DPWS

NSW DEPARTMENT
OF PUBLIC WORKS
AND SERVICES

Manly Hydraulics Laboratory

Lake Ainsworth Management Study

Report MHL1010
June 2001

LAKE AINSWORTH
MANAGEMENT STUDY

Report No. MHL1010

NSW Department of Public Works and Services
Manly Hydraulics Laboratory

In association with

GeoLINK
Peter Parker Environmental Consultants
Environmental Sciences and Engineering
Department of Land and Water Conservation
(Centre for Natural Resources)
Water Research Laboratory

Report No. MHL1010
DPWS Report No. 99076
ISBN 0 7347 4091 3
MHL File No. LRE6-00055
First published June 2001

Summary

Estuary management in NSW is guided by the NSW Government's Estuary Management Policy, details of which are provided in the Estuary Management Manual (NSW Government 1992 in draft). While Lake Ainsworth is not an estuary as such, the management process has been jointly funded by Ballina Shire Council and the Department of Land and Water Conservation's (DLWC) Estuary Management Program. The management process at Lake Ainsworth has been guided by the NSW Government's Estuary Management Policy, and overseen by the Lake Ainsworth Management Committee.

The Estuary Management Manual suggests a structured eight-step process leading to the eventual implementation and monitoring of an estuary management plan. This study relates to Step 4 of this process, which is to carry out an estuary management study.

A variety of community consultation activities were undertaken throughout the study to inform and seek input from the community (see Section 1.4). These activities included:

- meetings with the Lake Ainsworth Management Committee
- an initial media release and community information sheet
- a stall at Lennox Markets
- meetings with local community groups
- general community liaison via the GeoLINK project office at Lennox Head
- establishment of a community access Internet site
- a second community information sheet and questionnaire, and
- a value management workshop with key stakeholders.

A review of the Lake Ainsworth Lake Processes Study was undertaken (see Section 2.1) together with a review of community submissions that were received about the processes study (see Section 2.2). The processes study was completed in August 1996 by Australian Water and Coastal Studies (AWACS 1996). As well as providing an understanding of the processes affecting Lake Ainsworth, the processes study summarised the significant issues to be addressed during the management study and provided some potential management strategies to deal with some of these issues.

Ballina Council commissioned Water Resources Consulting Services to carry out a trial aeration program for the control of the blue green algae at the lake (WRCS 1996). The trial program involved the design and construction of an artificial aerator system and a monitoring system to test its effectiveness. A review of available information on the performance of the trial aerator system is provided in Section 2.3. Key findings of this review are summarised below.

- The aerator causes mixing over the whole water column leading to reduced residence times of both surface and deeper waters when compared to the naturally stratified case.
- The aerator operation has improved the DO concentration in the deep water of the lake.
- It is not possible to definitively state that the 1998-99 algal cell counts would have been higher if the aerator was not operating.
- The aerator generally appears to meet the design specification, however, it may be that a far greater energy input is required to create sufficient turbulence and create an environment unsuitable to cyanobacteria than that provided by the design specification.

As a result of this assessment it was recommended that a database of all data collected since 1994 should be compiled, and ongoing monitoring data added. This database should form the basis of a reasonably detailed assessment of inter-annual variability algal counts and the environmental forcings such as solar radiation, rainfall, water level, nutrients, etc.

The values of Lake Ainsworth are identified in Section 3. These include:

- the lake is an important 'natural' area in an otherwise urban environment
- the lake is a popular active and passive recreational resource
- there are a number of local businesses that rely directly on the lake area for their income, whilst others gain indirect benefit
- Lake Ainsworth is valued as an important educational resource for the region, and
- Lake Ainsworth is the largest dunal lake north of Lake Hiawatha on the far north coast of NSW and the lake and environs contain a remarkable diversity of native biota.

Key issues for the management of Lake Ainsworth, including conflicts between users, is outlined in Section 4. Management issues, summarised into appropriate categories, are outlined in Section 4. The following issue-related categories were adopted:

- Water Quality
- Coastal Dunes
- Traffic Management
- Recreation
- Ecology
- Planning and Development
- Lake Water Level and Flooding
- Erosion and Sedimentation
- Hydrogeology
- Climate
- Aboriginal Heritage.

The management objectives for Lake Ainsworth are presented in Section 5. They have been categorised into primary and secondary objectives and were developed following consideration of the values of the lake and through understanding and consideration of the lake processes and management issues.

An assessment of potential management strategies is provided in Section 6. These strategies were compiled from a variety of sources including previous studies, community and stakeholder submissions, as well as those developed by the study team over the course of the investigation. Strategies were proposed to specifically address the management issues identified for the lake.

These strategies are then compared and ranked in Tables 7.2 to 7.10 of Section 7 to arrive at the preferred suite of management strategies (see Section 7.2). Some of the key management strategies that have been recommended include:

- Continued operation of the trial aeration system with improved data monitoring and management in order to make a more quantitative assessment of the effectiveness of the system.
- Further assessment of potential long-term management strategies to deal with the algal bloom problem, in particular:
  - Sediment capping (particularly developing technologies such as 'Phoslock')
  - Enhanced flushing by groundwater
  - Biomanipulation
  - Sediment removal.
- The suite of water quality improvement strategies outlined in Section 6.2.2.2 should be implemented on an opportunity basis.
- The current dune management practices, as co-ordinated and undertaken by the Lennox Head Dune Care group, should be continued and supported. It is recommended that long-term dune protection strategies be reassessed following the proposed coastal hazard study for Ballina Shire.
- The preferred strategy for traffic management at Lake Ainsworth is to close the eastern and southern foreshore roads. Access to the Sport and Recreation Centre and Camp Drewe on the northern side of the lake would be via a new link road on the outside of the caravan park. The existing foreshore roads could then be converted to provide bicycle and walking tracks with some designated car parking bays.*
- The existing 4WD track, located mid-way along the eastern foreshore of the lake, should be blocked and the dune raised and rehabilitated at this location.*
- Ecological management strategies should include management of aquatic weeds within the lake and terrestrial weeds around the lake's margin, and management of introduced fauna.
- Existing undeveloped Crown land on the western side of the lake (exact area to be determined) should be zoned to allow only minimal low impact recreational development (e.g. walking tracks), environmental educational facilities, environmental protection works, drainage and bushfire hazard reduction.

*Subsequent to completion of this Management Study, the issue of traffic management has been further advanced at a specialist workshop. The results of the final assessments on traffic management will be incorporated in the Management Plan.

Table of Contents

Appendices

Tables

Figures

1. Introduction

1.1 NSW Estuary Management Policy

Estuary management in NSW is guided by the NSW Government's Estuary Management Policy, details of which are provided in the Estuary Management Manual (NSW Government 1992 in draft). While Lake Ainsworth is not an estuary as such, the management process has been jointly funded by Ballina Shire Council and the Department of Land and Water Conservation's Estuary Management Program and has been guided by the NSW Government's Estuary Management Policy. The general goal of the estuary management policy is 'to achieve an integrated, balanced, responsible and ecologically sustainable use of the State's estuaries', and one of the mechanisms for achieving this goal is through the preparation of estuary management plans. The Estuary Management Manual suggests a structured eight-step process leading to the eventual implementation and monitoring of an estuary management plan, as outlined below:

Step 1	Form an Estuary Management Committee
Step 2	Assemble existing data
Step 3	Carry out an Estuary Processes Study
Step 4	Carry out an Estuary Management Study
Step 5	Prepare a draft Estuary Management Plan
Step 6	Review the Estuary Management Plan
Step 7	Adopt and Implement the Management Plan
Step 8	Monitoring and Review of the Management Plan.

This study relates to Step 4 of the above process, leading on to Steps 5 through to 8.

1.2 The Lake Ainsworth Management Process

As discussed above, the management process to date has been guided by the NSW Government's Estuary Management Policy and has been overseen by the Lake Ainsworth Management Committee (LAMC).

Steps 1 to 3 of the management process were completed prior to the commencement of the management study. Australian Water and Coastal Studies completed Step 3 of the process, the Lake Ainsworth Lake Processes Study, in August 1996.

AWACS completed Step 2 of the process, data compilation, in August 1996 in conjunction with the lake processes study, following a preliminary collection of information undertaken by the Lake Ainsworth Management Committee . As part of this process a data collection exercise was undertaken in February 1996 by AWACS in collaboration with DLWC to obtain missing data to assist with the processes study.

1.3 Lake Ainsworth Management Committee

The Lake Ainsworth Management Committee was formed in 1994 to instigate and oversee a co-ordinated approach to the management of Lake Ainsworth. The first meeting of the LAMC was held on 23 November 1994. The LAMC is composed of representatives of key stakeholders and the community, and currently includes representatives of the following organisations:

- Ballina Shire Council
- Department of Land and Water Conservation
- Lake Ainsworth Sport and Recreation Centre
- Lennox Head Residents Association
- Lennox Head Dune Care
- Ballina Environment Society.

1.4 Community Consultation Process

A variety of community consultation activities were undertaken throughout the study to inform and seek input from the community. Submissions received during this process are provided in Appendix A. For the purposes of the Lake Management Study, the following community consultation process was adopted:

1.4.1 Initial Meeting with Lake Management Committee

At the commencement of the project, the consultants attended a meeting of the Lake Management Committee. At this meeting, the consultants described the process to the Committee and discussed various issues associated with the project and the lake.

1.4.2 Media Release and Information Sheet

At the commencement of the project, a media release and a community information sheet were prepared. These were used to advise the public of the commencement of the project, its nature and the process to be undertaken.

One of the main objectives of this early stage was to advise the public of the community involvement measures proposed and to invite their input into all stages of the project.

The community information sheets were distributed to local businesses for handout and 'letterbox dropped' to all residences in the Lennox village area and the Figtree Hill area.

1.4.3 Stall at Lennox Markets

In early August, a stall was established at the Lennox Head market, held on the shores of the lake. At this stall the initial community information sheets were available, as was the previously prepared lake process study. Staff from GeoLINK and Peter Parker Environmental Consultants manned the stall to talk with the public about the project.

1.4.4 Meetings with Local Community Groups

Rob Van Iersel from GeoLINK addressed meetings of the Lennox Head Residents Association, the Lennox Head Chamber of Commerce and the local View Club to advise them of the project and get them thinking about the values of the lake and their desires for its future.

1.4.5 General Community Liaison

The GeoLINK office, located in the main street of Lennox Head, has provided a focal point for the community involvement throughout this project. The information sheets advised the public of the location of this office and let people know that they were able to call into the office during normal business hours to discuss the project and/or leave submissions and the like.

A small 'sandwich-board' sign was located on the footpath of the main street to further advise of the office location.

1.4.6 Internet Community Access Site

A community access Internet site was established to provide the community with unrestricted access to general project advice as well as inviting input during both the management study and the formation of the management plan.

1.4.7 Second Community Information Sheet

Towards the end of the lake study phase of the project, a second community information sheet was prepared and distributed. This summarised the findings of the study to that point and advised of the community workshop.

1.4.8 Value Management Workshop

Towards the end of the study process, a value management workshop was held. This workshop, which involved key stakeholder representatives, was chaired by GeoLINK, with MHL personnel providing an overview of study results to date.

The aim of the workshop was to confirm the lake's values and management objectives, and to discuss and rank management strategies and actions.

2. Processes Study Review

2.1 Overview of the Processes Study Findings

The Lake Ainsworth Lake Processes Study was completed in August 1996 by Australian Water and Coastal Studies (AWACS 1996). The following section provides an overview of the findings of the processes study. It is noted that chapter and figure numbers referred to in this section of the report (Section 2.1) are those of the processes study, and not of this report.

At the commencement of the processes study a review of available information indicated a number of areas where there were gaps in the required data to define the processes. There was a lack of data on long-term trends (years). Reliable information on the occurrences of algal blooms was lacking. There was also a paucity of information on short-term trends and characteristics of the lake such as nutrient levels, stratification, biota composition, flora and fauna species and succession, and sediment type and quality.

A water level recorder operated by MHL has been in the lake since 1994 and a water quality recorder was added in 1995. Information from that installation was included in the processes study.

Additional information was obtained during field data collection exercises conducted through the course of the processes study, which included:

- An intensive field data collection exercise on 5-9 February 1996 by personnel from AWACS, DLWC and Southern Cross University. Elements of this field exercise included lake bathymetry, lake bed surface and core sediments, in-lake nutrients and algae, water temperature, groundwater levels and quality, flora and fauna survey, inspection of foreshore erosion and vegetation rehabilitation.

- Ongoing monitoring of groundwater levels and quality in bores to the south, east and west of the lake including installation of new bores, cores from which data were used for interpretation of local stratigraphy.

- Four weeks of monitoring of in-lake water quality including algal sampling in association with the groundwater monitoring.

- Monitoring of water quality of stormwater discharges to the lake during rainfall events.

- Counts of traffic visiting the lake in March and April, including over the Easter weekend and over Anzac Day.

A description of the regional setting is provided in Chapter 4 to provide a context for assessment of lake processes.

The climate is characterised by high temperatures and humidity in summer with heavy periodic rains, and mild temperatures and some significant rain in winter.

The regional geology is described in detail in Appendix E and shown in Figures 4.4, 4.5, 4.6 and 4.7. The northern and western margins of the region consist of bedrock hills of metamorphic, sedimentary and volcanic rock type. Tertiary basalt hills occur on the coast between Ballina and Lennox Head. Between the hills and the coast is a sandy, swampy coastal plain with barrier and estuarine deposits within which the lake is situated.

Regional groundwater flows are shown conceptually in Figure 4.8. Groundwater flows away from the hills towards the coast or into North Creek and other water courses draining to the Richmond River.

Lake usage and cultural aspects are presented in Chapter 5 to provide an overview of the cultural value of the lake and a background for the impact of human activities on lake processes.

Land use zoning at Lake Ainsworth is presented in Figure 5.1. Land uses include the caravan park, the surf lifesaving club, the Department of Sport and Recreation Centre and urban areas to the south of the lake. Land surrounding the southern half of the lake is a public recreation reserve; and land at the northern end is both a 'bird and animal' sanctuary and a reserve for national fitness and physical education.

A range of recreational uses is undertaken at Lake Ainsworth including sailboarding, sailing, ski paddling, swimming, picnicking, sunbathing and walking. Areas of particular activities are shown in Figure 5.3. During March and April 1996 the average number of vehicle visitations on Saturdays and Sundays was approximately 570 and 835 respectively; and total number of visitors on a Sunday has been estimated at over 3,100, with nearly 1,600 present at any one time. A survey conducted in 1988 indicated a social carrying capacity of about 560 persons. Accordingly, overcrowding and associated problems are experienced at Lake Ainsworth.

The Lake Ainsworth Caravan Park at the southern end of the lake can accommodate approximately 1,200 people. Visitor numbers are in the range of 1,500 to 2,000 per week over the peak Christmas period. Over the last three years annual occupancy rate at the caravan park has remained relatively constant.

The Lake Ainsworth Sport and Recreation Centre, formerly the National Fitness Camp, was opened in 1944 and currently can accommodate 210 people. There are plans for its expansion. The centre occupies 12 hectares of the Crown reserve and has some 30 buildings and various recreational facilities. The estimated number of campers per year is currently 5,500 with an average stay of 5.5 days.

While no Aboriginal archaeological studies were identified in this study, various Aboriginal sites, including camp sites have been found in the vicinity of Lake Ainsworth. The sites are of a type well represented on the north coast. The Jali people are the traditional occupiers of land around Lake Ainsworth, and the area has significance to the contemporary Jali people.

The characteristics and processes affecting the lake are described through an interpretation of the available information in Chapter 6. For some processes, including those related to nutrients, there is a lack of long-term data, which limits the level of understanding of the processes.

The flora of the lake and its environs includes coastal heath and paperbark swamps in the surrounding areas and large stands of macrophytes in the shallows. Blue-green algae blooms have been observed in recent years and a number of phytoplankton species have been identified in the lake. The few studies of aquatic fauna of the lake have found very few species and the exotic species may be out-competing the native species. It is thought that the mosquito fish, an exotic species, may have already altered the lake ecosystem. Invertebrates also exhibit low diversity and abundance with a single species of crustacean zooplankton and an occasional planktonic water mite.

The surface runoff catchment is about six times the lake surface area and is comprised of a relatively narrow band of less than 300 m width around the west, south and eastern sides and extends 1.5 km to the north (Figure 6.3). It is relatively flat and consists of grassed areas, coastal heath, urban area and the caravan park.

A conceptual model for the local hydrogeology has been developed in Section 6. Groundwater flows into the lake predominantly from the west and south, and flows out of the lake through the eastern dunes into the ocean (Figure 6.4). The surface and groundwater catchments are not completely coincident. After significant rainfall, the groundwater catchment to the west of the lake is limited by a groundwater mound within the western dune separating the lake from Newrybar Swamp. Following extended dry periods, groundwater from sources west of the dune may flow to the lake at very low rates.

The Woodburn Sand Unit (WSU) which controls the local hydrogeology becomes indurated with humic matter at depth, which impedes groundwater flow. Accordingly, the majority of groundwater flow occurs in the aquifer above a level of 4 m below Australian Height Datum (AHD) as indicated in Figure 4.9. The groundwater is fresh and has a high total organic carbon content comprised mainly of humic substances. Total phosphorus concentrations in the groundwater are generally around 0.01 mg/L except in localised areas around the bowling club and near the Sport and Recreation camp. Total nitrogen concentrations vary between 0.7 and 5 mg/L. High total organic carbon levels (30-100 mg C/L) in porewaters sampled from lake sediments indicate the organic rich sediment typically associated with swampy ground and anaerobic microbial processes.

The lake morphology consists of a deep main basin (8-9 m deep) with a shallow arm extending northward along a swale within the ridge-swale system of the local dunes. A detailed bathymetric survey was completed in February 1996 and is presented in Figure 6.5. The variations in lake surface area and lake volume as functions of water depth were derived from the bathymetry (Figure 6.6).

Bottom sediments of the lake are comprised of two distinct types: well sorted medium grained quartz sands occur in shallower areas (< 4 m depth) and a gelatinous organic rich mud occupies the deeper central part of the lake. The organic rich muds are about 4-6 m deep in the central lake and shoal to about the 4 m depth contour. Nutrient analyses of sediment samples showed relatively low concentrations in the sandy sediments and very high concentrations in the organic muds.

A conceptual model of the initial formation and subsequent infilling of the lake has been postulated. The Pleistocene barrier was eroded by a storm surge to form the lake basin and subsequent deposition of the Holocene outer barrier blocked the eastern boundary of the basin. With rising sea level the associated rise in regional groundwater would have led to the flooding of the depression. The lake morphology appears to have changed little over the past 50 years. Carbon dating of the deeper organic sediments suggests an average sedimentation rate of 0.4 mm/year over the last 2,500 years.

Estimates of sediment inputs from the catchment using the Universal Soil Loss Equation gave a maximum rate of infill for the shallow sandy perimeter of about 1 mm/year.

Estimates of the effect of surface waves on resuspension showed that for the sand particles this process is only important in the shallow areas (depths < 1.5 m) and for the finer organic particles down to depths of about 2.5 m. The limited fetch of the lake effectively inhibits the development of rough seas and hence effects such as foreshore erosion by waves are assumed to be negligible.

The lake water budget is determined by a balance between inflows due to direct rainfall, surface runoff and groundwater, and outflows due to evaporation and through the groundwater. Estimates of each of these contributions indicated that direct rainfall and evaporation were the most important from November 1994 to May 1996. The lake water level responds mainly to these contributions, while the groundwater throughflow tends to balance (input ≈ output). The flushing of the lake occurs via groundwater outflow through the eastern boundary to the sea.

Lake water quality is strongly influenced by the stratification, which is determined by a balance between thermal energy inputs (solar radiation), and mixing due to wind or convection. During stratified periods the deeper waters become depleted in dissolved oxygen, producing conditions favourable to the release of nutrients from the sediments. Subsequent mixing events transport the nutrient rich deeper waters to the near surface where they become available to algae. The algae require light and nutrients and prefer calm conditions for optimal growth and the occurrence of blooms.

The heat fluxes to the lake that determine the temperature signal were estimated from meteorological data collected at the lake in February 1996. Solar radiation causes heating of the near surface waters down to a depth determined by the water clarity. High levels of humic compounds in the lake cause a strong brown coloration that effectively inhibits the depth of penetration of surface light. As a consequence the stratification is comprised of a thin surface layer (~ 1-1.5 m) that heats up to about 33°C during the day and cools down to around 30°C overnight in February (Figure 6.16).

Vertical mixing in the lake is driven by a combination of wind events and convective processes introduced by an influx of relatively cold water by direct rainfall. It appears that wind and rainfall events continually erode the stratification while solar heating continually builds it up. Whether an event will completely mix the lake depends on the time since the last complete mixing event, the strength of wind and the rainfall intensity. Vertical profiles of temperature and dissolved oxygen reflect the current stratification and time since the previous complete mixing event (Figure 6.15).

Faecal contamination was assessed using the BSC data collected over 20 years to 1996, and recent measurements during a rain event (Figure 6.19). The levels are generally within the recommended guidelines, with levels peaking around 1990. Stormwater drains near the south of the lake showed high faecal coliform bacteria concentrations during one rainfall runoff event that occurred during the study.

Nutrient concentrations in the lake have only been sampled over the past three years on an ad hoc basis. Concentrations are generally high and appear to fluctuate with mixing events (Figure 6.20). A phosphorus budget indicated that the major source of phosphorus for the water column was from the sediments. Annual estimates of the phosphorus loads due to sediment release were approximately 10 times larger than the combined loads due to runoff and groundwater.

Algal data have also only recently been collected on the lake and it was not possible to infer any long-term trends in algal characteristics. The microalgae community is comprised of a number of species of phytoplankton and cyanobacteria (blue-green algae).

Blue-green algae were identified in the lake in 1986 and anecdotal evidence suggests that the levels are increasing. Experience in similar systems suggests that water temperatures, strong stratification, calm conditions, high light and excess nutrients are favourable to cyanobacteria blooms. These conditions commonly occur in Lake Ainsworth but their relative magnitudes vary from year to year due to changing climatic conditions, and hence blooms may be common in some years but not in others. Algal cell counts exceeded the ANZECC and NCRACC guidelines in the summer of 1995/96 but not in the previous summer. The high nutrient levels in the lake suggest nutrients are not limiting algal growth.

The water quality criteria for nutrients set out in the ANZECC guidelines are generally exceeded although it is not possible to assess the frequency of exceedance. Application of the Organisation for Economic Co-operation and Development (OECD) classification scheme suggests that Lake Ainsworth is a eutrophic lake and the presence of high chlorophyll levels and algal blooms confirms this classification.

The continuation of the lake as a freshwater lake depends on the maintenance of the coastal frontal dune to prevent inundation by the ocean. Photogrammetric analysis indicates long-term recession of the dune scarp in front of the lake is of the order of 0.9 m per year. Short-term movements of the scarp due to storm action can be much greater, however there is subsequent recovery of the dune as sand is redistributed by the beach processes. A storm in May 1996 resulted in the dune scarp moving approximately 13 m landward. Predicted climate change and associated rise in sea level could further erode the frontal dune. Maintenance of an adequate store of sand in the frontal dune by maintenance of a good cover of dune vegetation, as is being implemented by the local Dune Care group, is the best way to retain the frontal dune.

A range of human activities has impacted on lake processes and these are listed in Section 6.9. Significant activities since the commencement of European settlement have included clearing of much of the native vegetation, the growth of Lennox Head township, the development of the Sport and Recreation centre, and sand mining of the frontal dune system. These activities have modified surface and groundwater flow patterns and quality, modified the lake nutrient budget and varied the composition and abundance of flora and fauna. The detailed impacts of human activities on processes need to be taken into account in planning management strategies.

To assist with the development of a management study and plan, significant issues are tabulated in Chapter 7. The occurrence of algal blooms and the consequential impact on recreation and the tourist industry is arguably the main issue at the present time. However, a well balanced management plan should take into account all significant issues due to the complexity of interactions between the lake processes and the effects on the values of the lake.

The processes study also provides some potential management in Chapter 8, for management of foreshore erosion, frontal dune erosion and algal blooms.

It is suggested that monitoring is required to further improve the understanding of the processes operating at Lake Ainsworth and to assess the performance of any management options that are implemented. Chapter 9 sets out a possible program for monitoring with three broad objectives: to satisfy public health requirements; to ensure maintenance of assets; and to understand processes including obtaining information for calibration and verification of any models of processes. It is envisaged that the monitoring could be undertaken jointly by Ballina Shire Council, local community groups and local educational institutions.

2.2 Review of Community Submissions on the Lake Processes Study

Mr John Duffy provides some useful observations on the report and further insights into the management issues. His statement that 'there appears to be somewhat of a kneejerk reaction to the high algal bloom counts last year (1995/96)' is quite possibly valid. The guidelines set by the North Coast Regional Algal Coordinating Committee and recent public focus on algal issues coupled with the high counts in Lake Ainsworth may have led to more exposure of the issue than was realistically justified. His assumption that if the algae are toxic then exposure to the lake water should lead to visitations to the local GPs is not necessarily correct. The level of algal toxicity to humans is not well known and hence the guideline values for safe immersion are generally well below levels that may lead to human health effects. He has pointed to the deficiency in drawing conclusions about the frequency of algal blooms from limited data. This is acknowledged in the processes study report, and our conclusion that the algal blooms are a persistent occurrence was based on the limited data and observations by local residents over a number of years. The term persistent is used to imply blooms will continue to occur but not necessarily every year.

His suggestion that the management options should only be considered after the proper evaluation of their use in other systems is in keeping with the findings of the report where the potential options were presented as examples of what may be considered. It would appear that he has misunderstood our suggestions of the biomanipulation strategies. The microbial processes and associated chemical reactions that lead to sediment nutrient release were not targeted as having potential bioremediation. The biomanipulation strategy that has been used in the European lakes generally involves an attempt (typically stocking with larger fish) to reduce the population of small fish that eat the zooplankton that in turn graze on the microplankton. This approach has been successfully applied to a number of systems but requires careful assessment (particularly of the present interactions between the components of the food chain) before such an approach could be considered for Lake Ainsworth.

We fully support his concluding remarks that longer term monitoring (5-8 years) is required to provide an adequate picture of the algal bloom issue, its interannual variability and links to the environmental forcings.

Mr Stanley Rosolen states in his letter 'I have designed a simple and cheap machine that will remove algae and the blue green algal bloom to a depth of 24 inches, eight feet wide at 3 knots per hour, from the water'. This type of filtering device has been adopted for cleaning waterways of larger plants. Without further documentation on the design, its costs and likely effectiveness it is not possible to comment further on the merit of such a system. Tests of skimming devices elsewhere have indicated that they are ineffective, expensive to operate, and there may be problems with disposal of the algae, which may be classified as toxic waste.

Ms Marelle Lee has provided comments very similar to those of Mr John Duffy and the above response to Mr Duffy's comments is again applicable. She has also made comment on management issues that should be considered during the management study.

Mr J. C. Wharton provided some useful comments on papers presented at the Biological Manipulation workshop held in Berri, South Australia in October 1996. These notes will be used in the Management Study.

2.3 Review of Available Information on the Performance of the Trial Aerator

Following completion of the processes study, Ballina Council, as a matter of urgency, commissioned Water Resources Consulting Services to carry out a trial aeration program for the control of the blue green algae at the lake (WRCS 1996). The trial program involved the design and construction of an artificial aerator system and a monitoring system to test its effectiveness. The trial acknowledged the need for longer-term management options to be considered but deemed that the success of the aeration in other NSW reservoirs was sufficient justification to proceed with the trial as a potential means of minimising the summer algal blooms.

The destratification process has had mixed success at reducing algal blooms. The general theory suggests that destratification can be used to break down the thermal stratification and in so doing increase oxygen levels in the deeper waters leading to reduced nutrient release and impeding the growth rate of algae. The program led to the installation of an aerator in late 1997. The WRCS (1996) report recommended a detailed performance monitoring program be implemented to assess the trial program.

BSC commissioned Judith Betts to undertake a 12-month monitoring study of Lake Ainsworth in mid-1998. The aim of this study was to fill data gaps identified in the lake processes study and to provide monitoring data to assist in assessing the performance of the trial aeration scheme. The study was completed in August 1999 (BSC 1999). A qualitative assessment of this and other information is provided below.

In essence the aerator is installed to provide a source of energy for mixing the cooler deeper water and the warmer surface waters and thereby break down the stratification. The follow-on effects of introducing a continual source of turbulence into the water column, more oxygen into the bottom waters, possibly reducing nutrient release and impeding the growth of micro algae are secondary effects. The level of stratification present during any given summer is highly dependent upon the weather conditions and rainfall. Similarly it is well known that the chemical and biological response of the system varies annually.

The assessment of aerator performance must be measured at a number of levels and the following questions should be addressed:

- has the aerator destratified the system?
- how often does it need to be operated?
- has the aeration led to improved oxygen conditions in the deep water?
- has there been a reduction in algal blooms during aerator operation?

Each of these questions is addressed below with reference to the available data.

Has the aerator destratified the system?
Thermistor chain data collected over the past two years provide an indication of the aerator destratification performance. It is also known that the lake destratifies in response to natural events such as severe cold changes and rainfall. Rainfall and lake water levels for the period 1 July 1997 to 30 June 1999 are shown in Figure 2.1. The period of interest in terms of algal blooms is generally from November to April and for that period there are quite distinct differences between the 1997-98 summer and the 1998-99 summer, which was considerably wetter.

The water temperatures at 1 m and 9 m depth recorded by the thermistor chain are shown in Figure 2.2a and the temperature difference which provides a measure of the stratification in Figure 2.2b. These figures were derived after recalibration of the thermistor temperatures, which had severe data quality and accuracy problems. It is not clear when the aerator was operating but various notes suggest that it was on during most of the latter half of November and most of December.

The period of stratification between about 5 and 10 November is typical of the natural development of a thermal gradient due to surface heating in the absence of artificial mixing (aeration). Note the bottom water temperature remains almost constant while the surface water warms by some 2.5°C before the aerator begins to operate on 7 November. The aerator is able to partially mix the water column but through the warmest part of the day solar heating is sufficient to restratify the water column. The presence of a persistent weak stratification is typical of these devices. Note the sudden drop in temperature that coincides with rainfall events and presumably cooler weather on 20 and 27 November and 20 December. The period 6 to 20 December was relatively dry and warm and in spite of the aerator operation the stratification remained above 0.5°C while the lake water temperature increased from 22°C to around 26°C before the rainfall event and cooling over the next three days.

The aerator is causing mixing of the water column in summer but during hot clear days surface heating is capable of generating a weak stratification that varies between 0.5 and 1.5°C top to bottom temperature difference. The brown, humic stained nature of Lake Ainsworth would contribute to this, causing the rapid absorption of heat close to the surface, and increasing the resistance to mixing by day. It is important to recognise that although a weak stratification persists the aerator causes mixing over the whole water column leading to reduced residence times of both surface and deeper waters when compared to the naturally stratified case.

How often does it need to be operated?
The data presented in Figure 2.2 indicate that during hot weather the thermal gradients build up within a few days, especially with the absorption of most heat occurring close to the surface due to the dissolved colour.

The exact operating times of the system cannot be recorded at present, however Council has taken a conservative approach to operation of the compressor. It has been run for many hours longer than it probably had to because of the thermistor chain failure. The aim was to prevent algal blooms, therefore the system was operated except during the winter months and major storm events when profile data indicated no stratification present. Assuming, therefore, that the aerator was operating most of the time in December it would appear that this mode of operation needs to be supported. It could be switched off during cooler weather and rainfall events and hence is likely to require less frequent operation in autumn and spring than in high summer.

Has the aeration led to improved oxygen conditions in the deep water?
Vertical profiles of the dissolved oxygen (DO) concentrations were monitored by BSC during the 1998-99 summer roughly two times per week (BSC 1999). These data were collected during the aerator operation and show that the bottom water DO has improved as a result of the aerator-induced mixing compared to previous years when there was no aeration (AWACS 1996). The deep water DO concentration is generally similar to the surface water DO concentration. A number of profiles collected over the 1995-96 summer (see Figure 4.9 of the Summary Processes Study report) indicate the rapid depletion of the DO during stratified periods. The DO profile during December 1995 consisted of well-oxygenated surface waters (8 mg DO/L) and was anoxic in the deep waters. Some mixing events during heavy rainfall events increased the bottom water DO but the subsequent redevelopment of stratification again led to rapid DO depletion in the deeper waters. This natural cycling of low DO during stratified periods followed by rapid increase during mixing events is typical of natural water bodies with high organic content.

The aerator operation has therefore improved the DO concentration in the deep water of the lake.

Has there been a reduction in algal blooms during aerator operation?
Establishing links between aerator operation and the presence/absence of algal blooms requires a good understanding of the natural response of the algae to environmental conditions. Unfortunately our level of understanding is not sufficient that we can confidently predict the occurrence of an algal bloom. The success (or otherwise) of the aerator can therefore only be assessed by comparing algal data from summers with similar weather conditions but for when the aerator was and was not operating. A comprehensive long-term data set with algal counts, stratification measurements, aerator operation and weather conditions would be required to make a detailed assessment. These data should be collected as part of the comprehensive performance monitoring recommended by Preece et al (1996). A one-year monitoring program was undertaken from mid-1998 to mid-1999 (BSC 1999). Unfortunately these data are currently insufficient to allow anything more than a preliminary assessment of aerator performance.

Comparing algal cell counts recorded during the 1994-95, 1995-96 and 1998-99 summer periods indicates that the highest readings occurred during 1995-96 and the lowest readings in 1994-95. Counts during the summer of 1998-99 were low but still higher than the 1994-95 period. Records of algal warnings for Lake Ainsworth indicate a period of mostly medium and high alerts from mid-November 1995 to mid-January 1996. While alerts ranged from high and low between mid-December 1997 to early January 1998, some medium-to-low alerts were issued in May and June of 1998. Mostly low and medium alert levels were issued on eight occasions in the period between early August 1998 and mid-January 1999. These data illustrate the natural variability in algal presence that occurs in Lake Ainsworth, with or without the aerator operating.

It is not possible to definitively state that the 1998-99 algal cell counts would have been higher if the aerator was not operating. As pointed out above, the responses of cyanobacteria to the environment in Lake Ainsworth has not been sufficiently studied to allow such a prediction. The data supplied in Figures 2.3 to 2.5 for the period 4 November 1988 to 20 April 1999 also provide little insight to these responses. Maximum cyanobacterial numbers occurred when mixing was at its best, while numbers decreased when stratification was present in early January and early March.. Decreases in conductivity in February and pH from February onwards are possibly due to rain and dilute, humic acid-laden inflows. These rainfall events are likely to have kept cyanobacterial presence low as well. Any algal response to nutrients, or effects of aerator operation on nutrient concentrations, cannot be assessed from the limited data available.

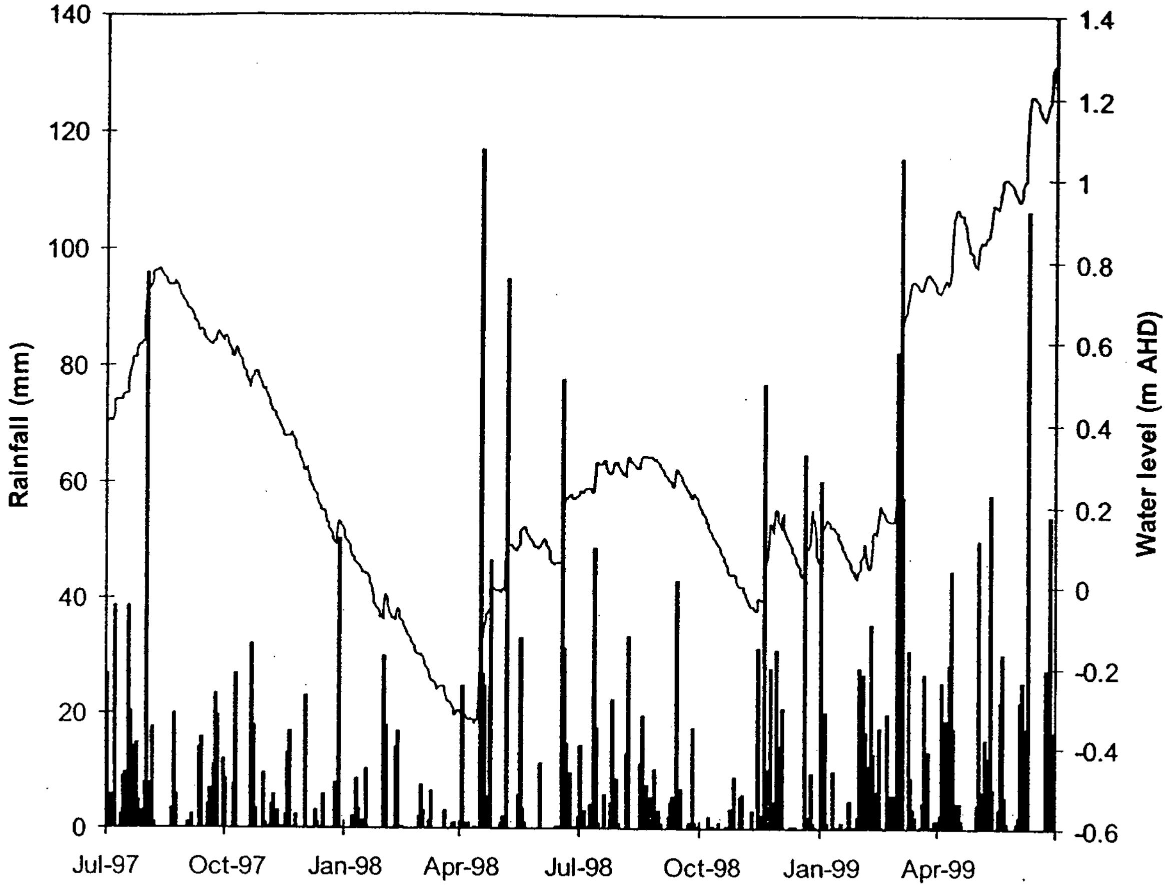
Mixing caused by aerators is known to have variable success in terms of algal control. This feature was spelt out prior to aerator installation by Preece et al (1996). The aeration system does not appeared to have had any adverse effects on Lake Ainsworth and has been successful in maintaining a mixed water column and elevated levels of dissolved oxygen (BSC 1999). In Lake Ainsworth, the system was designed to supply sufficient energy to disrupt the maximum stability due to thermal stratification previously measured there. Despite the slight thermal stratification that still occurs, mainly on a diurnal basis, the aerator generally appears to meet this design specification. However, given that a conservative approach has been adopted in the operation of the system to date, it may be that a far greater energy input is required to create sufficient turbulence and create an environment unsuitable to cyanobacteria than that provided by the design specification.

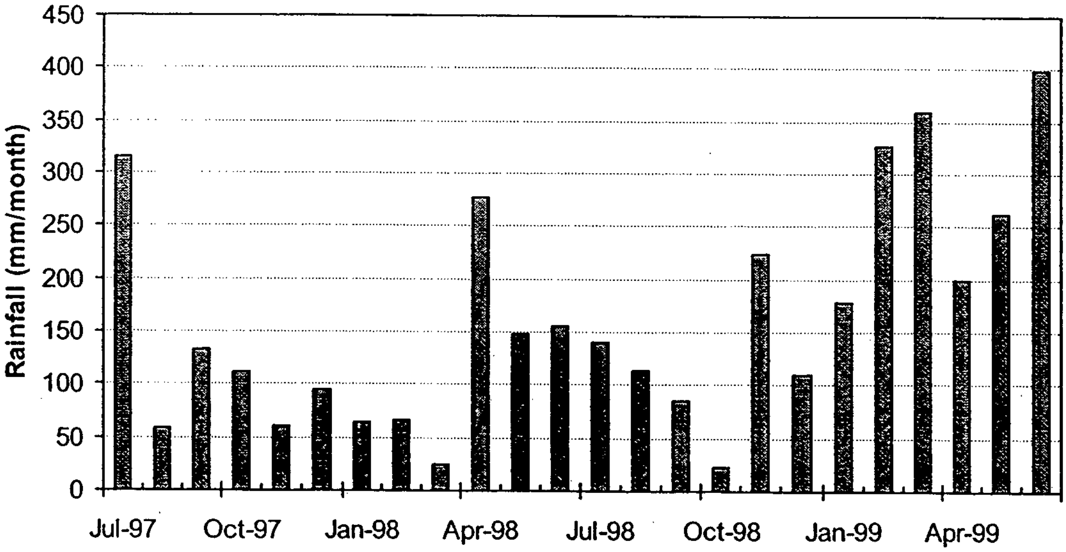
2.4 Recommendations in Relation to the Trial Aerator

The following recommendations are made in relation to the assessment of the performance of the trial aerator at Lake Ainsworth:

Data storage and accessibility for future long-term assessments
While much of the existing data has now been compiled into spreadsheets (BSC 1999), it would be beneficial for Council to compile these data into an environmental database for the long-term storage and future assessment of a number of years of collected data. The current situation with different data sets stored using a range of formats in Excel files is not conducive to integrative analyses.

Data analysis and assessment of aerator performance
The data set currently available is not sufficient to adequately assess aerator performance. Future assessment of performance would be aided through the compilation of this data into an environmental database with additional data from ongoing performance assessment continually being added to it. This data set could then form the basis of a reasonably detailed assessment of inter-annual variability algal counts and the environmental forcings such as solar radiation, rainfall, water level, nutrients, etc.





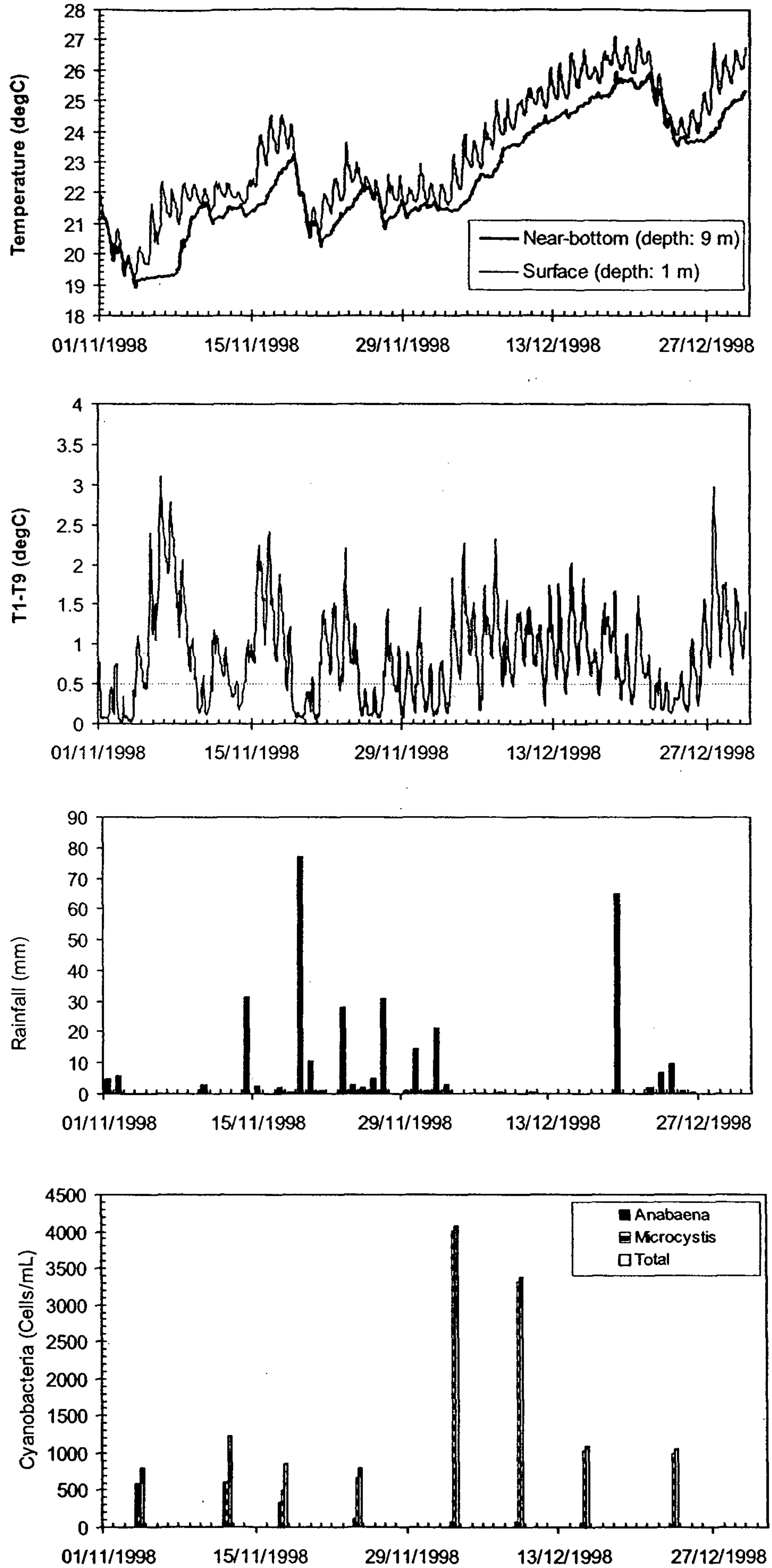
NSW DEPARTMENT OF PUBLIC WORKS AND SERVICES
MANLY HYDRAULICS LABORATORY

WATER LEVEL AND RAINFALL AT LAKE AINSWORTH 1997 TO 1999

MHL Report 1010

Figure 2.1

DRAWING 1010AIN1.CDR



NSW DEPARTMENT OF PUBLIC WORKS AND SERVICES

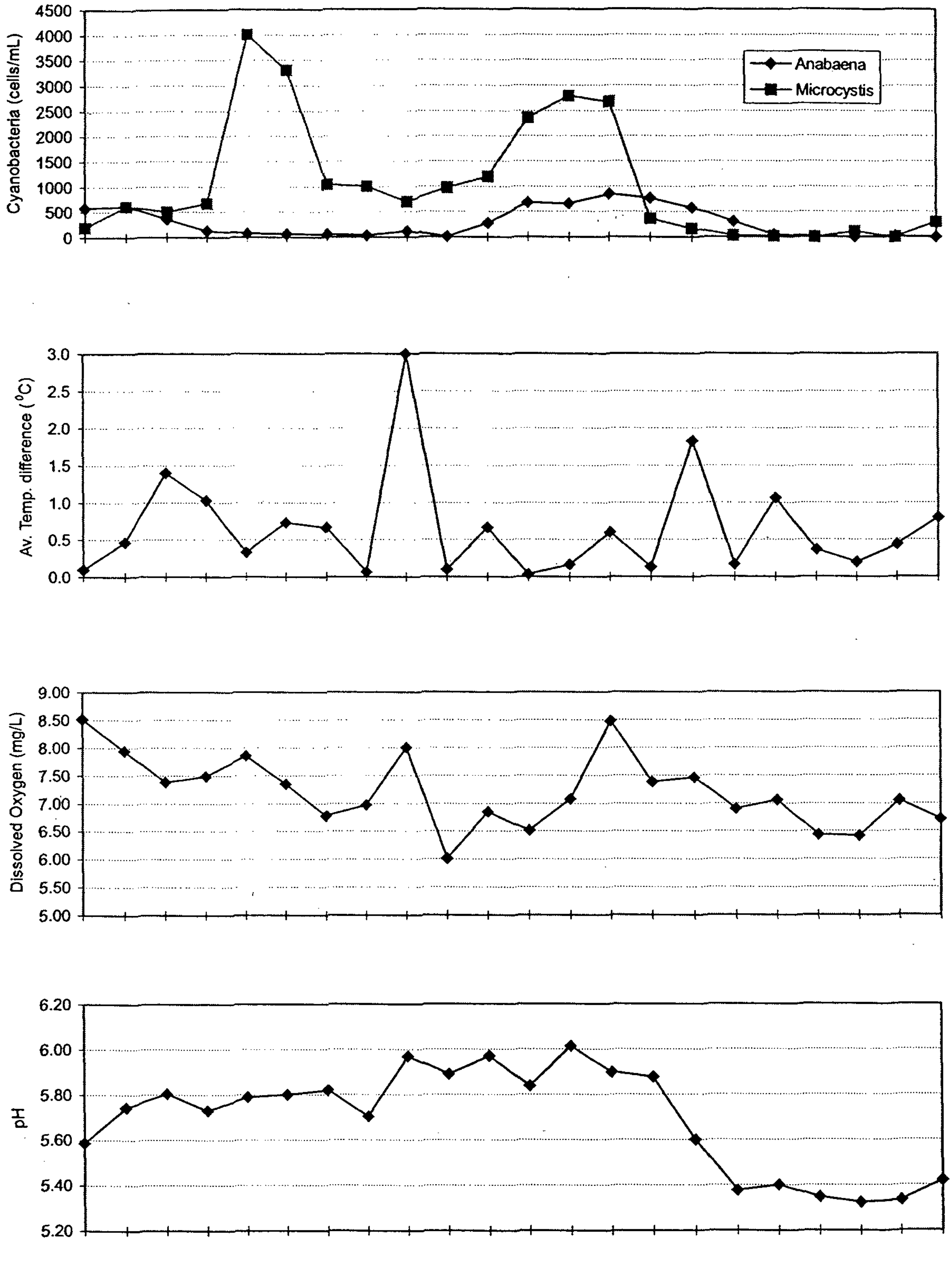
MANLY HYDRAULICS LABORATORY

WATER TEMPERATURE, TEMPERATURE DIFFERENCE, RAINFALL AND CYANOBACTERIA COUNTS DURING NOVEMBER AND DECEMBER 1998

MHL Report 1010

Figure 2.2

DRAWING 1010AIN2.CDR



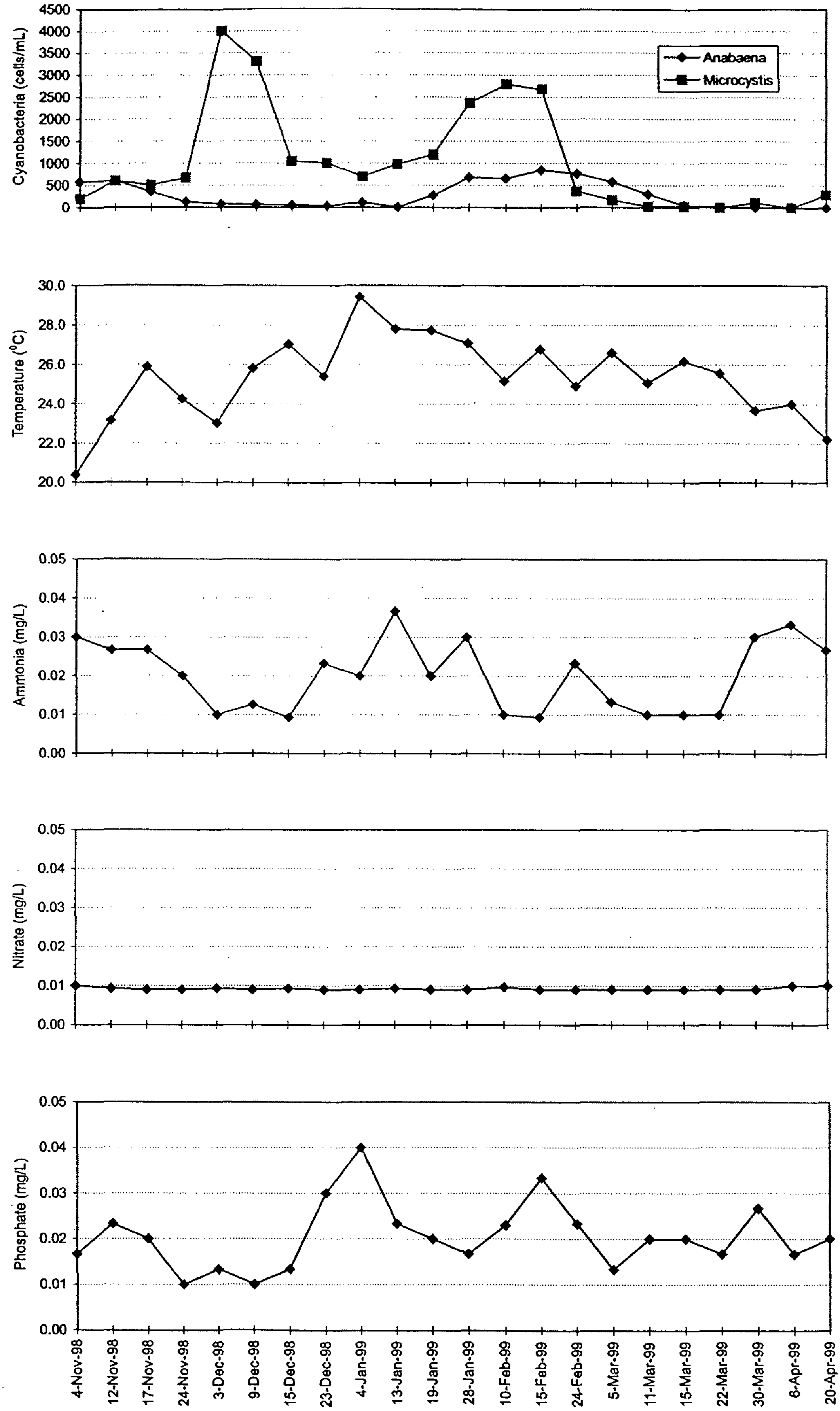
NSW DEPARTMENT OF PUBLIC WORKS AND SERVICES
MANLY HYDRAULICS LABORATORY

CYANOBACTERIA COUNTS, TEMPERATURE DIFFERENCE, DISSOLVED OXYGEN, PH AND CONDUCTIVITY CONCENTRATIONS

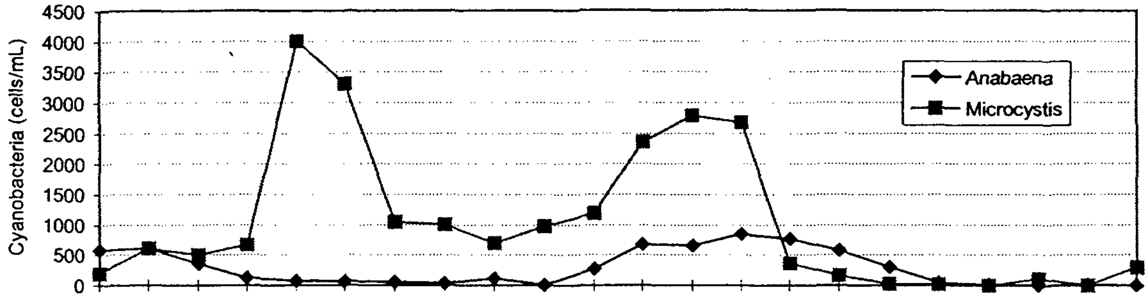
MHL Report 1010

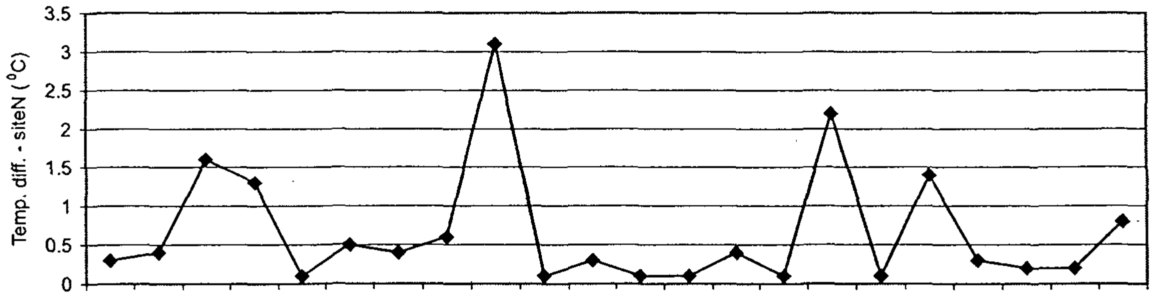
Figure 2.3

DRAWING: 1010AIN4.CDR



NSW DEPARTMENT OF PUBLIC WORKS AND SERVICES MANLY HYDRAULICS LABORATORY	CYANOBACTERIA COUNTS, SURFACE TEMPERATURE, AMMONIA, NITRATE AND PHOSPHATE CONCENTRATIONS	MHL Report 1010 Figure 2.4 DRAWING 1010AINS.CDR





NSW DEPARTMENT OF PUBLIC WORKS AND SERVICES
MANLY HYDRAULICS LABORATORY

CYANOBACTERIA COUNTS AND TEMPERATURE DIFFERENCE

MHL Report 1010

Figure 2.5

DRAWING 1010AIN6.CDR

3. The Values of Lake Ainsworth

3.1 Location and Management Plan Area

Lake Ainsworth is a coastal freshwater lake located behind the frontal dunes at the northern end of the village of Lennox Head, near Ballina on the far north coast of New South Wales (Figure 3.1).

The study area is shown in Figure 3.2. It consists of the surface runoff catchment boundary of Lake Ainsworth, extended to incorporate the adjacent section of Seven Mile Beach to the east, one block of Lennox Head township to the south, and a section west of the catchment adjacent to the lake.

3.2 Regional Significance

3.2.1 Tourist Destination

Visitors to Lennox Head can choose from a range of accommodation in caravan parks, hostels, motels and holiday units. The Lake Ainsworth Caravan Park can accommodate nearly 1,200 people, based on four people per site for 300 sites and 13 cabins with a capacity of 48 people. The permitted length of stay in the caravan park is three months, with a possible extension of two months depending on circumstances. The manager of Lake Ainsworth Caravan Park estimates caravan park visitor numbers to be between 1,500 and 2,000 per week over the peak Christmas holiday break.

The current capacity of the caravan park is 13 onsite vans, 177 other power sites and 110 unpowered sites. Statistics on occupancy rates are kept in terms of site nights; a site night is every night a van is occupied or reserved. The typical annual pattern is for occupancy rates to peak in December-January, with smaller peaks in April and September.

The Lake Ainsworth Sport and Recreation Centre can accommodate 210 people and is planning to expand. Other accommodation in Lennox Head includes many holiday units, three motels (capacity 161 people), hostels (capacity 140 including Camp Drewe, about 100 people) and the Headland Caravan Park (18 sites, say 72 people plus accommodation for 100 in cabins). Visitation is very seasonal with occupancy rates provided by the Sante Fe Motel and the Lennox Head Backpackers being about 60% to 70% during January and ranging from about 20% to 40% for the remainder of the year, school holidays accounting for the higher end of the occupancy rates.

3.2.2 Educational Resource

Lake Ainsworth is one of the few freshwater lowland dune lakes in NSW, and as such is an important educational resource for the region. Outdoor education programmes are conducted at the lake for school children at the Sport and Recreation Centre for 41 weeks of the year.

3.2.3 Recreational Resource

The lake and surrounding areas are used heavily for recreation. The lake is a popular location for a variety of recreational pursuits for local users and also regional and interstate users, particularly during school holiday periods. An overview of the recreational activities undertaken at the lake is provided in section 3.3.2.

3.2.4 Local Business

There are a number of local businesses that rely directly on the lake area for their income, whilst others gain indirect benefit. Some of the former include the Lennox Head Sailing School, the Lake Ainsworth Caravan Park, and the Sport and Recreation Centre. In addition to these individual businesses, the Lennox Head Markets operate on the second and fifth Sunday of every month at the lake. Whilst these markets attract people in addition to regular users/visitors, they rely on the lake area for their site, and are therefore currently totally dependent on this area. The markets generally involve in the order of 100-120 stallholders, many of whom come from the local area.

With respect to other businesses, they range from general stores to motels, with the common factor being that they derive some of their business from visitors to the lake. Indeed, it could be argued that all businesses in the village of Lennox Head derive some economic benefit from the lake.

3.3 Key Values and Features

3.3.1 Aesthetics

Lake Ainsworth provides an important area of 'naturalness' in an otherwise urban environment. Located at the edge of the township of Lennox Head, it allows residents and visitors alike easy access to a pleasant and attractive natural setting. Many of the responses received to the initial community consultation indicate that passive enjoyment of this area is an important pastime.

This passive enjoyment is heightened by the generally calm water and the vegetated western backdrop, adding to the peaceful ambience of the area. The vegetation on the western side of the lake is visually very appealing, set off with the water in front and with a backdrop of vegetated hills in the distance.

Whilst these natural aesthetics are enjoyed and valued by many users of the lake, they are also part of a range of 'intangible' values that are an important part of why so many people continue to visit and use the lake and its surrounds. It provides a link between the natural environment and people's more familiar urban existence.

3.3.2 Recreation

The lake is a popular recreational resource. It is a very popular place for sailing, and particularly windsurfing. It is well known as a safe place for beginners and many sailboarders have used the lake to gain proficiency and confidence in the sport. Swimming is also very popular, with people using the lake both for exercise and enjoyment. A floating line and signs designate the southern part of the lake for swimming and the remainder for watercraft. The surrounding areas are very popular for passive recreational pastimes such as picnicking, walking and birdwatching. Facilities include picnic tables, barbecues, two toilet blocks and a kiosk. Markets are held at the lake on the second and fifth Sunday of the month except at the peak Christmas and Easter holiday times. Dogs are permitted at Lake Ainsworth, provided they are leashed. Many respondents also noted that the lake provides a calm and safe swimming environment on occasions when the adjacent beach is unsafe or unsuitable. A summary of the recreational activities undertaken at the lake is provided below:

Waterway Recreation:

- swimming
- sailing/sailboarding
- canoeing/kayaking/ski paddling
- diving

Catchment/Foreshore Recreation:

- picnicking
- walking
- birdwatching
- markets
- photography/painting
- dune care/revegetation
- relaxation/meditation
- sunbathing
- enjoying wildlife (e.g. feeding ducks)
- horse riding, dog walking
- Sport and Recreation Centre educational and recreational activities

3.3.3 Flora and Fauna

Eight types of freshwater lakes are recognisable on geomorphic, chemical and biological criteria. Six of these, the greatest diversity for any area in eastern Australia, are located in north-eastern NSW (Timms 1997).

Timms (1982) describes Lake Ainsworth as a lake of 12.4 ha in area with a maximum depth of 10 m and a pH range of between 4.9 and 5.1. In an earlier paper Timms (1977) described the lake as lying within a widespread watertable (Type 7). Other types of dunal lakes described included those open to the ocean (Types 1 and 2), those on calcareous dunes (Type 3), those within siliceous dunes (Type 4), those in well-leached dunes away from the shoreline (Type 5) and those perched above the watertable on an organic seal (Type 6).

As far back as 1977 Lake Ainsworth was described as being impacted by recreational activities. Timms (1977) listed these impacts as the clearing of littoral vegetation to make the lake more attractive for swimming and enrichment by nutrients (e.g., septic absorption trenches and gardening near the lake). These impacts, in particular the loss of littoral fauna habitat, have abated over the years but nutrient enrichment still remains a management issue.

An assessment of flora and fauna was carried out by The Ecology Lab for the lake processes study, and by Peter Parker Environmental Consultants Pty Ltd for this management study.

The Ecology Lab suggested that much of the littoral and riparian vegetation of Lake Ainsworth had been cleared to provide space for recreational activities, such as swimming, camping, boating and tennis. However, significant vegetated areas remain and have been managed for at least the past eight years by the Lennox Head Dune Care group and for the past two years by Mr Phil Buckland of the Lake Ainsworth Sport and Recreation Centre. The management initiatives shown by individuals involved in weed management programs extend way beyond the frontal dunes to the waters of the lake itself.

The catchment to the north of the lake includes extensive areas of low-lying coastal heath, dominated by coast banksia (*Banksia integrifolia*), Wallum banksia (*Banksia aemula*), broom heath (*Monotoca elliptica*) and coast wattle (*Acacia sophorae*). The diversity of plants and animals in this area is extremely high. For example, over 60 plants species have been identified by Mr Don Apps of Lennox Head Dune Care, in the narrow strip of land south of the Sport and Recreation camp. Moreover, the area to the north of the lake is expected to support an even higher species richness.

Since the lake processes study was completed, opportunistic or incidental fauna records from the Sport and Recreation Centre environs have been gathered by Phil Buckland. These include nine frog species, 21 lizards and snakes, eight mammals including the threatened common planigale, (*Planigale maculatus*) and 115 species of birds.

During the 1960s most of the eastern and southern portions of the lake were cleared of nearly all riparian and littoral vegetation to provide areas for recreation. However, enrichment plantings have been undertaken along the lake's foreshore in recent years by the Lennox Head Residents Association and the Lennox Head Dune Care group. These plantings, which comprised mainly broad-leaved paperbark (*Melaleuca quinquenervia*), are now well established in clumps and protected by shadecloth fences.

The Ecology Lab suggested that recreational use of the foreshore may be preventing cumbungi (*Typha orientalis*) from recolonising more of the south-western corner. However, the heavy rainfall over the past year has caused the level of the lake to rise considerably and to remain at a level that was commonly higher than the southern access road to the Sport and Recreation Centre. This elevated water level is more likely to have led to a decline in cumbungi in more recent times than recreational activities.

The Ecology Lab described the western fringe of the lake as being bordered almost completely by cumbungi, except for areas that appear to have been cleared for boating and/or camping purposes. More recently, however, water primrose (*Ludwigia peploides* ssp.

montevidensis) has extended extensively into the lake. Water primrose was also well established along the eastern shoreline but was removed by hand and used for mulch on the frontal dunes (Don Apps pers. comm.).

Patches of macrophytes, including the introduced yellow waterlily (*Nymphaea mexicana*), native water snowflake (*Nymphoides indica*), the noxious salvinia (*Salvinia molesta*) and duckweed (*Lemna sp.*) occur along the eastern perimeter of the lake. Rushes (Family Juncaceae), sedges (Family Cyperaceae) and grasses (Family Poeaceae) are poorly developed due to the elevated water levels experienced over the last 12 months.

The Ecology Lab described the few aquatic fauna studies undertaken at Lake Ainsworth as not comprehensive. However, firetailed gudgeons (*Hypseleotris galii*) and the freshwater or eel-tailed catfish (*Tandanus tandanus*) were reported (Timms 1982, Saenger 1988 cited in Ecology Lab 1996) and more recently, bass (*Macquaria novemaculeata*) has been captured (Don Apps pers. comm.) The ubiquitous mosquito fish (*Gambusia holbrooki*) was reported by The Ecology Lab and noted during site inspections undertaken for this management study.

Two species of freshwater turtle/tortoise have been recorded in the lake by Phil Buckland. These are the saw-shelled turtle (*Elseya latisternum*) and eastern long-necked tortoise (*Chelodina longicollis*). Phil Buckland has also recorded nine species of frogs although the most common species is the introduced cane toad (*Bufo marinus*).

Invertebrates in Lake Ainsworth were studied by Bayly (1964), Timms (1982) and Saenger (1988). Timms suggested that the presence of the fish and the paucity of littoral vegetation accounted for a reduction in diversity and abundance of invertebrates compared to what he expected. The benthos sampled included several species of insect larvae (see Timms 1982; Saenger 1988), and the zooplankton contained a single species of crustacean, the copepod *Calamoecia tasmanica*, and occasionally an identified planktonic watermite (Timms 1982). *Eucyclops nichollsi* was often found in the littoral region, occasionally accompanied by *Macrocyclops albidus* (Bayly 1964).

3.3.4 Socio Economic

As previously discussed, Lake Ainsworth provides the environment for a range of local businesses, some of which rely wholly on users of the lake for their income. Whilst no definitive economic study has been undertaken, it is obvious that these businesses play a strong role in the local economy.

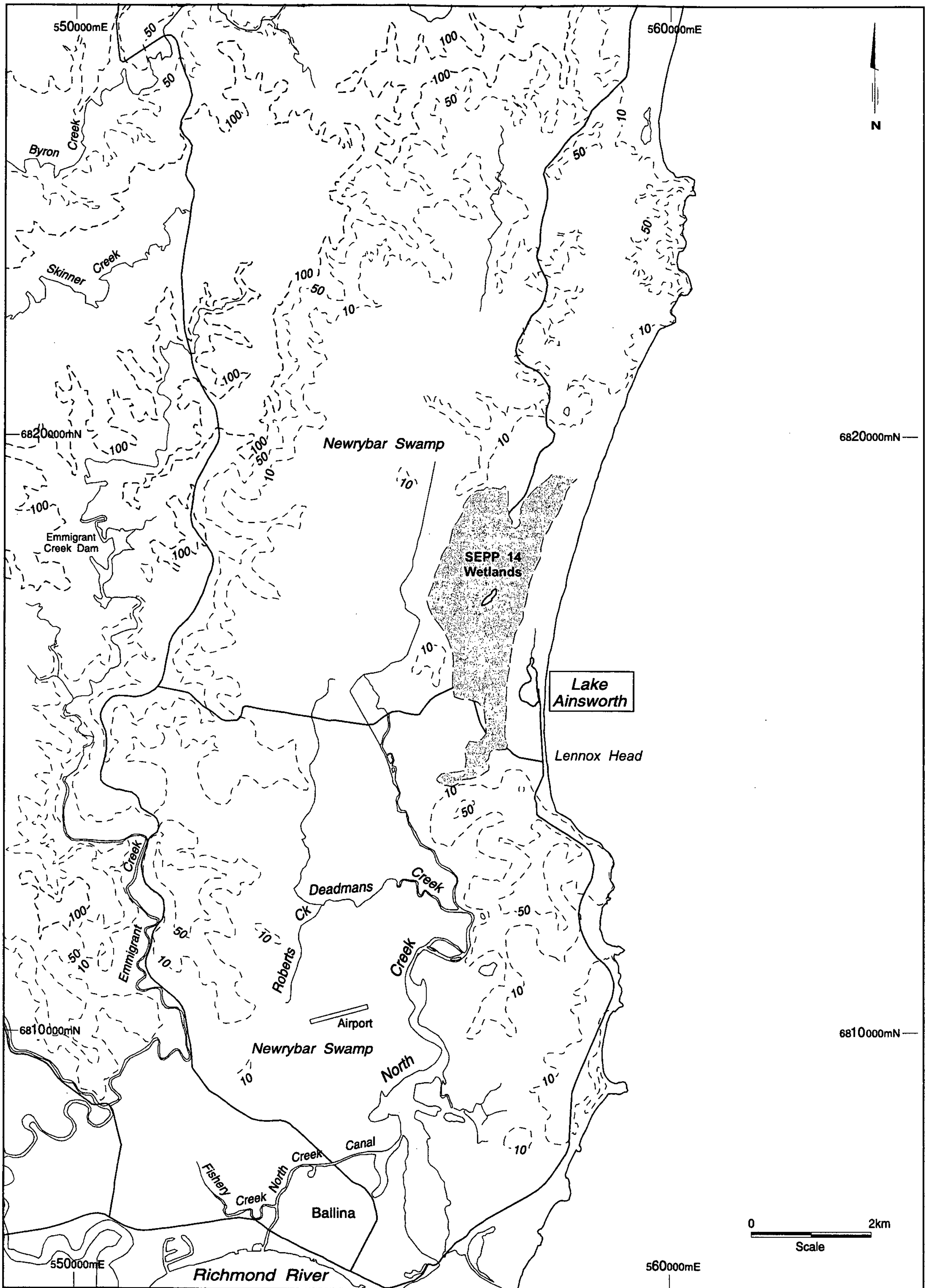
As an example, the owner/operators of the Lennox Head Sailing School live in Lennox Head as well as deriving all of their business from users of the lake. As local residents, the money made from their venture is 'reinvested' locally as they go about their daily lives. Similarly, much of the income generated by the local markets is spent in the local community.

3.3.5 Education

As previously discussed, Lake Ainsworth is one of the few freshwater lowland dune lakes in NSW, and as such is an important educational resources for the region. The Sport and Recreation Centre runs Primary Outdoor Education Programmes (POEP) which are conducted over five days in conjunction with the NSW Department of Education. These programmes are for groups of 120 school children accompanied by 7-8 teachers, and are held 41 weeks of the year. Based on a 93 percent occupancy rate, the POEP generates 22,755 camper days per year (NSW PW 1994).

3.4 The Need for Environmental Conservation and Rehabilitation

Lake Ainsworth is the largest dunal lake north of Lake Hiawatha on the far north coast of NSW and the lake and environs contain a remarkable diversity of native biota. The scarcity of dunal lakes generally and the high visual and recreational value of Lake Ainsworth make its management and protection even more important.



NSW DEPARTMENT OF PUBLIC WORKS AND SERVICES

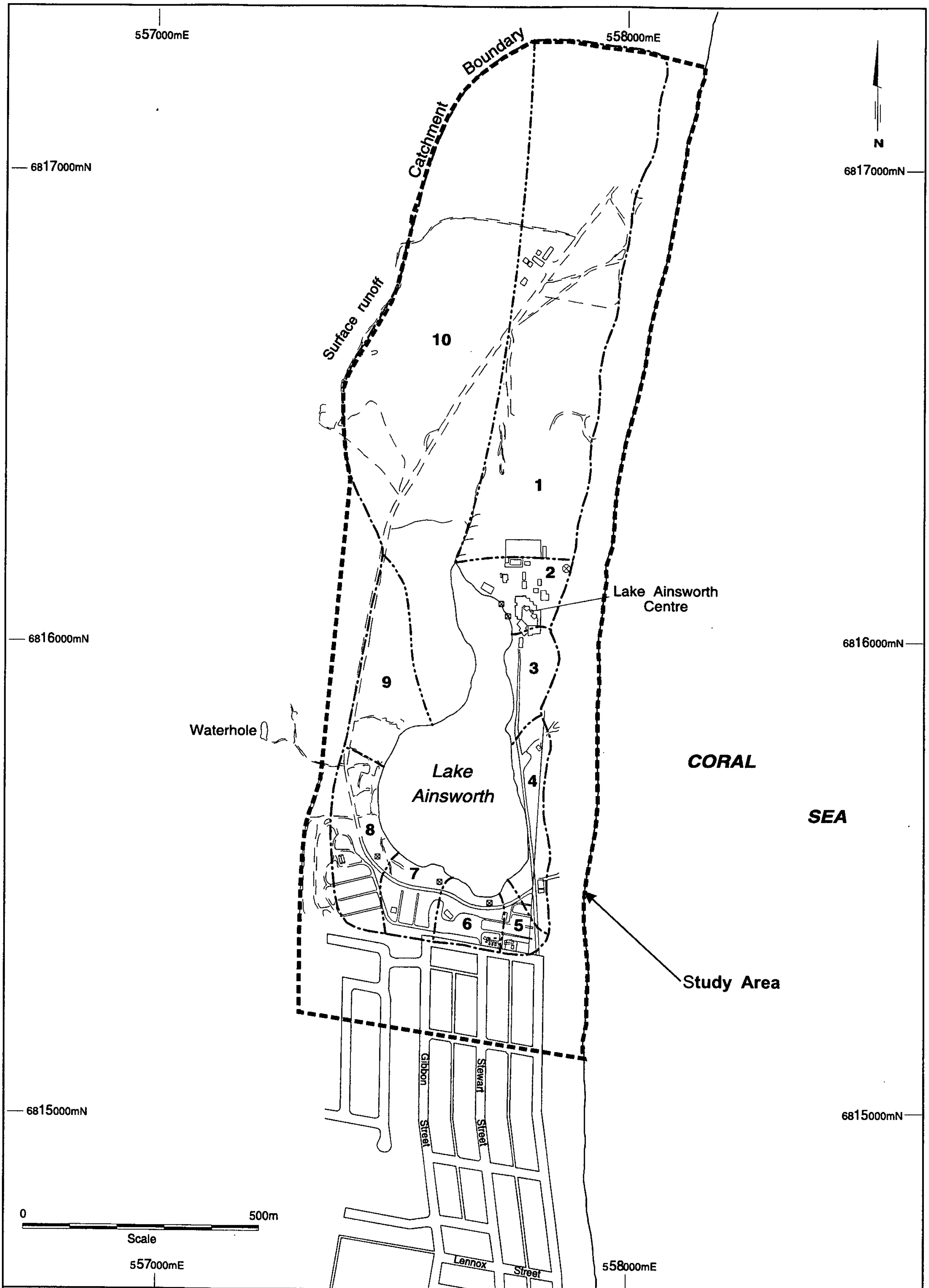
MANLY HYDRAULICS LABORATORY

REGIONAL LOCATION PLAN OF LAKE AINSWORTH

MHL Report 1010

Figure 3.1

DRAWING 1010LA31.CDR



NSW DEPARTMENT OF PUBLIC WORKS AND SERVICES

MANLY HYDRAULICS LABORATORY

STUDY AREA

MHL Report 1010

Figure 3.2

DRAWING 1010LA32.CDR

4. Management Issues

4.1 Current Uses and Conflicts

4.1.1 Land Tenure, Control and Operation

Land uses adjoining Lake Ainsworth are:

- Lake Ainsworth Caravan Park directly to the south and urban development further south;
- Lennox Head Surf Life Saving Club to the south-east;
- Lake Ainsworth Sport and Recreation Centre land to the north and west, and Camp Drewe further to the north; and
- Aboriginal land further to the north and west.

Crown Reserve 82783 for Public Recreation covers the southern half of Lake Ainsworth and the caravan park and is managed by Ballina Council. Crown Reserve 84109 for National Fitness and Physical Education is managed by the Department of Sport and Recreation.

4.1.2 Environmental Planning Controls

As well as the environmental planning controls mentioned above, other relevant State policies that are applicable to the management of the lake and surrounds include:

- NSW Government Estuary Management Policy
- NSW Coastal Policy (1997)
- Department of Lands Coastal Crown Lands Policy
- Crown Land Foreshore Tenures Policy, and
- Crown Lands Caravan Parks Policy.

Land use in the local area is controlled under the Ballina Local Environmental Plan 1987. Ballina Shire Council zonings and reserve boundaries are shown in Figure 4.1. Pursuant to this plan, the lake itself, together with the majority of the surrounding land, is zoned 7(f) Environmental Protection (Coastal Lands). The objectives of this zone are shown below:

A. *The primary objectives are:*
   (a) to protect environmentally sensitive coastal lands; and
   (b) to prevent development which would adversely affect or be adversely affected, in both the short and long term, by the coastal processes.

B. *The secondary objective is to enable the development of public works and recreation amenities where such development does not have significant detrimental effect on the habitat, landscape or scenic quality of the locality.*

C. The exceptions to these objectives are:

(a) to permit the development of public works, outside the parameters outlined in the primary and secondary objectives, only in cases of demonstrated and overriding public need and subject to the impact on the coastal lands being minimised, as much as is reasonably practical; and

(b) development of surf lifesaving, environmental education facilities and like facilities.

These objectives are obviously aimed at protecting the coastal environment, and this is further emphasised by the following 'Special Provisions' of the Plan:

Clause 23 – Development within Zone No. 1(d), 7(c), 7(d), 7(f), or 7(i)

A person shall not, on land within Zone No. 1(d), 7(c), 7(d), 7(f) or 7(i):

(a) notwithstanding clause 8 of the Environmental Planning and Assessment Model Provisions 1980, cut down, top, lop or otherwise destroy a tree (other than a tree planted for commercial or landscape purposes); or

(b) clear, fill or otherwise alter the surface level of land,

without the consent of the council.

Clause 32 – Concurrence of Director – Zone No. 7(f)

1. The council shall not consent to the carrying out of development within Zone No. 7(f) for any purpose except with the concurrence of the Director.

2. In considering whether to grant concurrence under subclause 1, the Director shall take into consideration:

(a) whether any environmental issues are involved in, or raised by, the proposed development;

(b) if so, whether adequate safeguards and rehabilitation measures have been, or will be, made to protect the environment;

(c) whether the development complies with the objectives of Zone No. 7(f) as set out in the Table to clause 9.

Note: The Director referred to in this clause is the Director-General of the Department of Urban Affairs and Planning.

To the north and west of the immediate lake area, land is zoned 7(a) Environmental Protection (Wetlands). The object of this zone is to protect sensitive wetlands areas and prohibit development which might result in environmental harm. This wetland area is further protected by the provisions of State Environmental Planning Policy No. 14 – Coastal Wetlands. This State Policy specifies a number of controls designed to assess the level of environmental impact associated with any proposed works within the protected area and prevent development that may result in significant impact.

4.1.3 Ancillary Legislation

In addition to the environmental planning controls summarised above, the following may also be applicable to any future management or development of the lake area:

- NSW Government Estuary Management Policy
- NSW Coastal Policy (1997)
- Department of Lands Coastal Crown Lands Policy
- Crown Land Foreshore Tenures Policy
- Crown Lands Caravan Parks Policy
- *Bush Fires Act 1949*
- *Catchment Management Act 1989*
- *Coastal Protection Act 1979*
- *Crown Lands Act 1989*
- *Local Government Act 1993*
- *National Parks and Wildlife Act 1974, and*
- *Protection of the Environment Operations Act 1998.*

4.1.4 Conflict Between Existing Users

An overview of the distribution of recreational usage at Lake Ainsworth is provided in Figure 4.2. Some of the conflicts that have been identified between users of the lake are outlined below.

Conflict with and between sail craft and swimmers

- Sail craft moving into designated swimming area (this is thought to occur because of the inexperience of most sailors).
- Risk of collision between catamarans and sailboards (again thought to be because of the inexperience of most sailors and sailboard riders). Jones (1988) found that 98% of sailboarders interviewed felt threatened by the presence of catamarans but this may have been exaggerated due to the windy weather conditions.

Conflict between motor vehicles and other users

- Alienation of, and damage to grassy foreshore areas which could be used for recreation due to haphazard parking arrangements.
- Child safety crossing the eastern road to the beach. Sight distance is poor due to informal car parking along the road. Jones (1988) found that 89% of those surveyed felt the risk of children being involved in an accident was too high.
- Vehicles using the western road around the lake can conflict with users of southern foreshore area (e.g. markets).

Alienation of Crown Reserve

- Public foreshore use is restricted due to the proximity of the caravan park.
- There is a large area of undeveloped Crown land under the control of the Department of Sport and Recreation which could be developed sensitively for passive recreation (e.g. walking trails) to decrease pressure on the developed reserve (encroachment of picnickers onto Sport and Recreation Centre already occurs). Jones (1988) noted that the Crown land reserves were under-utilised for walking.

Overcrowding and overuse

- Overcrowding of the three main areas around the lake (south, south-east and east sides of lake) occurs during peak periods. The estimated usage far exceeds estimated social carrying capacity during peak usage periods.
- Overuse of the water body can be an issue during peak periods.

4.2 Impact of Existing Uses on Lake Processes and the Environment

Significant activities that have impacted on lake processes since the commencement of European settlement have included:

- Clearing of much of the original native vegetation.
- The expansion of the township of Lennox Head which impacts on the drainage patterns and the water quality of Lake Ainsworth.
- The development of the National Fitness Camp, now the Department of Sport and Recreation Centre, with impacts on clearing of vegetation and Lake Ainsworth water quantity and quality.
- Sand mining in the 1960s and 1970s with impacts on the vegetation and topography of the beach dune system including the introduction of exotic vegetation in the dune rehabilitation process.

These activities have modified surface and groundwater flow patterns and quality, modified the lake nutrient budget and varied the composition and abundance of flora and fauna. Existing and future uses of the lake have the potential to similarly affect the natural processes of the lake if not adequately managed. Significant issues associated with the impact of existing lake uses on lake processes have been included in Section 4.4.

4.3 Future Lake and Catchment Use

4.3.1 Future Land and Lake Uses

Future use of the area will be guided, in part, by the provisions of Ballina Local Environmental Plan 1987. As described earlier, the lake and its surrounds are zoned 7(f) Environmental Protection (Coastal Lands). Within that zone, there is no development allowed without the consent of Council. Listed within the plan as being permissible with development consent are:

agriculture; beach amenities; bush fire hazard reduction; camping grounds; caravan parks; community buildings; drainage; dwelling-houses; environmental educational facilities; environmental protection works; forestry; golf courses; helipads; home industries; open space; pipelines associated with aquaculture; picnic grounds; recreational establishments; recreation facilities; refreshment rooms; roads; surf club houses; utility installations.

All other development is prohibited in the 7(f) zone.

The Department of Sport and Recreation has concept plans for the future expansion of their facility. Such plans include upgrading the existing accommodation, the provision of a purpose-built indoor recreation/sporting facility, and the upgrading of existing sporting fields. Such upgrades will provide for increased use of the facility for its various sporting/educational programs, and would also provide for greater community use of both the indoor and outdoor facilities.

4.3.2 Potential Impacts of Future Uses

Impacts on the biological values of Lake Ainsworth vary in magnitude and degree. Nutrification has been addressed previously and contributes to the proliferation of alien plant species (e.g. blue-green algae, water primrose and salvinia) and lower dissolved oxygen levels and consequent impacts on lake fauna assemblages.

Recreational activities along the lake's edge impact on littoral vegetation and result in localised erosion.

Car parking too close to the lake's edge and the use of the southern access road has the potential to introduce pollutants and nutrients into the lake.

4.4 Summary of Management Issues

A summary of the significant management issues that were identified during the study is provided below.

4.4.1 Water Quality

- Algal blooms have discouraged use of the lake with some impacts on the local recreation and tourist industry. This is a major issue to be managed. Algal cell counts at times exceed ANZECC and NCRACC guidelines.

- The long-term and seasonal variability in lake water quality is unclear due to the lack of long-term data.

- Artificial aeration destratification system – currently on trial.

- Faecal coliform contamination of the lake appears to have peaked in about 1990. The NSW Health Department guidelines for recreational waters have rarely been exceeded. However there is a need to continue monitoring and to review monitoring programs in light of draft ANZECC water quality guidelines (1999).

- Stratification of the lake is broken down by cooling, rainfall and wind. It is likely that in long periods of dry weather, stratification is persistent.

- Lake water quantity per se does not affect algal blooms; rather the important processes are light availability and mixing.

- Groundwater does not appear at the present time to be a major source of nutrients to the lake. Prior to the construction of the reticulated sewerage systems, there may have been high nutrient loads to the lake for several decades, from septic systems and sullage drains involving inter alia phosphate-based detergent, promoting a regime of high productivity of phytoplankton within the lake.

- Sediment nutrients have accumulated over a long period due to loading from groundwater and surface runoff. The lake sediments are the major source of nutrients for the present nutrient budget. Management strategies need to focus on this issue.

- At low lake water levels, a possible mechanism is that water drains from areas with riparian macrophytes, resulting in high nutrient concentrations in surface waters.

- Levels of nutrients and chlorophyll-a exceed the ANZECC guidelines (1992). In light of the release of the draft ANZECC guidelines (1999) there is a need to review the present monitoring systems and appropriateness of general guidelines.

4.4.2 Coastal Dunes

- The maintenance of Lake Ainsworth as a freshwater lake is dependent on maintaining the integrity of the coastal dunes.

- Coastal recession and lowering of the frontal dune could result in the lake being connected to the ocean.

- Management of the coastal dune system to control wind and wave erosion is extremely important, and the present efforts of the Lennox Head Dune Care group need to be maintained/enhanced and integrated into the management plan. The Lennox Head Dune Care group have made a concerted effort over the last decade to restrict the spread of bitou bush and other species that are more difficult to manage (e.g. turkey rhubarb, *Acetosa sagittata*). The cost in time and money of these activities is difficult to quantify. However, it is essential that areas under management are not neglected.

- The 4WD accessway has been identified as the most likely location for oceanic inundation of the lake to occur. It is recommended that this accessway be closed.

- Emergency vehicle/maintenance access will be required to the dunes and any associated protection works.

4.4.3 Traffic Management

- Traffic congestion during peak periods (e.g. holidays, markets).

- Inadequate parking during peak periods (although provision of more parking would increase traffic congestion problems). Blainey et al (1988) found that parking was the facility most visitors wanted to see upgraded and Jones (1988) found that 58% of those interviewed thought the present method of uncontrolled parking was undesirable.

- Alienation of grassy areas which could be used for recreation due to haphazard parking arrangements. Uncontrolled parking on lake foreshore, particularly southern and eastern banks causes loss/damage of vegetation.

- Proximity of eastern road to the lake reduces the amenity of the foreshore area and acts as a discontinuity between the natural lake-dune-ocean system.

- Child safety crossing the eastern road to the beach. Sight distance is poor due to informal car parking along the road. Jones (1988) found that 89% of those surveyed felt the risk of children being involved in an accident was too high.

- 4WD access to beach along eastern margin of the lake. Could increase the risk of erosion at this point and be a potential ocean break-through point. Increases traffic flow along the eastern margin of the lake as well as along the beach in front of the Sport and Recreation Centre.

- Vehicles avoiding the speed restriction humps by driving on the vegetated fringes.

- The main route to Sport and Recreation Centre is cut off during periods of high water level. At such times the western access road is used. Issues associated with this route include that it prohibits expansion of vegetation on the western side of the lake and conflicts with users of southern foreshore area (e.g. markets).

4.4.4 Recreation

- Lack of facilities or unacceptable facilities has been raised as an issue. These include:
  - need for pedestrian pathways/walkways
  - insufficient swimming only areas
  - inadequate picnic/BBQ facilities. BBQs should be gas/electric, not wood burning
  - inadequate sailboat launching area
  - access for disabled persons.

- Jones (1988) suggested that the swimming area did not include enough shallow shoreline area to cater for the number of children using the lake. However, the introduction of fill and the likely increase in aquatic vegetation in shallow sites may militate against changing the status quo.

- Overuse of the lake decreases recreational amenity at peak times (holidays, markets). While overuse does not appear to have significant deleterious effects on lake processes, it does cause some localised foreshore erosion and loss/damage to native vegetation, as well as other issues such as increased gross pollutant input. Concerns have been expressed about present overcrowding/overuse and future problems associated with projected population increases.

- Recreational facilities and services should be provided that are commensurate with the desired level of usage.

- 4WD access to beach along eastern margin of the lake. Could increase the risk of erosion at this point and be a potential ocean break-through point. Increases traffic flow along the eastern margin of the lake as well as along the beach in front of the Sport and Recreation Centre.

4.4.5 Ecology

- The impact of riparian flora on the nutrient budget is unclear, i.e. whether it is a source or sink. The creation of fringing wetlands may result in uptake of nutrients.

- There is a continuing need to manage exotic flora and encourage regrowth of native flora including around the lake foreshore. Of particular importance is the hand removal of water primrose from the western lake perimeter and the continuation of Dune Care activities.

- There is a continuing need to manage introduced fauna and to encourage native fauna. However, the most realistic way of achieving this goal is through habitat restoration and maintenance.

- Little is known about microbial processes and associated sediment-nutrient release processes.

- Clearing of littoral and riparian vegetation has resulted in a decrease in diversity and abundance of fauna. However, Dune Care activities in recent years have somewhat reversed this trend.

- The introduced mosquito fish may have modified the lake ecosystem by predating on frogs and fish larvae. The impact of this species may also include the overgrazing of zooplankton. Little can be done to eradicate or reduce the density of this species.

- Fish kills are possibly associated with lake overturning in winter/spring (the operation of the aerator may help to alleviated this).

- The prevalence of cane toads in the catchment has been noted over a number of years. The revegetation of the lake perimeter may result in the decline of this species, although it is unlikely that anything but biological control will reduce the density significantly.

- The loss/damage to native vegetation through inappropriate or intensive recreational use (e.g. pedestrian access, informal car parking, four wheel driving, clearing for caravan park). These impacts can be offset to a large extent by formal landscaping and Dune Care activities.

- Removal of fringing vegetation to facilitate recreational activities. The historical clearing of fringing vegetation has been offset over recent years by landscaping by the Lennox Head Residents Association and Dune Care. However, the sarlon fencing of planted areas along the lake margin has outlived its usefulness and needs to be replaced by Koppers logs or formal seating.

- The use of the introduced plant bitou bush to stabilise the frontal dunes after sandmining during the 1960s and 1970s has limited the ability of native vegetation to regenerate. Weed management by Lennox Head Dune Care has controlled the local spread of bitou bush. However, species such as turkey rhubarb are considered even more difficult to control and require a concerted effort over several years.

- The planting of exotic species in the Sport and Recreation Centre lead to 'garden escapees' establishing in neighbouring areas. Recent plantings and Dune Care activities within the Sport and Recreation Centre have emphasised native species.

- Domestic pets within the catchment have been raised as an issue. Some dog owners ignore 'dogs prohibited' signs. Dogs have been observed to behave viciously around picnickers and dog excrement can be a problem. Jones (1988) found that 73% of those interviewed considered the presence of dogs to detract from their recreational experience. Concerns have also been raised about the exercising of horses in and around the lake.

- Potential minimal loss of native vegetation through future expansion of the Sport and Recreation Centre. This has been offset recently by Dune Care works and native plantings.

- Periodic outbreaks of the noxious plant *salvinia*, water primrose (native) and Azolla sp. (native) may affect water sports if their coverage is extensive. According to Don Apps, *Salvinia* has not spread extensively due to the effects of biological control agents. Water primrose, on the other hand, has spread extensively and currently covers a large portion of the lake's western margin. It will require regular hand removal from the lake. Hand removal is recommended prior to infestations spreading over too great an area.

4.4.6 Planning and Development

- Large area of undeveloped Crown land under the control of the Department of Sport and Recreation which could be developed sensitively for passive recreation (e.g. walking trails) to decrease pressure on the developed reserve (encroachment of picnickers onto Sport and Recreation Centre already occurs). Jones (1988) noted that the Crown land reserves were under-utilised for walking.

- Sport and Recreation control the lands at the northern end of the lake and Ballina Shire Council controls lands at the southern end. This impedes coordinated management of the lake and its surrounds. Development of a coordinated management structure should facilitate improved management of the lake and its surrounds.

4.4.7 Lake Water Level and Flooding

- The major processes controlling the lake water budget are rainfall and evaporation. There is a direct and rapid response of lake water levels to rainfall. High rainfall in 1999 has led to elevated water levels in the lake with associated minor flooding of the low-lying basin to the south of the main building complex of the Sport and Recreation Centre, and flooding of the main access road to the Sport and Recreation Centre.

- Cutting off of the main access route to the Sport and Recreation Centre requires the western access road to be used. Problems with use of this route include that it prohibits expansion of vegetation on the western side of the lake and conflicts with users of the southern foreshore area (e.g. markets).

- Periods of prolonged elevated water levels can potentially affect foreshore vegetation and increase foreshore erosion.

- Elevated water levels affect recreational facilities/activities including picnic and BBQ facilities and foreshore access to the lake generally.

4.4.8 Erosion and Sedimentation

- Catchment development affects sediment runoff. However, the surface runoff catchment for the lake is relatively small, suggesting that management strategies related to control of surface runoff could be given lower priority compared to in-lake management strategies.

- Removal of stabilising vegetation for construction of the sealed road along the eastern perimeter of the lake and runoff from the road eroding land between the road and lake.

- Removal of riparian vegetation and intensive recreational use (e.g. launching sail craft) exposing the south and east banks of the lake to erosive processes.

- Gullies on the south-west side of the lake from road construction and pedestrian tracks on the western side resulting in gully erosion.

- Pedestrian traffic contributes to coastal dune erosion.

- 4WD track through the dune could increase erosion.

- Rehabilitation of dune vegetation by the Dune Care group helps to stabilise the dune movement and reduce wind-blown sand entering the lake.

- While there is some localised foreshore erosion from concentrated drainage paths and pedestrian movements, it is generally being controlled by the present vegetation rehabilitation programs. However, some rehabilitation projects have been threatened by overuse, traffic etc.

- There has been a slow but gradual accumulation of sediment in the lake since its formation several thousand years ago, with an estimated sedimentation rate of 0.4 mm per year.

- There is a thick organic-rich layer of fine sediment on the lake bed, with high levels of nutrients that have accumulated from decaying vegetation. This sediment is the major source of nutrients in the present lake processes.

4.4.9 Hydrogeology

- The surface and groundwater catchments for the lake are intimately linked although not completely co-incident. Groundwater entering the lake is mainly from a very localised area, with most of the regional groundwater flowing elsewhere.

- There are high nutrient levels in the groundwater within Lennox Head township, however, the majority of this groundwater flow does not enter the lake under normal conditions.

4.4.10 Climate

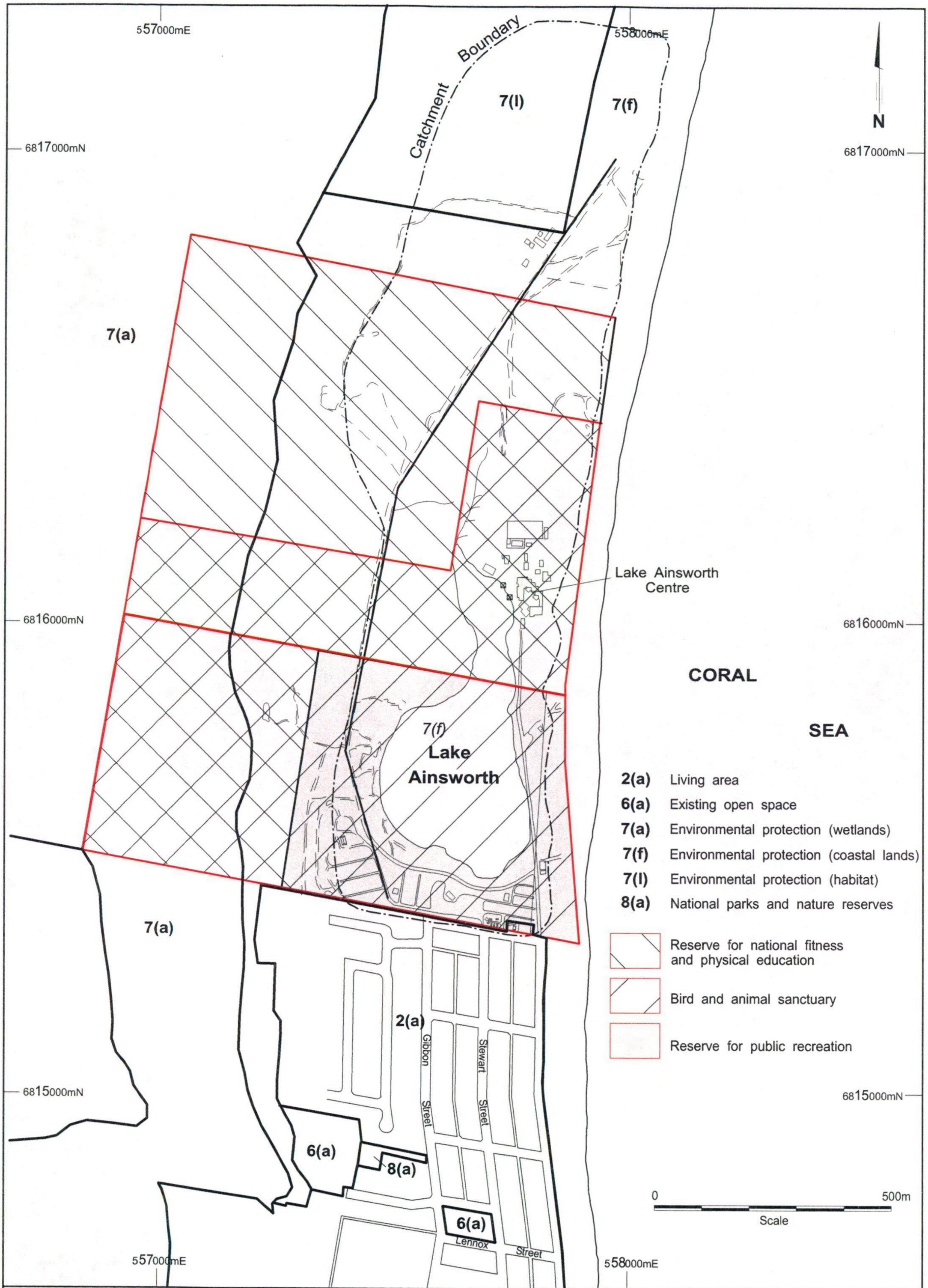
- Possible increase in sea level could increase risk of breaching the frontal dune. A rise in sea level could also increase lake water levels, and may lead to a shift in dominant algal species with positive or negative effects.

- Wind effects on the lake inhibited by buildings and Norfolk Island Pines.

4.4.11 Aboriginal Heritage

- Possible past destruction or disturbance of Aboriginal sites by land clearing and mineral sands mining.

- The disturbance of as yet unrecorded sites (particularly burials) as a result of development of land around Lake Ainsworth is a concern to the Jali people.



NSW DEPARTMENT OF PUBLIC WORKS AND SERVICES

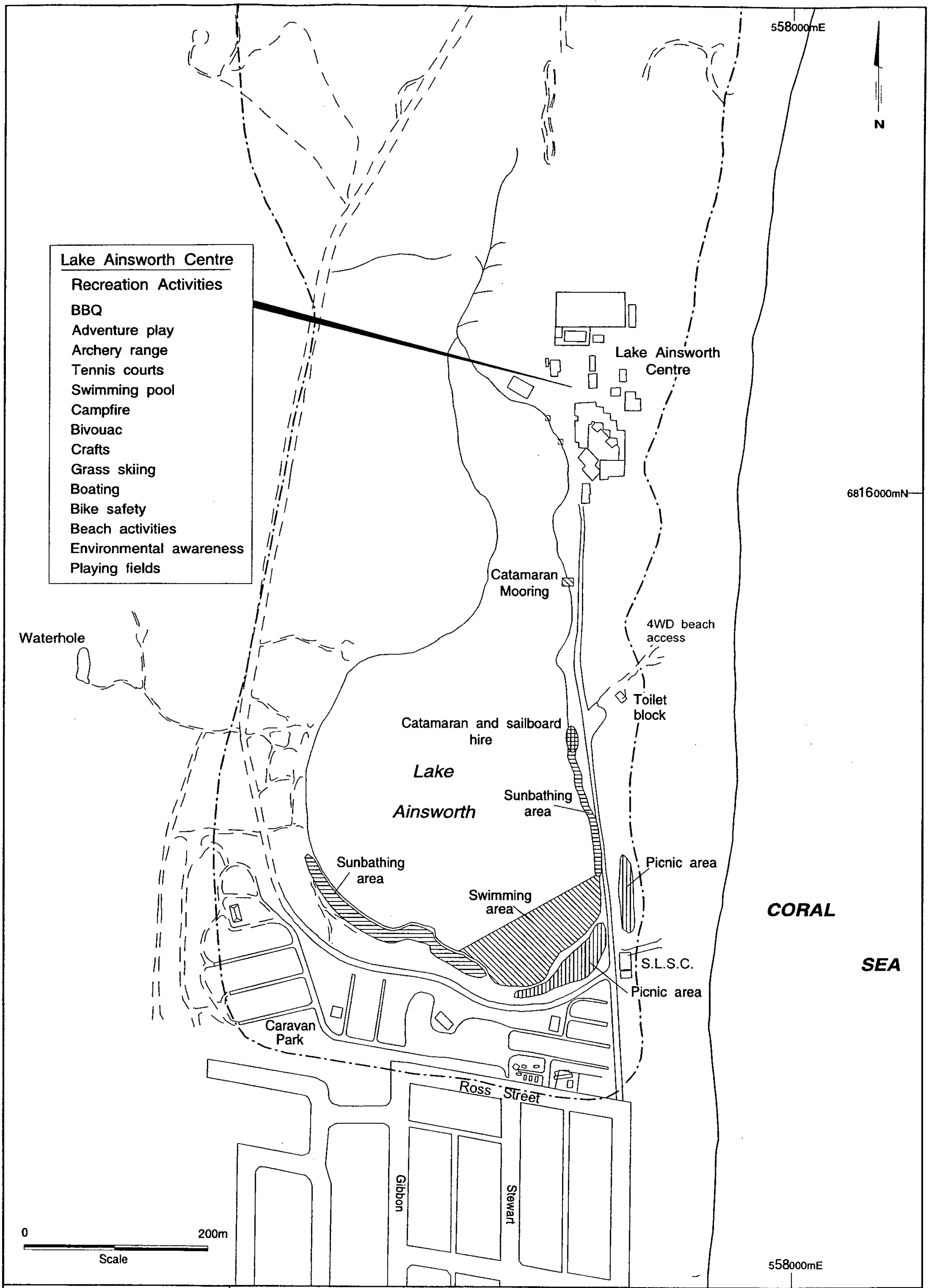
MANLY HYDRAULICS LABORATORY

BALLINA COUNCIL ZONING AND RESERVE BOUNDARIES

MHL Report 1010

Figure 4.1

DRAWING 1010LA41.CDR



NSW DEPARTMENT OF PUBLIC WORKS AND SERVICES

MANLY HYDRAULICS LABORATORY

RECREATIONAL USE

MHL Report 1010

Figure 4.2

DRAWING 1010LA42.CDR

5. Management Objectives

The management objectives for Lake Ainsworth are presented below. They were developed following consideration of the values of the lake and through understanding and consideration of the lake processes and management issues.

5.1 Primary Objectives

5.1.1 Lake Water Quality

A. To maintain and improve the water quality of the lake to a level required to sustain primary contact recreational uses and for the protection of aquatic ecosystems.

B. To assess and implement strategies to reduce the occurrence of algal blooms and to minimise the consequential impact of these blooms.

5.1.2 Coastal Dunes

A. To maintain and enhance the coastal dune system to increase biodiversity, to assist the survival of Lake Ainsworth as a freshwater lake and to protect the lake's natural values.

5.1.3 Traffic Management

A. To manage traffic flow and parking to enhance public safety and recreational opportunity, to improve access, reduce erosion and protect ecological values.

5.1.4 Ecological Conservation

A. To conserve and enhance the ecological values of the lake.

B. To eradicate where practicable exotic flora and fauna and to encourage native flora and fauna.

C. To maintain and enhance native foreshore flora commensurate with the aesthetic, recreational and ecological values of the lake.

D. To incorporate ecological monitoring into monitoring programs for lake management.

E. To maintain ecosystem integrity and promote biodiversity.

5.1.5 Hydrogeology

A. To protect the quality and quantity of the groundwater resource.

B. To ensure that groundwater flows are considered in the management of the lake.

5.1.6 Recreation

A. To maintain and enhance the recreational opportunities, the amenity, socio-economic and educational values of the lake for the entire community without impacting on the lake's ecological values.

B. To manage recreational activities so as to minimise any impact on the lake's aesthetic and ecological values.

5.1.7 Management Plan Implementation

A. To establish an integrated catchment management structure for the lake that allows for implementation, monitoring and review of the Lake Management Plan.

5.2 Secondary Objectives

5.2.1 Lake Water Level and Flooding

A. To minimise the impact of the natural variations in water level of the lake, both high and low, so as to protect terrestrial and aquatic ecosystems, and to reduce foreshore erosion and disruption to access and recreational use.

5.2.2 Sediment and Erosion/Catchment and Foreshore Management

A. To maintain and enhance the foreshore and catchment of the lake to protect the lake's aesthetic, ecological and recreational values.

B. To minimise erosion and sedimentation within the catchment, foreshore and lake.

5.2.3 Climate

A. To ensure that climatic conditions, and the effects of climate change are considered in the management of the lake.

5.2.4 Visual Amenity

A. To conserve and enhance the aesthetic value of the lake and its foreshores.

5.2.5 Aboriginal Heritage

A. To understand, protect and respect the aboriginal heritage value of the lake.

5.2.6 Development

A. To ensure that proposed and future development adjacent to the lake is carried out in an ecologically sustainable way and enhances the values of the lake.

5.2.7 Planning/Lake Management

A. To ensure co-ordinated management of all land in both the lake's surface and groundwater catchments.

B. To manage all undeveloped Crown land to enhance the lake's values.

5.2.8 Education, Information and Research

A. To develop systems and programs to educate and inform the community about the values of the lake and the impacts of human activity, to reduce adverse impacts and enhance the lake's values.

B. To encourage further research into the lake.

6. Assessment of Management Strategies

6.1 Introduction

The following section provides a description and assessment of potential management strategies. These strategies were compiled from a variety of sources including previous studies, community and stakeholder submissions, as well as those developed by the study team over the course of the investigation. Strategies were proposed to specifically address the management issues identified for the lake, and within the management plan each issue-related strategy will be categorised according to the following broad classification scheme:

SC - Statutory Controls and Policies: planning and development controls, and policies.

W - Rehabilitation and Improvement Works: includes rehabilitation works to repair and mitigate past damage, new works to improve the values of the lake including water quality, recreational amenity and the ecology of the lake.

E -Community Education and Awareness: programs to inform, educate the community about the implications of their actions on the values of the lake and to endeavour to modify their behaviour in situations where their actions are deemed to be detrimental to the management objectives for the lake.

EM - Environmental Monitoring: ecological and other monitoring and feedback programs to assess the health of the system and the impact of implementation of management strategies.

R - Further Research

Each of the proposed strategies was assessed in terms of the management objectives being addressed by the strategy, and the feasibility and impact of each strategy with respect to:

- technical feasibility
- environmental impact
- social impacts
- impact on lake processes
- community acceptance
- cost (low < $50,000, medium $50,000 to $100,000, high $100,000 to $500,000, very high > $500,000).

The costs shown within this section are indicative costs only and are not detailed design-based quantitative estimates. Future costing of management strategies will need to consider the implications of the introduction of GST in July 2000.

Subsequent to completion of this Management Study, the issue of traffic management has been further advanced at a specialist workshop. The results of the final assessments on traffic management will be incorporated in the Management Plan.

6.2 Water Quality

6.2.1 Algal Blooms

6.2.1.1 Biomanipulation

Biomanipulation is a series of manipulations of the biota of lakes and of their habitats to facilitate certain interactions which are beneficial in the reduction of algal biomass and in particular, of blue-green species. In the case of Lake Ainsworth it has been suggested that increasing the zooplankton population may lead to increased predation of the blue-green algae. This may be achieved by stocking the lake with a larger fish that eat the Gambusia and would reduce the zooplankton grazing, thereby leading to an increase in the zooplankton and an increase in cyanobacteria predation.

Discussion between Mr Graham Plumb and Dr Jones established that a study of the existing food web would need to be carried out to determine the potential for this approach. Such a study would probably cost around $50,000.

Advantages:
The biota of the lake removes the algae, so chemical or mechanical methods are not necessary.

Disadvantages:
A long-term technique that requires detailed assessment of its viability and potential impacts prior to implementation in the lake.

Uncertainty as to whether the method would be effective in an aquatic ecosystem such as Lake Ainsworth.

Costs:
Uncertain.

6.2.1.2 Sediment Removal

Experience with removal of sediment in similar systems indicates that this technique can lead to a decrease of the phosphorus concentration, reduce algal growth, particularly blue-green algae species and in some cases increase water clarity. Sediment removal is generally carried out by a dredging operation.

Two types of dredges are mostly used for removal of sediments in lakes, namely mechanical and hydraulic types. Grab-type mechanical dredges are commonly used in lakes. There are many variations of hydraulic dredges, including suction dredge, hopper, dustpan, and cutter-head section dredge and barge-mounted excavators. Inland lake sediment removal is most commonly accomplished with a cutter-head hydraulic pipeline dredge. Operationally, sediment loosened by the cutter moves to the pickup head by suction from the dredge pump, which usually is of the centrifugal type. The sediment slurry is then discharged by pipeline to a remote disposal area. Barge-mounted excavators generally use a clam shell bucket to grab the sediment and transfer it to a hopper barge.

Advantages:
Removal of nutrient-enriched sediments from lakes, preventing future internal nutrient loading from this source. Dredges can also be used for selective sediment removal in confined areas of a lake.

Disadvantages:
A common limitation of all grab bucket dredges is that they must discharge in the immediate vicinity of the sediment removal area or into barges or trucks for transportation to the disposal area. Production rates are relatively slow and its operation creates uneven bottom contours. Most slurry from hydraulic dredges contain only 10 to 20% solids; 80 to 90% of the slurry volume is water. This means that relatively large areas, with adequate residence times, must be designed to precipitate solids from the dredge slurry. Also, it means that the large pumping capacity of hydraulic dredges might produce unplanned lake drawdowns, unless disposal-area overflow water is returned to the lake.

There are mainly two environmental concerns with sediment removal from a lake. In-lake concerns commonly centre on the resuspension of sediment during its removal by dredging. One of the most common problems is liberation of nutrients. While nutrient enrichment due to dredging can become a problem, in most cases the effects are short term and negligible relative to long-term benefits. Another, and potentially greater, concern associated with resuspended sediment is the liberation of toxic substances. A relatively common concern about dredging is the destruction of the benthic habitat and fish-food organisms. EPA approval would probably be required for any sediment removal management option.

The major non-lake impact of sediment removal concerns the area chosen for disposal of dredged material. The problem of finding disposal sites in urban areas is more acute in Australia with the promulgation of EPA regulations.

Costs:
High to very high.

Dredging costs to remove 120,000 m^3 of sediment - $570,000, assuming the cost of productive dredging sediments is about $4.50 to $5.00/$m^3$.

Capital costs would be around $230,000 including removal of sediments to a suitable disposal area to be identified. The above estimate makes no allowance for construction of a deposition area or earthworks in that deposition area.

Sediment removal/sediment capping would only be cost effective if the majority of nutrients are released from the sediments during periods of anoxia, and these nutrients can be controlled in this manner. If only a small amount of nutrient can be controlled by this method, the cost may not be worth the ultimate result. Alternative methods at preventing internal loading may be cheaper.

6.2.1.3 Sediment Capping (Lime, Alum or Proprietary Product Dosing)

Sediment capping involves a number of chemical techniques including alum, lime or proprietary product dosing, or injection of nitrate to essentially cap the sediments and bury the nutrients below the sediment surface. These chemicals generally come as a powder that can be spread over the lake which then settle to the bottom. Sediment capping essentially reduces the transfer of nutrients from the sediment to the water by capping the sediment surface.

The proprietary product 'Lysofoss' has been suggested as a potential remedy for the lake algal problems. This is an organic powder that can be readily applied to the lake. It has been used in a small lake at Lismore with some apparent success.

An alternative substance that may be used for sediment capping is manufactured clay, 'Phoslock', developed by CSIRO in Western Australia. Tests have indicated that the clay may prevent the release of up to 95% of the nutrients that would otherwise come from the sediments through internal loading processes. Large scale field tests of the clay are to take place on the Swan River during the summer of 1999/2000. (Contact Grant Douglas, CSIRO Land and Water, Perth, for information).

Advantages:

Lime is inexpensive, simple and safe to apply, and without toxic effects (unless pH increases above 10). It is widely used for sediment capping of farm dams in Canada.

Alum also supposedly has similar advantages, although any possible toxic effects are not well documented.

Lysofoss is also easy to apply and would achieve a reduction in nutrients and algal populations.

Disadvantages:

Sediment capping is generally only a short-term option, and recurrent dosing, possibly annually, may be necessary. The dosage to produce long-term effects is unknown.

The use of lime, alum and gypsum may also have an impact on the humic nature of Lake Ainsworth, with associated ecosystem changes. Alum application in particular will cause the flocculation and removal of gilvins dissolved in the lake, leading to a clearing of the water column and increased transparency. This will change the natural condition of the lake, and possibly cause ecosystem changes with more light available for algal and macrophyte photosynthesis. Alum in particular will cause pH changes.

The apparent success of this system elsewhere has been questioned (comments provided at the value management workshop).

An environmental assessment and EPA approval would be necessary.

Costs:

Initial: Medium to high

Ongoing: Uncertain.

Costs would include the cost of the chemical used, and the cost of application to the lake. Total cost for lime application is approximately $10,000, and for alum approximately $25,000. For an application of Lysofoss to Lake Ainsworth approximately 4-8 tonnes of Lysofoss would be required for the lake at a cost of $15,000 per tonne, or a total cost of $60,000 to $120,000. The powder would be deployed from a small boat.

6.2.1.4 In Situ Sediment Treatment (Limnofix Inc.)

Golder Associates Pty Ltd provided a brochure on their capabilities in the area of sediment remediation including the use of dredging and treatment options and the use of an injection system to essentially oxidise the top layer of the sediment to bind the phosphorus to the sediment and release nitrogen gas (according to the manufacturer's brochure). This is achieved by pumping calcium nitrate into the sediment. While these techniques have potential, their viability would require a detailed assessment.

Costs:
Uncertain: Potentially more expensive than sediment capping techniques.

Aeration

Aeration has been installed in the lake for the past two years. Its performance in terms of algal reduction has been difficult to assess but qualitative evidence suggests there has been a degree of success. This may stem from a reduction in fluxes of soluble phosphorus from the sediments, thereby depriving the cyanobacteria of some bioavailable nutrient.

Advantages:
While performance has been difficult to assess from the available data, qualitative evidence suggests that there has been some degree of success. However, while the degree of mixing produced by the aerator has been sufficient to break down thermal stratification, and possibly prevent phosphorus release from the sediment (internal loading), it is unlikely to produce the amount of turbulent mixing required to make the lake an entirely unsuitable habitat for cyanobacterial growth.

The system is currently in place and operational.

There is potential to make further savings on operational costs through a more detailed long-term assessment of system performance.

Disadvantages:
The system requires ongoing operational and maintenance costs, with a substantial upgrade likely to be required in the not-too-distant future.

The optimal mode of operation of the system is uncertain and yet to be determined.

Costs:
Initial: High (initial costs for the installation were approximately $170,000).
Ongoing: Low.

6.2.1.5 Ozonation

Council has received a proposal from Neatlink Pty Ltd for the installation of an ozonation system as a means of controlling the algal blooms.

Advantages:
The system is apparently effective at reducing algal blooms under specific conditions.

Disadvantages:
The system is apparently harmful to the ecosystem and would likely result in adverse impacts on the lake flora and fauna.

The addition of ozone to the lake waters would most likely require approval from the EPA.

There is uncertainty about the suitability of the system for reducing algal blooms in Lake Ainsworth.

Ozonation as a management tool for Lake Ainsworth would require further research. The ozone may alter the natural brown-water nature of the lake through the destruction of gilvins, leading to greater water clarity and associated changes to the habitat and ecosystem.

Costs:
Initial: High (estimated installation costs of $330,000)
Ongoing: Low (estimated operating costs of $1,200 per month).

6.2.1.6 Enhanced Flushing by Groundwater

The lake volume may be exchanged by pumping groundwater from the adjacent Newrybar Wetland (to the west of the lake) into the bottom of the lake and extracting the surface waters at the same rate and discharging back into the wetland. The natural stratification would ensure that only surface waters would be extracted through the process known as selective withdrawal.

Advantages:
Potential to be combined with a flood mitigation system.

Disadvantages:
The impact on the groundwater resource and the Newrybar wetland is uncertain.

This option would require further assessment of the groundwater resource, both quantity and quality and an assessment of the pumping requirements and potential impacts of the surface water discharge to the wetland.

Costs:
Initial: Medium to high
Ongoing: Uncertain (probably less than the aerator as a compressor is not required).

6.2.1.7 Mechanical Water Filtration System

The proposal by Mr Stanley Rosolen to install a filtering device that would essentially skim a surface layer to a depth of 20 cm and remove the algae, presumably by filtration, is worthy of further investigation. Tests of skimming devices elsewhere, such as the use of a Baleen harvester to remove a cyanobacterial bloom in Chaffey storage near Tamworth have indicated that they are ineffective, expensive to operate, and there may be problems with disposal of the algae, which may be classified as toxic waste. This proposal would require a substantial demonstration of its viability before it could be considered for further assessment.

Advantages:
Removes algae, and hence nutrients from the system.

Disadvantages:
Effectiveness of the device is unproven, with skimming devices elsewhere having proved to be ineffective and expensive to operate. A trial of this system would have to be arranged.

It is a reactive strategy, which operates after a bloom has occurred.

Disposal of the captured algae, which may be classified as toxic waste, could be an issue.

Costs:
Uncertain.

6.2.1.8 Chemical Dosing - Use of Alum and Gypsum

Laboratory and field trials have shown that alum and gypsum dosing is effective in removing turbidity in water and preventing algal growth by removing phosphorus from the water column. Cheng (1992) suggests the following working procedure:

- Dosage: 50 kg of alum and 50 kg of gypsum per megalitre of water. Because of local variation in water quality, it is advisable to conduct a preliminary trial in a '44 gallon drum' to establish the required dosage.

- Dosing procedure: Add alum granules to the water and mix well using a boat with an outboard motor to help mixing. Allow the water to stand for a few hours, then add gypsum granules. Allow water to stand for at least 24 hours or until it clears. If the water does not clear within two days, add a further 25% to 50% of the recommended dosage to promote flocculation. The water should clear.

- pH check: After dosing check the pH of the water, pH should be within the range 6-9. If it is outside the range, allow the water to stand for a further two days, and check again. However this may not be possible in Lake Ainsworth.

- Time of dosing: Dosing should ideally be carried out before summer, and certainly before a bloom has developed.

Advantages:
Removes both nutrients and algae from the water column.

Disadvantages:
Only a short-term remedy (days to weeks).

Alum, and to a lesser extent gypsum, will also remove some of the dissolved humic substances from the water (i.e. clarify the water), which may not be desirable for Lake Ainsworth. Use of alum will also lead to changes in pH, which may not be desirable for the lake ecology.

The use of chemicals to control blue-green algae is likely to cause ecosystem damage with unknown ramifications.

If they must be used, EPA permission should be obtained, which is unlikely to be granted.

The main use of alum and gypsum is as an algistat, being applied in spring or early summer to remove nutrients from the water column, and thus prevent an algal bloom from occurring later in the season. However, because alum also flocculates, sinks and kills algae, it is at times used as a surrogate algicide after cyanobacterial blooms are already present. This is an inappropriate use.

Costs:
Uncertain.

6.2.1.9 Chemical Dosing - Use of Copper Sulphate and Coptrol

Copper can be a highly effective algicide in some cases, but these effects are always temporary (days/weeks), annual costs are high, there are major negative impacts on non-target organisms and significant contamination of sediments with copper is possible. Use of copper sulphate will kill fish, zooplankton, and macroinvertebrates. A chelated copper compound, 'Coptrol' is also available commercially, which manufacturers claim is more environmentally friendly than copper sulphate. However their label now states that species of native fish and other organisms may also be susceptible to this chemical. Any use of copper-based chemicals would require EPA approval, which is unlikely to be obtained.

Use of copper sulphate or Coptrol should also follow the protocols for algicide and algistat use published by ARMCANZ (1997). Of the two, the National Registration Authority registers only Coptrol for use against cyanobacteria. Although previously widely used as a commodity chemical, copper sulphate is not a registered chemical for algal control, and its use would therefore require a temporary permit from the NRC, as well as a licence issued by the EPA.

Advantages:
Can be an effective algicide in some cases.

Disadvantages:
Effects are temporary (days to weeks).

Can be harmful to other species, including fish, zooplankton and macroinvertebrates.

Copper sulphate is not a registered chemical for control of cyanobacteria.

EPA approval is unlikely to be given for the use of copper sulphate or Coptrol.

Costs:
Uncertain. Depends on dosage required and frequency of treatment.

6.2.2 Lake and Groundwater Water Quality

6.2.2.1 Do Nothing

AWACS (1996) reported that the application of the OECD lake trophic classification scheme suggests that Lake Ainsworth is a eutrophic lake, and that high chlorophyll levels and algal blooms confirms this classification. An annual phosphorus budget for 1995 indicated that the major source of phosphorus for the water column was from sediment release, which was an order of magnitude larger than the combined loads due to runoff and groundwater.

Faecal contamination assessment by BSC from data collected over 20 years (AWACS 1996) showed that NSW Health Department guidelines for recreational waters were rarely exceeded, and that levels appeared to have peaked in about 1990. The NSW Health Department standard states that waters are considered unsuitable for bathing where the faecal coliform count, calculated as the geometric mean of the number of organisms in three water samples taken at the same time from the area being tested, exceeds 300 organisms per 100 mL, with an upper limit of 2,000 organisms per 100 mL in any one sample. Council has consistently monitored unprotected swimming areas, and in the event of non-compliance with the above standard the current practice is to undertake an immediate re-test. If this test also indicates non-compliance, consideration is given to issuing warnings.

Recent testing between October 1998 and June 1999 (BSC 1999), showed that the NSW Health Department guideline levels were exceeded on two sampling occasions out of a total of eight. One of these high readings was associated with a high rainfall event, and stormwater drains to the south of the lake have shown high faecal coliform bacteria counts during previous rainfall events (AWACS 1996). It should be noted that faecal coliform bacteria are only an indicator of faecal contamination, but do not distinguish between human and animal sources. Pressure dye testing of the sewerage rising main between the Sport and Recreation Centre and the town sewer confirmed its integrity, suggesting that this did not contribute to elevated coliform counts. Other potential sources include dogs, horses and birds.

The high blue-green algae counts monitored in recent years are also of concern for recreational users. These blue-green algal counts have led to the lake closure on a number of occasions over the past three years. In addition the low dissolved oxygen concentrations associated with the stratified periods are also an indication of deteriorating water quality.

Advantages:
No requirement for capital expenditure.

The release of nutrients from the bed sediments has been identified as the main source of nutrients in the water column and hence the main water quality issue in the lake. This is attempting to be addressed by other means (see *Algal Blooms*).

Disadvantages:
Assumes that algal bloom strategies will be adequate to address the water quality issues. If not then continued closure of the lake will occur. As the blooms are closely linked with the weather their severity and hence lake closures will be worse in some years than others.

Costs:
Initial: Low
Ongoing: Will depend on the success of strategies to deal with the algal bloom issue and the long-term effects of other contaminant sources.

6.2.2.2 Water Quality Improvement Strategies

Following are strategies that have been suggested to improve the water quality of the lake, either through reducing the influx, or the removal of contaminants from the lake. These strategies are minor management techniques that if applied together will have cumulative effects.

- Construct water quality improvement systems, such as mini-wetlands, at the outlets of the five stormwater drains. Gross pollutant traps (GPTs) are probably not warranted due to diffuse nature of litter sources and the limited catchment of each of the drains.
- Cultivation of further reed beds around the lake foreshore. While they have the potential to reduce nutrients from the lake they may also provide additional benefits such as reducing foreshore erosion and providing habitat for aquatic fauna.
- Treatment of runoff from road/parking areas through filter swales (hydrocarbons, PARs, heavy metals etc).
- Tighter controls and policing of controls, to reduce the amount of faecal contamination from domestic pets (dogs, horses).
- Bund storage and refuelling areas (Sport and Recreation Centre and caravan park) to reduce risk of hydrocarbon contamination.
- Remove grass clippings when mowing grass to reduce nutrient influx.
- Improve the distribution of litter bins and regular emptying of bins. Bins should be readily accessible to high use areas, however, they should be located in such a way as to minimise their impact on the recreational and visual amenity of the lake. There will need to be a means of preventing the litter in the bins from being removed by seagulls and other animals.
- Encourage swimmers and sun bathers to 'cover up' as a means of sun protection rather than using excessive amounts of sunscreen. The occurrence of sunscreen-related 'slicks' has been reported during peak usage periods.
- Minimise erosion and sediment influx to the lake (see 6.8 Erosion and Sedimentation).

Advantages:
Improving the quality of surface inflow waters entering the lake through the use of wetlands and reed beds as nutrient and sediment traps. Expansion of the reed beds and other aquatic vegetation around the edge of the lake will also provide an additional alternative sink for nutrients, and extra habitat for other aquatic organisms that may benefit the water quality through grazing the algae or other processes.

Some strategies can incorporate a significant component of community involvement (e.g. reed beds and mini-wetlands).

Some strategies may only involve a change of current practice with minimal cost involved (e.g. removal of grass clippings and provision and frequent emptying of garbage bins).

Involves a suite of strategies, each of which aims to improve the water quality to some degree. It does not rely on a single strategy being successful.

Disadvantages:
Establishing additional aquatic vegetation around the lake shorelines will be difficult, as the brown water limits light penetration, leading to a shallow euphotic depth. Most of the bed of the lake is below the euphotic depth, thus preventing the establishment of additional aquatic vegetation. There is also pressure to keep areas of the foreshore free of aquatic vegetation, to allow ease of access to the lake for recreational users.

Involves a number of strategies and the contribution of each to an improvement in the water quality of the lake is uncertain.

Costs:
Initial: Low to medium (depending on the strategies adopted).
Ongoing: Low (but again would depend on the strategies adopted).

6.2.3 Monitoring

6.2.3.1 Continue with Current Monitoring Programs

Council has monitored for faecal contamination once per month during the swimming season (October till March) since 1977. This involves the enumeration of faecal coliforms and E.coli from samples taken at three shore locations.

An ongoing weekly program of sampling for cyanobacteria has been undertaken by Council since 1998. The program involves analysing samples from four shore locations. Shoreline water samples collected in accordance with the protocol issued by the North Coast Regional Algal Co-Ordinating Committee (NCRACC) are collected by Council Environmental Health Officers and submitted to Tweed Shire Council Laboratory for algal identification and count each month throughout the year. This is stepped up to weekly during spring and in the period before and during school holidays. When blue green algae is known to be present in the lake sampling may be undertaken several times in a week.

When significant algal slicks become visible or the cell count in any sample exceeds 15,000 cells per mL signs warning of the presence of blue green algae are erected in prominent positions near the lake shore. The signs remain until two successive counts indicate that algae levels have diminished below 10,000 cells per mL. The results of all work is provided promptly to the NCRACC Secretary at Grafton. When appropriate, press releases are made by that body.

Nutrient samples have also been collected during Council's algal bloom monitoring. Parameters that have been collected are total phosphorus, ammoniacal nitrogen, total nitrogen, and nitrate nitrogen.

A continuously logging water quality instrument has been deployed by DLWC since December 1995. This instrument collects data on temperature, conductivity, dissolved oxygen and pH, and lake water level.

Additionally, following the installation of the trial aerator destratification system, a thermistor chain was also installed to measure the vertical temperature profile in the lake. It is noted that during analysis of these data to assess the performance of the aerator for this study, recalibration of the thermistor temperatures was required due to severe data quality and accuracy problems.

Council has recently completed a one-year data collection program, the primary aim of which was 'to gather information to both fill data gaps outlined in the Lake Ainsworth Processes Study and to provide monitoring data on the trial aeration scheme' (BSC 1999). This program ran from mid-1998 to mid-1999 and as well as physio-chemical monitoring, it included biological monitoring of phytoplankton, macroinvertebrates, and zooplankton. The program is not ongoing.

Advantages:
Ongoing water quality monitoring is essential to obtain a detailed understanding of the processes leading to poor water quality and algal blooms in Lake Ainsworth. It is also necessary to adequately assess the effectiveness of the thermal destratification system. These data will then provide the basis to make informed management decisions for the lake. At present, although some data are available, they are as yet insufficient to provide effective background for these decisions. Given the valuable recreational amenity the lake provides the Lennox Head area, there is a ready management use for the data that a routine water quality monitoring program can provide.

A routine water quality monitoring program should include thermal and dissolved oxygen profiling of the entire water column, the presence of nutrients, pH and algal counts. Faecal coliform levels should also be regularly taken, especially in periods of peak recreational usage, to ensure that the lake meets the primary contact recreation guidelines of the NSW Health Department, or the National Health and Medical Research Council.

Disadvantages:
Routine monitoring has its costs. These may have to be met by ratepayers or lake users. As well as sampling and analysis costs, there are also the costs of equipment and its routine maintenance.

It also requires a commitment of staff dedicated to undertake the monitoring at specific times, as part of their duties. This may take staff away from their otherwise normal duties. Some training to enable staff to carry out the program effectively may also be needed.

Costs: The one-year monitoring program completed by Judith Betts in August 1999 cost $30,000 plus on costs, lab costs and consumables (minimised by access to the Department of Agriculture lab at Wollongbar), vehicle expenses – estimated at approximately $45,000 all up. Algal counts at Tweed lab currently cost Council $120 per time plus staff time to take samples and $5 freight. Council job expenditure numbers will provide a closer estimate of this expenditure.

6.2.3.2 Develop New Guidelines and Monitoring Systems Specific to Lake Ainsworth

Develop an integrated set of biological, physical and chemical guideline levels and appropriate monitoring and assessment systems.

The current draft release of the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC & ARMCANZ July 1999, public comment draft, yet to be endorsed by either council), suggests that site specific guideline trigger levels be developed for a range of indicator types, and they be based on the desired level of protection and management objectives. These selected indicator trigger levels should be ecologically based, and may include both water and sediment physio-chemistry as well as biological assessment (e.g. rapid biological assessment (RBA) and/or quantitative biodiversity measurement). Having developed appropriate guidelines and water quality objectives, a suitable integrated monitoring and assessment program would then be established. This program should be ongoing and both scientifically and statistically valid, to enable the health of the system and the progress of various management strategies to be assessed. Monitoring of the groundwater should be considered in developing a comprehensive monitoring program.

Advantages:

The new guidelines will be specific to Lake Ainsworth, and thus more appropriate for the management of the lake. As well as allowing for ecosystem protection, the guidelines promote a philosophy of continual improvement where some degradation is apparent, as in Lake Ainsworth.

As well as applying guidelines for ecosystem protection, appropriate recreational guidelines can also be established.

Disadvantages:

The guidelines have yet to be published.

The guidelines for the protection of aquatic ecosystems will require an adequate database to be available for Lake Ainsworth to provide sufficient information to allow the development of appropriate lake-specific guidelines. These data will need to be collected through an ongoing water quality monitoring program. For the interim, it may be necessary to apply the default trigger levels provided by the new guidelines to the lake, until sufficient data become available for more specific guidelines.

Costs:

Would depend on parameters being monitored and frequency of monitoring (indicative cost: low to medium).

6.3 Coastal Dunes

6.3.1 Overview

It is currently postulated that there is a long-term trend of a rise in sea level resulting from the global increase in average world temperatures. In the shorter term the rise in sea level will result from the thermal expansion of the ocean waters while in the longer term melting of the polar ice caps will also contribute. The rate of rise of sea level is predicted to accelerate over time. The rising sea level will result in a landward movement of the shoreline (beach recession) on a natural beach and increased potential for dune erosion on a developed beach where the dune line is being held against erosion. There is also a likelihood of increased storminess as world weather patterns change, causing changes in erosion and deposition of unconsolidated beach sands.

The Institution of Engineers Australia in 1991 published *Guidelines for Responding to the Effects of Climatic Change in Coastal Engineering Design* (IE Australia 1991). These guidelines present a set of procedures to be followed in developing coastal engineering designs and plans such that appropriate risk and sensitivity analysis is undertaken. In respect of sea level rise, the guidelines recommend a range of sea level rise scenarios for various planning periods based on the IPCC predictions of 1990.

These predictions have subsequently been updated (IPCC 1995). The Institution of Engineers Australia, in their position paper on Greenhouse (IE Australia 1990) suggests allowance of approximately 0.25 m over a fifty-year period for a mid-scenario sea level rise. The International Panel on Climate Change (IPCC 1995) revised their 1991 estimate of predicted sea level rise and now suggests a 0.54 m rise from the present to 2100, using a mid-scenario estimate (IPCC 1995). This is a lower estimate than recommended previously and adopted by the Institution of Engineers Australia. An update of the IPCC scenario will be released shortly.

In addition, regional climate modelling is currently being undertaken by CSIRO. Whilst most of this research remains inconclusive, some tentative findings have been presented (CSIRO 1996). Modelling work on the effect of increases in sea surface temperature on east coast lows found that 'climate change has the potential to intensify east coast lows and may exacerbate associated storm surges' (CSIRO 1995). The 1996 CSIRO report *Regional Impact of the Greenhouse Effect on NSW* states: 'We remain convinced, however that over the next half century or so, possible changes in extreme events due to changes in meteorological forcing may well have greater effects than the small rise in mean sea level.'

The scenario of a rising sea level associated with the postulated warming of the atmosphere, (the enhanced Greenhouse effect), will result in beach recession and a change to predominant weather patterns. These potential changes need to be accommodated in planning coastal development. Shoreline position and alignment may change as foreshores adjust to increased storminess, higher waves, increased sea levels and any changes to the direction of wave attack (NSW Government 1990). The future changes in storminess and the associated realignment of foreshores to new weather patterns is not well defined at present. These possibilities are generally accommodated through the implementation of management strategies which are flexible and robust; able to accommodate or be adapted to a range of possible future changes.

The revised predictions of sea level rise (IPCC 1995) are best estimates of the likely impact of climate change over the next 100 years. These predictions have been made on the basis of improved models that generate results with increased confidence. These results predict a slightly reduced rate of sea level rise in comparison to the previous estimates but the general scenario is unchanged. Low, mid and high range estimates are tabulated for 50-year and 100-year planning periods in Table 6.1.

Table 6.1 Projected Global Mean Sea Level Rise

Planning Period (Years)	Low (m)	Best Estimate (m)	High (m)
50 (2045)	0.08	0.23	0.43
100 (2095)	0.22	0.54	0.94

Source: IPCC (1995)
Note: Based on 50 and 100-year planning period from 1999 and derived from the projected global mean sea level rise curve 1990 to 2100.

A method for estimating foreshore recession associated with a sea level rise based on the nearshore slopes and the depth of the active profile has been postulated by Bruun (1962) and may be generally applied to sandy beach systems. As an example, for an average beach slope of 1 (vertical) in 40 (horizontal), a landward recession of 9 m would occur following a 0.23 m sea level rise over a 50-year period. The postulated sea level rise of 0.04 m over the next 10 years equate to a 1.5 m landward movement of the dune scarp.

It should be noted that Ballina Shire Council is considering engaging consultants to undertake a coastline hazard definition study, which would include analysis of aerial photography up to and including 1999. The findings of such a study would provide a more up-to-date assessment of the coastal hazard throughout Ballina Shire and would provide the opportunity to reassess management strategies for the whole of Seven Mile Beach, including the section adjacent to Lake Ainsworth. However, in the absence of this study, the following management strategies have been considered.

6.3.2 Do Nothing

The estimated average long-term recession for Seven Mile Beach, defined by the movement of the back beach escarpment for the period 1947-1994, is between 0.66 m and 0.9 m per year (MHL 1996a and 1996b). In addition to this long-term recession, PWD (1994) advised Ballina Council that the likely recession resulting from Greenhouse-induced sea level rise over the next 50 years would be an additional 15 m. This estimation was based on the assumption of no protection being provided by rock revetment works in this vicinity. Further analysis would be required to determine the likely 50-year recession given the protection work constructed to the north and south of Lake Ainsworth. However, if a similar projection is made for the section of beach immediately to the north of the Lennox Head surf lifesaving club, then the dune would be in jeopardy of being breached within a 50-year period, providing a connection between the lake and the ocean at this location. The status of Lake Ainsworth as a freshwater lake would thus be compromised.

Advantages:
This strategy requires no capital or recurrent expenditure.

It does not intervene with the natural processes.

The dune system may remain in an acceptable state for a number of years to come depending on the weather conditions.

Disadvantages:
There would be a high ultimate cost of this strategy, with the eventual loss of Lake Ainsworth as a freshwater lake. This is unlikely to be acceptable to the local community, and would potentially impact on tourism in the area.

While this strategy involves allowing the natural processes to proceed, in many ways the processes are no longer 'natural', having been modified by development and adjacent protection works.

The long-term outcome is likely to be the degradation of the beach as the community tries to protect and preserve the lake.

Costs:
Short term: Low
Long Term: Very high.

6.3.3 Continue Current Dune Rehabilitation Management Practices

Under this strategy the existing dune care works, as co-ordinated and undertaken by the Lennox Head Dune Care group, would be continued and possibly expanded. The aim of this work is to restore and maintain the natural dune buffer between the lake and the ocean to accommodate allowance for storms.

Observations of beach scarp by DLWC in 1996 indicated that the scarp had been stable in the two-year period following the last date of photogrammetric analysis (i.e. 1994). AWACS (1996) attributed this to the good dune management undertaken in the area, and to this period being relatively free of major storm events. The purpose of an effective dune vegetation management system is to provide stability to the dune system, and to aid in the quick recovery following severe storms, 'whilst providing the means for the community to enjoy the widest possible range of coastal oriented activities without degrading the resource base which supports them.' (Coastline Management Manual 1990). While such a system can serve to buffer the effects of coastal erosion, on a receding coastline as has been identified at Seven Mile Beach, it can only serve to reduce the rate of shoreline recession but not stop the recession altogether.

AWACS (1996) noted the excellent maintenance measures that had been provided by the activities of the Dune Care group up to 1996. However, it was noted that 'due to the dynamic nature of dune processes, these measures need to be maintained on an ongoing basis.'

Advantages:
This strategy relies on a high level of community involvement, which has the flow-on benefits of promoting community awareness and education.

It is relatively cost effective compared with some alternative management options.

It reduces the immediate need for 'hard' protection works.

Dune rehabilitation can address a range of issues including beach access and usage, vegetation etc.

Disadvantages:
This is a temporary approach with a high level of damage to rehabilitation works occurring during storms. Under these conditions it can become difficult to maintain community motivation and involvement.

Ultimately as shoreline recession proceeds and the natural processes are no longer able to regenerate the dune following storm events, intervention works of some description will be required to facilitate the maintenance of the dune buffer.

Delaying intervention works may be viewed by some sections of the community as prolonging the inevitable.

Costs:
Short Term: Low
Longer Term: High to very high (depending on the eventual strategy adopted).

6.3.4 Beach Scraping

Under this strategy the existing dune care rehabilitation activities would be continued and would be augmented with sand being moved from the beach berm to the dunes so as to bolster the dunes. This work would be undertaken on an opportunity basis at times when the beach has sufficiently recovered or accreted following storms. This technique is sometimes referred to as beach nabbing, or beach NABE (nature assisted beach enhancement)

Advantages:
This strategy increases the efficiency of the dune care process by accelerating and enhancing the natural dune building process.

It is a relatively cost effective process.

The immediate need for hard protection works is reduced.

Disadvantages:
It is a temporary approach, with a high level of damage to works during storms.

It removes sand from the active beach system until storms occur.

This strategy requires an ongoing commitment and expenditure from Council.

Delaying intervention works may be viewed by some sections of the community as prolonging the inevitable.

6.3.5 Beach Nourishment

Involves replacing lost sand on the section of beach to be protected with sand from an external source. This strategy requires regular commitment to maintain beach dune volumes with imported sand from a suitable borrow site. Large scale nourishment requires placement of five to ten years of estimated sand requirements, while continuous nourishment requires regular, diligent restoration of the beach and dune system (of the order of twice yearly, depending on loss rate).

Advantages:
This system works to augment and enhance the natural beach and dune processes rather than against them.

It provides security for the lake while maintaining the amenity of the beach and dune system.

Beach nourishment results in a net gain of sand to the coastal system with benefits downdrift of the nourishment site.

Disadvantages:
This strategy requires an ongoing commitment and expenditure to maintain beach volumes and replace erosion losses.

Beach nourishment is difficult to plan for. Losses are variable and weather dependent.

This strategy can be difficult for some sections of the community to accept as an effective option due to the ongoing and repetitive nature of the works.

Costs:
Ongoing: Medium to high (depends on strategy and level of performance).

6.3.6 Terminal Revetment (Sea Wall)

Involves the construction of a revetment along a specified alignment to limit the landward excursion of waves and in so doing prevent shoreline recession. A properly designed revetment would provide a high level of protection to the land west of the revetment, and hence to the lake itself. A 75 m section of revetment adjoining the Lake Ainsworth Sport and Recreation Centre was recently upgraded and the entire 370 m section will require upgrading as the beach recedes over time (MHL 1997).

Advantages:
Works to limit the natural erosion processes.

Provides a high level of security against erosion.

This strategy would be consistent with management strategies adopted on Sport and Recreation land in the north and Lennox Head to the south.

Construction of a terminal revetment may also be used in conjunction with beach nourishment to provide a sandy beach amenity.

It is a permanent 'one off' solution to the threat of erosion.

Disadvantages:
On a receding beach, such as Seven Mile Beach, a terminal revetment structure would result in the loss of the sandy beach amenity in the absence of associated nourishment works.

This strategy may simply transfer the erosion downdrift along the beach (i.e. to the north).

Initial costs are high and it may be seen as an option that is adverse to the public beach amenity.

Requires ongoing maintenance with possible future upgrading.

Costs:
Initial: Very high
Ongoing: Low.

6.4 Traffic Management

The following presentation of information on traffic management strategies is presented to record the historical development of strategies As noted earlier, traffic management strategies have been developed further, subsequent to the work on this management study.

6.4.1 Do Nothing

Involves maintaining the current situation with regards to traffic movement and parking.

Advantages:
No capital costs (ongoing maintenance costs of existing infrastructure would still be required).

Disadvantages:
Traffic flow and parking are viewed as significant issues by the community and therefore the *do nothing* option is unlikely to gain community acceptance.

Fails to address the many issues associated with traffic management around the lake including:

- Loss of foreshore amenity and damage to riparian vegetation through parking arrangements.
- Restricted amenity on the eastern side of the lake due to the road acting as a discontinuity between the lake and the beach and dune system.
- Traffic congestion during peak periods (e.g. markets, holidays, surf carnivals).

- Safety of children crossing the road between the lake and the beach, site distances are poor.
- 4WD access track increases traffic movements around the lake and is a potential breakthrough point in the dune system.
- As regional growth continues the pressures on the lake associated with increased traffic are likely to escalate.

Costs:
Initial: Minimal.
Ongoing: Long-term costs associated with doing nothing are potentially high.

6.4.2 Close Eastern and Southern Foreshore Roads to Traffic

The eastern road would be blocked to traffic, with access to the Sport and Recreation Centre being via the western side of the lake. Access to the western road would be via a new link road on the outside of the caravan park. The existing foreshore roads could be converted to bicycle and walking tracks with additional picnic and BBQ facilities provided on the eastern side of the lake to ease the load on the southern and south-eastern foreshore areas. Upgrading of the western road would be required. In the longer term, vehicular access would need to be maintained to the dune system for emergency requirements. Restricted access could be maintained, via a boom gate system, for the sailing school.

Advantages:
Improves the amenity of the eastern and southern foreshore areas.

Provides more of a continuous linkage between the lake, the dunes and the beach.

Reduces the risk to pedestrians, particularly children, moving between the beach and the lake, and between the lake and the caravan park.

The alternative routes are not affected by elevated lake water levels.

This option is consistent with the opportunities identified in the Sport and Recreation Centre's master plan (PWD 1994), which identified that a north entry would improve traffic management.

Disadvantages:
Extends the route to the Sport and Recreation Centre by approximately 1.5 km. The Sport and Recreation Centre has suggested that the closure of the eastern road would have a negative impact on the business of the centre, although the level of impact was not quantified.

Access to the 4WD track would be blocked. The track would either have to be moved to the north or not provided at all.

Costs:
Initial: High to very high (depending on strategies adopted).
Ongoing: Similar to current maintenance costs.

6.4.3 Close Eastern Road to Traffic

The eastern road would be blocked to traffic, with access to the Sport and Recreation Centre being via the western side of the lake. Access to the western road would be via the current sealed road on the southern foreshore of the lake, which runs between the lake and the caravan park. The eastern foreshore roads could be converted to bicycle and walking tracks with additional picnic and BBQ facilities provided to ease the load on the southern and south-eastern foreshore areas. Upgrading of the western road would be required. In the longer term, vehicular access would need to be maintained to the dune system for emergency requirements. Restricted access could be maintained, via a boom gate system, for the sailing school and/or the Sport and Recreation Centre, or alternately a new sailboat hire and launching area could be provided on the southern foreshore area.

Advantages:
Improves the amenity of the eastern and southern foreshore areas.

Provides more of a continuous linkage between the lake, the dunes and the beach.

Reduces the risk to pedestrians, particularly children, moving between the beach and the lake, and between the lake and the caravan park.

The alternative routes are not affected by elevated lake water levels.

This option is consistent with the opportunities identified in the Sport and Recreation Centre's master plan (PWD 1994), which identified that a north entry would improve traffic management.

Disadvantages:
Extends the route to the Sport and Recreation Centre by approximately 1.5 km. The Sport and Recreation Centre has suggested that the closure of the eastern road would have a negative impact on the business of the centre, although the level of impact was not quantified.

Increased traffic levels along the southern foreshore with associated conflicts with other users of this area (caravan park visitors, markets etc).

Access to the 4WD track would be blocked. The track would either have to be moved to the north or not provided at all.

Costs:
Initial: High
Ongoing: Similar to current maintenance costs.

6.4.4 Remove or Relocate 4WD Beach Access Track

The existing 4WD track, located mid-way along the eastern foreshore of the lake, would be blocked and the dune raised and rehabilitated at this location. If an alternative 4WD track is to be provided, in deference to Council's current policy of allowing 4WD access to this section of Seven Mile Beach, then this would be provided to the north of the Sport and Recreation Centre.

Advantages:
Removes an identified 'weak' point in the dune system.

Reduces the traffic flow along the eastern foreshore area and the associated impacts such as conflict with users, and erosion along road fringes. Currently people using the track are using the lake reserve as a route to get to the beach. This conflicts with people using the lake for recreational purposes.

Removal of the track altogether would reduce 4WD usage of the beach between the surf club and the Sport and Recreation Centre, reducing conflict with other beach users.

Disadvantages:
Access to the beach for 4WD users would be further away from Lennox Head (if an alternative access track is provided).

If an access track is provided to the north it would increase traffic flow along the southern foreshore road, impacting on users of this area, unless this is combined with the provision of an alternate route around the caravan park (see 6.4 Traffic Management, strategy *6.4.2).*

Removal of the track altogether is currently in conflict with Council's policy of permitting 4WD access to the beach.

Costs:
Initial: Medium to high (depending upon option chosen)
Ongoing: Low.

6.4.5 Maintain and Upgrade Existing 4WD Track

If the 4WD beach access track is to be left in its current position, then it should be upgraded. This should involve raising the dune at this location, rehabilitation of the dune vegetation, and the construction of a vehicular board and chain accessway, as recommended by the Soil Conservation Service of NSW.

Advantages:
The track is used regularly and is consistent with Council's policy of permitting 4WD access to the section of Seven Mile Beach from the access track to the north.

Upgrading of the track would reduce the risk of dune breakthrough at this location by reducing erosion of the dune.

Disadvantages:
Traffic flow along the eastern foreshore area is increased by the presence of the 4WD track. Associated impacts include conflict with users, and erosion along road fringes. Currently people using the track are using the lake reserve as a route to get to the beach, which conflicts with people using the lake for recreational purposes.

This strategy is incompatible with the strategy of blocking the eastern foreshore road to traffic altogether.

Even following upgrading, the 4WD accessway would continue to be a relatively 'weak' point in the dune system.

Costs:
Initial: Medium
Ongoing: Low (although potentially high in the long term should the dune be breached at this location).

6.4.6 Prohibit Foreshore Parking

Parking along the foreshore of the lake would be restricted (through the provision of physical barriers) and designated parking areas would be provided elsewhere. Some of the areas that have been suggested for the provision of car parking include:

- Turning Ross Street into a one-way street with rear-to-kerb parking on the northern side. Minimal parking facilities and disabled parking facilities would be provided within the lake reserve. A pedestrian thoroughfare (possibly through the caravan park) could be provided to link Ross Street with the lake reserve.
- Providing parking facilities on the southern side of the lake between the southern foreshore road and the caravan park.
- Reclaiming a section of the caravan park nearest to the surf club for a parking area and relocating those camping sites to the west of the caravan park site.

Advantages:
Improves the recreational and visual amenity of the lake foreshore reserves.

Reduces the amount of damage occurring to riparian vegetation and subsequent erosion.

Allows vehicular contaminants (e.g. hydrocarbons) to be better managed through the use of porous pavements and stormwater control systems at drain outlets.

Depending on the number of spaces provided it would ease the current shortfall in parking during peak periods.

Disadvantages:
If additional parking is provided within the lake catchment this would also lead to increased traffic around the lake, particularly during peak periods. The provision of parking areas on the southern foreshore area would also encourage the use of these facilities by patrons of the caravan park, further adding to the traffic around the lake.

The provision of purpose-built parking areas reduces the amenity of that portion of land designated for parking. This does not apply to the Ross Street option as this land is already a road surface.

The option of occupying the eastern-most section of the caravan park involves removing prime camping sites that are close to both the beach and the lake.

Costs:
Initial: Medium to high (depending on option chosen and number of parking spaces provided)
Ongoing: Low.

6.5 Recreation

6.5.1 Do Nothing

Maintain recreational facilities and the management of recreational activities at their current level.

Advantages:
No capital expenditure required.

Disadvantages:
Would have low community acceptance since recreation is one of the identified key values of Lake Ainsworth.

Fails to address the recreational issues, many of which are likely to be exacerbated in the long term as regional population, and hence lake usage, increases.

Has the potential to impact on tourism in the long term as recreational facilities become inadequate, or are viewed to be inadequate.

Costs:
Initial: Low
Long-term: Potentially high (through loss of recreational amenity and tourism).

6.5.2 Provide Launching Area for Sailboats and Sailboards

This would involve upgrading the existing area on the eastern foreshore with a launching ramp and foreshore facilities (e.g. jetty and/or pontoon) or alternately, providing new launching facilities elsewhere (e.g. south-west of the swimming area). This second option may be preferred if the removal of the eastern access road is chosen as an option.

Advantages:
Would provide launching facilities for a chosen range of water levels.

Would reduce localised erosion in the vicinity of launching areas.

Provides for easier access to sailing vessels.

The existing catamaran and sailboard hire site is a suitable distance away from the swimming area in the south-east corner of the lake.

Disadvantages:
Facilities would largely be used from mid-spring to mid-autumn.

In the absence of other recreational facilities may be viewed as favouring one particular user group.

Costs:
Initial: Medium to high (depending on extent of facilities)
Ongoing: Low.

6.5.3 Upgrade Picnic and BBQ Facilities

Provision of new electric BBQs and improved picnic facilities, and replacement of existing wood-fired BBQs with electric BBQs. If the eastern road is closed then additional facilities could be provided along the eastern foreshore where toilet facilities are already provided.

Advantages:
Would reduce the load on the existing facilities particularly during holiday periods and distribute picnickers around the southern and eastern foreshores. This would reduce the stresses on the south-east corner of the lake.

Replacement of wood-fired BBQs with electric BBQs would reduce damage to vegetation caused by people gathering kindling to light fires.

Disadvantages:
Requires capital expenditure.

Additional facilities may be under-utilised outside of peak season.

Costs:
Initial: Would depend on the number of new BBQs and picnic tables provided and existing ones replaced (potentially medium to high).
Ongoing: Low.

6.5.4 Provide Pedestrian Access Paths and Walking Tracks

This strategy would involve constructing pedestrian access paths and walking tracks/ boardwalks around the lake. Concrete paths could be provided on the eastern and southern foreshore areas that could also serve as bicycle tracks. It has been suggested that a minimum impact raised timber boardwalk be provided on the western side of the lake that could link with a similar structure to be constructed from the Sport and Recreation Centre in the north. This walkway would be designed to pass through all of the vegetation types with educational plaques at strategic locations to explain the various habitats.

Advantages:
This would provide improved access for pedestrians as well as reducing damage to vegetation and hence minimising erosion.

Would provide a minimal impact usage for the western side of the catchment that would be consistent with the desire to preserve the visual amenity and ecological importance of this area. It would also provide educational benefits and would reduce some of the pressures on the south-eastern side of the lake.

Disadvantages:
Pathways on the south-eastern side of the lake would encroach on grassy reserve areas unless combined with traffic management strategies of blocking the foreshore roads (see 6.4 Traffic Management).

Costs:
Initial: Medium to high (depending on the options chosen)
Ongoing: Low.

6.5.5 Provide Designated Swimming and Watercraft Areas

This strategy involves ensuring that designated swimming and watercraft (sailing/canoeing) areas are provided, particularly during high usage months, and ensuring that these areas are adequately explained through appropriate signage and education. The existing swimming area is difficult to distinguish from the water, which may lead to sailcraft inadvertently straying into this zone. An information board at the entrance to the lake and in the vicinity of the launching areas, which provides a map of the lake showing the various uses permitted in different zones, may be useful. When hiring sailing equipment, clients should be made aware of the restricted areas (see 6.9 Education).

The use of buoys to delineate swimming zones from other areas has been suggested, however it has proved difficult to maintain buoys in Lake Ainsworth in the past due to theft and/or vandalism. Another suggestion has been to provide a floating pontoon offshore from the swimming area that could serve to delineate the swimming area from the rest of the lake as well as easing the load on the foreshore from swimmers during peak periods.

Advantages:
Separates swimmers from sailors to avoid conflict between the two groups and reduce the risk to swimmers in particular.

An offshore pontoon would visibly delineate the swimming area from the boating areas and would be obvious from the water. It would have the added benefit of easing congestion on the foreshore during peak periods.

Disadvantages:
Policing of these zones could be problematic.

Costs:
Initial: Low (with pontoon potentially low to medium)
Ongoing: Low.

6.5.6 Provide an alternative location for the Lennox Markets

Markets are held on the second and fifth Sunday of each month on the southern foreshore area of Lake Ainsworth. Several public submissions were received suggesting that the markets should be relocated away from the lake. The main areas of concern regarding siting of the markets at the lake are:

- The intensive use of the southern foreshore when the markets are on damages the riparian vegetation.
- The markets and associated pedestrian movement conflict with traffic attempting to access Camp Drewe. There has also been concern expressed regarding emergency access to this facility. Access problems were heightened when the eastern road to the Sport and

Recreation complex was closed by flooding, necessitating the movement of one market to Ballina, and vehicular access being made through the Council caravan park (with professional traffic redirection) for several of the other market days. Such a situation would be a permanent result if the eastern road to the Sport and Recreation complex were closed and the southern road to Camp Drewe and the Sport and Recreation complex were to remain open.

- There has been comment that there has been wind-blown material entering the lake on market days.

This issue of the markets was discussed at the value management workshop (see Section 1.4.8). The consensus at this workshop was that markets are an important asset for Lennox Head and the lakeside location provides them with a unique setting that sets the Lennox Markets apart from others in the region. It was also agreed at this workshop that the main issue associated with the markets being held at the lake is one of traffic congestion and inappropriate parking, and that if these issues are dealt with then there should not be a need to move the markets elsewhere.

Advantages:
Relocating the markets would potentially reduce damage to riparian vegetation on the southern side of the lake and reduce traffic in the local vicinity during the one or two days per month when the markets are normally held.

Disadvantages:
The main issues associated with the use of the markets are traffic congestion and damage associated with a lack of formal parking, and disruption to traffic trying to access the western road (e.g. Camp Drewe). If these traffic management issues are solved independently by an alternative route around the caravan park then there should not be a need to relocate the markets.

The markets are an important asset for Lennox Head and the lakeside location provides them with a unique setting that sets the Lennox Markets apart from others in the region. Shifting to a less unique location is likely to result in a corresponding decrease in patronage.

6.6 Ecology

6.6.1 Management of Aquatic Weeds Within the Lake

This strategy involves ensuring that the spread of water primrose and other aquatic weeds is controlled. A trial hand removal program of water primrose has been conducted by Don Apps of Lennox Head Dune Care over a two-year period along the lake's eastern margin. This program amply demonstrated that five man-days in the first year followed by four days in the subsequent year was sufficient to remove the major infestation of water primrose. A similar effort is urgently required along the western lake margin as water primrose currently covers a significant portion of the lake. Other aquatic species (e.g. salvinia) are of lesser concern but require monitoring. There has been release of a biological control agent to combat salvinia in the lake. This was believed to have occurred a number of years back with NSW Agriculture at Grafton having been involved. This may be the reason why salvinia is now of lesser concern.

Advantages:
Reduces ecological impacts such as stratification of water column and low dissolved oxygen levels.

Disadvantages:
None.

Costs:
Initial: Low and easily quantifiable. Assistance can be obtained from Green Corps and other bodies (e.g. individual undertaking community service hours)
Ongoing: Low

6.6.2 Management of Terrestrial Weeds Around the Lake's Margin

The management of the coastal dunes and the lake margin has been successfully undertaken over the past decade by the Lennox Head Dune Care group. More recently, the Lennox Head Residents Association and the staff, especially Mr Phil Buckland, of the Lake Ainsworth Fitness Camp have undertaken some significant regeneration and management programs.

The increase in species richness as a result of these programs is remarkable and contrasts with areas of coastal dunes to the south of the site that are heavily infested with bitou bush. Much of the dune management work in the immediate vicinity of the lake and Sport and Recreation Centre has been completed. However, bitou bush is known to spread seeds at a rate of 4,000 per m^2 and will require monitoring and management for a considerable period of time.

The management programs undertaken to date allow for accurate predictions of the effort and costs required to complete. Council should liaise with the stakeholder groups to determine their needs and priorities.

Advantages:
Provides an increase in biodiversity, maintenance of stable dune systems, aesthetic improvement of coastal scenery and educative role in dune management.

Strategic placement of plants can be used to restrict and regulate pedestrian and vehicular movements and thus minimise erosion.

Disadvantages:
None.

Costs:
Initial: Low and easily quantifiable. Assistance can be obtained from Lennox Head Dune Care, Lennox Head Residents Association and Green Corps.
Ongoing: Low and readily quantifiable.

6.6.3 Management of Introduced Fauna

Two introduced vertebrate species, the mosquito fish and cane toad, are known to impact on native animal assemblages.

The Scientific Committee, established by the *Threatened Species Conservation Act*, recently made a final determination to list predation by *Gambusia holbrooki* (mosquito fish or plague minnow) as a key threatening process under Schedule 3 of the Act. However, programs to eradicate or reduce the density of this species are unavailable.

The cane toad is also known to impact on native fauna and some management strategies have been recommended to reduce their density. The most practical management option is the revegetation of riparian margins and the reduction of grassed areas near water bodies (Seabrook 1991).

Advantages:
Management of the cane toad by the revegetation of the lake margin and the reduction in grassed areas can be undertaken simultaneously with landscaping for erosion control and aesthetic purposes. These works are likely to increase the diversity of native animals.

Disadvantages:
Some loss of grassy open space for recreational and picnic purposes.

Costs:
Initial: Low and quantifiable. Assistance can be obtained from Lennox Head Dune Care, Lennox Head Residents Association and Green Corps.
Ongoing: Low and quantifiable.

6.7 Planning and Development

6.7.1 Do Nothing

The lake and its surrounds are currently zoned 7(f) – Environmental Protection (Coastal Lands). Listed as being permissible with the development consent of Council within this zone are:

agriculture; beach amenities; bed and breakfast establishments; bush fire hazard reduction; camping grounds; caravan parks; community buildings; drainage; dwelling-houses; environmental educational facilities; environmental protection works; forestry; golf courses; helipads; home industries; open space; pipelines associated with aquaculture; picnic grounds; recreational establishments; recreation facilities; refreshment rooms; roads; surf club houses; utility installations.

Advantages:
Allows for, with Council consent, a variety of uses and developments within the as yet undeveloped catchment areas.

Disadvantages:
The primary objectives of the 7(f) zoning, as outlined in the Ballina LEP (1987) are:

(a) to protect environmentally sensitive coastal lands; and
(b) to prevent development which would adversely affect or be adversely affected, in both the short and long term, by the coastal processes.

It could be argued that some of the permissible developments listed above, such as golf courses, dwelling-houses, caravan parks and camping grounds, and forestry and agriculture, would not serve to protect the environmentally sensitive nature of the lake's catchment, but could adversely affect the lake processes both in the short and long term.

Costs:
Initial: Low
Ongoing: Potentially high depending on types of development approved.

6.7.2 Control Development and Usage of Existing Undeveloped Crown Land

Modify the Ballina LEP to restrict further development of existing undeveloped Crown land on the western side of the lake (exact area to be determined) to allow only minimal low impact recreational development, environmental educational facilities, environmental protection works, drainage and bushfire hazard reduction. An example of the type of development that may be permitted would be an elevated walking track (see 6.5 Recreation, strategy 6.5.4).

This would be achieved by either the creation of a new land use zone for the identified area, or by incorporating into the LEP a 'Special Provisions' clause limiting development in the area to these uses listed above.

Advantages:
This would maintain the natural western backdrop, which has been identified as one of the valued features of the lake, and would preserve the habitat value of this area.

It is consistent with the objectives of the 7(f) zoning.

Disadvantages:
Further restricts the type of development permitted within undeveloped areas of the catchment.

Costs:
Low.

6.7.3 Provide Additional Storage Facilities Adjacent to the Lennox Head–Alstonville SLSC

The surf club is the largest on the far north coast of NSW and is growing more rapidly than other clubs. The space currently available to the SLSC is deemed to be insufficient to meet the projected future needs. Specifically, a substantial storage area of about 150 to 200 m^2 is required somewhere close to the club to house the larger equipment such as rescue boats, rescue vehicle, skis and boards. This storage area would need to have ready access to both the beach and the lake (public submission, Lennox Head–Alstonville SLSC).

Advantages:
Would allow the Lennox Head–Alstonville SLSC to grow in response to the needs of the increasing regional population.

Reduces pressures on the existing facilities and resources of the surf club.

Disadvantages:
Land availability nearby to the surf club is limited. Development of land adjacent to the existing club would involve encroachment onto the dune system and/or existing parking facilities. The land opposite to the surf club is currently occupied by the caravan park.

Improved facilities, allowing increased membership and patronage of the surf club, will increase pressures associated with recreational use of the lake.

Costs:
Low to high depending on the type and extent of facilities provided.

6.8 Erosion and Sedimentation

6.8.1 Do Nothing

The surface runoff catchment for the lake is relatively small and this is reflected in the low estimated historical sedimentation rate of 0.4 mm per year (AWACS 1996). The examination of aerial photographs dating back to the 1940s showed no sign of significant foreshore erosion in the lake (AWACS 1996). Some localised foreshore erosion was identified from concentrated drainage paths, pedestrian movements and at road fringes but overall erosion is generally being controlled by present vegetation rehabilitation activities. However, increased usage of the lake, associated with unregulated vehicular and pedestrian movements could increase the level of erosion and hence the amount of sediment entering the lake. (Refer to 6.3 Coastal Dunes for the issue of coastal erosion).

Advantages:
Foreshore erosion is generally not a significant problem at present and to date has generally been mitigated by vegetation rehabilitation activities.

Disadvantages:
Could develop into a problem in the not-too-distant future if appropriate preventative management strategies are not adopted.

There is some public perception of foreshore erosion being a problem in certain areas, particularly along the southern side of the lake.

Costs:
Initial: Low
Ongoing: Depends on the extent of the problem, which may or may not develop.

6.8.2 Control and Regulate Vehicular and Pedestrian Movements

Involves restricting vehicular and pedestrian movements to specific areas to minimise damage to riparian vegetation and in so doing minimising erosion. Refer to 6.4 Traffic Management and 6.5 Recreation.

Advantages:
Disadvantages: Refer to 6.4 Traffic Management and 6.5 Recreation.
Costs:

6.8.3 Continue and Enhance Current Riparian Flora Management Strategies

The Lennox Head Dune Care group has successfully undertaken the management of the coastal dunes and the lake margin over the past decade. More recently, the Lennox Head Residents Association and the staff, especially Mr Phil Buckland, of the Lake Ainsworth Sport and Recreation Centre have undertaken some significant regeneration and management programs. Future activities could be co-ordinated with vehicular and pedestrian management strategies to further enhance the native riparian vegetation of the lake and aid in minimising further erosion.

Advantages:
Disadvantages: Refer to 6.6 Ecology.
Costs:

6.9 Education

6.9.1 Provision of an Information/Education Display Board

An information display board could be provided near the south-eastern entrance to the Lake Ainsworth reserve. Containing a large map of the lake, the board could be used for a variety of purposes including:

- Advising of the location and type of recreational facilities available (i.e. public amenities, BBQs, sailcraft launching areas, parking areas, disabled access facilities, waste disposal areas, walking tracks etc.)
- Highlighting restricted usage zones (i.e. swimming and sailing areas).
- Advising of the latest contact recreational status of the water (i.e. is it suitable for swimming) and the fire hazard status of the reserve.
- A section on public management strategies advising users of the lake on steps that they can take to help maintain and improve the qualities of Lake Ainsworth (e.g. appropriate removal or disposal of dog droppings and litter; avoid using excess sun screen, vegetation conservation).
- Advising on current management strategies aimed at reducing the occurrence of algal blooms (e.g. trial aeration system).
- Providing dates of upcoming events (e.g. the next market day, surf carnivals, sailing regattas).
- Providing contact numbers to report matters of concern or obtain more information (Council, Dune Care, and Ballina Environment Society).

The board should be placed in a visible and readily accessible location but not in a way that will detract from the visual amenity of the lake itself. Information provided should be concise and where possible in pictorial format. The board should be designed to enable the information on it to be readily updated.

Advantages:
Advises users of the importance of the lake and the implications of their actions on lake processes, and therefore reduces the risk that some of the damage and problems associated with usage of the lake are occurring through the ignorance of lake users.

It is an efficient means of educating and providing information as it specifically targets those people who use the lake.

It is relatively inexpensive.

Disadvantages:
None.

Costs:
Initial: Low
Ongoing: Low.

6.9.2 *Educating and Informing Sailcraft Users of Sailing/Swimming Zones*

Sailcraft users should be informed of the restricted swimming areas to avoid conflict with swimmers. As well as advising of these areas on an information display board (see strategy 6.9.2) hire operators should be required to advise people hiring sailcraft of these restricted areas. Hire operators could also be invested with the responsibility of 'policing' these areas by warning sailors who stray into swimming zones.

Advantages:
Ensures that tourists and non-regular sailcraft users are advised of the permitted sailing zones.

Investing the sailcraft hire operators with the role of enforcing the restricted sailing zones ensures that these zones will be 'policed' during peak periods.

Disadvantages:
Imposes further responsibility on the sailcraft hire operators.

Costs:
Low.

6.10 Lake Water Level and Flooding

6.10.1 Do Nothing

The issue of flooding of the foreshore of the lake was brought to prominence as a result of an extended period of elevated water levels in 1999. During this period the eastern access road to the Sport and Recreation Centre was inundated, blocking access to the centre via this route. The section of road leading to the 4WD beach access track was also cut; however, it was reported that some 4WD users were continuing to use the flooded road to access the beach. High water levels also inundated significant areas of foreshore land, in the process flooding vegetation and reducing the recreational amenity of the area. Increased traffic use of the western road when the eastern road is blocked can cause conflict with users of the southern foreshore area (e.g. the markets).

Lake water level records are available from late September 1994 onwards. This data was analysed, together with rainfall data over the same period. Water level exceedance statistics for the period of record are shown in Figure 6.1. Annual and monthly rainfall statistics over the same period are presented in Figures 6.2 and 6.3 respectively.

Figure 6.1 shows that between September 1994 and October 1999 the water level in the lake exceeded the lowest point on the eastern road about 7.5% of the time. The levels of some of the other facilities around the southern and eastern foreshores of the lake are provided in Table 6.2.

Table 6.2 Reduced Levels of Foreshore Facilities

Facility	Reduced Level (m AHD)
Picnic tables	2.71, 2.80, 2.99, 3.19, 3.91 and 4.69
BBQ	3.29
Public toilets (near 4WD access track)	4.14

The annual rainfall statistics for Lake Ainsworth show that during this period 1996 and 1999 were above average rainfall years. 1999 was a particularly high rainfall year, with more than 2,500 mm of rainfall recorded to the end of October, compared with the long-term average annual rainfall of 1,689 mm. The lake water level tends to respond almost immediately to high intensity rainfall events. Figure 6.3 shows monthly rainfall at Lake Ainsworth between September 1994 and October 1999, together with the long-term average monthly rainfall for the far north coast, and those months during which the lake water level reached the lowest point of the eastern road. The lake water level reached the level of the eastern road during six months in this period, from June to October 1999, and in June 1996. In both cases the elevated water levels were triggered by high rainfall, with rainfalls at or above 400 mm for the month. In 1999, the water was maintained at an elevated level by ongoing monthly rainfalls that were considerably higher than the long-term average. Another contributing factor appears to be evaporation, with all recorded high water level events over the period occurring during the months associated with lower evaporative losses.

While flooding has been an issue during much of 1999, the available information suggests that it is an infrequent occurrence. In fact, input from stakeholders and community representatives (Value Management Workshop, 29 November 1999), suggested that although flooding may be seen as a minor issue at the moment, it is generally not as problematical as low water levels.

Advantages:
No requirement for capital expenditure.

Allows the natural processes to proceed.

Flooding is an infrequent occurrence, hence most of the time it is not an issue.

Disadvantages:
Fails to address present issues and concerns regarding flooding, therefore likely to have low community acceptance.

In the long term water levels could increase due to climatic changes, hence flooding could become more prevalent.

Costs:
Low.

6.10.2 Implement Strategies to Mitigate the Effects of the Natural Variation of the Lake Water Level

Various strategies could be implemented to deal with cutting off the access road to the Sport and Recreation Centre, sailboard/boat launching area, 4WD track, and picnic facilities. Strategies to be considered include:

- Artificially blocking passage along the eastern road when the water reaches a predetermined level (say 2.8 m AHD), and redirecting traffic to the Sport and Recreation Centre via the western road.
- Postponing, rescheduling, or moving events that utilise the southern foreshore area (e.g. the markets) during periods when traffic is being redirected.
- Preventing access to the 4WD track when the water reaches a predetermined level (say 2.8 m AHD) or provide an alternate access track to the north of the lake (see 6.4 Traffic Management).

Ensure that littoral and riparian revegetation schemes incorporate species that are tolerant to infrequent but potentially prolonged periods of inundation.

Placement of new and/or replacement of existing recreation facilities (BBQs, walking paths etc.) beyond levels likely to be inundated for prolonged periods.

Implement strategies to mitigate post-flooding impacts (e.g. fencing off foreshore areas and/or mulching of foreshore areas to allow vegetation to recover and minimise erosion).

Advantages:
Addresses flooding issues and concerns.

Allows the natural lake processes to proceed unhindered.

Disadvantages:
Requires that a range of strategies be implemented to fully address the issues.

Many strategies are reactionary (e.g. fencing off sections of foreshore) which would require protocols and systems in place to enable them to be promptly implemented after prolonged periods (several years) without flooding.

Costs:
Would vary depending on the strategies adopted.

6.10.3 Implement a System to Control/Regulate Lake Water Level

Predetermined or adjustable high water level off-take system to transfer lake water to the west of the catchment. This may be in the form of a spillway, viaduct or culvert system, or by mechanically pumping the water. An environmental assessment of the impact of diverting offtake water into adjoining plant associations will need to be undertaken prior to the adoption of this option.

An emergency drawdown system to lower the lake level during peak periods, e.g. by pumping the water over the dune to the ocean when the lake level is high during peak periods. Erosion mitigation devices will need to be installed to avoid loss of dunal sands should this option be adopted.

Advantages:
Allows the water level of the lake to be set or adjusted according to operational requirements.

The system of bypassing water to Newrybar Wetlands to the west could potentially be linked with the flushing strategy to reduce the incidence of algal blooms.

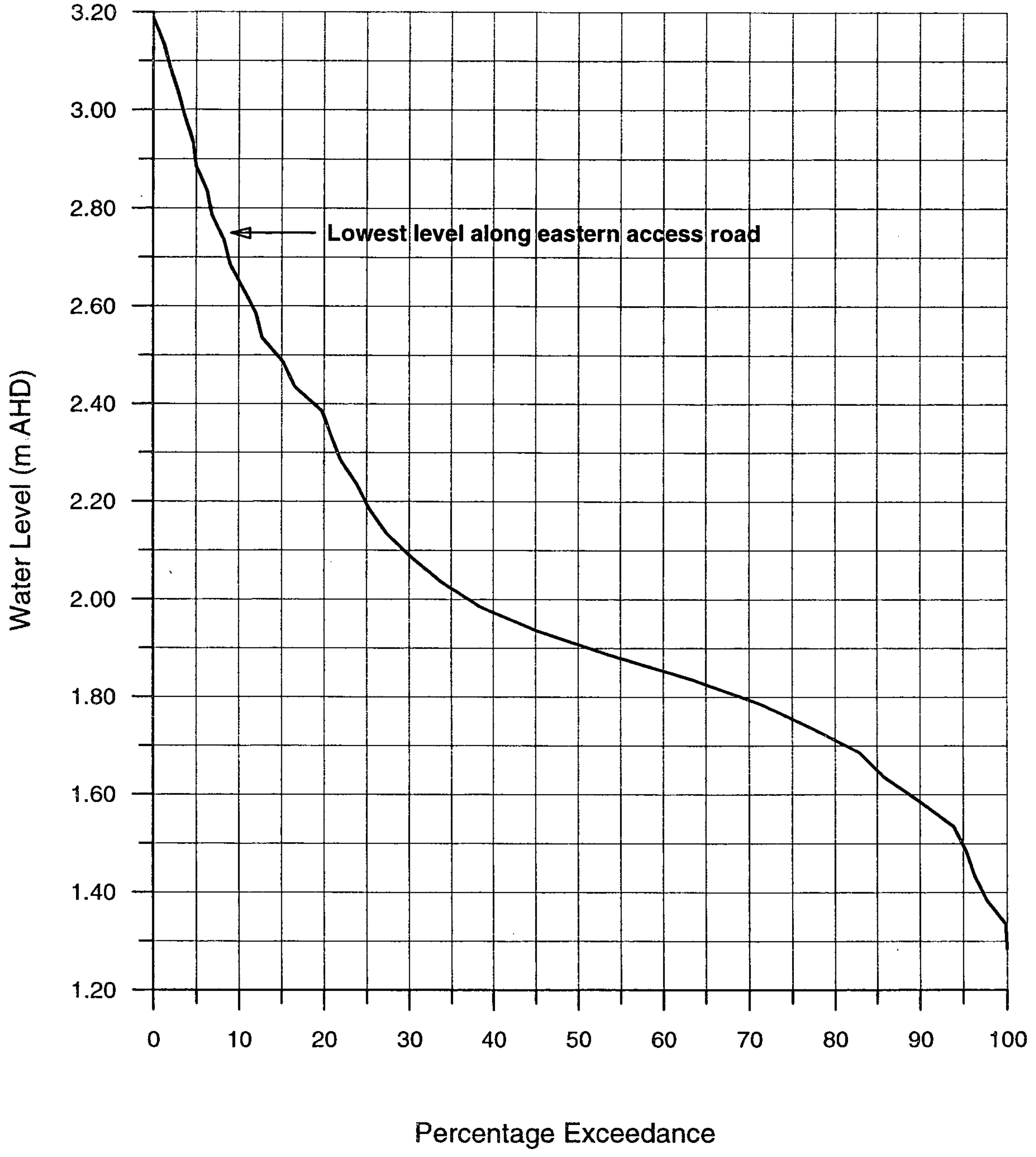
Disadvantages:
Would alter the natural processes of the lake with potentially undesirable effects on aquatic ecology.

During drawdown or bypass situations the lake would become a local groundwater 'sink', altering the groundwater flow patterns. Possible implications of this would include the redirection of elevated nutrient levels in the groundwater of Lennox Head township toward Lake Ainsworth.

The impact on the groundwater resource and on Newrybar Wetland generally is uncertain. Detailed assessment of the quality and quantity of groundwater, the hydraulic requirements of the system, and the impacts of surface water discharge to the wetland would be required.

Approvals for such systems would be required under Part 5 of the *Environmental Planning and Assessment Act 1979*.

Costs:
Initial: medium to high
Ongoing: would depend on system chosen and frequency of operation.



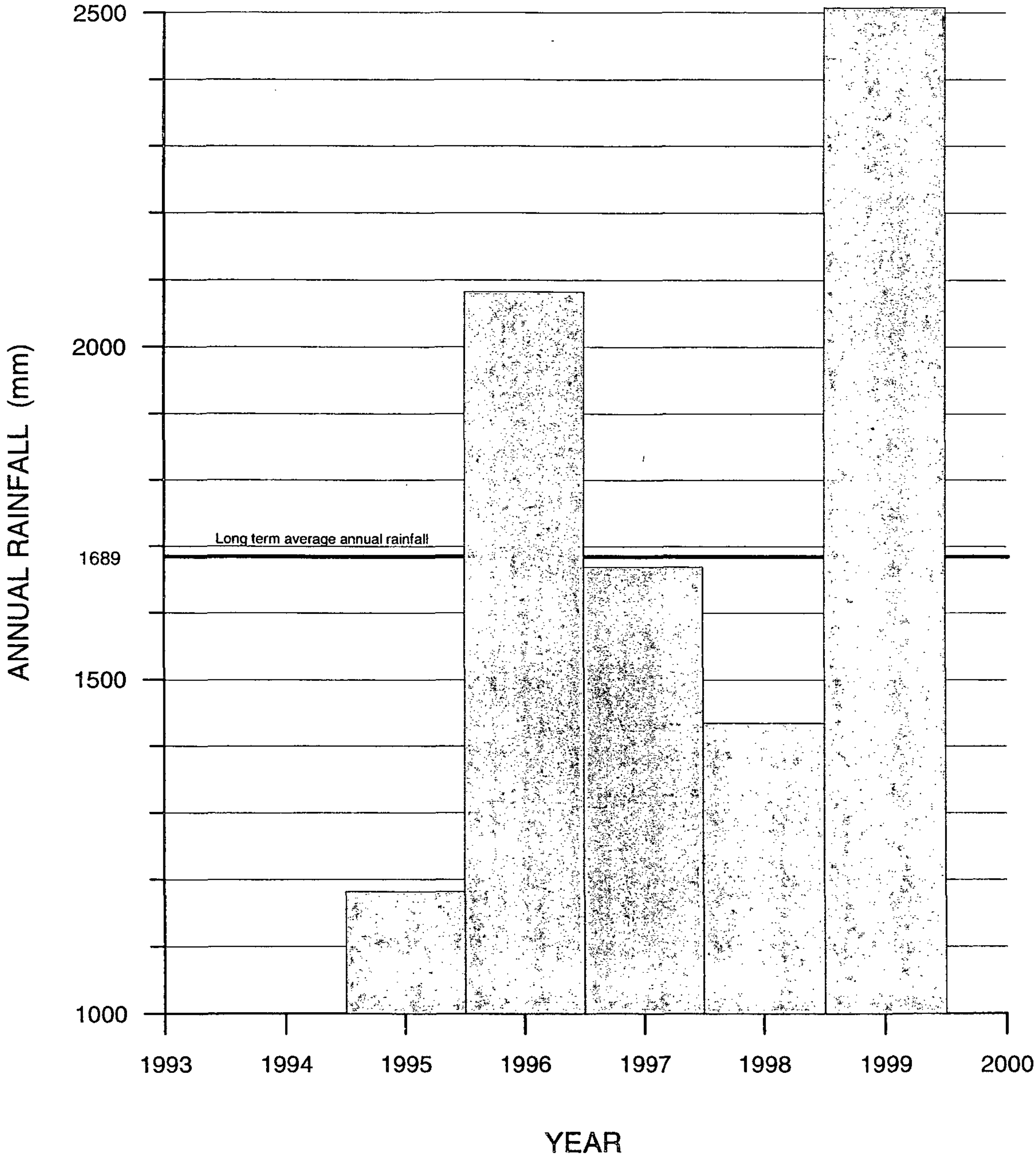
NSW DEPARTMENT OF PUBLIC WORKS AND SERVICES
MANLY HYDRAULICS LABORATORY

WATER LEVEL EXCEEDANCE STATISTICS OVER PERIOD OF RECORD 30 SEPTEMBER 1994 TO 21 OCTOBER 1999

MHL Report 1010

Figure 6.1

DRAWING 1010LA62.CDR



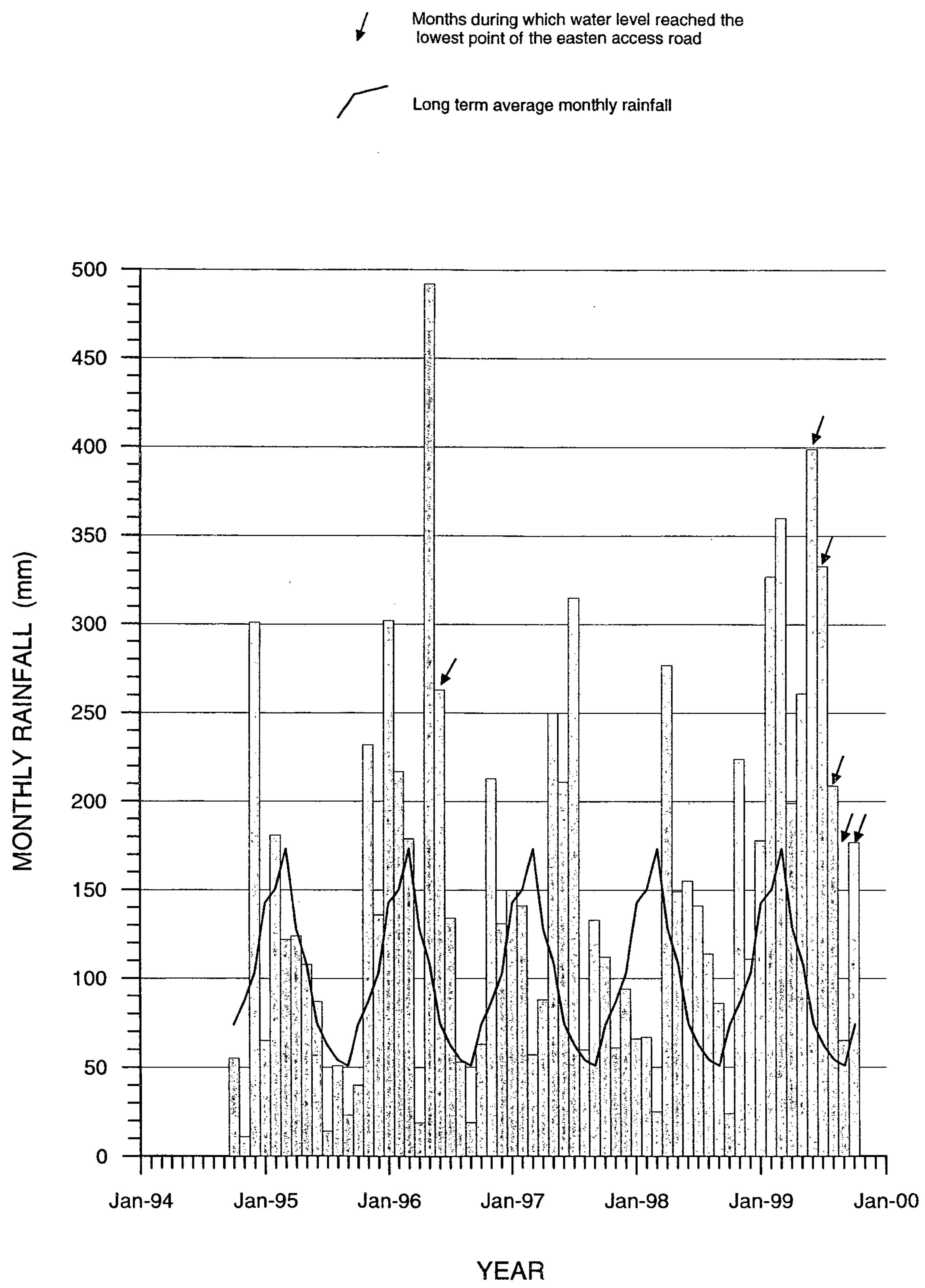
NSW DEPARTMENT OF PUBLIC WORKS AND SERVICES
MANLY HYDRAULICS LABORATORY

ANUAL RAINFALLS FROM 1995 TO 1999 (UP TO OCTOBER)

MHL Report 1010

Figure 6.2

DRAWING 1010LA63.CDR



NSW DEPARTMENT OF PUBLIC WORKS AND SERVICES
MANLY HYDRAULICS LABORATORY

MONTHLY RAINFALLS FROM OCTOBER 1994 TO OCTOBER 1999

MHL Report 1010

Figure 6.3

DRAWING 1010LA64.COR

7. Comparison of Strategies

7.1 Comparison and Ranking of Strategies

A comparison of the strategies that were assessed in Section 6 is provided in Tables 7.2 to 7.10. A legend explaining the symbols and terms used in these tables is provided in Table 7.1. This table is also provided as a 'fold-out' A3 page behind Tables 7.2 to 7.10 for ease of reference.

Table 7.1 Legend of Symbols and Terms used in Tables 7.2 to 7.10

Column Heading	Symbol/Term	Description
Category	SC W E EM R	Statutory Controls and Policies Rehabilitation and Improvement Works Community Education and Awareness Environmental Monitoring Further Research
Advantages vs. Disadvantages	-- - ≈ + ++	Disadvantages significantly outweigh advantages Disadvantages slightly outweigh advantages Advantages and disadvantages approximately equal Advantages slightly outweigh disadvantages Advantages significantly outweigh disadvantages
Objectives Targeted Primary Secondary	e.g. 5.1.2 (A)	Relates to the particular management objective (primary or secondary) described in Section 5
Costs Initial and Ongoing	Low Medium High Very High	< $50,000 $50,000 to $100,000 $100,000 to $500,000 > $500,000
Short-term or Long-term Strategy	Short Term Long Term	Could be implemented within one calendar year Would take longer than one calendar year to implement or may be implemented some time in the future pending availability of funding and results of further research and/or monitoring programs.

Column Heading	Symbol/Term	Description
Community Support		% results presented here are based on the number of responses to individual questions in the second community consultation survey. 219 respondents completed the survey. Other comments relate to additional submissions or comments received.
Priority Ranking	0 to 3	Lowest priority (not recommended) Highest priority (high likelihood of success – implementation to be considered) Each management strategy was given a priority ranking by four members of the study team independently (from 0 – lowest, to 3 – highest). The number in this column represents the average of those four independent rankings. When assigning these rankings, strategies within each grouping (e.g. Water Quality) were compared.
Aggregate Score	0 to 12	Lowest Highest This number represents the sum of the four independent priority rankings for each strategy, hence the possible range of aggregate scores between 0 and 12. In the case where more than one strategy had the same priority ranking, the aggregate score was used to differentiate between strategies.

Table 7.2 Comparison of Water Quality Strategies

Management Strategy	Category	Advantages vs. Disadvantages	Objectives Targeted		Costs		Long-term or Short-term Strategy (L,S)	Community Support (based on survey results)	Priority Ranking 0 – low 3 - high	Aggregate Score 0 to 12
			Primary	Secondary	Initial	Ongoing				
6.2.1 Algal Blooms										
6.2.1.1 Biomanipulation	W	-	5.1.1 (A,B)		?	?	L	Support investigation (52%)	2	6
6.2.1.2 Sediment Removal	W	--	5.1.1 (B)		High to very high	-	L	Some support for investigation (26%)	1	5.5
6.2.1.3 Sediment Capping (Lime, Alum or Proprietary Product Dosing)	W	≈	5.1.1 (B)		Medium to high	?	S	Little support (6%)	2	6.5
6.2.1.4 In Situ Sediment Treatment (Limnofix Inc.)	W	?	5.1.1 (A,B)		?	?	S/L	Little support (5%)	1	4
6.2.1.5 Aeration	W	+	5.1.1 (A,B)		High	Low	S	Majority support for continuing trial (94%)	2	9
6.2.1.6 Ozonation	W	--	5.1.1 (B)		High	Low	S	Some support (25%)	0	1
6.2.1.7 Enhanced Flushing by Groundwater	W	-	5.1.1 (B)		Medium to High	(Low ?)	S/L	Some support (18%), however also opposition (2 respondents)	2	6.5
6.2.1.8 Mechanical Water Filtration System	W	-	5.1.1 (B)		?	?	L	Some support (36%)	1	5
6.2.1.9 Chemical Dosing - Use of Alum and Gypsum	W	--	5.1.1 (B)		?	?	S	No support	0	1
6.2.1.10 Chemical Dosing - Use of Copper Sulphate and Coptrol	W	--	5.1.1 (B)		?	?	S	No support	0	0

Management Strategy	Category	Advantages vs. Disadvantages	Objectives Targeted		Costs		Long-term or Short-term Strategy (L,S)	Community Support (based on survey results)	Priority Ranking 0 – low 3 - high	Aggregate Score 0 to 12
			Primary	Secondary	Initial	Ongoing				
6.2.2 Lake and Groundwater Quality										
6.2.2.1 Do Nothing		≈	5.1.1 (A)		Low	?	S	Not in survey	1	5
6.2.2.2 Water Quality Improvement Strategies	W, E, SC	++	5.1.1 (A) 5.1.4 (C)	5.2.2 (B) 5.2.4 (A)	Low to Medium	(Low ?)	S/L	Not in survey. However some support for strategies in additional comments	3	12
6.2.3 Monitoring										
6.2.3.1 Continue with Current Monitoring Programs	EM, R	≈	5.1.4 (D) 5.1.1 (B)	5.2.8 (B)	?	?	S	Not in survey	1	4
6.2.3.2 Develop New Guidelines and Monitoring Systems Specific to Lake Ainsworth	EM	+	5.1.1 (A) 5.1.4 (D) 5.1.5 (A, B) 5.1.6 (B)	5.2.6 (A) ? 5.2.7 (A) ?	Low to Medium	Low to Medium	L	Not in survey	3	12

Table 7.3 Comparison of Coastal Dune Strategies

Management Strategy	Category	Advantages vs. Disadvantages	Objectives Targeted		Costs		Long-term or Short-term Strategy (L,S)	Community Support (based on survey results)	Priority Ranking 0 – low 3 - high	Aggregate Score 0 to 12
			Primary	Secondary	Initial	Ongoing				
6.3.2 Do Nothing		+ (short term) -- (long term)	5.1.2 (A)		Low	Potentially very high long term	S	Not in survey	0	2
6.3.3 Continue Current Dune Rehabilitation Management Practices	W,E	+ (short term) - (long term)	5.1.2 (A) 5.1.4 (B,E)	5.2.2 (A,B)	Low	Potentially high to very high long term	S	Majority support (92%)	3	12
6.3.4 Beach Scraping	W	≈	5.1.2 (A)		?	?	S/L	Some support (15%) when combined with continued dune care	2	9
6.3.5 Beach Nourishment	W	≈	5.1.2 (A)		?	Medium to high	S/L	Some support (15%)	2	6
6.3.6 Terminal Revetment (Sea Wall)	W	≈	5.1.2 (A) ?		Very high	Low	L	Little support (7%)	2	7

Table 7.4 Comparison of Traffic Management Strategies

Management Strategy	Category	Advantages vs. Disadvantages	Objectives Targeted		Costs		Long-term or Short-term Strategy (L,S)	Community Support (based on survey results)	Priority Ranking 0 – low 3 - high	Aggregate Score 0 to 12
			Primary	Secondary	Initial	Ongoing				
6.4.1 Do Nothing		--	N/A		Low	Potentially high long term	S	Not in survey	0	1
6.4.2 Close the eastern and southern foreshore roads and provide a new route outside of the caravan park.	W	++	5.1.3 (A) 5.1.4 (A) 5.1.6 (A,B)	5.2.2 (A,B)	High to Very High	Similar to current maintenance costs	L	Support closure of eastern rd (60%). Of the respondents for the closure, 57% support the new route	3	12
6.4.3 Close the eastern road to traffic, with access to the north via the southern foreshore	W	+	5.1.3 (A) 5.1.4 (A) 5.1.6 (A,B)	5.2.2 (A,B)	High	Similar to current maintenance costs	L	Support closure of eastern rd (60%). Of the respondents for the closure, 39% support continued access to the north via the southern foreshore	2	8.5
6.4.4 Remove or relocate the 4WD beach access track	W	++	5.1.3 (A) 5.1.6 (A,B)	5.2.2 (A,B)	Medium to High	Low	L	Support closure (66%). Some support for relocation of access (21 respondents)	3	11
6.4.5 Maintain and upgrade the existing 4WD track	W	-	N/A	N/A	Medium	Low	S/L	Not in survey	1	3
6.4.6 Prohibit foreshore parking and provide designated parking areas	W	+ to ++ (depending on option chosen)	5.1.3 (A) 5.1.4 (C) 5.1.6 (A)	5.2.2 (A, B) 5.2.4 (A)	Medium	Low	L	Support for suggested parking areas: Southern side of lake (44%); Caravan Park (37%); Ross St (37%) None (4%)	3	11

Table 7.5 Comparison of Recreation Strategies

Management Strategy	Category	Advantages vs. Disadvantages	Objectives Targeted		Costs		Long-term or Short-term Strategy (L,S)	Community Support (based on survey results)	Priority Ranking 0 – low 3 - high	Aggregate Score 0 to 12
			Primary	Secondary	Initial	Ongoing				
6.5.1 Do Nothing		--			Low	Potentially high long term	S	Not in survey	0	2
6.5.2 Provide a launching area for sailboats and sailboards	W	+	5.1.6 (A, B)	5.2.2 (B)	Medium to High	Low	S/L	Not in survey. Some support for jetty/pontoon in additional comments	2	8
6.5.3 Upgrade picnic and BBQ facilities	W	≈	5.1.4 (A) 5.1.6 (A)		Potentially Medium to High	Low	S/L	Not in survey	2	9
6.5.4 Provide pedestrian access paths and walking tracks	W, E	++	5.1.6 (B)	5.2.2 (B) 5.2.4 (A) 5.2.8 (A)	Medium to High	Low	L	Not in survey. Some support for boardwalk on western side (5 respondents)	3	11
6.5.5 Provide designated swimming and watercraft areas	E	+	5.1.6 (A)		Low (pontoon potentially Low to Medium)	Low	L	Current designated areas considered adequate (82%)	3	11
6.5.6. Provide an alternative location for the Lennox Markets	SC	-	5.1.6 (B)	5.2.2 (A)	Low	Low	S	8 submissions received suggesting relocation	1	4

Table 7.6 Comparison of Ecology Strategies

Management Strategy	Category	Advantages vs. Disadvantages	Objectives Targeted		Costs		Long-term or Short-term Strategy (L,S)	Community Support (based on survey results)	Priority Ranking 0 – low 3 - high	Aggregate Score 0 to 12
			Primary	Secondary	Initial	Ongoing				
6.6.1 Management of aquatic weeds within the lake	W	++	5.1.4 (A,B,D,E)		Low	Low	S/L	Not in survey	3	12
6.6.2 Management of terrestrial weeds around the lake's margin	W, EM	++	5.1.4 (A,B,C,D,E)	5.2.2 (A) 5.2.8 (A)	Low	Low	S/L	Not in survey	3	12
6.6.3 Management of introduced fauna	W, EM	+	5.1.4 (A,B,C,D,E)	5.2.2 (A)	Low	Low	S/L	Majority support for additional foreshore planting (suggested as management tool for introduced fauna) (85%). Majority support for planting around entire lake (70%)	3	11

Table 7.7 Comparison of Planning and Development Strategies

Management Strategy	Category	Advantages vs. Disadvantages	Objectives Targeted		Costs		Long-term or Short-term Strategy (L,S)	Community Support (based on survey results)	Priority Ranking 0 – low 3 - high	Aggregate Score 0 to 12
			Primary	Secondary	Initial	Ongoing				
6.7.1 Do Nothing		--			Low	Potentially high	S	Not in survey	1	3
6.7.2 Control development and usage of existing undeveloped Crown Land	SC	+	5.1.4 (A)	5.2.4 (A) 5.2.6 (A) 5.2.7 (A,B)	Low	Low	L	Not in survey	3	12
6.7.3 Provide additional storage facilities adjacent to the Lennox Head–Alstonville SLSC	W	-	5.1.6 (A)		Low to High		S/L	Not in survey	2	8

Table 7.8 Comparison of Erosion and Sediment Strategies

Management Strategy	Category	Advantages vs. Disadvantages	Objectives Targeted		Costs		Long-term or Short-term Strategy (L,S)	Community Support (based on survey results)	Priority Ranking 0 – low 3 - high	Aggregate Score 0 to 12
			Primary	Secondary	Initial	Ongoing				
6.8.1 Do Nothing		-			Low	?	S	Majority support for existing dunecare (92%)	0	2
6.8.2 Control and regulate vehicular and pedestrian movements	W, E	+	5.1.3 (A) 5.1.6 (B)	5.2.2 (A,B)	Low to Very High (depending on option chosen)	Low / similar to current costs	L	See Table 7.4	3	11.5
6.8.3 Continue and enhance current riparian flora management strategies	W	++	5.1.3 (A) 5.1.4 (A,B,C,E)	5.2.2 (A,B)	Low	Low	S/L	Majority support for additional foreshore planting (suggested as management tool) (85%)	3	12

Table 7.9 Comparison of Education Strategies

Management Strategy	Category	Advantages vs. Disadvantages	Objectives Targeted		Costs		Long-term or Short-term Strategy (L,S)	Community Support (based on survey results)	Priority Ranking 0 – low 3 - high	Aggregate Score 0 to 12
			Primary	Secondary	Initial	Ongoing				
6.9.1 Provision of an information/education display board	E, W	++	5.1.1 (A) 5.1.4 (A,C,E) 5.1.6 (A)	5.2.4 (A) 5.2.8 (A)	Low	Low	S	Not in survey	3	12
6.9.2 Educating and informing sailcraft users of sailing/ swimming zones	E	+	5.1.6 (A)	5.2.8 (A)	Low	Low	S/L	Not in survey. Some support to define swimming/sailing areas with signs (11 respondents)	2	9

Table 7.10 Comparison of Lake Water Level and Flooding Strategies

Management Strategy	Category	Advantages vs. Disadvantages	Objectives Targeted		Costs		Long-term or Short-term Strategy (L,S)	Community Support (based on survey results)	Priority Ranking 0 – low 3 - high	Aggregate Score 0 to 12
			Primary	Secondary	Initial	Ongoing				
6.10.1 Do Nothing		≈	5.1.4 (A,E) 5.1.5 (A,B)		Low	Low	S/L	Majority support for natural water level variation (89%)	1	4
6.10.2 Implement strategies for mitigating the effects of the natural variation of the lake water level	W	≈	5.1.3 (A) 5.1.4 (A) 5.1.5 (A,B) 5.1.6 (B)	5.2.1 (A)	Dependent on options chosen	?	S/L	Not in survey	3	10
6.10.3 Implement a system to control/regulate lake water level	W, SC (?)	-		5.2.1 (A)	Medium to High	Dependent on options chosen	L	Some support (11%)	2	6

Table 7.1 Legend of Symbols and Terms used in Tables 7.2 to 7.10

Column Heading	Symbol/Term	Description
Category	SC W E EM R	Statutory Controls and Policies Rehabilitation and Improvement Works Community Education and Awareness Environmental Monitoring Further Research
Advantages vs. Disadvantages	-- - ≈ + ++	Disadvantages significantly outweigh advantages Disadvantages slightly outweigh advantages Advantages and disadvantages approximately equal Advantages slightly outweigh disadvantages Advantages significantly outweigh disadvantages
Objectives Targeted Primary Secondary	e.g. 5.1.2 (A)	Relates to the particular management objective (primary or secondary) described in Section 5
Costs Initial and Ongoing	Low Medium High Very High	< $50,000 $50,000 to $100,000 $100,000 to $500,000 > $500,000
Short-term or Long-term Strategy	Short Term Long Term	Could be implemented within one calendar year Would take longer than one calendar year to implement or may be implemented some time in the future pending availability of funding and results of further research and/or monitoring programs.
Community Support		% results presented here are based on the number of responses to individual questions in the second community consultation survey. 219 respondents completed the survey. Other comments relate to additional submissions or comments received.
Priority Ranking	0 to 3	Lowest priority (not recommended) Highest priority (high likelihood of success – implementation to be considered) Each management strategy was given a priority ranking by four members of the study team independently (from 0 – lowest, to 3 – highest). The number in this column represents the average of those four independent rankings. When assigning these rankings, strategies within each grouping (e.g. Water Quality) were compared.
Aggregate Score	0 to 12	Lowest Highest This number represents the sum of the four independent priority rankings for each strategy, hence the possible range of aggregate scores between 0 and 12. In the case where more than one strategy had the same priority ranking, the aggregate score was used to differentiate between strategies.

7.2 Preferred Management Strategies

Based on the comparison and ranking of strategies shown in Section 7.1, the following suite of preferred management strategies is proposed:

7.2.1 Water Quality Strategies

Algal Blooms

In the short-term it is recommended that the aeration system be continued. Qualitative evidence suggests that the system has had some degree of success, however, the system was unable to prevent the occurrence of an algal bloom during the 2000 Easter holiday period, which affected primary contact recreation in the lake.

While much of the existing data has now been compiled into spreadsheets (BSC 1999), it would be beneficial for Council to compile these data into an environmental database for the long-term storage and future assessment of a number of years of collected data. The data set currently available is not sufficient to adequately assess aerator performance. Future assessment of performance would be aided through the compilation of this data into an environmental database, with additional data from ongoing performance assessment continually being added to it. This data set could then form the basis of a reasonably detailed assessment of inter-annual variability algal counts and the environmental forcings such as solar radiation, rainfall, water level, nutrients, etc.

While the degree of mixing produced by the aerator has been sufficient to break down thermal stratification, and possibly prevent phosphorus release from the sediment (internal loading), it is unlikely to produce the amount of turbulent mixing required to make the lake an entirely unsuitable habitat for cyanobacterial growth in the long term.

In terms of potential long-term management strategies to deal with the algal bloom problem, the following strategies, in order of highest to lowest ranking, were considered most worthy of further consideration:

- Sediment capping (particularly developing technologies such as 'Phoslock')
- Enhanced flushing by groundwater
- Biomanipulation
- Sediment removal.

Lake and Groundwater Quality

The suite of water quality improvement strategies outlined in Section 6.2.2.2, should be implemented on an opportunity basis. While the contribution of each of these strategies to an improvement in lake and groundwater quality could not be quantified, it is felt that the adoption of as many of these strategies as possible will have a positive net long-term effect.

Apart from an improvement in water quality, some of the other reasons for implementation of these strategies include:

- Some strategies, such as the removal of grass clippings and frequent emptying of garbage bins merely involve a modification or firming of current practice, with minimal cost involved.

- Strategies such as cultivation of reed beds and construction of mini-wetlands can incorporate a significant component of community involvement, perhaps through the involvement of Lennox Head Dune Care and the Ballina Environment Society.
- Funding for stormwater runoff improvement strategies, i.e. mini-wetlands and filter swales, may be able to be funded through the EPA's stormwater grant system.

Monitoring

A comprehensive review of the existing database and monitoring systems for Lake Ainsworth should be undertaken with the aim of developing an integrated set of biological, physical and chemical indicator trigger levels and monitoring system specific to Lake Ainsworth. An updated version of the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC and ARMCANZ) is due for release in 2000. This document should provide assistance in developing an appropriate system for Lake Ainsworth.

7.2.2 Coastal Dunes

The current dune management practices, as co-ordinated and undertaken by the Lennox Head Dune Care group, should be continued and supported. The aim of this work is to restore and maintain the natural dune buffer between the lake and the ocean to accommodate allowance for storms. This strategy promotes a high level of community involvement, which has flow-on benefits of promoting community awareness and education, as well reducing the immediate need for 'harder' and more costly protective measures.

Ultimately, as shoreline recession proceeds and the natural processes are no longer able to regenerate the dune following storm events, intervention works of some description will be required to facilitate the maintenance of the dune buffer. It is recommended that a proposed up-to-date assessment of the coastal hazard throughout Ballina Shire be undertaken. This will provide the opportunity to reassess the degree of hazard and suitable management strategies for the whole of Seven Mile Beach, including the section adjacent to Lake Ainsworth. Pending the outcomes of this investigation, long-term management strategies that might be considered to augment the dune rehabilitation activities include:

- beach scraping
- beach nourishment, and
- terminal revetment (sea wall).

7.2.3 Traffic Management

The following description was the situation at the time of preparing the Management Study and is retained to record development of strategies. Following additional consideration, the final adopted traffic management strategies will be presented in the Management Plan.

Through Traffic

The preferred strategy for traffic management at Lake Ainsworth is to close the eastern and southern foreshore roads. Access to the Sport and Recreation Centre and Camp Drewe on the northern side of the lake would be via a new link road on the outside of the caravan park. The existing foreshore roads could then be converted to provide bicycle and walking tracks with some designated car parking bays.

Parking

Parking on the foreshore of the lake should be prohibited. Revegetation of the eastern foreshore has been effective in restricting parking in this area; however, the amenity of the southern foreshore is greatly reduced by the presence of vehicles parking on the grassy fringes. Native vegetation could be used as a barrier with fencing or log barriers protecting the vegetation until it becomes established. Designated parking areas would need to be provided to compensate for the loss of foreshore parking area. Areas that have been suggested, and for which there appears to be a similar level of community support, are:

- Turning Ross Street into a one-way street with rear-to-kerb parking on the northern side. Minimal parking facilities and disabled parking facilities would be provided within the lake reserve. A pedestrian thoroughfare (possibly through the caravan park) could be provided to link Ross Street with the lake reserve.
- Providing parking facilities on the southern side of the lake between the southern foreshore road and the caravan park.
- Reclaiming a section of the caravan park nearest to the surf club for a parking area and relocating those camping sites to the west of the caravan park site.

However, if in the long term the foreshore roads are closed to traffic, then the option exists to convert a portion of these roads into designated parking areas.

Seven Mile Beach 4WD Access Track

The existing 4WD track, located mid-way along the eastern foreshore of the lake, should be blocked and the dune raised and rehabilitated at this location.

If an alternative 4WD track is to be provided, in deference to Council's current policy of allowing 4WD access to this section of Seven Mile Beach, then this could be provided to the north of the Sport and Recreation Centre. It is noted, however, that this would increase traffic flow along the foreshore roads, and possibly through the Sport and Recreation Centre, unless this is combined with the closing of the foreshore roads and the provision of an alternate route around the caravan park.

7.2.4 Recreation

The following strategies are recommended to improve recreational amenity at the lake in order of priority:

- Provide pedestrian access paths and walking tracks.

- Continue to provide designated swimming and watercraft areas. Signage to delineate the two zones should be made clearer. The provision of an offshore pontoon would help to delineate the two zones as well as easing foreshore congestion during peak periods.

- Upgrade existing BBQ and picnic facilities. In particular, the replacement of wood-fired BBQs with electric BBQs would reduce damage to vegetation caused by people gathering kindling to light fires.

- The Lennox Markets should be allowed to continue at the lake on the proviso that the preferred traffic management strategies are implemented. However, if the southern foreshore road is to continue to operate and if alternative parking areas are not provided, then consideration will need to be given to finding a suitable location to relocate the markets.

- The provision of a launching ramp and pontoon or jetty would provide improved access to the lake under varying water levels and reduce localised erosion in the vicinity of launching areas.

7.2.5 Ecology

The following strategies should be undertaken to enhance the lake's ecological values:

- Management of aquatic weeds within the lake. Of particular concern is the spread of water primrose. Council should liaise with and provide assistance to community stakeholder groups (i.e. Lennox Head Dune Care and Lennox Head Residents Association) in this regard.

- Management of terrestrial weeds around the lake's margin. Past efforts by the Lennox Head Dune Care group, and more recently the Lennox Head Residents Association and Lake Ainsworth Sport and Recreation Centre, has resulted in an increase in species richness around the lake. Such programs should be supported and continued. Once again, Council should liaise with and provide assistance to community stakeholder groups in this regard.

- Management of introduced fauna. The development and introduction of introduced species should be monitored and steps taken to eradicate them where practical. While programs to eradicate or reduce the density of species such as the mosquito fish are unavailable at this time, research in this area should be monitored for possible future application. Revegetation of some of the grassy margins around the lake is recommended as a means of reducing the development of the cane toad population.

7.2.6 Planning and Development

Land Zoning and Development of Crown Land

The Ballina Local Environment Plan (1987) should be modified to restrict further development of existing undeveloped Crown land on the western side of the lake (exact area to be determined) to allow only minimal low impact recreational development, environmental educational facilities, environmental protection works, drainage and bushfire hazard reduction.

This would be achieved by either the creation of a new land use zone for the identified area, or by incorporating into the LEP a 'Special Provisions' clause limiting development in the area to these uses listed above.

Some developments currently permissible under the current 7 (f) zoning, such as golf courses, dwelling-houses, caravan parks and camping grounds, and forestry and agriculture, would not serve to protect the environmentally sensitive nature of the lake's catchment, and could adversely affect the lake processes both in the short and long term.

Lennox Head–Alstonville SLSC

The future development requirements of the Lennox Head–Alstonville SLSC need to be considered by Council. The surf club is the largest on the far north coast of NSW and is growing more rapidly that other clubs. The space currently available to the SLSC is deemed to be insufficient to meet the projected future needs

Land availability nearby the surf club is limited. Development of land adjacent to the existing club would involve encroachment onto the dune system and/or existing parking facilities. The caravan park currently occupies the land opposite the surf club.

7.2.7 Erosion and Sedimentation

Recommended strategies to reduce erosion and sedimentation are:

- Continue and enhance current riparian flora management strategies (see strategies for Ecology).
- Control and regulate vehicular and pedestrian movements (see strategies for Traffic Management and Recreation).

7.2.8 Education

An information display board should be provided near the south-eastern entrance to the Lake Ainsworth reserve. Containing a large map of the lake, the board could be used for a variety of purposes, including but not limited to:

- Advising of the location and type of recreational facilities available (i.e. public amenities, BBQs, sailcraft launching areas, parking areas, disabled access facilities, waste disposal areas, walking tracks etc.)

- Highlighting restricted usage zones (i.e. swimming and sailing areas).

- Advising of the latest contact recreational status of the water (i.e. is it suitable for swimming) and the fire hazard status of the reserve.

- A section on public management strategies advising users of the lake on steps that they can take to help maintain and improve the qualities of Lake Ainsworth (e.g. appropriate removal or disposal of dog droppings and litter; avoid using excess sun screen, vegetation conservation).

- Advising on current management strategies aimed at reducing the occurrence of algal blooms (e.g. trial aeration system).

- Providing dates of upcoming events (e.g. surf carnivals, sailing regattas).

- Providing contact numbers to report matters of concern or obtain more information (Council, Dune Care, and Ballina Environment Society etc).

Sailcraft users should also be better informed of the restricted swimming areas to avoid conflict with swimmers.

7.2.9 Lake Water Level and Flooding

Management strategies should be implemented for mitigating the effects of the natural variation of the lake water level.

The cutting off of the main access road to the Sport and Recreation Centre will be solved by the strategies recommended in Traffic Management. Other strategies that could be implemented to mitigate the effects of prolonged high water levels include:

- Ensure that littoral and riparian revegetation schemes incorporate species that are tolerant to infrequent but potentially prolonged periods of inundation.

- Placement of new and/or replacement of existing recreation facilities (BBQs, walking paths etc) beyond levels likely to be inundated for prolonged periods.

- Implement strategies to mitigate post-flooding impacts (e.g. fencing off foreshore areas and/or mulching of foreshore areas to allow vegetation to recover and minimise erosion).

Strategies to mitigate the effects of the natural variation of the lake's water level are preferred to the implementation of a system to control and regulate the water level in the lake. However, if over time enhanced flushing of the lake's water with groundwater becomes the preferred long-term strategy for controlling algal blooms, then the idea of controlling and regulating the lake's water level should be revisited.

8. References

Australian & New Zealand Environment and Conservation Council 1992, *Australian Water Quality Guidelines for Fresh and Marine Waters, National Water Quality Management Strategy*, November.

AWACS 1996, *Lake Ainsworth Lake Processes Study,* Report 96/07 August 1996.

Ballina Shire Council 1999, *Lake Ainsworth Monitoring Study, Final Report,* prepared by Judith Betts, August.

Bayly, I. A. 1964, 'Chemical and Biological Studies on Some Acidic Lakes of East Australian Sandy Coastal Lowlands', *Australian Journal of Marine & Freshwater Research,* 15, 56-72.

Blainey, S., Callaghan, J., Dalziel, J., Ryffel, T., Somerville, G. and Wilson, S. (1988), 'A Proposed Plan for the Future Development of Lake Ainsworth', Student Project for Bachelor of Applied Science (Coastal Management), Northern Rivers College of Advanced Education.

CSIRO 1996, *Regional Impact of the Greenhouse Effect on NSW - Final Report,* CSIRO Division of Atmospheric Research, Climate Impact Group.

Institution of Engineers Australia 1991, *Guidelines for Responding to the Effects of Climatic Change in Coastal Engineering Design,* Prepared by the National Committee on Coastal and Ocean Engineering of the Institution of Engineers Australia, No 1 September 1991 ISBN 85825 564 2.

International Panel on Climate Change 1995, *Climate Change 1995-The Science of Climate Change,* contribution of WG1 to the second assessment report of the IPCC, Cambridge University Press.

Jones, A. 1988, 'Carrying Capacity of Lake Ainsworth', Student Project, B. Applied Science, Northern Rivers College of Advanced Education.

NSW Government 1990, *Coastline Management Manual*, prepared under the guidance of a Steering Committee comprising government authorities and interested community groups, ISBN 0730575063.

NSW Government 1992, *Estuary Management Manual*, draft, October, ISBN 0731009339

Saenger, P. 1988, letter to Ballina Shire Council.

Seabrook W. 1991, 'Range expansion of the introduced cane toad *Bufo marinus* in New South Wales', *Aust. Zoo* 27: (3&4) 58-63.

Timms B.V. 1982, 'Coastal dune waterbodies of north-eastern New South Wales', *Aust. J. Mar. Freshwater Res.*, 1982 33: 203-222.

Timms, B.V. 1977, 'Man's influence on dune lakes or the derogation of the delectable lakes of northeastern NSW', *Hunter Natural History*, August 1977.

WRCS 1996, *Trial of Short Term In-Lake Options for the Control of Blue Green Algae at Lake Ainsworth, Artificial Aeration Destratification,* Water Resources Consulting Services, Report CS 96.028, November 1996.