quality: January 1991– February 2003***. Report to the National Capital Authority.

Ecowise Scientific and Aquatech (1995). ***Lake Burley Griffin Water Quality: July 1994– June 1995 Management Report***. Report to the National Capital Planning Authority.

Godden Mackay Logan. (2009). ***Lake Burley Griffin and Adjacent Lands Heritage Management Plan***. Volumes 1, 2, 3 and 4. Report to the National Capital Authority. Available at www.nationalcapital.gov.au.

Gutteridge Haskins and Davey (1982). ***Review of water quality issues for Lake Burley Griffin***. Report to the National Capital Development Commission.

Hillman T.J. (1980). 'Lake Burley Griffin' ***An ecological basis for water resource management***. (Ed. Williams W.D.). Australian National University Press, Canberra.

Joint Government Technical Committee (1974). ***Mine Waste Pollution of the Molonglo River: Final Report on Remedial Measures***. Australian Government Publishing Service, Canberra.

Joint Government Technical Committee (1978). ***Mine Waste Pollution of the Molonglo River***. Australian Government Publishing Service, Canberra.

Lawrence I. (2001). ***Review of reported faecal pollution of Lake Burley Griffin, March/ April 2001***. Report by CRC Freshwater Ecology, to the National Capital Authority.

Maher W.A., Norris R.H., Curran S., Gell F., O'Connel D., Taylor K., Swanson P. and Thurtell L. (1992). 'Zinc in the sediments, water and biota of Lake Burley Griffin, Canberra' ***Science of the Total Environment*** 125:235–252.

Nagy L.A. and Butters D.C. (1987). 'The influence of lake sediment upon eutrophication; laboratory and in situ experiments'. ***Federal Convention 12***, 440–447. Australian Water and Wastewater Association, South Australia, Australia.

Nagy L.A. and Butters D.C. (1988). 'Development of water quality models for the control of eutrophication in Lake Burley Griffin'. ***Water*** 15(1):14–17 and 43.

National Capital Development Commission (1981). ***Waters of the Canberra Region, Metropolitan Planning Issues***. Technical Paper 30, National Capital Development Commission, Canberra.

National Capital Development Commission (1988). ***ACT Water Policy Plan***. Commonwealth of Australia.

National Capital Planning Authority (1995). ***Lake Burley Griffin Management Plan***. Commonwealth of Australia.

National Capital Authority (2011). ***Lake Burley Griffin Recreation Policy 2010***. Commonwealth of Australia. Available at www.nationalcapital.gov.au.

Nazer C.J. (1986). 'Management of aquatic macrophytes in Canberra's lakes'. ***In Proceedings of the 59th Annual Conference of the Royal Australian Institute of Parks and Recreation.***

Norris R.H. (1983). ***Water quality monitoring of the Molonglo River and Lake Burley Griffin***. Report to the National Capital Development Commission.

Office of ACT Administration (1987). ***Water quality monitoring, Lake Burley Griffin and Lake Ginninderra, December 1981 to June 1986***. Volumes I and II. Report to the National Capital Development Commission.

Scientific Services and Aquatech (1994). ***Lake Burley Griffin water quality: July 1993–June 1994 management report***. Report to the National Capital Planning Authority.

Environment Protection Regulation 2005 (ACT)

APPENDIX A

WATER QUALITY TESTING METHODS

All samples were analysed according to the American Public Health Association's (APHA) Standard Methods for the Analysis of Water and Wastewater, 21st edition.

Sites

Routine sampling is carried out at the below specified sites during the months of August, October, November, December, January, February, March and May. Beach sampling is carried out weekly between the second week of October and the mid week in April, however this can be varied according to the needs existing at the time.

Midstream Sites

LBG529 – East Basin. Due to the shallow depth of water all analysis at this site is carried out on samples taken at approximately 0.3m below the water surface. These samples are considered surface samples.

LBG530 – Central Basin. The microbiological samples are collected from the surface, while the chemical and biological samples are collected using a purpose-built tube sampler. The tube depth is at least 0.5m off the bottom, and a maximum of 5 metres in depth.

LBG504 – West Lake. The microbiological samples are collected from the surface, while the chemical and biological samples are collected using the tube sampler. The tube sample is 5 metres in depth.

LBG507 – Scrivener Dam. The microbiological samples are collected from the surface, while the chemical and biological samples are collected using the tube sampler. The tube sample is 5 metres in depth.

LBG505 – West Lake (2). The microbiological samples are collected from the surface, while the chemical and biological samples are collected using the tube sampler. The tube sample is 5 metres in depth (site added April 2009).

Beach Sites (Designated Recreational Sites)

LBG512 – Boathouse – East Basin – Secondary contact

LBG511 – Ferry Terminal – West Basin – Primary contact

LBG510 – Lotus Bay – West Lake – Secondary contact

LBG514 – Yarralumla Beach – West Lake – Primary contact

LBG516 – Weston Park East – Tarcoola Reach – Primary contact

LBG515 – Black Mountain Beach – Tarcoola Reach – Primary contact

LBG517 – Weston Park West – Yarramundi Reach – Primary contact

LBG532 – Rond Terrace – Central Basin – Secondary contact (added February 2011)

Water Temperatures

Measurements are taken of water temperature at each site by calibrated thermometer concurrently with the collection of beach water samples.

Sample Sheets

A sample-reporting sheet is used to record the presence/absence of blue-green algae by visual inspection, evidence of stormwater discharge from nearby (obvious) piping and noting the presence of any surface scums or discharge at each site. Note is also taken of any noticeable odours occurring at the sampling site, and anything else that might be considered unusual.

CHEMICAL AND BIOLOGICAL ANALYSIS OF SAMPLES

Standards/Accreditation

All tests are to be National Association of Testing Authorities (NATA) accredited with accreditation number. All procedures and quality assurance within the laboratory are based on AS/NZS ISO 9002 standards, and have to have been recently audited under the NATA Guide 17025 standard.

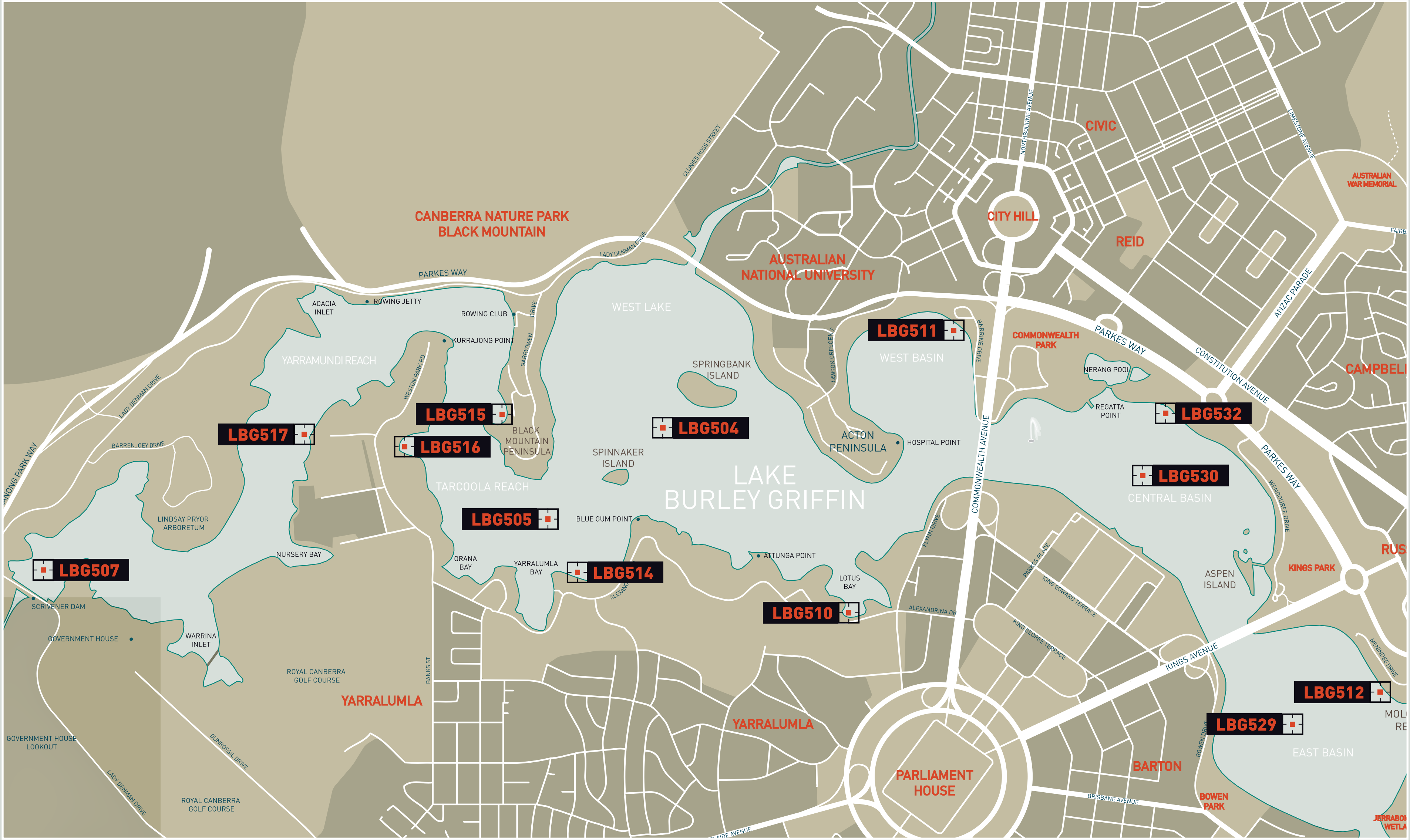
Testing Regime

There is a combination of chemical, microbiological and biological testing done at each site, since an assessment of water quality, especially in open environmental waters such as this, must be based on the results of comprehensive data analysis.

The beach sites are routinely monitored for temperature, dissolved oxygen, and intestinal enterococci, although additional testing is carried out on some samples.

APPENDIX B

LAKE MAP WITH WATER QUALITY SAMPLING SITES



The National Capital Authority was established under the *Australian Capital Territory (Planning and Land Management) Act 1988*

NATIONAL CAPITAL AUTHORITY

GPO Box 373, Canberra ACT 2601

Telephone: +61 2 6271 2888 **Facsimile:** +61 2 6273 4427

Email: natcap@natcap.gov.au

WWW.NATIONALCAPITAL.GOV.AU