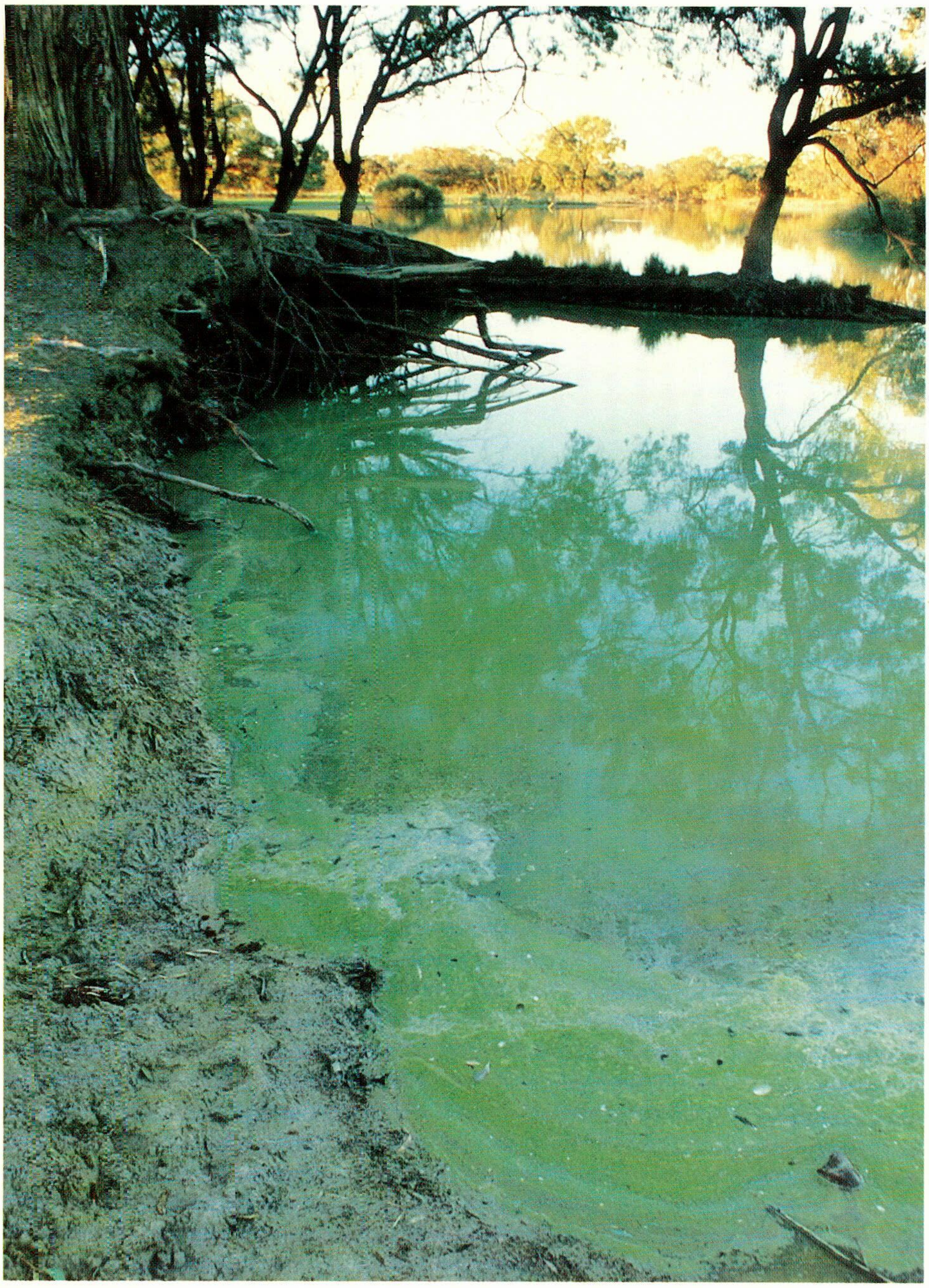
BLUE-GREEN ALGAE



August 1992

FINAL REPORT-SUMMARY

NEW SOUTH WALES

BLUE-GREEN ALGAE TASK FORCE

BLUE - GREEN ALGAE

August 1992

FINAL REPORT-SUMMARY

NEW SOUTH WALES

BLUE - GREEN ALGAE TASK FORCE

ISBN 0 7305 7887 9

Published for the Blue-Green Algae Task Force
by the Department of Water Resources
10 Valentine Avenue
PARRAMATTA
New South Wales 2150
AUSTRALIA

Front Cover: Darling River Anabranch, NSW, November 1991
Back Cover: Lake Wetherell, NSW, February 1992

Photographs by Peter Bek

Inside pages printed on environmentally friendly paper

FOREWORD

Urgent action resulted from the occurrence in late 1991 of the world's largest recorded riverine blue-green algal bloom, stretching for 1000km in the Darling-Barwon River System in New South Wales. The Minister for Natural Resources established the Blue-Green Algae Task Force to minimise algal problems statewide during the 1991/92 summer, and to provide recommendations for actions and policies to minimise the occurrence and extent of blue-green algal blooms in the medium and longer terms.

This Summary outlines the work of the Task Force, its findings and recommendations as detailed in the Final Report. That document is the major assessment of the subject for NSW, and will also be of interest to a wider national and international audience. To meet the range of audience needs, three documents have been produced:

- Final Report
- Final Report . Appendices
- Final Report . Summary (this document).

The science of blue-green algae is described at length to demonstrate the considerable complexity in the causes and effects of blooms. As a consequence of this complexity, an integrated management approach is needed to minimise the problems associated with blooms.

The report links the science of blue-green algae to:

- The State Algae Contingency Plan, which will help minimise the effects of algal blooms;
- Bloom management measures in the short to medium term, to manipulate the factors affecting blooms and their development; and,
- Land and water management measures in the short to longer term, to minimise nutrient input to NSW waterways.

Many measures, particularly short term ones, have already been implemented following release and acceptance of the Interim Report of the Task Force in March 1992.

Management options should only be implemented where the benefits (economic, social and environmental) of minimising blooms and their impacts outweigh or equal the costs of control works and activities.

The Final Report contains a number of 'firsts' of national interest, including results of research on blue-green algae and toxins; development of methodologies; and comprehensive Australia-wide listings of individuals and organisations with interests in algal research, and of current research activities.

Report findings have been shaped considerably by the participation of the NSW community. Their involvement is vital if management options are to be successfully implemented at the community level.

Acknowledgements

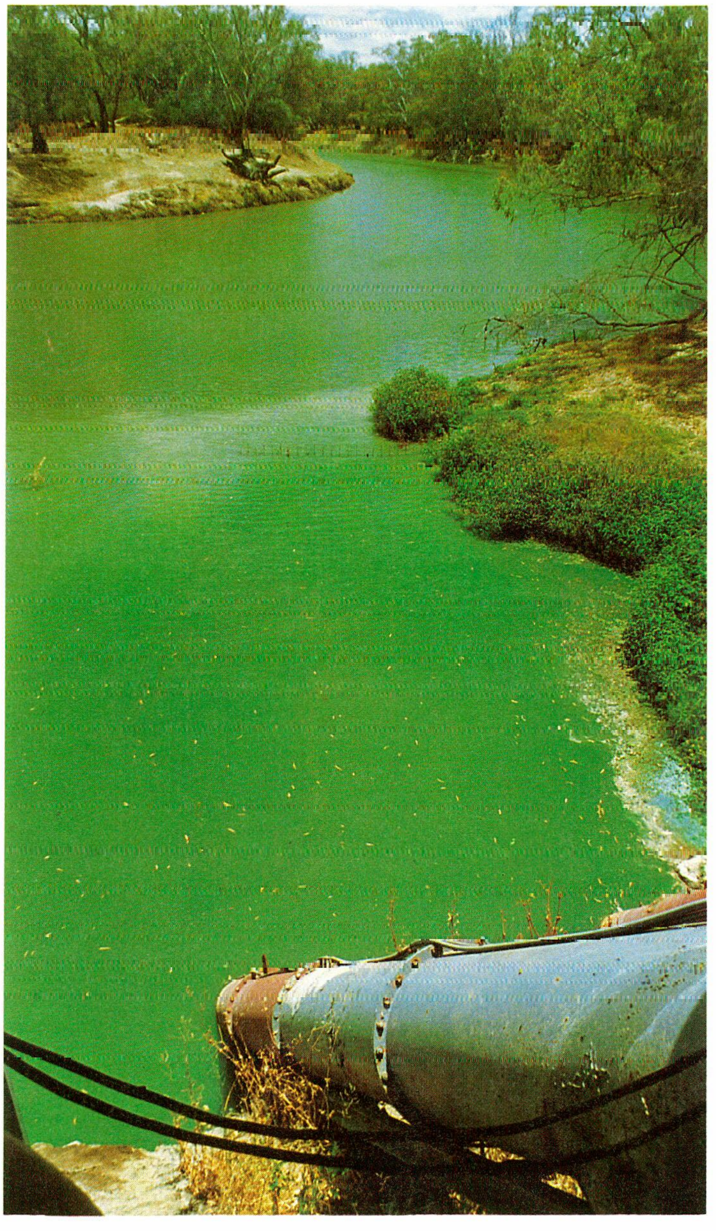
My personal thanks to all members of the Blue-Green Algae Task Force (listed in Chapter 1) for their strong support and commitment over the past nine months.

Special votes of thanks to Mr N. Chapman for his exceptional assistance as Secretariat to the Task Force, and to Mrs R. Kirpal for her dedication in the typing of this report, the Final Report, the Interim Report, and other Task Force documents.

There are no references made in this Summary; the reader should consult the Final Report with its extensive list of references and annotated personal communications, and the Appendices Volume with acknowledged papers.

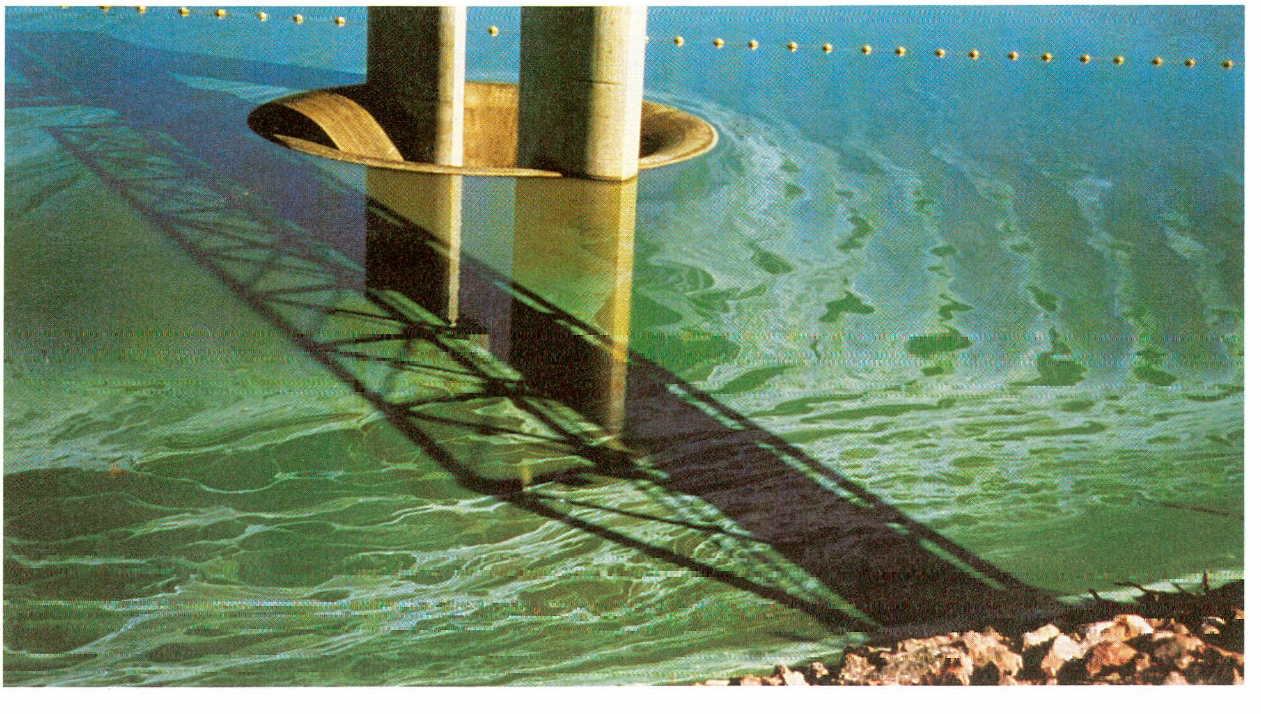
T.J. Verhoeven
Chairman Blue-Green Algae
Task Force
August 1992

CONTENTS



Left: Bourke weir pool
A large water pump (for agricultural and domestic supply) in the Bourke weir pool on the Darling River in December 1991. The discolouration of the water by blue-green algae is very obvious.

Below: Chaffey Reservoir water off-take
A severe bloom of blue-green algae in Chaffey Reservoir, NSW in September 1991. The off-take and spillway (which discharges to the river downstream) is surrounded by the bloom.



1. INTRODUCTION

The New South Wales Blue-Green Algae Task Force was formed on 28 November 1991 in response to the world's largest recorded riverine bloom of blue-green algae, which extended for 1,000 km along the Darling-Barwon River System, in western New South Wales, Australia (Figure 1.1).

This is the Summary of the Final Report of the Task Force, prepared for the NSW Minister for Natural Resources.

The Final Report describes the 1991/92 blue-green algal blooms in NSW, and places them in perspective with the occurrence and causes of blooms elsewhere. It contains a lengthy description of the physical, chemical and biological factors which cause blue-green algal blooms and also describes their many impacts. It illustrates the complexity of the system which needs to be understood if the algal problem is to be successfully minimised. Sources of nutrients in NSW are examined as a part of this study.

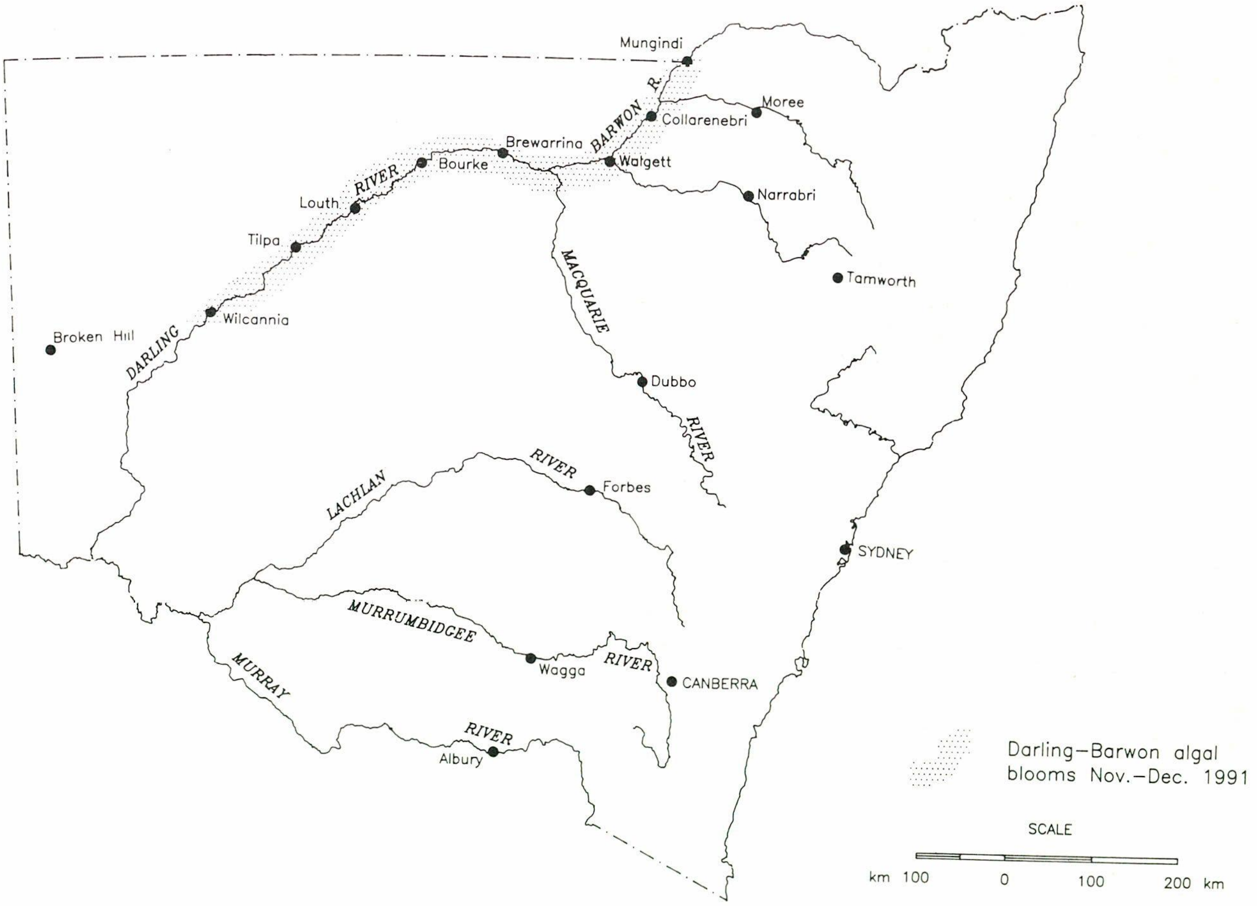


Figure 1.1 Darling-Barwon algal blooms November-December 1991

Eutrophication, the enrichment of water by nutrients, and the effects of such enrichment, are increasing problems in NSW. Over the last 20 years, toxic and non-toxic algal blooms have been reported with increasing regularity on water storages, weir pools and rivers throughout the state. Their development can be directly attributed to eutrophication, coupled with an increase in water abstraction from the state's waterways.

The eutrophication problem was highlighted by the record-breaking bloom in the Darling-Barwon River System, which focused Australian and overseas attention on this symptom of an environment under stress. The problem was brought dramatically close to Sydney with algal blooms in the Hawkesbury River in December 1991 and January 1992.

Faced with this serious situation in the Darling-Barwon, and with conditions favouring development of the problem statewide, the Minister for Natural Resources announced the establishment of the Blue-Green Algae Task Force to minimise the impacts of the immediate problem as well as developing longer term solutions to it. A strong commitment to the Total Catchment Management (TCM) approach was foreseen, particularly in the long term.

Membership of the Task Force was drawn from TCM, a broad range of NSW Government agencies (natural resources, primary industries, environment protection, health, water supply), two universities and the Murray-Darling Basin Commission (MDBC). Queensland, Victoria, South Australia, CSIRO and the Australian Water Resources Council (AWRC) had observer status, thereby speeding information transfer. This membership reflects an important principle; that management measures must be implemented as part of an integrated resource management approach which may cut across established agency, or geographical boundaries.

Members were:

Mr J. Verhoeven	Chairman of the Task Force, Department of Water Resources
Mr I. Smalls	Department of Water Resources
Mr G. Noonan	Environment Protection Authority
Ms B. Richardson	NSW Fisheries
Dr V. Edge	NSW Agriculture
Mr W. Watkins	Department of Conservation and Land Management
Mr M. Tooth AM	Total Catchment Management representative
Dr D. Fox	Department of Health
Professor I. Falconer	University of Adelaide (formerly of the University of New England)
A/Professor D. Cheng	University of Technology, Sydney (UTS)
Mr F. King	Public Works Department
Mr C. Heath	Water Board (Sydney, Illawarra, Blue Mountains)
Mr B. Cole	Hunter Water Corporation
Dr N. Mackay	Murray-Darling Basin Commission

Observers:

Mr C. Hazel	Queensland Water Resources Commission
Mr M. Anderson	Victorian Algal Project Team
Mr D. Bursill	South Australian Algal Task Force
Dr K. Bowmer	CSIRO
Dr P. Johnstone	Australian Water Resources Council

Secretariat to the Task Force:

Mr N. Chapman	Department of Water Resources

As the algal problem extended along the Darling-Barwon River System and it assumed a disaster of significant proportions, the Premier declared a State of Emergency for the river system. The State of Emergency, in force from 2 to 24 December 1991, was declared to coordinate the provision of safe domestic water supplies for towns, aboriginal communities and land-holders. Its declaration provided for a lead agency, the Public Works Department, to resolve the problem, with all other departments and the community being required to act on that department's advice, including the provision of necessary resources.

Both the State of Emergency and the studies commissioned by the Task Force have confirmed the complexity of the system which gives rise to the blue-green algae problem. It therefore follows that the solutions are equally complex. They must integrate cause and effect relationships in both the short and long term, and they must also be cost effective.

In its Final Report, the Task Force recommends a range of management strategies to achieve this end. They include the State Algal Contingency Plan to minimise the impact of algal blooms in the short term. In the medium term, the Task Force recommends measures to control the factors which affect blooms and, in the longer term, outlines those land and water management measures which are required to control the causes of blooms, in particular nutrients. It also contains proposals for additional research to improve our understanding and management of the problem.

2. OBJECTIVES AND TERMS OF REFERENCES

In the course of its nine month term, the Blue-Green Algae Task Force has worked to its four objectives:

(i) Oversee the establishment of Regional Algal Coordinating Committees, monitor their operation, and facilitate resourcing and coordination of these committees where necessary.

(ii) Review the problems associated with blue-green algae in NSW.

(iii) Produce reports for the Minister for Natural Resources and the Natural Resources Subcommittee of Cabinet; including regular reports on algal blooms and responses during the 1991/92 summer, an interim report by end March on progress, and a final report by end August 1992.

(iv) Make recommendations to minimise the problem in the future (both short and longer term).

The terms of reference for the Task Force were to:

- Prepare an assessment of the 1991/92 problem, including cost.
- Summarise the historical problems in Australia and overseas.
- Review and update information on factors affecting blue-green algal blooms and their trigger mechanisms.
- Review nutrient sources in NSW and their quantification.
- Review and update information on the influence of biotic factors.
- Review water management strategies as they apply to algal blooms.
- Review and update information on toxicological aspects, including current research.
- Recommend measures to manage the problem in 1992/93 and beyond.
- Identify the status of research and development and future requirements.
- Make other recommendations for the future as appropriate.

While the focus of the Task Force was the investigation of blue-green algae in NSW inland waterways, most of the findings apply to more general algal and water quality management. Similarly, land and water management measures apply to estuarine as well as freshwater bodies.

3. TASK FORCE OPERATION

The Task Force met its objectives by completing a range of activities including research and investigations; literature reviews; technical workshops; monitoring; contingency planning; information exchange, negotiation and dissemination; and participation of the broader state community.

Issues associated with minimising the impact of algal blooms can be grouped as modelled in Figure 3.1, and include:

- Resource management issues underlying algal bloom development.
- Factors affecting blue-green algal blooms and their trigger mechanisms.
- Controlling algal blooms and toxin development.
- Managing the effects of blooms, including toxins.

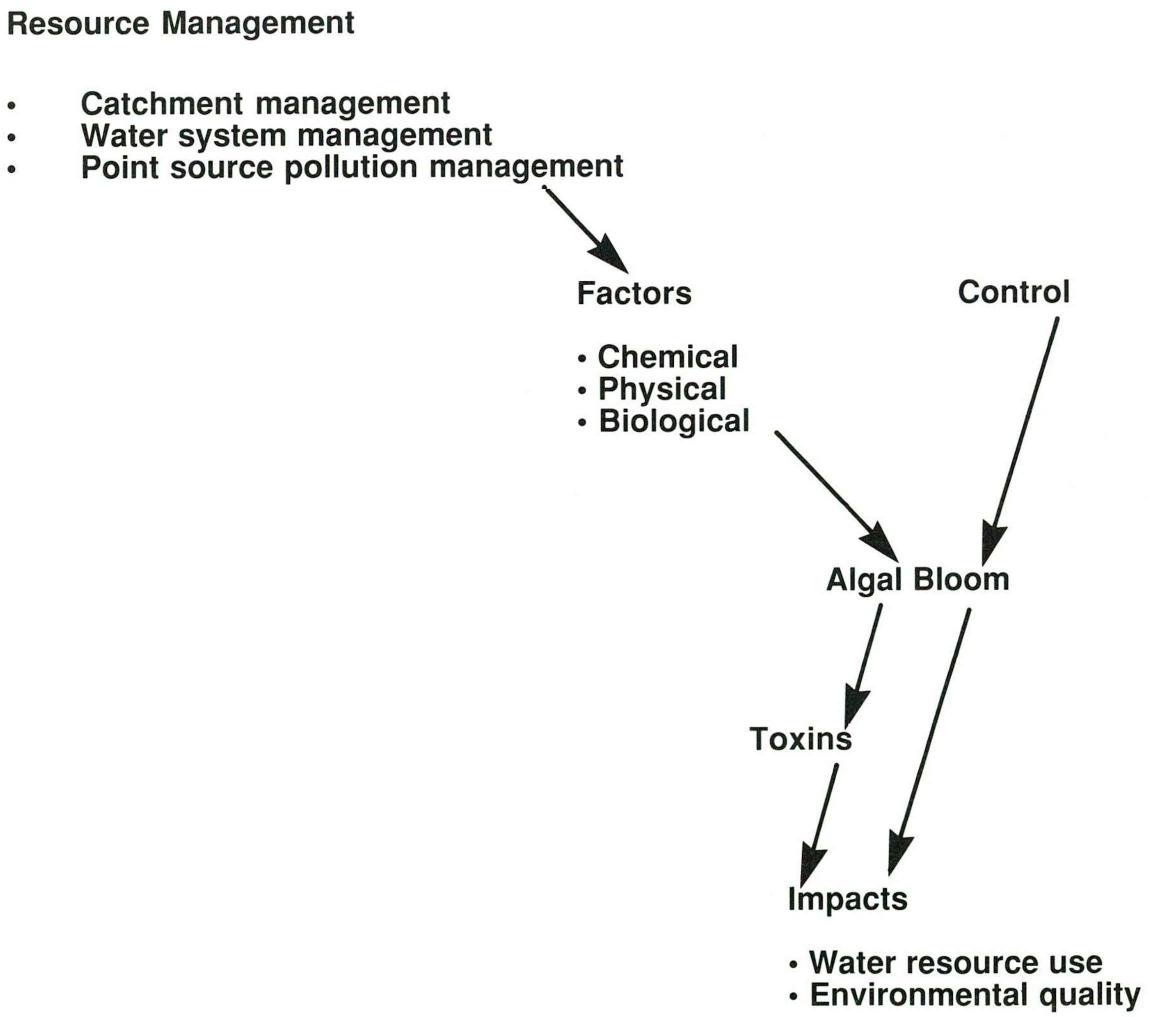


Figure 3.1 Issues associated with minimising algal impacts

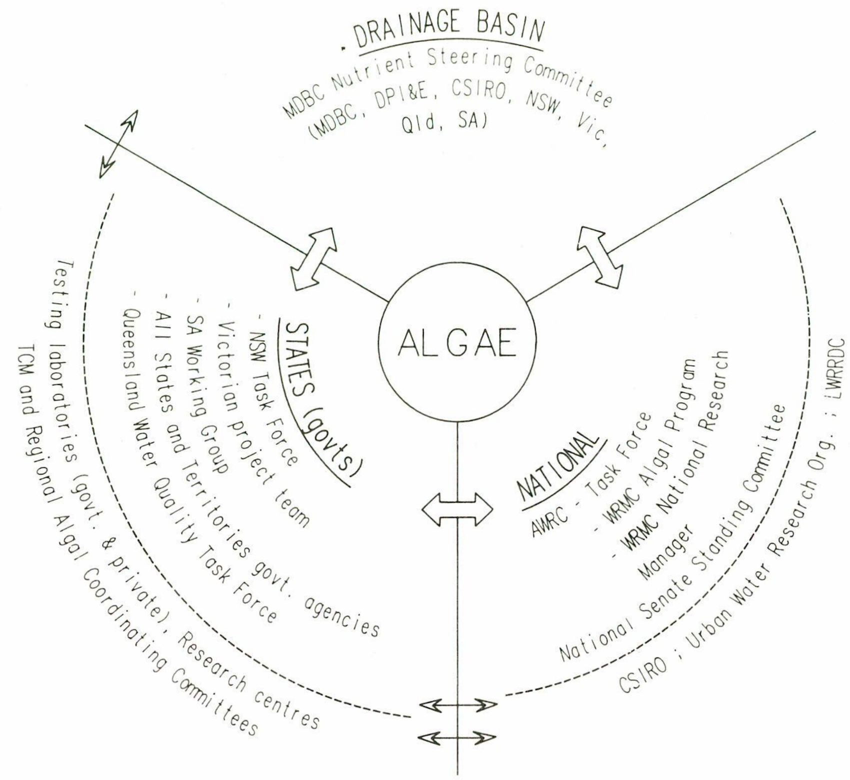


Figure 3.2 Organisations and Linkages: algal bloom management

The Task Force has not operated in isolation. Its work programs linked with and complemented the work of a large number of other bodies at national (AWRC), basin-wide (MDBC), state and regional levels, as shown in Figure 3.2.

The Interim Report of the Task Force was completed on 31 March, 1992. That report, its executive summary and a broadsheet have been widely distributed, receiving interest nationally as well as within NSW.

An essential part of Task Force operation was the participation of the broader community in providing statewide input to help shape this final report. This participation was achieved by:

(i) The Task Force receiving a large number of letters, submissions and products from the general public, water users, industry and other interested parties, covering all the issues being addressed.

(ii) Members of the Task Force addressing or participating in a large number of interstate and intrastate workshops, community forums, Land Care meetings, conferences, seminars and service club meetings.

(iii) Task Force members meeting with catchment management committees throughout the state. These meetings, and the feedback received, were particularly important as many of the measures to minimise algal bloom problems in the future will need to be implemented through the TCM approach, with appropriate resourcing from communities and all levels of government.

(iv) A study tour conducted by seven members of the Task Force of communities affected by algal blooms last summer. Meetings were held with community representatives, shire councillors, TCM and river management committee members, concerned citizens, environmental groups and staff of government agencies.

4. OVERVIEW OF BLUE-GREEN ALGAE

Blue-green algae are primitive photosynthetic organisms which are found in many environments, notably inland waterways, estuaries and the sea. They are now known to be bacteria, the Cyanobacteria, but in common with other contemporary documents this report will refer to them by their popular term, the blue-green algae. Their bacterial properties have major implications in their behaviour and management.

Blue-green algae in low numbers are important contributors to the aquatic biology of Australian waterways. However, their numbers can often rise to a level where their noxious properties can cause problems for a range of water users. They are unsightly and create an extremely unpleasant odour. Importantly, their toxins have been known to cause sickness in humans and death in livestock and pets.

In Australian waters, two genera of blue-green algae dominate the records of nuisance blooms; Anabaena (a filamentous form with special types of cells as shown in Figure 4.1) and Microcystis (a colonial form with coccoid shaped cells as shown in Figure 4.2).

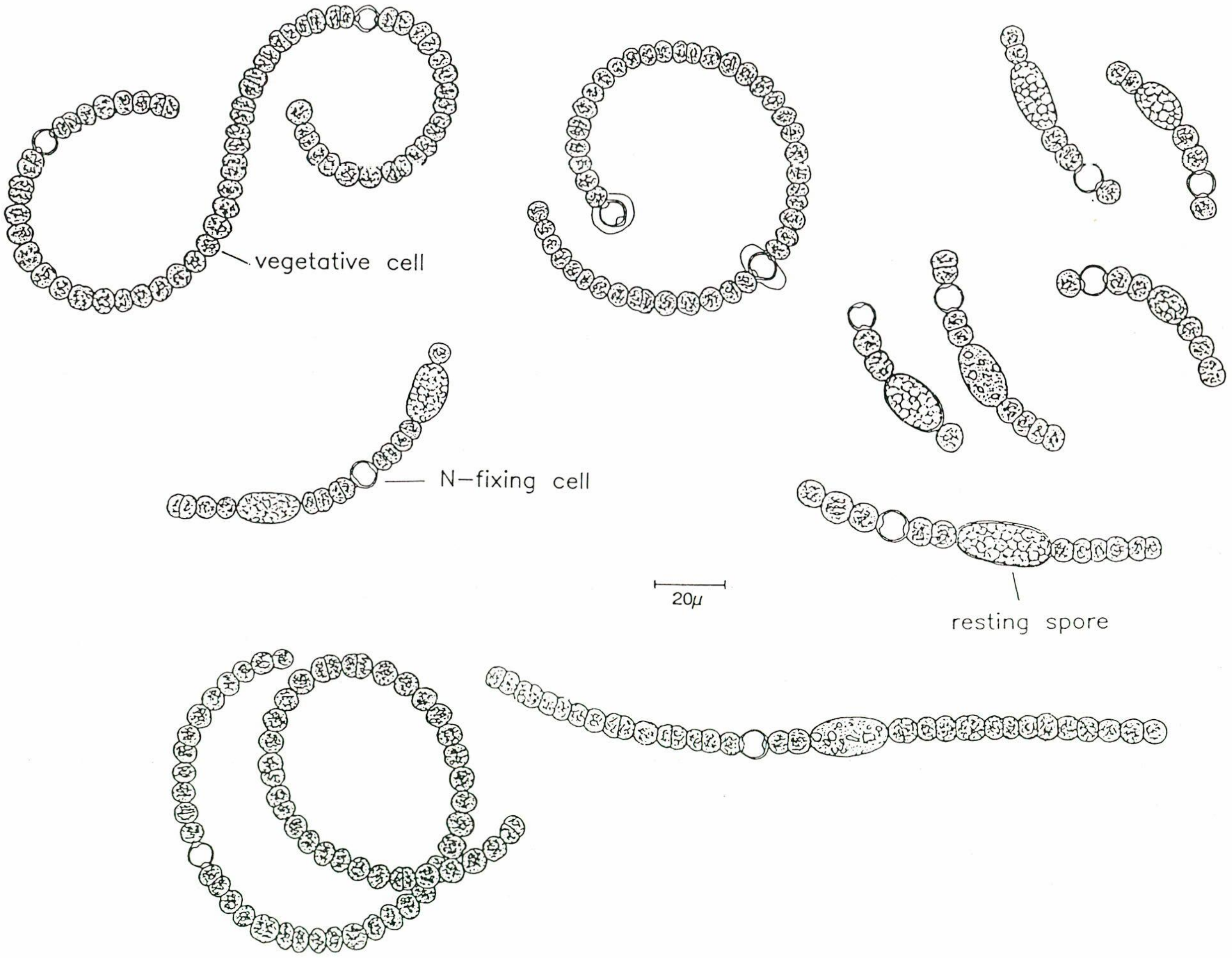


Figure 4.1 Anabaena circinalis (from Baker 1990). The dominant algal species of the Darling-Barwon Bloom, November-December 1991

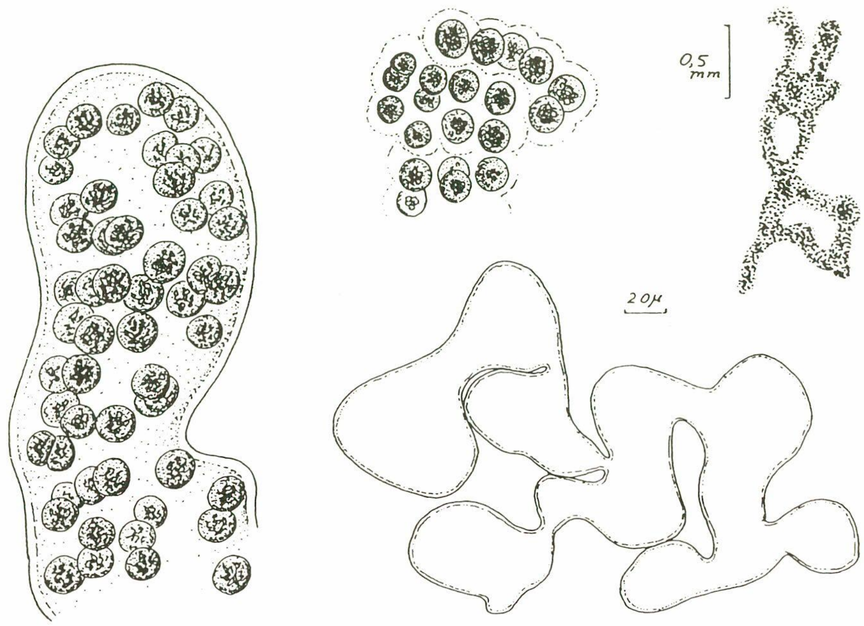


Figure 4.2 Microcystis spp. (from Bourelly, 1985)

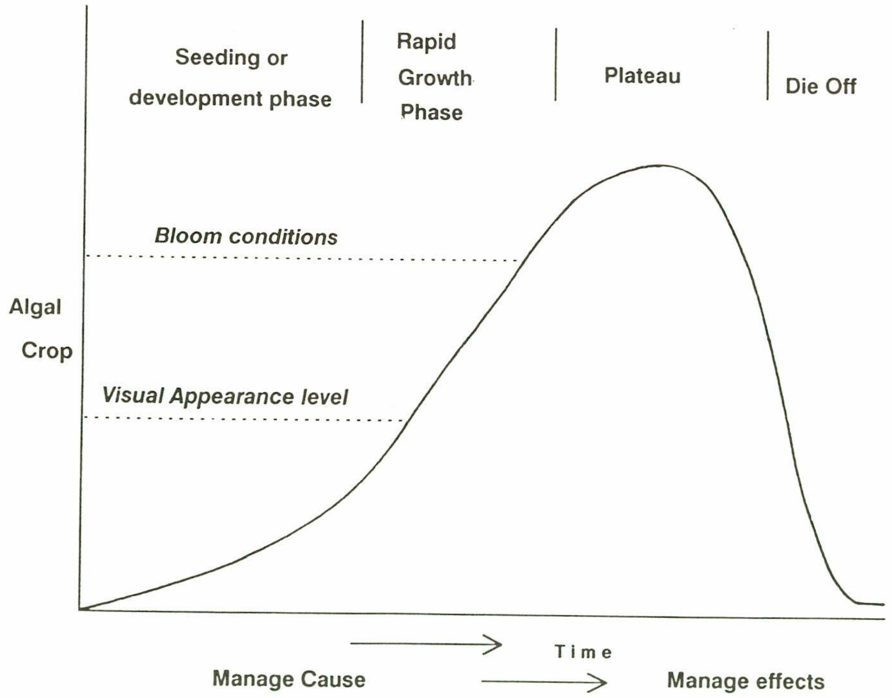


Figure 4.3 Algal growth curve

A blue-green algal bloom progresses through a number of phases in its development, as shown diagrammatically in Figure 4.3.

The sudden appearance of blue-green blooms is not a feature of explosive growth, but of vacuolation where increased buoyancy results in a surface concentration of cells. Surface blooms are vulnerable to wind effects and will be driven to the leeward side of water bodies, concentrating first as windrows, then as scums. Algal scums have the appearance of paint being trailed through the water and as they concentrate they can form more solid mats. As they mature, surface scums may become bleached by light.

Troublesome blue-green blooms have been recorded worldwide for centuries, and the first toxic bloom was noted in South Australia in 1878. In recent years there has been an increase in reporting of noxious blooms, despite the fact that existing algae monitoring systems have not been sufficiently resourced to cover the whole state

For 1991/92 the NSW Task Force reported 48 waterways throughout the state with blue-green algal blooms, of which 30 were regarded as serious events, having the potential to cause problems with water resource use. Major locations are shown in Figure 4.4.

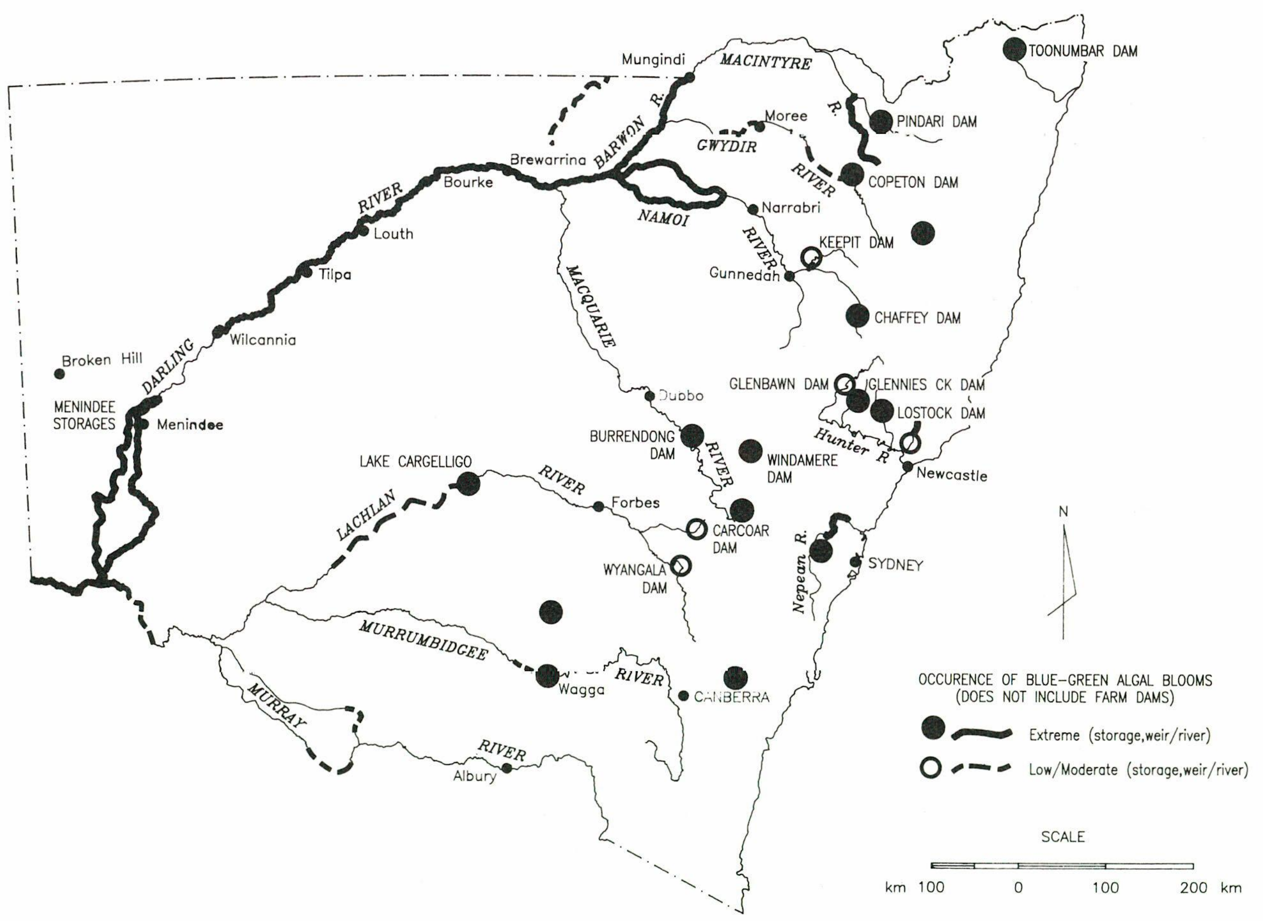


Figure 4.4 Occurence of blue-green algal blooms in NSW during 1991/92

The multiple causes and effects of blue-green blooms create a complex interactive system which is summarised in Figure 4.5. An understanding of the relationships is vital if successful management is to be implemented. In resource management, decisions may need to focus on one or more target areas, such as the causative factors, the algae itself, or the effects of their growth.

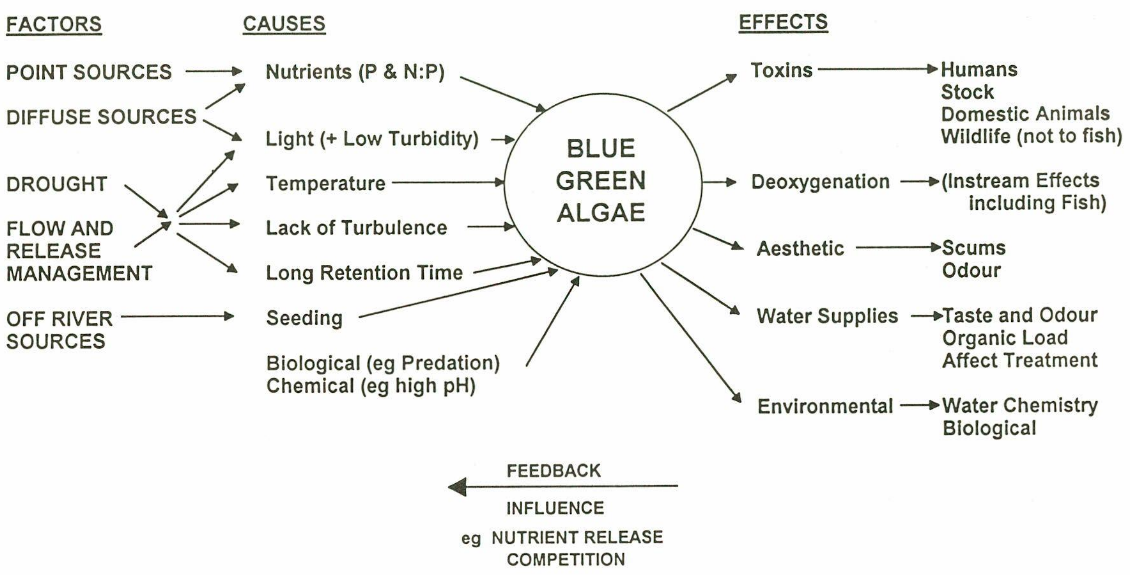


Figure 4.5 Blue-green algae blooms - Major causes and effects

5. 1991/92 ALGAL BLOOMS IN NSW

The first objective of the Task Force was to minimise the problems associated with algal blooms during 1991/92. To meet this objective, an interim State Algal Contingency Plan was put into operation in late November 1991. A two-tier organisation structure comprising the Task Force and nine Regional Algal Coordinating Committees (RACCs) was established to develop and implement the plan.

The role of the Task Force in this objective was to oversee the establishment of the RACCs, to monitor their operation and to facilitate their resourcing and coordination where necessary. The roles of the RACCs included rapid identification and monitoring of algal blooms, provision of timely and accurate advice to the community, development and implementation of bloom management measures, provision of safe drinking water supplies, and support of the Task Force.

From this experience it is concluded that an effective response to algal bloom problems requires a combination of regionally based technical and professional staff supported by a centrally based core of specialists (engineers, scientists, etc). This is reflected in the State Algae Contingency Plan for the minimisation of algal bloom problems (outlined in Chapter 10) which was developed from NSW experience augmented by models in use interstate.

The Darling-Barwon algal blooms generated intense media interest (within NSW, nationally and internationally). The Task Force responded with factual information to make the public more aware of algal and nutrient issues, and of more general water quality issues; an important first step if solutions are to be implemented in the long term. This communication and information related experience gained in 1991/92 has been used to develop relevant sections of the State Algae Contingency Plan.

Darling River, North Bourke

The Darling River at North Bourke in November 1991. The only green features in this semi-arid landscape are the river itself (in bloom) and the irrigated paddock in the background.

Algal monitoring by the Department of Water Resources, other government agencies and individual shires was of considerable value and included the provision of weekly reports and maps of algal occurrence and severity. However the 1991/92 experience has revealed shortcomings in the NSW monitoring program and these have been addressed by the Task Force (Chapter 10).

Blue-green algal blooms have a range of economic, social and environmental costs and impacts. They include impacts on water supplies, human health, recreation and tourism, agriculture, fish and wildlife. Not all costs associated with the 1991/92 algal blooms could be obtained. In many cases impacts were not identified, or costs could not be clearly separated from other related issues such as the impact of drought, or of the recession, which have also imposed costs on the community.

Costs which were assembled include:

(i) The direct cost to the NSW and Commonwealth Governments to provide water supplies during the State of Emergency for the Darling-Barwon blooms is estimated to be $1,260,000. The direct cost of operating the interim State Algae Contingency Plan for 1991/92 and of the Task Force was $730,000. These costs have a very narrow definition; they do not include the operational costs of state government agencies working on algal and related water problems not tagged with the Task Force label, nor do they include the costs incurred by individuals, communities, local government or research organisations.

(ii) Lost income from tourism and recreation in local regions is estimated to be $9.4 million, the result both of the occurrence of blooms, and of the negative media coverage which they received.

(iii) Up to 1600 sheep and 40 cattle deaths were suspected of being caused by the Darling-Barwon algal blooms.

Human health impacts in NSW were not rigorously assessed for the whole of 1991/92 for two reasons. Firstly, the urgency of the State of Emergency precluded the opportunity to prepare and conduct a detailed case-control study (see Chapter 8). Secondly, incidents of contact with toxin bearing water may not have been reported to health officers, especially if the effects were only mild and of relatively short duration.

By comparison, in South Australia eight suspected cases of illness associated with blue-green algae were documented in the summer of 1990/91 and another 25 possible cases are being followed up for assessment during 1992. Most of the South Australian cases had been exposed to blue-green algae during showering, swimming or water skiing. It is possible that other individuals who had exposure to blue-green algae and subsequently developed symptoms might have been missed by these studies.

An impact far more difficult to measure was the fear experienced by small communities along the Darling River; fear and lack of knowledge of:

- The longer term health impacts of using untreated river water for domestic water supply;
- Whether water treatment would remove toxins;
- The duration of the algal blooms; and,
- The economic impacts of algal blooms on the pastoral industry, already stressed by drought and the recession.

There were no apparent adverse effects on fish collected from bloom infested waters, but information obtained is not conclusive.

6. FACTORS CAUSING BLUE-GREEN ALGAL DOMINANCE

It is important to understand the factors controlling blue-algae blooms in order to develop effective management programs to minimise the problems which they cause.

Blue-greens have a number of characteristics which give them a competitive advantage. This includes their possession of gas vacuoles providing buoyancy regulation (the ability to move up or down the water column) which enables them to overcome the spatial separation between light and nutrients. The nitrogen fixing capability of some species enables them to dominate in low nitrogen waters. Some blue-green algae produce spores or "akinetes" which can not only last for several years, but also provide a means of seeding water bodies. Finally, they may produce toxins which kill or inhibit their predators and which may inhibit their competitors.

The growth of blue-green algae is determined by many environmental factors (physical, chemical and biological). Since these factors are continually interacting with one another in a very complex way, it is not possible to attribute algal occurrence to any specific set of factors.

Physical factors affecting the growth of blue-greens include temperature, evaporation, light, turbidity, colour, flow, turbulence, flooding, thermal stratification, depth and morphology of water bodies, and sediment.

The main chemical factor is nutrients. Nutrients come from point and diffuse sources in catchments, and from internal recycling from sediments in waterways. Nitrogen and phosphorus are the most important nutrients with phosphorus being the limiting nutrient for blue-green algae (that is, the one most likely to influence growth). In catchment areas disturbed by human activity phosphorus is rarely in short supply. It is present in a variety of forms, from the mineral hydroxyapatite through to phosphorus based detergents. Phosphate phosphorus appears to be the form preferentially assimilated by blue-greens. Other chemical factors influencing blue-green algae include carbon dioxide, pH, micronutrients and dissolved oxygen.

Biological systems are very complex, as shown in Figure 6.1. Biological interactions between blue-green algae and other members of the food web can affect algal biomass; the roles of zooplankton grazers, macrophytes, fish (including carp) and other microorganisms (viruses and bacteria) are also significant.

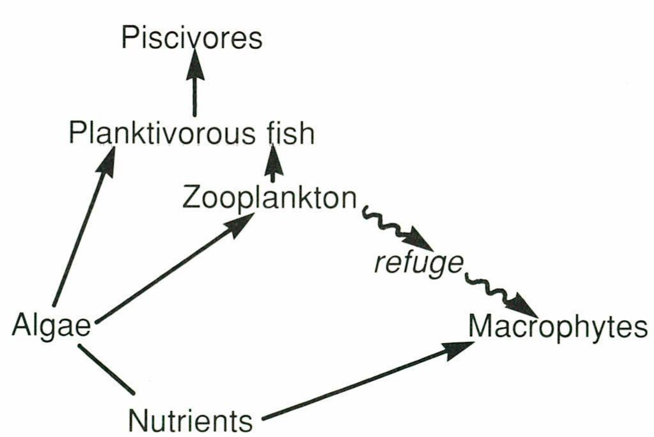


Figure 6.1 Simplified view of biological interactions in the aquatic food web

A scientific advisory team working for the Task Force inspected and sampled the Darling-Barwon bloom in December 1991. Their findings support the literature review conducted by the Task Force.

It is concluded that the environmental conditions which favour the development of blue-green algal blooms are:

- High nutrient levels, particularly phosphorus;
- Low N:P ratios (less than 29:1);
- High water temperature (above 20 degrees Celsius);
- High pH (pH 8-10) and low carbon dioxide concentration;
- Abundant zooplankton (blue-greens are relatively inedible and their populations are less affected);
- Low flows, leading to long retention times and calm water conditions; and,
- Reduction in turbidity to moderate levels, leading to increased light intensity.

The Australian environment is characterised by many of these environmental conditions, which make Australia's waterways particularly vulnerable to blue-green algae blooms.

To determine the triggering mechanisms of blue-green algal blooms, the effect of each of the above environmental conditions must be quantified since all conditions are rarely, if ever, optimal for algal growth at any one time. Strategies to manipulate some of these environmental parameters may then be developed on a catchment by catchment basis to prevent blue-green algal dominance.

7. NUTRIENTS IN NSW

Phosphorus is essential to sustain life, and as such it is a part of the foundation of the economic, social and environmental structure of NSW. Phosphorus is also a limiting factor in blue-green algal growth. The challenge facing NSW is to minimise the input of phosphorus to the state's waterways.

Various trophic classification models predict that the nutrient levels (particularly phosphorus) in NSW waters cause significant water quality problems. The median levels of phosphorus exceed a nominated desirable level of 50ug/L at 60% of sites sampled throughout the state; with exceedance in all western river basins and some coastal basins. Over the past 18 years total phosphorus levels have risen by an average rate of 5% per year statewide. There have been significant increases in the Namoi and Hunter valleys. North-western basins generally have the highest phosphorus values (Darling, Intersecting Streams and Border Rivers, Gwydir) or the greatest upward trend (Namoi).

Where there are other environmental conditions favouring algal bloom development, these high nutrient levels demonstrate an existing and increasing potential for algal problems throughout most of western NSW and in many coastal rivers.

Turbidity is a measure of suspended material, including colloidal material in water. High turbidity is a feature of many Australian waters and is usually the result of soil erosion. Turbidity reduces light penetration and hence plant (and algal) growth. However, during long periods of low river flow such as during drought, turbidity in waterways can markedly decrease as sediment particles sink to the riverbed or lakebed.

Bourke residents described a clearing of the river for some weeks prior to the appearance of the Darling-Barwon algal bloom. This type of occurrence, which happens for shorter periods in most years in the vicinity of Bourke, would enable the penetration of light into a river which would normally be protected against significant algal growth by turbidity.

From 1978 to 1986 the total nitrogen to total phosphorus ratio (N:P ratio) for the Darling River at Burtundy was about 3:1. This overall ratio will not necessarily apply to specific flow events. Nitrogen to phosphorus ratios of this magnitude favour the growth of nitrogen fixing blue-green algae. In the case of the 1991/92 bloom in the Darling-Barwon River, the total nitrogen to total phosphorus ratio was about 5:1. The dominant algae present in the bloom was the nitrogen fixer Anabaena circinalis.

Research is still needed to identify nutrient sources and the proportion of nutrients which they each contribute to the state's waterways. A recent report "An Investigation of Nutrient Pollution in the Murray-Darling River System" (released by the MDBC) estimates the annual input of phosphorus throughout the Murray-Darling River System contributed by point sources (sewage treatment plants, irrigation drains, industrial inputs and intensive animal industries) and diffuse sources (forest, pasture, crops and urban stormwater). The study was based on limited data which was most complete for point sources and only derived for diffuse sources. It did not take into account processes such as in-stream assimilation (which takes up phosphorus), or the recycling of phosphorus from sediments back to the water column.

An example of a rural study which helps quantify nutrient contributions from different rivers is the Central and North West Rivers Water Quality Survey which has been operating since 1990. The study is funded jointly by irrigators and the Department of Water Resources, and covers the Barwon, Gwydir, Namoi and Macquarie Rivers, and Gil Gil Creek. The Task Force has been presented with some of the preliminary results of this nutrient study which covers the major inflows of the Upper Darling River System. These are valuable in that they cover the 243 days from 1 September 1991 to 30 April 1992. This period coincides with the Darling River blue-green algal blooms and the subsequent flushing storms which dispersed them.

Of the measured sites, the Namoi River contributed 47% of the flow to the Upper Darling River, but a much higher 66% of the total phosphorus load to the system. This preliminary data set shows that for this part of the state, nutrient management priorities should first focus on identifying and then controlling (where practicable) Namoi River phosphorus. The nutrient ratios of nitrogen and phosphorus are all low (as based on published information) which means that they will favour blue-green growths. The only satisfactory way of changing these ratios will be the selective management of phosphorus sources in the Darling River basin.

An environmental and process audit of the Lower Molonglo Water Quality Control Centre (Canberra's sewage treatment plant; the largest inland sewage treatment facility in Australia and one of the most advanced), is outlined in the Final Report. It examines the plant's contribution of nutrients to the receiving waters of the Murrumbidgee River. The audit report by SCM Consultants concluded that a low risk of blue-green blooms occurs above an N:P ratio of 24:1, which is marginally lower than the United Kingdom experience of 29:1. The study highlighted the need to put a cap on nutrient discharges from growing cities such as Canberra, the need to store and treat the bypasses of sewerage storm flows (which can add significantly to phosphorus loads), and the high cost of nutrient control, especially in dealing with small levels of residual control.

The Task Force has joined the worldwide debate concerning the quantities and proportions of phosphorus contributed to sewage from various sources. The nutrient study for the MDBC described above indicated that significant external inputs of phosphorus to rivers in the Murray-Darling Basin in dry years are discharges from sewage treatment plants. Phosphorus in sewage effluent is derived from humans and detergents. The Task Force estimates that up to 55% of phosphorus discharged from these plants may be from detergents and other cleaning agents, but qualifies this by stating that the figure is derived and that further studies are needed to confirm this.

8. IMPACTS OF ALGAL BLOOMS

Blue-green algal blooms have a wide range of social, economic and environmental impacts. There are impacts on water supplies, human health, agriculture (livestock), fish, wildlife, recreation and tourism. There are also potentially broader economic impacts; the widespread coverage of the Darling-Barwon algal bloom by the media overseas has created an image of an environment of polluted waterways, with potential commercial consequences (such as lost tourist income).

The impact of blue-green algae blooms on country town water supplies is particularly significant. These water supplies are of three types; treated supplies (usually coagulation, flocculation, sedimentation, filtration and disinfection), disinfected supplies and dual supplies. Those water supply schemes with conventional treatment can remove algae (at a cost) but not the toxins produced by blue-green algae. This requires an additional treatment process in the form of activated carbon which can adsorb the toxins. Water supply schemes whose only treatment is disinfection are much more vulnerable. The disinfection process will normally kill the algal cells, releasing toxins. Water supply mains can be contaminated with dead, decaying cells which will cause odour and taste problems. The algae can also produce odour and taste problems, can cause skin irritations, and result in illness if consumed. Dual water supplies will perform as two seperate supplies; fully treated and disinfected. In such cases the partially or non-treated water can present problems for body contact or ingestion.

Statewide there are major cost implications for water treatment works should upgrading be required to handle increasing taste and odour problems, toxins and organic loads arising from algal blooms.

Proven cases of human poisoning by blue-green algal blooms are rare. Examples include people who have been exposed to algae accidentally when participating in water sports or through contamination of drinking water supplies. Nevertheless the toxin threat is of major concern to users of blue-green alage contaminated water.

One of the most obvious direct impacts is on local tourism and recreation. The 1991/92 losses to local NSW communities are in the order of $10 million (although this figure may be influenced by factors such as drought and recession). A significant amount of these losses can be attributed to intense media coverage surrounding the presence of blue-green algae in waterways (for example, television pictures of deserted caravan parks along the Hawkesbury River).

Blue-green algal toxins have resulted in the deaths of livestock and pets. Livestock are further weakened by their avoidance of algae infested water, if no alternative water supplies are available. Livestock deaths are likely to occur in future algal blooms, as the majority of primary producers claim that it is not practicable for them to prevent livestock having direct access to river banks, nor is it practicable for them to treat water to remove toxins.

The impacts on fish and shellfish are examined in the Final Report in terms of the impact on their populations, the accumulation of toxins in their tissues and the safety of these organisms as natural foods. The best understood impacts are those associated with the death and decay of algal blooms. The extra organic loading takes up more of the available oxygen within the water body, and commonly accounts for fish kills. The toxicity of individual algal species to fish is not known, but needs to be researched.

Research into the toxicity of edible mussels has clearly shown a consumer hazard; the mussels ingest the toxic blue-green algae and accumulate toxins in their digestive system. The toxins are retained, even after freezing and boiling the mussels. Fish sampled and analysed to date have not shown toxins in their tissues. However it is advised that the liver and gastro-intestinal tract of fish taken from toxic algae infested waters are likely to be poisonous to human consumers.

It is difficult to assess the impact of chronic poisoning on wildlife populations because sporadic deaths pass unnoticed, and the long term effects of toxins on animal populations has yet to be been established. Animal deaths will only become obvious when there are too many carcasses to be disposed of by predators and carrion feeders. The mortality rate due to toxin poisoning will be higher if the toxin is more potent, and if the algal bloom persists for a long period of time.

The impact of algal blooms is related to the levels of toxins present in them. Three major classes of toxins have been isolated from blue-green algal blooms; neurotoxins, hepatotoxins and lipopolysaccharides.

The availability of methods for testing toxitity is also a significant issue. Methods for testing the toxin content of algal blooms and related water supplies include bioassay, immunoassay, enzyme assay and chemical measurement. The Task Force concluded that the only secure and comprehensive method for the monitoring of toxin presence and concentration is by mouse bioassay; subsequent monitoring can use other more specific tests as an important augmentation of bioassay. At present this work can only be done by a small number of laboratories in Australia.

Research is underway into 'dipstick' rapid assay techniques. Until such a simple test is available for water treatment plant operators, a useful guide is the absence of taste or odour from treated water.

9. MEASURES TO MINIMISE BLOOMS AND THEIR IMPACTS: AN OVERVIEW

As described in the preceding Chapters 4 to 8, blue-green algal blooms have a considerable complexity in their cause and effect. This is not a single issue problem with a simple quick-fix solution. Minimising algal problems in NSW will require cost effective measures which integrate the cause and effect relationships.

This includes integrating:

- Immediate, short and longer term measures.
- Land and water resource management, much of it through the TCM approach.
- Measures catchment-wide and basin-wide.
- Ideas to fast track 'best bet' solutions.
- The efforts of the community and government to attack the problems.

Table 9.1 of this pivotal chapter summarises this integrated approach, placing in context the detailed management strategies outlined in Chapters 10, 11 and 12 with recommendations in Chapter 14. The approach includes a State Algae Contingency Plan to minimise the effects of blue-green algal blooms; bloom management measures in the short to medium term to control the factors affecting their development; and short to longer term land and water management measures to minimise nutrient inputs to our waterways.

Table 9.1 Integrated management approach to minimise algal bloom problems

Timing	**Immediate**	**Short to medium term**	**Short to long term**
Chapters	10,14	11,14	12,14
Algal issues	Bloom effects	Algal crop	Bloom causes
Management Strategies	State Algae Contingency Plan	Manage Blooms	Land and Water Management
	• contingency plans	• water allocation and water systems management	• nutrient control strategy
	• monitoring and action levels	• chemical methods	• waterway management
	• communication and information	• biological methods	

These management options should only be implemented where the benefits (economic, social and environmental) of minimising blooms and their impacts outweigh or equal the costs of control works or activities. At times it may be considered appropriate to 'live with the problem', by avoiding blue-green infested waters and using alternative water sources where available.

The benefits of minimising problems associated with algae need to be quantified for each catchment. In general terms benefits include:

- Secure, reliable supplies of good quality water for a range of uses, which eliminates fear and concern of water users.
- Clean, healthy waterways for the enjoyment by future generations of Australians and overseas visitors.
- A healthy, balanced river ecology to support Australia's diverse native plants and wildlife, and the livelihoods which depend on the quality water which the environment provides.
- Considerable savings (several million dollars each year nationally) in water treatment, reservoir costs and tourist income.
- Additional benefits and savings from improved management of river catchments (reductions in soil erosion and loss of agricultural capital).

Costs also need to be identified and quantified as recommended in Chapter 8.

10. STATE ALGAE CONTINGENCY PLAN

Blue-green algal blooms will decrease in occurrence and impact as the range of measures descibed in the Final Report are implemented and take effect. However they will not disappear altogether, especially in those areas where it is considered appropriate to 'live with the problem'; such as where the costs of minimising blooms outweigh the benefits of their control, or where alternative water sources may be available. The State Algae Contingency Plan is being finalised, to effectively manage and control algal blooms in order to minimise their impact. The Plan is to be implemented at two levels; by the State Algal Coordinating Committee (SACC) and by nine Regional Algal Coordinating Committees (RACC's). Membership, meetings, roles and responsibilities are described in detail in the Final Report.

The regions are based on the six inland TCM regions, with the coast divided into three broad regions based on those of the Department of Water Resources. While these boundaries (Figure 10.1) do not coincide with many of the regional boundaries of member organisations, they are based on major surface water catchment divisions for the state and are therefore a logical division for dealing with this major surface water quality issue.

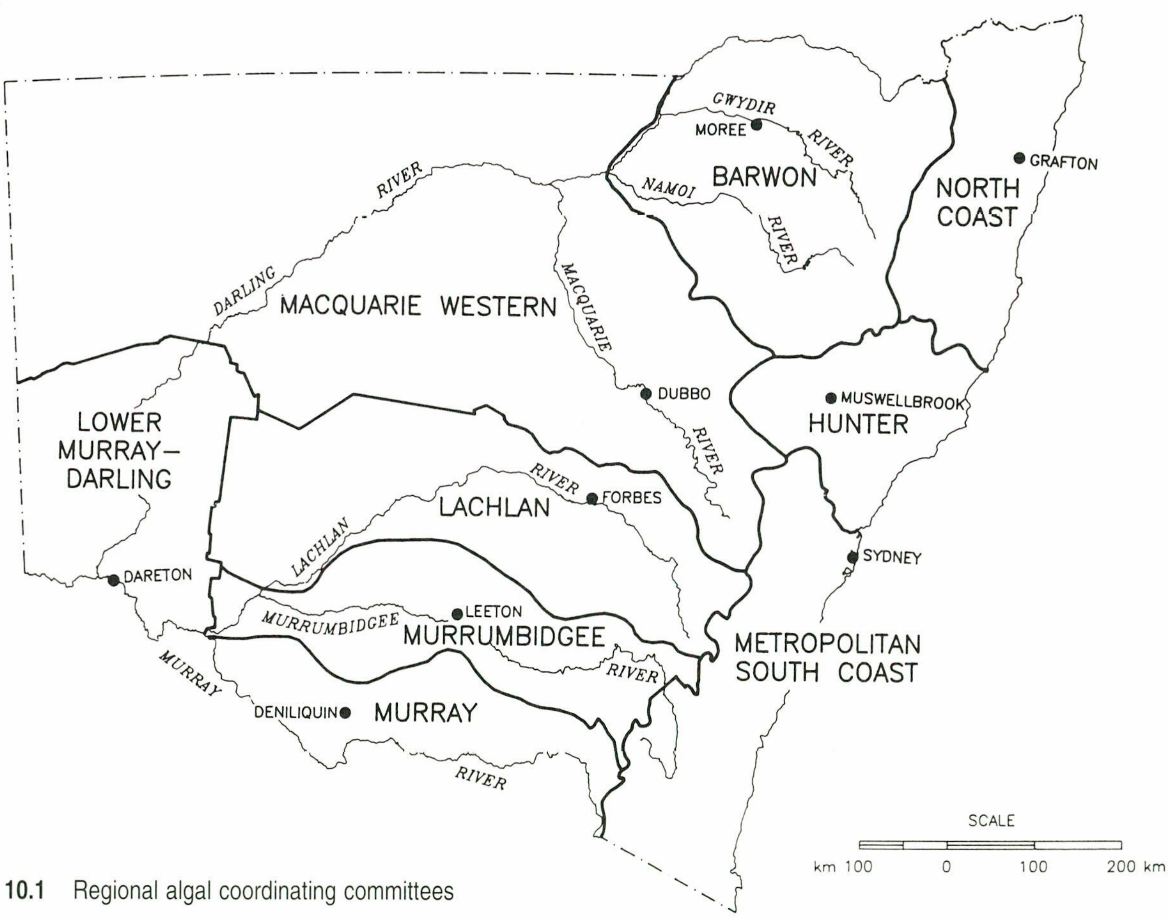
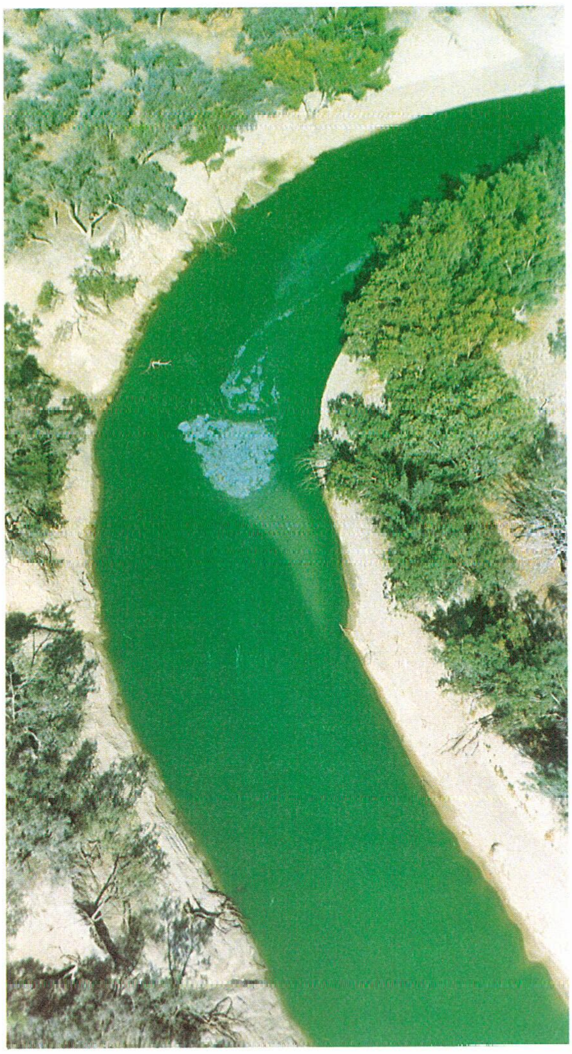


Figure 10.1 Regional algal coordinating committees

The state and regional levels of the Plan are at various stages of completion. They will contain an outline of agency responsibilities, guidelines for the development of action plans, training programs, public information material and press releases, and mechanisms for information dissemination, the majority of which have already been developed. The Plan will be further refined over the years, as the management of blooms is progressed.

At the core of the contingency planning process are alert levels for water uses. The Task Force has established provisional guidelines for water quality. The most sensitive issue for domestic water supplies is that of taste



Left: Darling River, between Bourke and Wilcannia

Part of the blue-green algae bloom in the Darling River between Bourke and Wilcannia in December 1991. Thick scums have formed which have been bleached by the sunlight.

Right:Carcoar Reservoir, NSW

An algal bloom extends along the shoreline of Carcoar Reservoir, NSW in summer 1990. Warm, still weather conditions favour blue-green algal growth.

and odour. Domestic water suppliers should be alerted when known taste and odour forming blue-greens exceed 2000 cells/mL, or when taste and odour are detected (in the absence of cell count information). At such levels water suppliers will need to apply their judgement to local conditions; they may need to consider alternative sources of raw water or to implement water treatment to remove taste and odour for drinking use. This is also the alert level for repeat sampling and toxicity testing.

Alert levels for other domestic uses, recreation and stock watering use should be issued when potentially toxic blue-greens exceed 15000 cells/mL. Water users should avoid direct consumption or bodily contact; they should treat contaminated waters to remove toxins, or use alternative water sources.

The entire closure of water bodies contaminated by blue-green algae is often impractical and unnecessary. There is a need to provide sufficient warning against inappropriate use of such waters, but land-based recreation can continue.

The Task Force has produced a multi-layered approach to algal monitoring which fills the present gap between the laboratory analysis of routine algal counts and casual field observation. The approach as shown in Figure 10.2 ranges from observation by the public to observation by a water system operator, water system operator with field aids, specialist operator with field laboratory, to the use of central laboratories. This monitoring approach needs to be tested and further developed within NSW.

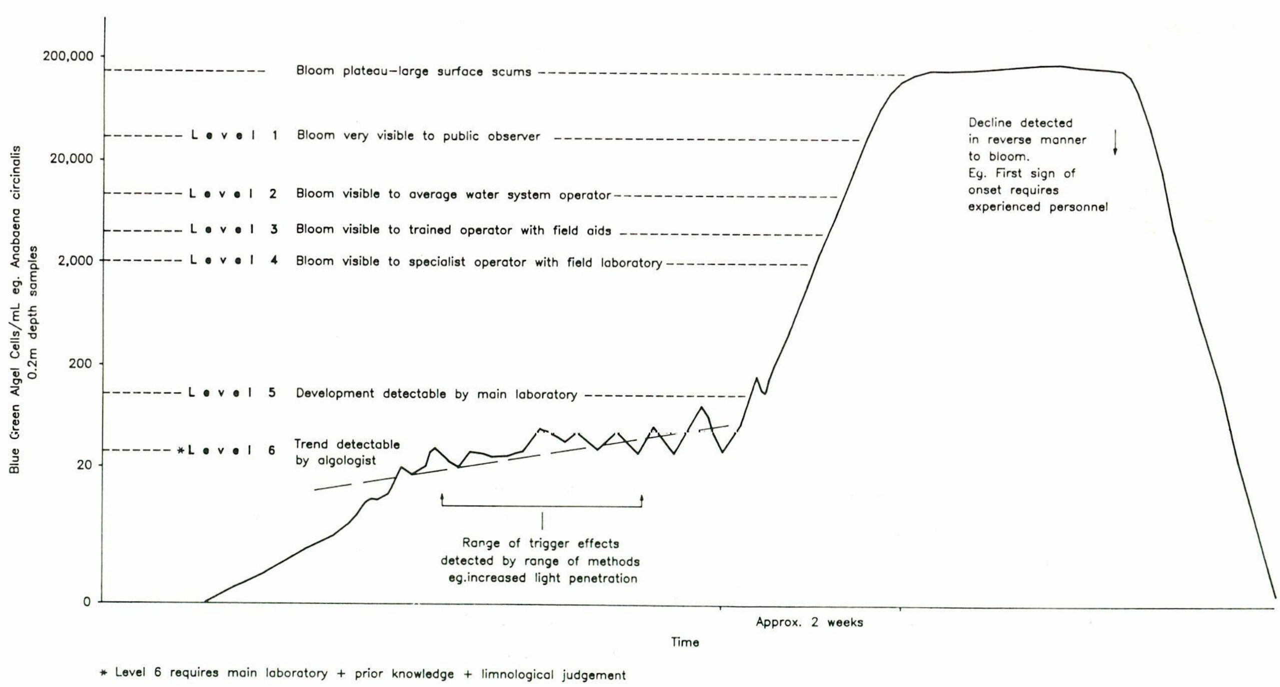


Figure 10.2 Blue-green algal growth curve and detection levels

The Task Force has also recognised the need for the development of Algal Watch Kits, which would be used routinely by personnel at key river and reservoir sites. The kits are an integral part of the contingency planning process, providing for routine statewide monitoring coverage and enabling algal alert conditions to be activated locally. The Final Report contains details of these kits, provides an estimate of the costs of their production, and recommends that they be developed

Effective two-way communication between government and the community is an important part of contingency planning, as it assists in the early detection of algal blooms, facilitates in bloom management, and helps reduce their impact on the community. The Task Force has produced or obtained a range of information items for general community use, with additional materials for people who need help in dealing with the effects of an algal bloom, or for people who may be affected by blue-green algae in the future.

11. MANAGING BLOOMS AND THEIR EFFECTS

Blue-green algae bloom management options for the state's waterways are categorised into physical, chemical and biological controls.

Feasible physical control options for NSW waterways include flow regulation, destratification, light restriction, variable offtakes, aeration, turbidity, floating booms, dredging and mechanical harvesting.

The Task Force recognises the need for a river flow regime which will maintain the health and function of the state's waterways and related environments, while integrating the needs of communities and other water users. An effective and efficient approach is to provide this additional water at times of maximum environmental benefit, with one of the aims being to minimise the physical factors (such as low flows) which favour the development of blue-greens. To succeed, the approach must reintroduce important features of natural variability in river flow and address other particular bloom development factors. Components of this approach include:

- Managing flow in the state's regulated waterways, (Figure 11.1), including a review of abstraction licences.
- Managing unregulated flows (Figure 11.1).
- Managing releases from the state's storages, including flushing flows, minimum release rules and variable offtakes.

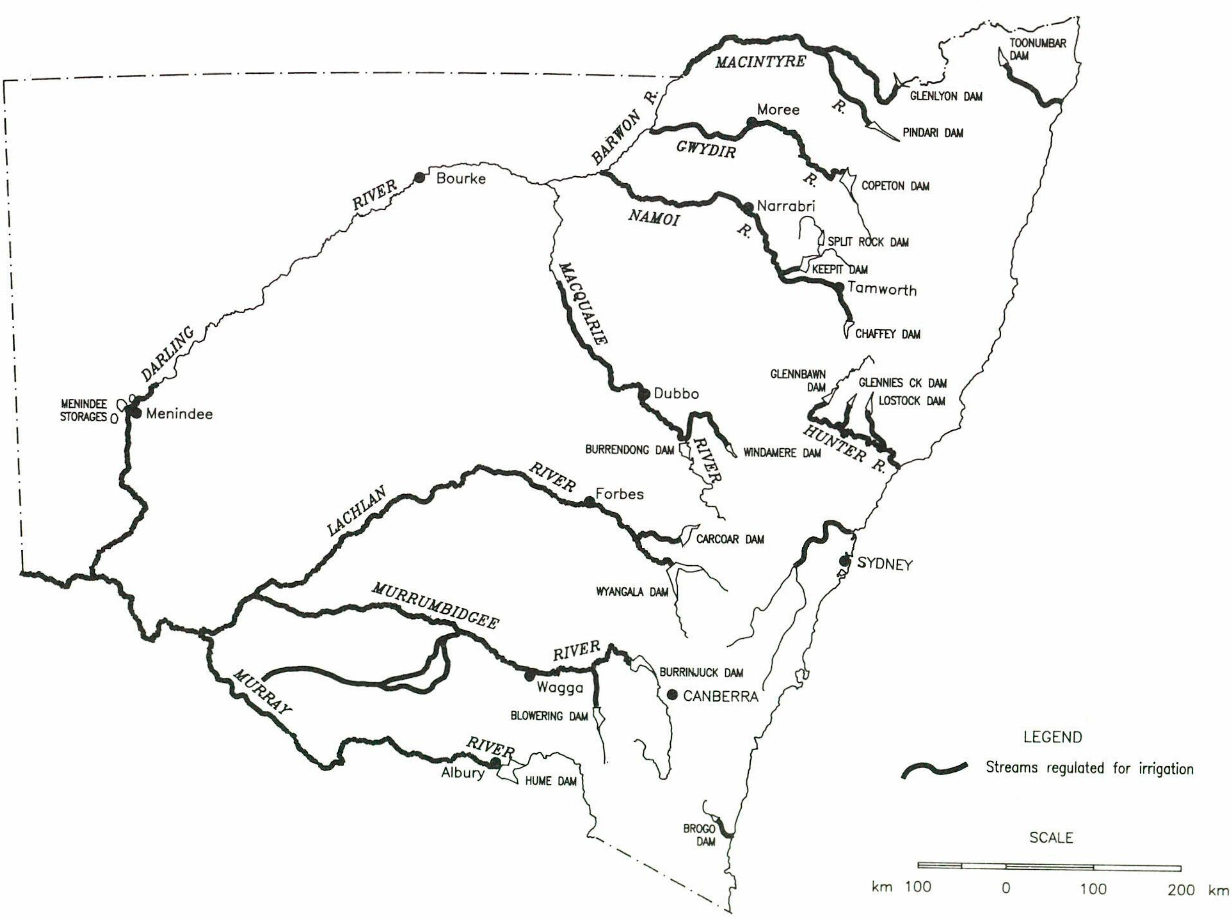


Figure 11.1 Regulated and unregulated streams in NSW

The Task Force notes that the Department of Water Resources has started to address each of these components as part of an Environmental Flows Policy, and urges that the Department's timetable of staged implementation over the next five years be adhered to.

Chemical control options include the use of algicides and algistats (in off-river, water supply storages and farm dams) and various nutrient controls. Algicides should not be used in the natural environment.

The Task Force sponsored laboratory and field trials which showed that alum and gypsum dosing were effective in removing turbidity in water and preventing algal growth by the removal of phosphorus from the water column. The dosing procedure, described in detail in the Final Report, has been developed for farm dams and other off-river storages, to provide drinking quality water for livestock.

Biochemical/biological methods involving enzymes and bacteriophages are still experimental, with no proven field information. Biological control options include the use of macrophytes, wetlands, bank vegetation, biomanipulation and artificial substrates.

Though control measures will minimise the occurrence and impacts of algal blooms, there will be occasions when communities will be faced with "living with the problem". In such instances there is a responsibility for water supply authorities to continue to supply potable water (either treated water or alternative source).

12. MANAGING THE CAUSES OF BLOOMS: LAND AND WATER MEASURES

There are a range of solutions to the nutrient problem in any catchment. Each solution will need to be tailored to the particular source(s) and its (their) nature as well as to the benefits and costs involved, on a catchment by catchment basis. Success will depend on extension and education programs based on catchment demonstration works.

Examples of activities which may be used to control diffuse sources include control of runoff; improved techniques of fertiliser application (both timing and quantity); holding dams, land application of effluent and reduced water use for intensive rural industries; riparian buffer strips; erosion control strategies to reduce soil loss; control of livestock access to waterways; grassed spoon drainage systems in urban environments; limitations on use of phosphate based detergents; and improved siting, design and operation of septic tanks.

Examples of works to control point sources of pollution include improved sewage treatment through phosphorus removal, land application of treated sewage effluent, abattoir waste and feedlot waste; on-farm and in-stream phosphorus removal; and amelioration works including detention ponds, contour banks and artificial wetlands.

Examples of waterway management activities (most already outlined in Chapter 11) include the development of sustainable levels of water abstraction, environmental flow allocation in waterways, fine-tuning of water flows to improve water quality, instream management to utilise available nutrients, and restoration of riverine ecology to restore the food web.

One of the sources of phosphorus to the state's waterways is detergent phosphorus. As noted in Chapter 7, the Task Force estimates that up to 55% of the phosphorus discharge from sewage treatment plants is from detergents and other cleaning agents. As one of a range of strategies targeting different sources of phosphorus, the Task Force has developed a strategy for detergent phosphorus control (Chapter 14, Recommendation 23).

Costs and benefits of nutrient control are still to be quantified and are likely to be considerable. For example, preliminary costs to minimise nutrient output from key sewage plants in the Murray Darling Basin is estimated to be in excess of $200M. Land management and waterway management costs are likely to be considerably higher.

Given the magnitude of the problem and the potential range of works required, funds made available for control works will need to be allocated wisely, by choosing catchments where nutrient enrichment of waterways is highest and where control activities will reduce the likelihood and outweigh the costs of algal blooms. This is best achieved through the development and implementation of a Nutrient Control Strategy which has three phases:

1. Identify the activities requiring control on a catchment by catchment basis.
2. Using environmental, economic and social criteria, determine the key catchments, nutrient sources and waterway conditions that can be targeted for nutrient control.
3. Implement the Strategy through a program of works and activities.

The Task Force concludes that the magnitude of the nutrient control problem and the need to weigh up environmental, social and economic considerations necessitates that NSW develop a Nutrient Control Strategy. This will ensure that those funds available are allocated to where they can most effectively reduce the likelihood of algal blooms; and where the benefits of bloom control outweigh or equal the costs of control works or activities.

Work has already commenced on a number of activities to manage the causes of blooms:

- Phase 1 of the Nutrient Control Strategy has commenced.
- Work has commenced on an extension/education program, with the allocation to the Department of Water Resources of $750,000 for the construction of catchment water quality control demonstration works such as artificial wetlands, riparian vegetation buffer strips, etc.
- The concept of tradeable property rights in nutrients, using market forces to optimise the reduction of nutrients to waterways, is being researched.
- Nutrient control strategies are being investigated in the Hunter Valley.
- A project aimed at reducing the impact of septic tanks on nutrient levels in NSW waterways will be completed by mid 1993.
- A State Environmental Flows Policy is being developed and implemented in stages over the next five years; the first interim off-allocation flow plan is in operation.

Responsibility for overseeing the development and implementation of the Nutrient Control Strategy will be with the State Algal Coordinating Committee.

Constructed Wetland

This newly constructed wetland on the Belubula River, NSW will help remove nutrients which would otherwise enter Carcoar Reservoir immediately downstream of this site. Wetland plants are being progressively established with the help of school and community groups.

13. RESEARCH

From its investigations and deliberations, it is clear to the Task Force that there is still much to be learned about blue-green algae, their causes and effects, if the problems they cause are to be minimised.

The Task Force recognises the need to establish an integrated research program in NSW which is complementary to the National Algal Research Program and gives focus to the more specific research needs of this state. The incoming State Algal Coordinating Committee is the appropriate body to oversee this state package of complementary and coordinated research and investigation projects. The Task Force recommends that State Government fund the Committee $500,000 annually for the needed research.

As a result of a collaborative effort between the Task Force and the AWRC National Algal Bloom Research Manager, a register of Australian researchers and activities in algal bloom research has been compiled and is included in the Appendices Volume.

The Task Force has identified and described 42 research needs which will lead to minimising the problems caused by blue-green algae in NSW. The description in the Final Report indicates whether this research is required in the short, medium or longer term, and suggests the organisations which are likely to be involved.

These research needs are categorised into the following major issues:

(i) Factors causing blue-green algal dominance

- Physical factors. One topic, on retention times.
- Chemical factors. Topics on phosphates in detergents; nutrient export coefficients; water quality parameters; nutrient sources, loads and their fate; N:P ratios; bloom trigger mechanisms; bioavailability of phosphorus.
- Biological factors. Seven topics, on seed sources; biomanipulation; macrophytes as refuges and nutrient removers; roles of fish; herbicides/pesticides; zooplankton.

(ii) Impacts of algal blooms

- Impacts on human health.
- Safe drinking water supplies. Topics on activated carbon; and analytical kits for toxin testing.
- Costs of blooms. Three topics, including protocol for assessing costs and benefits; assessment of costs for town water supplies, livestock, fish and aquaculture; tourism and recreation.
- Toxic compounds. Topics on their measurement; skin irritants; release and fate of toxins in water; tumour production.
- Effects on other organisms. Five topics, on procedures for basic monitoring; toxins in fish muscle; effects on fish; tumour production; broad environmental implications.

(iii) Monitoring

- Water quality alert levels.

(iv) Managing blooms and their effects

- Task Force sponsored field trials on localised artificial aeration/destratification; "Baleen" mechanical harvester.
- Importance of unregulated river flows; studies to fine-tune the off-allocation flow management plan.

- Investigate algicides and algistats.
- Weir pool management. Three topics, on management strategies; minimise algal intake into treatment plants; sediment conditions.

(v) Managing the causes of blooms

- Nutrient Control Strategy. Two topics, on nutrient control measures; agricultural practices.

14. RECOMMENDATIONS

The Blue-Green Algae Task Force has already taken many steps on the road to minimising the problems of blue-green algae and their impacts. Recommendations for further action are categorised under issue and management headings; they are not presented in any order of priority.

14.1 Measures to minimise blooms and their impacts: an overview

1. That management options only be implemented where the benefits (economic, social and environmental) of minimising blooms and their impacts outweigh or equal the costs of control works and activities.

14.2 Administration of blue-green algae management strategies

2. That the Blue-Green Algae Task Force be disbanded in mid September 1992 after public release of its final report.
3. That the Task Force be replaced with the State Algal Coordinating Committee whose core membership includes the Departments of Water Resources (chair), Public Works, Conservation and Land Management, Health; Environment Protection Authority, NSW Agriculture; three TCM representatives (of environmental interests, rural interests and a chairperson of a regional TCM committee); Sydney Water Board; Hunter Water Corporation; and State Rescue and Emergency Services Board. Other organisations such as UTS will be co-opted as required.
4. That the State Algal Coordinating Committee be responsible for developing and implementing algal policy and strategies; facilitating algal contingency response within the state; liaising with organisations intrastate, interstate and overseas; identifying and coordinating research; public information; planning and implementing phases of the Nutrient Control Strategy; monitoring strategies; coordinating procedural developments; preparing an annual report.
5. That the State Algal Coordinating Committee be structured under and report to the State Catchment Management Coordinating Committee for the development and implementation of the Nutrient Control Strategy. Government will need to adequately resource the TCM structure to implement the measures arising from recommendations of the Task Force and the State Algal Coordinating Committee.

   The State Algal Coordinating Committee will also need to liaise with and report to:

   (i) State Emergency Management Committee, on the occurrence of extreme algal bloom events.

   (ii) NSW Water Resources Council for water management related issues.

14.3 State Algae Contingency Plan

6. That the State Algae Contingency Plan, its proposed state and regional structure, and the roles and responsibilities as described in Chapter 10 be adopted to minimise the impact of blue-green algal blooms.
7. That the State Algae Coordinating Committee direct the establishment of Regional Algae Coordinating Committees, provide guidelines for the development of Regional Algae Contingency Plans, monitor progress, and facilitate resourcing of regional committees.

8. That the nine Regional Algal Coordinating Committees be responsible for ensuring monitoring, communications, implementation of response(s), and training in their regions. These committees will liaise with and report to the State Algal Coordinating Committee, as they are only responsible for algal bloom contingency plans.

9. That mouse bioassay be used as the first test for toxicity of algal blooms (after sample concentration, if required). Subsequent monitoring using specific tests can then be used as an important augmentation of bioassay. A useful guide for water treatment plant operators is the absence of taste or odour from treated water.

10. That water quality guidelines for blue-green algae are:

    - Domestic water suppliers be alerted when known taste and odour forming blue-greens exceed 2000 cells/mL or when taste and odour are detected (in the absence of cell count information), for drinking use.
    - Alerts for other domestic use, recreation and stock watering be issued by RACCs when potentially toxic blue-greens exceed 15000 cells/mL.

11. That closure of water bodies contaminated by blue-green algae is not necessary. Rather, there is a need to provide sufficient warning against inappropriate use of contaminated water.

12. That the multi-layered approach to algal sampling and monitoring proposed by the Task Force be tested and further developed within NSW.

13. That State Government fund the development of an Algal Watch Kit. The kit will form part of Regional Algal Contingency Plans, enabling local sampling and monitoring, and the activation of alert conditions on a local basis. Development costs are estimated to be $33,000.

14. That effective monitoring programs be implemented to determine causative factors, bloom size and occurrence, toxicity and the effects of blooms.

15. That accurate information be prepared for water treatment plant operators on algal related issues including activated carbon dosing and the operation of treatment plants.

16. That every effort is made to inform the community of algal problems, impacts and coping measures, including the use of:

    - Fact sheets in a format accessible to non English speaking people.
    - A 008 telephone number carrying general algal information and a hotline to be used in emergencies.

17. That the public be educated not only on the problems caused by blue-green algal blooms, but also that waterways can be safely used for water supply, recreation and other uses once blooms are dispersed.

14.4 Managing blooms and their effects

18. That the various water allocation and water system management measures (to provide water to meet environmental needs) being developed by the Department of Water Resources in consultation with water user groups and communities be finalised as quickly as practicable, and within five years. Measures include:

- Review of regulated flow management and licensing, resulting in an Environmental Contingency Allowance for all the state's river valleys by 1997.
- Developing unregulated flow plans for all regulated rivers by late 1993, and then for unregulated rivers.
- Developing minimum flow rules for all Department of Water Resources storages, and incorporating them into the water system management and Security of Supply agreements for the state's river valleys.

19. That algicides and other intrusive toxic chemicals not be used to control blue-green algae in natural waterways. If they must be used, do so in off-river storages.
20. That prevention of bloom development is the best course of action in reservoirs and off-river storages. Only low doses of algicides or algistats are then required.

Signs at Carcoar Reservoir, NSW

Signs erected at Carcoar Reservoir advise the public of both the problem of blue-green algae, and a potential solution. Education is an important first step in gaining community acceptance of programs to improve water quality.

14.5 Managing the causes of blooms: land and water measures

21. That the Nutrient Control Strategy be implemented for NSW, as outlined in Chapter 12. Phase 1 of the Nutrient Control Strategy is being undertaken in 1992. This involves the identification of the types of activities and the extent to which they contribute to the nutrient problem on a catchment-by-catchment basis.

22. That Phase 2 of the Strategy be funded by State Government in 1993. It is estimated that identification and prioritising of control works and activities, including options for grants, subsidies, incentives and guidelines will take a multidisciplinary team of natural resource managers about 12 months and cost $500,000 (this is in addition to annual funding for research, see Recommendation 30).

23. That the following strategy for detergent phosphorus control be implemented:

    - A study be carried out within the next two years, by the State Algal Coordinating Committee working with urban water authorities, to quantify the contribution of detergent phosphorus to sewage and to waterways.
    - Truth in labelling of phosphorus content in detergents.
    - Industry aim for a target of 5% or less by weight of phosphorus in detergents and other cleaning agents, within 18-24 months.
    - Government set a 5% by weight phosphorus limit in detergent and other cleaning agents within 18-24 months.
    - Government raise public awareness on the use and control of phosphorus in the broad environment.
    - Integrate future detergent phosphorus controls with the findings of Phase 2 of the Nutrient Control Strategy after two years. This will identify whether there is priority for further reductions in detergent phosphorus.

24. That programs be developed for other phosphorus mitigation measures including increased phosphorus removal at sewage treatment plants as part of the Nutrient Control Strategy.

25. That current extension/education programs directed at the prevention and control of soil structural decline and erosion, and the appropriate use of fertilisers be reviewed and modified as necessary.

26. That Government continue to support the use of demonstration catchment models and field extension services provided by the natural resource agencies as a means of implementing 'best bet' solutions with communities to reduce the amount of phosphorus and other nutrients entering the state's waterways.

27. That government agencies complete by mid 1993 studies already commenced into:

    - The concept of tradeable property rights in nutrients, and the feasibility of using market forces to optimise the reduction of nutrients to waterways.
    - Reducing the impact of septic tanks on nutrient levels in NSW waterways.

14.6 Research

28 That the State Algal Coordinating Committee oversee the development of a package of complementary and coordinated research and investigation projects for NSW to address the many unresolved questions regarding blue-green algae.

29. That the 42 research needs be brought to the attention of the National Algal Research Board, and national and state research agencies.

30. That State Government fund the State Algal Coordinating Committee $500,000 annually, to accelerate research needed to resolve key identified algal issues for NSW.

Darling River, Lake Wetherell

The Darling River as it enters Lake Wetherell, February 1992. The different shades of green are caused by a mixture of blue-green and green algae of various ages.

15. GLOSSARY

Absorbtion	to absorb substances within a material
Adsorption	to gather substances on the surface of a material
Aerobic	when free oxygen is available
Algicide	a chemical that kills algae
Algistat	a chemical that inhibits algal growth
Anaerobic	when no oxygen is readily available
Assimilation	taking up materials, (e.g. nutrients) into a physical, chemical or biological system
Bacteriophage	virus which attacks bacteria
Bioassay	measurement of the effect of substances on organisms
Biomass	the weight of living material
Biota	all plants and animals present in an environment
Bloom	a visible appearance of free floating algae
Cyanobacteria	blue-green algae
Cyanophages	viruses which attack blue-green algae
Diffuse source	materials originating from a widespread area and entering at multiple sites (e.g. agricultural runoff)
Eutrophic	having water high in nutrients
Eutrophication	the process of nutrient enrichment and the consequences of such
Filament	threadlike row of adjoining cells
Filamentous	threadlike
Gas-vacuoles	bladderlike, buoyancy-conferring cavities in blue-green algae
Gastroenteritis	inflammation of the intestine
Genus	a number of close-related species
Hepatotoxin	toxin affecting the liver
Limiting Factor	circumstance or substance which restricts growth when in short supply
Lyse	disintegrate
Macrophytes	large aquatic plants, e.g. lilies, reeds
Mass balance	the load of materials from a total of catchment sources

pH	scale of acid to alkali
Photosynthesis	manufacture of carbohydrates using energy from light
Phytoplankton	floating or weakly motile small aquatic plants
Planktoniverous	plankton eating
Point source	materials entering a water at single defined sites (e.g. sewage effluent)
Protozoa	small single-celled animals
Retention time	time that water remains within a lake or river
sp	species
Spp	multiple species
Standing crop	total biomass (e.g. amount of algae) at any one time
Stratification	formation of layers
Total Catchment Management	managing natural resources on a whole of catchment basis with a view to long term sustainability
Total P (Phosphorus)	the sum of all analytically determined forms of phosphorus present in a sample
Toxins	products generated by blue-green algae which are poisonous
Trophic	the nutrient status of a water body
Tumour promoting properties	properties which allow tumours to grow faster (this is not carcinogenicity)
Turbidity	opaqueness or muddiness of water with suspended particulates
ug	microgram, 10^{-6}g
ug/L	microgram/Litre, 10^{-9} kilogram/litre
Zooplankton	small animals which are weakly motile or are carried passively in the main body of water