The National Eutrophication Management Program – A Review

Peter Chudleigh

Sarah Simpson

With a special contribution by Roger Croome

Land & Water Resources
Research & Development Corporation

Published by: Land and Water Resources Research and Development Corporation
GPO Box 2182
Canberra ACT 2601
Telephone: (02) 6257 3379
Facsimile: (02) 6257 3420
Email: public@lwrrdc.gov.au
WebSite: www.lwrrdc.gov.au

Publication data: 'The National Eutrophication Management Program – A Review' by Peter Chudleigh and Sarah Simpson, with a special contribution by Roger Croome, Occasional Paper 5/00.

ISSN 1320-0992

ISBN 0 642 76026 8

Authors Peter Chudleigh and Sarah Simpson
Agtrans Research
PO Box 385
Toowong QLD 4066
Telephone: (07) 3870 9564
Facsimile: (07) 3371 3381
Email: agtrans@powerup.com.au

Edited and designed by: Green Words & Images, Canberra

Printed by: Panther Publishing & Printing

April 2000

Contents

List of abbreviations

AGSO	Australian Geological Survey Organisation
ANU	Australian National University
CANDI	Sediment diagenesis model
CQU	Central Queensland University
CET	CSIRO Division of Coal and Energy Technology
CRC	Cooperative Research Centre
CRCFE	CRC for Freshwater Ecology
CRCSLM	CRC for Soil and Land Management
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DLWC	Department of Land and Water Conservation
DNRE	Department of Natural Resources and Environment
DOC	Dissolved organic carbon
ICMS	Integrated Catchment Management Software
LWRRDC	Land and Water Resources Research and Development Corporation
MDBC	Murray-Darling Basin Commission
MDFRC	Murray-Darling Freshwater Research Centre
NEMP	National Eutrophication Management Program
NIFT	Nutrient-induced fluorescence transient
NPIRD	National Program for Irrigation Research and Development
NRHP	National River Health Program
QDNR	Queensland Department of Natural Resources
R&D	Research and development
RCC	Rockhampton City Council
UTA	University of Tasmania
UWA	University of Western Australia
WRC	Western Australian Water and Rivers Commission
WSAA	Water Services Association of Australia

Acknowledgments

Particular acknowledgment is made to Richard Davis who assisted in the review by making time available for discussions and interpreting some of the more technical aspects of the program. Also, Roger Croome is acknowledged as providing the component of the report associated with science quality. Further acknowledgment is made to the following people who made useful input during the course of the review:

Interviewed by telephone

Anna Porter, Coordinator, Namoi Focus Catchment

Pat Feehan, Coordinator, Goulburn-Broken Focus Catchment

Peter Davies, Coordinator, National River Health Program

Brett Tucker, Coordinator, National Program for Irrigation Research and Development

Jann Williams, Coordinator, Remnant Vegetation Program

Phil Price, Program Manager, LWRRDC Vegetation Program

Klaus Koop, New South Wales Environment Protection Authority, Sydney

Bob Banens, Atech, Canberra

Peter Dempster, Atech, Canberra

Viv McWaters, Communications Coordinator, NEMP

Meg Keen, Australian National University

Brian Lawrence, Murray-Darling Basin Commission

Steve Mills, dairy farmer, Victoria

Peter Donlon, Goulburn Valley Water

Chris Gunby, Waters and Rivers Commission, Western Australia

Christine Forster, former NEMP Management Committee Member, Victoria

Peter Vollebergh, Department of Natural Resources and Environment, Victoria

Jean Webb, Wilson Inlet Catchment Authority

Ian Smalls, New South Wales

Ian Wallace, Queensland Department of Natural Resources, Rockhampton

Interviewed in person

Nick Schofield, Program Manager, LWRRDC, Canberra

Richard Davis, Program Coordinator, CSIRO, Canberra

Tony Jakeman, Australian National University, Canberra

Phillip Ford, CSIRO Land and Water, Canberra

Myriam Bormans, CSIRO Land and Water, Canberra

Peter Thompson, Coordinator, Fitzroy Focus Catchment

Vlad Matveev, CSIRO Land and Water, Brisbane

Candace Martin, Australian National University, Canberra

David Fredericks, Australian Geological Survey Organisation, Canberra

Ian Lawrence, University of Canberra

Peter Wallbrink, CSIRO Land and Water, Canberra

Assisted with facilitation

Helen Wilson, CSIRO Land and Water, Canberra

Bobbie Heath, LWRRDC, Canberra

Glenn Conroy, LWRRDC, Canberra

Kerri Morson, LWRRDC, Canberra

Executive summary

The National Eutrophication Management Program (NEMP) has made, and continues to make, an important and useful contribution to knowledge since its commencement in August 1995. The focus of the program has been on understanding the sources of nutrients and other factors contributing to the development of algal blooms, which impose a cost of $200 million per annum on Australian water users. The program has contributed significantly to knowledge of this complex system and will establish a platform for further applied research. Implications for management are already being developed from the results of the program. The quality of the science contained in the program and the overall program management have been excellent. Improved networking and communication between researchers and catchment and water managers has also been evident.

Outputs

Examples of various results from the program to date include:

- finding that light availability, not nutrients, is the factor controlling algal growth in the Rockhampton barrage of the Fitzroy River;
- the introduction of predatory fish has successfully suppressed cyanobacteria in mesocosm trials;
- the flow management techniques, developed prior to NEMP for nutrient-rich rivers, have been extended to nutrient-deficient rivers;
- the diffuse sources of phosphorus and sediments from catchments will be estimable from geomorphic attributes before NEMP is completed;
- guidelines for reservoir managers have been drafted, based on analysis of long-term data sets from Lake Burrinjuck; no guidelines exist at present and these will allow reservoir managers to manage inflows and outflows in a way that minimises the chance of algal blooms occurring.

New techniques have also been generated:

- the nutrient-induced fluorescence transient (NIFT) and iron-strip methods have been accepted by water quality managers; the latter technique is being used in two laboratories to provide significantly cheaper and quicker assessments of bioavailable phosphorus;
- a standard phytoplankton sampling procedure has been developed, approved by water managers and distributed to laboratories, and will lead to more nationally consistent information on algal blooms in standing waters.

Shifts in understanding have occurred:

- contrary to previous beliefs, large loads of phosphorus can travel through subsoil pathways in a wide range of east Australian soils, thereby bypassing surface interception measures; this has major local management implications;
- nitrogen is equally important to phosphorus in controlling algal growth in the Murray-Darling Basin and possibly elsewhere;
- light, and not nutrients, is commonly the factor that controls algal growth in inland rivers; this has major implications for current phosphorus control strategies and the program is disseminating this result widely;
- the bioavailable fraction of phosphorus is roughly equal from dryland, irrigation and sewage treatment plant sources in the Goulburn River; it had been hypothesised that phosphorus from sewage treatment plants was more available to algae than phosphorus from dryland sources.

Overall, the complexity of the various factors operating in the development of algal blooms has been increasingly recognised in NEMP. Many projects within the program are not yet completed and the final year of the program will focus on the integration of all project outputs into management guidelines.

Outcomes and impact

Notwithstanding the contribution to knowledge that NEMP has made so far, it is too early to assess outcomes and overall impact on reducing algal bloom incidence and intensity. The program is not due to be completed until June 2000 – a number of projects are still incomplete and the implications for management still to be determined. It is not likely that resulting specific management interventions to reduce the severity and frequency of algal blooms will be applied within the lifetime of the program. The same conclusion is likely with respect to policy changes within catchments and more broadly within State agencies.

Nevertheless some of the outputs listed above may result in significant management changes in the future. For example, a fine clay will be trialled by Rockhampton City Council to artificially suppress growth when light reaches critical levels defined from NEMP research. Also, the biomanipulation project using predatory fish has potential to make a significant impact if the lake trial is successful.

Many projects selected in the program were 'understanding' or strategic research in nature. In many cases results are likely to be used only in a general sense to focus management efforts in the future, or be used to build more applied research projects. The bias towards strategic research can be explained in part by the environment that existed during the genesis of NEMP.

At the beginning of NEMP there was considerable uncertainty as to whether existing and proposed management actions would be effective in controlling algal blooms. This uncertainty arose from:

- conflicting views on the sources and bioavailability of phosphorus;
- little information on the role of nitrogen and micronutrients;
- limited understanding of stratification and related control measures;
- where and how flow strategies might be used;
- the role of instream sediment sources and their control;
- the importance of episodic events.

All management plans emphasised phosphorus reduction; the MDBC's algal management strategy also proposed flow management. Thus managers had few tools for algal management and new approaches had to be developed. It was contended that such issues needed to be better understood in order for future management interventions to be soundly based.

In this regard, NEMP has contributed to improved understanding of processes that will help resolve these uncertainties. There will need to be further investment in more applied research to translate much of this improved understanding to more specific management guidelines.

Although the program has developed a number of alternative management techniques and guidelines, these have yet to be thoroughly tested in practice. There have been strenuous efforts to engage managers and community coordinators in this work, although there have been only a limited number of practical tools delivered to managers at this stage of the program.

It should be recognised that the expectations for specific and relevant management guidelines to be provided in the final year in most of the focus catchment communities are currently very high. The community groups express confidence that their management needs will be met over the remainder of the program.

However, the on-ground impact of the first phase of NEMP is not yet apparent and is not likely to emerge until after the end of the program in June 2000. Any further funding by partners should focus on capitalising on the strategic understanding gained, and trialling and disseminating the new management techniques developed.

Economic evaluation of projects and programs

A synthesis of past investment analyses for four NEMP projects showed net present values ranging from $0.6 million to $105 million and benefit-to-cost ratios of 2.4 : 1 up to 20 : 1. However, the studies showed difficulties in the benefit-to-cost approach to measuring impact or potential impact in economic terms. These mainly referred to the valuation of benefits from eutrophication research as well as the difficulty of attributing benefits quantified directly to the NEMP projects funded.

An investment analysis for the whole program carried out within this review, and using conservative assumptions, showed that the $8.7 million investment in NEMP should provide a positive net present value of $50 million using a discount rate of 7% real. The internal rate of return was 27%, well above market interest rates, and the benefit-to-cost ratio was 5.6 : 1. This analysis assumed that some benefits would flow directly from NEMP in a few years time but also allowed for a further investment cost of $1.5 million per year for four years to build on the results of the existing program, in order to achieve continuing reductions in algal outbreaks.

Meeting objectives and addressing priorities

Three objectives were set for the program. The first was concerned with gaining an improved understanding of processes leading to the initiation and development of algal blooms. The program met this objective quite clearly. The second objective was associated with developing techniques, including predictive models and decision support systems to help prevent and manage the impacts of eutrophication. This objective is likely only to be partly met due to the balance of the program being geared towards strategic research. The third objective, concerned with effective communication, was met.

Six priorities were set for the program:

A. Bioavailability of phosphorus, nitrogen and other nutrients;

B. Sources and transport of nutrients in catchments;

C. Management of sediment nutrient sources;

D. Effects of episodic events on waterbody ecology;

E. Factors leading to the initiation and development of blooms;

F. Evaluation of effectiveness of actions to manage nutrients.

The program addressed these priorities rather unevenly with most (69%) of resources for research being committed to Priorities B and E and approximately 31% to Priorities A and C. Although a considerable effort was made to develop projects in the area of Priority D, this was unsuccessful. Few proposals were forthcoming in the area of Priority F and no attempt was made to fund research in that area.

Science quality

The quality of the science undertaken in the program has been excellent. This applies to project design, methods used, adaptability and analysis of results. This conclusion has been reached after an evaluation, by Dr Roger Croome, of the science associated with six NEMP projects selected as case studies. The well defined structure of project proposal, refereeing, negotiation/refinement and milestone reporting – all set within a program with well defined aims and objectives – has ensured effective establishment, conduct and progress within each project. Each of the six projects reviewed was of high scientific merit and involved experienced researchers of national or international standing producing meaningful results with respect to nutrient and algal management.

Program management

The program has been well managed by the Management Committee, the Program Manager and the Program Coordinator. In fact it appears to have been a very well run program from many perspectives, such as:

- the excellent science supported;
- the use of scoping studies across scientific issues and prospective projects;
- the support of various workshops and knowledge integration overall in:
  - developing and following communication plans; and
  - accountable project and program management.

Communications

The program emphasised the need for close integration of research effort with uptake of results by managers in the focus catchments. This was achieved by making catchment coordinators members of the NEMP team. Coordinators had the role of highlighting information needs, thus guiding research projects and assisting in communicating research results to stakeholders. This worked better in some catchments than in others.

While it might be said that the specific management interventions that will reduce the severity and frequency of algal blooms (a goal of the program) are unlikely to be achieved during the life of the program, it is clear that results will be used to focus management efforts in the future. It is envisaged that clear management guidelines on some issues will be developed in consultation with resource managers in some of the focus catchments. This will address the expectation of at least some focus catchment communities that NEMP will produce management guidelines specific to the local catchments while at the same time providing a framework of information which can be adapted more widely.

Program Management made a significant effort in ensuring that communication between stakeholders and researchers, as well as between researchers (both inside and outside the program), was prominent and effective. This was done by a range of means including:

- annual program meetings;
- focused workshops;
- establishment of a NEMP web site and Internet discussion group; and
- production of articles highlighting results as they became available.

This interaction has its difficulties because of the sometimes disparate perspectives and expectations of the clients and stakeholders. Interaction of scientists with the catchment communities varied according to capacity and interest on both sides; communication between researchers was good and some synergies between various projects resulted. Focus Catchment Coordinators played an important and effective role in facilitation and ensuring that information flowed to the communities as well as to other groups in the State agencies.

NEMP is writing a major summary document covering the latest understanding of the causes of eutrophication and algal blooms and the increased management opportunities that have arisen in this area. This document will be disseminated widely and will be a major resource for water managers.

Focus catchment approach

The focus catchment approach used in NEMP was aimed mainly at producing information that was transferable to other catchments. A secondary objective was to provide information for improved management within the catchment itself. The actual approach adopted in NEMP could be viewed as somewhat of a compromise between these two objectives, although more emphasis was given to the transferability objective in focus catchment selection.

The approach was largely successful in producing some synergy between researchers and providing interaction between the research effort and the community. Overall it has worked reasonably well.

One of the key potential benefits from the focus catchment approach is to engender ownership of the research, and therefore the research findings, to the decision-makers in the catchment. For this to be achieved, more interaction with the catchment community and resource managers into priority-setting for the catchment (including issue identification and project design) should occur. If this is the case, an improved balance of strategic and management-orientated research may be developed. The early involvement of catchment managers and water managers in any new program is essential.

However, such an approach should be considered against the alternative of carrying out research in selected catchments (one or more) according to which catchments can potentially transfer most information to the maximum number of catchments. Process-type research carried out in various catchments may have greater prospects for extrapolation.

National leadership

NEMP has provided national leadership in a number of ways. Firstly, NEMP has incorporated research and researchers outside of the program into its workshops and general communications. Secondly, it has introduced stakeholders to a coordinated program in a structured manner, at least in those States in which focus catchments are located. By encouraging networks, NEMP has facilitated information exchange across Australia regarding matters of eutrophication which transcends the NEMP projects themselves.

Recommendations for the remainder of NEMP

1. The development of guidelines and principles for management actions from projects should be a major activity in the remaining period of NEMP and should be encouraged by NEMP Management.
2. While the primary objective of the focus catchment approach was not to provide solutions to local catchment issues, there is an expectation by some communities that that this will be forthcoming. It is important that a significant effort is made in this endeavour.
3. A stocktake, categorisation and synthesis of models produced or refined under NEMP should be effected. How the models might be used in other research or by land and water managers, together with their data requirements, should be explored in detail.

4. Integration of the outputs of NEMP regarding the implications for other programs would be useful and a small workshop across four or five other relevant programs and NEMP should be considered.

Recommendations for any continuing program

1. Any future program associated with eutrophication should consider scoping studies focusing on management information needs as important inputs to the structure and priorities of the program. Such scoping studies should be carried out before any other projects are funded and should cover:
   - the decisions currently being made by land and water managers that take into account the development of blue-green algal blooms;
   - the scope for interventions at different locations along the water chain (for example, land use and practices, nutrient export, maintaining stream bank integrity, flow control, reservoir management interventions and so on);
   - the potential for cost-effective solutions at different points along the water chain.
2. The balance between strategic and applied research should be given more prominence in developing priorities and selecting projects for future research and development (R&D), with a bias in any future program towards more management-orientated or applied research that capitalises on the opportunities provided by NEMP.
3. For all research projects funded in future, there should be stronger definition and expression of the linkages between the potential research outputs and how these outputs will be used. This could be achieved by detailing the type of management and policy decisions that may be assisted by such outputs.
4. A higher level of interaction should be pursued between any future NEMP and other programs associated with interacting processes and strategies such as riparian lands, river health and irrigation. In addition, various land-use-based programs of the commodity R&D corporations (dairy, meat and so on) should be consulted in order to determine where a program such as NEMP can best contribute in terms of information needs at the catchment level.
5. Consideration needs to be given to the argument that small reductions in nutrient exports from land use may not necessarily be effective for many years or perhaps never, given river sediment sources of phosphorus and episodic events.
6. Careful consideration should be given as to whether to use a focus catchment approach in future. Such considerations should take into account the major purpose of the program (process understanding, localised case studies, producing management guidelines for all catchments) and the synergies expected (between researchers and between researchers and the community, including personnel of State agencies). If a focus catchment approach is to be used in the future, sufficient numbers of projects within each catchment should be funded to provide sufficient scope for interaction and synergy. This may mean limiting the number of focus catchments.

1. Introduction

1.1 Background

NEMP was established in 1995 and is jointly funded by the Land and Water Resources Research and Development Corporation (LWRRDC) and the Murray-Darling Basin Commission (MDBC). The goal of NEMP is:

> *"to undertake the research and communications activities necessary to reduce the frequency and intensity of harmful or undesirable algal blooms in Australian fresh and estuarine waters."*

The funding partners required a review of the program in the latter part of 1999. The program had been running for about four years and the evaluation was to be one input as to whether it should be extended when the existing phase nears completion in June 2000.

1.2 Terms of reference

The terms of reference for the review were:

1. Review the extent to which NEMP has:
    - met the objectives specified in the NEMP program plan;
    - added to the nation's knowledge base on eutrophication through quality scientific research;
    - produced outputs and brought about outcomes of value to natural resource managers, land owners and communities;
    - had an impact on the management of eutrophication in Australia.
2. Review the management of NEMP, in terms of:
    - setting priorities;
    - selecting projects;
    - managing projects;
    - involving clients and stakeholders;
    - interpreting results into management needs;
    - communicating results to stakeholders;
    - providing national leadership in eutrophication.
3. Estimate the return on investment in eutrophication-related R&D in NEMP, including a summary of benefit cost analyses conducted to date.
4. Make recommendations on how to maximise the impact of the existing NEMP investment and how to improve strategies, program management and adoption of results in any future program.

1.3 Methods

The review was based on project and program documentation provided by LWRRDC, as well as discussions with the Program Manager, Program Coordinator and other members of the Management Committee. A major part of the review focused on briefly summarising all project outputs and outcomes in order to assess how the program had met its objectives and priorities and to assess the overall positioning and impact of the program. Drafts of these summaries were sent to principal investigators for comment, modification and extension as appropriate. One member of the evaluation team provided an assessment of science quality by anaylsing a sample of six projects.

Nine principal investigators were also personally interviewed in order to gain their perceptions of the program as a whole as well as to gather further details of their specific projects.

A range of Focus Catchment Coordinators, policy personnel in State governments, people associated with catchment and water management authorities and other stakeholders and program support professionals were also interviewed by telephone.

1.4 Layout of report

The second chapter of the report provides a brief description of the program including its genesis, scope and timing. The objectives and priorities for the program are stated and a listing of all projects funded since its inception provided. The resources invested in the program are detailed. Chapter 3 of the report provides an assessment of the current program. This includes whether the program has achieved the objectives set and whether it was focused on the priorities developed for the program. Outputs and outcomes for the program are described and assessed, as is the overall impact.

Program management is addressed in Chapter 4, including:

- priority-setting and project selection;
- the management of projects and the involvement of clients and stakeholders;
- interpreting and communicating results; and
- the extent to which the program has provided national leadership.

Chapter 5 focuses on previous investment analyses concerning eutrophication projects and summarises their findings. This chapter also attempts a benefit cost analysis for NEMP as a whole.

Chapter 6 provides an indication of lessons learned from the program and makes an assessment of future directions that could be taken with any subsequent programs or extensions to NEMP.

The report concludes in Chapter 7 with a summary of findings and a list of recommendations for the remainder of the program as well as for any continuation into the future.

2. Brief description of program

2.1 Genesis, scope and timing

Before the program commenced, both LWRRDC and the MDBC were involved in supporting research and investigation projects in the area of eutrophication. In 1994, each organisation separately contracted a consultancy to identify priorities in algal management and nutrient management research. Both consultants were from the Commonwealth Scientific and Industrial Research Organisation (CSIRO). At that time the CSIRO was in the last year of its multidivisional research program on blue-green algae. Also in 1994, a workshop was held for researchers and catchment and water managers to refine the priorities emerging from the consultants' reports.

NEMP was established with equal funding from each of the two funding partners (LWRRDC and MDBC). A Program Management Committee was established, comprising LWRRDC and MDBC representatives. A Program Coordinator was appointed. Financial and operational management of the program was vested in LWRRDC.

The scope of the program was fairly wide although there was a deliberate strategy of concentrating on catchment, instream and reservoir processes and management. Farm dams were not included in the scope of the program, nor were the consequences of algal blooms on the supply of water for human consumption. Processes and management pertaining to estuaries were included. Emphasis was on rural catchments, as opposed to urban catchments.

The program officially commenced in mid-1995, with the first meeting of the Management Committee held in August of that year.

2.2 Goal and objectives

As stated in Section 1.1, the goal of the program is to undertake the research and communication activities necessary to reduce the frequency and intensity of harmful or undesirable algal blooms in Australian fresh and estuarine waters.

The program has three objectives and a set of strategies for achieving each objective. The three objectives are set out below with the strategies qualifying each objective also listed:

1. Undertake research to gain a better understanding of the processes that lead to the initiation and development of algal blooms and other eutrophication effects in Australian waters.

   Strategies:

   (a) identify focus catchments in which the research effort can be integrated and outcomes taken up by local stakeholders;

   (b) establish a portfolio of R&D projects that address key questions necessary to meet this objective; and

   (c) establish a Reference Committee to assist the development and conduct of the projects in each of the focus catchments.

2. Develop techniques, including predictive models and decision support systems, to help prevent and manage the impacts of eutrophication.

   Strategies:

   (a) identify the management support requirements of different management groups;

   (b) ensure that management techniques are developed in full collaboration with management groups and reference committees; and

   (c) subject management techniques to benefit cost analysis at an early stage.

3. Ensure that research findings are communicated to all relevant stakeholders.

   Strategies:

   (a) develop a communications plan for the program;

   (b) develop a communications plan for each research project;

   (c) institute a newsletter or similar mechanism for keeping local regional and State stakeholders informed of the program's progress;

(d) form links with existing regional and State-wide catchment management bodies and algal coordinating groups to ensure that research findings are disseminated; and

(e) organise workshops and other occasions where research groups funded by NEMP can discuss their progress.

2.3 Program plan, priorities and priority-formation

A Program Plan (NEMP, 1996a) was developed for the period 1995–2000. The plan states the program's goal, objectives and strategies as well as priority research topics to be addressed. The priorities include:

A. Bioavailability of phosphorus, nitrogen and other nutrients;

B. Sources and transport of nutrients in catchments;

C. Management of sediment nutrient sources;

D. Effects of episodic events on waterbody ecology;

E. Factors leading to the initiation and development of blooms;

F. Evaluation of effectiveness of actions to manage nutrients.

These priorities were developed from the two consultants' reports and then refined during the workshop held in 1994. These final six emerged from a longer list of priorities that had been developed. Other areas coverered in the long list included the ecology of algal blooms and socioeconomics or policy impediments.

2.4 Focus catchment approach

A focus catchment approach was adopted for part of the program. Four catchments were chosen, each in different States and geographical areas of Australia. Three were freshwater catchments and one an estuarine catchment. The choice of the actual catchments was made in conjunction with State government departments. The catchments were required to meet five criteria. They were to:

- have significant algal bloom problems;
- be representative of larger regions impacted by algal blooms;
- have an existing base of knowledge to allow process studies;
- have active catchment management and other community groups;
- have support from State management agencies.

Those selected to be focus catchments were:

- Fitzroy River Catchment (Queensland);
- Namoi Catchment above Narrabri (New South Wales);
- Goulburn-Broken Catchment (Victoria); and
- Wilson Inlet (Western Australia).

2.5 Projects funded

There were two calls for projects against the six priority areas. One was a generic call and the other a call for projects relevant to the four focus catchments. A two-stage process was used in the call, with those whose two-page proposals were favoured then invited to prepare full proposals.

Funding for projects under this arrangement commenced in the year ending June 1996, but several projects inherited from LWRRDC and MDBC that had already begun were also included in the program. It was not until 1999 that the last science-focused project was funded. In addition, there were a number of other 'projects' (concerned with coordination and communication, scoping studies, workshops and so on) that were funded over the four-year period. Titles of all projects funded are listed in chronological order in Table 2.1, together with the project code, the name of the principal investigator, the organisation funded, and the start and completion dates of the project. Summaries of all projects funded under the program are provided in Appendix 1.

2.6 Financial investment

The base funding for NEMP was sourced from LWRRDC and MDBC in equal proportions. The total amount of funds expended across the 38 projects from the beginning of NEMP to the expected completion date of the last project is $3.99 million.

However, funding was also provided for many projects by both the research organisation carrying out the research and other stakeholders. These contributions are expected to total $4.67 million. The total program funding is therefore $8.66 million.

The leverage ratio for external funds across the whole program was 1.17 (that is, for every dollar committed by LWRRDC and MDBC, a further $1.17 was provided either in cash or in kind by other organisations). Many of the coordination, communication, scoping and workshop support projects were entirely funded by NEMP. If only those projects that were science-based are included, the leverage ratio rises to 1.37.

Appendix 2 contains details of the funding amounts for individual projects.

Table 2.1: NEMP projects funded from 1994 to 1999

Code	Title	Start date	Finish date	Principal investigator	Institution
CNR1	The relationship between nutrient (phosphorus) loading and algal growth in aquatic ecosystems	Jan '94	Feb '94	Dr Graham Harris	CSIRO Institute of Natural Resources and Environment
UAD7	Movement of phosphorus through soils	Oct '94	Jul '97	Dr David Chittleborough and Jim Cox	University of Adelaide and CRC for Soil and Land Management
UAD10	Measurement and treatment of phosphorus and carbon subsoil movement	Jul '95	Aug '99	Dr David Chittleborough	University of Adelaide
CWA18	NEMP Program Coordinator	Aug '95	Jun '00	Richard Davis	CSIRO Land and Water
EMM1	Assisting the NEMP Management Committee identify the major research needs within Priority B – sources and transport of nutrients in catchments	Jul '96	Aug '96	Dr Emmett O'Loughlin	
CEM4	Modelling nutrient release from sediments in lowland rivers and storages	Sep '96	Apr '99	Dr Phillip Ford	CSIRO Land and Water
CWS7	Retrospective study of nutrient variations in some riverine systems	Sep '96	Apr '99	Dr Andrew Herczeg	CSIRO Land and Water
UNS24	The role of sulphur in nutrient release	Oct '96	Dec '96	Professor D Waite	University of New South Wales
CEM7	Management strategies for control of cyanobacterial blooms in the Fitzroy River barrage	Nov '96	Jun '00	Dr Myriam Bormans	CSIRO Land and Water
GMW2	Eutrophication-related coordination in the Goulburn-Broken catchment	Dec '96	Jun '00	Mr P Feehan	Goulburn-Murray Water
NDW15	Eutrophication-related coordination in the Namoi catchment	Dec '96	Jun '00	Mr C Glennon	Department of Land and Water Conservation
QNR5	Eutrophication-related coordination in the Fitzroy catchment	Dec '96	Jun '00	Mr Peter Thompson	Queensland Department of Natural Resources
WRC2	Eutrophication-related coordination in the Wilson Inlet catchment	Dec '96	Jun '00	Mr M Robb	Water and Rivers Commission

continued on page 7

Table 2.1: NEMP projects funded from 1994 to 1999, continued

Code	Title	Start date	Finish date	Principal investigator	Institution
CNR2	Effects of episodic events on aquatic ecology in tropical and subtropical areas: Project scoping consultancy	Jan '97	Feb '97	Mr Graham Harris	CSIRO Institute of Natural Resources and Environment
AGS2	Nutrients in Wilson Inlet: Are sediments a major source of nutrients for biomass production?	Jan '97	Dec '99	Dr D Heggie	Australian Geological Survey Organisation
ANU9	Sources and delivery of suspended sediment and phosphorus to four Australian Rivers: Part B, Nd and Sr isotopes and trace elements	Jan '97	Jun '00	Dr Candace Martin	Australian National University
UTA8	The phytoplankton ecology of Wilson Inlet	Jan '97	Dec '99	Dr Peter Thompson	University of Tasmania
ANU10	Communication plan for the sediment and nutrient tracing and modelling project in the Namoi Valley	Feb '97	Apr '97	Ms Meg Keen	Australian National University
UWA17	Nutrient cycling by *Ruppia megacarpa* and epiphytes in Wilson Inlet	Feb '97	Feb '00	Associate Professor Di Walker	University of Western Australia
MDR17	Algal availability of phosphorus discharged from different catchment sources	Mar '97	Oct '00	Dr Rod Oliver	Murray-Darling Freshwater Research Centre
UOC12	Physical and nutrient factors controlling algal succession and biomass in Burrinjuck Reservoir	Mar '97	Sep '99	Dr Ian Lawrence	University of Canberra
WRC3	Compendium for Wilson Inlet	Apr '97	Mar '99	Mr M Robb	Water and Rivers Commission
CWA21	Sources and delivery of suspended sediments and phosphorus to Australian Rivers: Part A, Radionuclides and Geomorphology	Apr '97	Jun '00	Dr Peter Wallbrink	CSIRO Land and Water
QNR10	Fitzroy catchment eutrophication compendium	May '97	Jun '98	Mr Peter G Thompson	Queensland Department of Natural Resources
CSU19	Limiting nutrients workshop	Nov '97	Feb '99	Professor A Robertson	Charles Sturt University
MDR18	Validation of the NIFT assay for identifying nitrogen and phosphorus limitation of phytoplankton growth	Jan '98	Sep '99	Dr Rod Oliver	Murray-Darling Freshwater Research Centre

continued on page 8

Table 2.1: NEMP projects funded from 1994 to 1999, continued

Code	Title	Start date	Finish date	Principal investigator	Institution
DAV20	Identifying sources of phosphorus in agriculture run-off (Phase 1)	Jan '98	Feb '99	Mr David Nash	Department of Natural Resources and Environment
INT2	NEMP Communications Coordinator	Jan '98	Jun '00	Ms Viv McWaters	Integra Pty Ltd
CLW2	Whole-lake biomanipulation for the reduction of nuisance microalgae	Feb '98	Jul '02	Dr Vlad Matveev	CSIRO Land and Water
WQT1	Toxic algae workshop	Apr '98	Apr '98	Mr D Bursill	CRC for Water Quality and Treatment
CSF1	The interaction of physics, biology and nutrient regimes on the initiation and development of algal blooms	Jul '98	Mar '00	Dr Susan Blackburn	CSIRO Division of Marine Research
UMO36	Nutrient release from river sediments: Phase II validation and application of sediment-release model	Jul '98	Oct '00	Professor Barry Hart	Monash University
RMM1	NEMP conceptual model web page	Aug '98	Sep '98	Ms B Moon	The Reef Multimedia Company
ULN2	Extending the 'Rivers' Phytoplankton Monitoring' manual to Australian standing waters	Oct '98	Jun '99	Dr Roger Croome	La Trobe University – Albury
ANU16	Modelling the effects of land use and climate on erosion, phosphorus and sediment movement in the Namoi River	Dec '98	Sep '99	Dr Anthony Jakeman	Australian National University
AQU3	Consultancy into the cost of algal blooms to selected water-user groups in Australia	Jun '99	Sep '99	Mr Peter Dempster	Atech Group Pty Ltd
AGT7	Review of National Eutrophication Management Program	Sep '99	Dec '99	Dr Peter Chudleigh	Agtrans Research
AQU5	Scoping study for a national river contaminants program	Sep '99	Dec '99	Dr B Banens	Atech Group Pty Ltd
CLW16	A quantitative basis for setting flows to control algal blooms in the Fitzroy Basin	Oct '99	Dec '01	Dr Myriam Bormans	CSIRO Land and Water

3. Assessment of performance

3.1 Attainment of objectives

Of the three objectives stated in the 1995–2000 program plan, two have been met by NEMP and the other only partly met. The latter is associated with decision support and management guidelines and is important as management is embedded in both the title and goal of the program.

The program has not produced (and is not likely, in its last year, to produce) a great number of decision support systems for management. Nor has it produced specific management guidelines for action at the catchment, river, estuary, or water-storage levels that will reduce the frequency or severity of algal blooms. This is in part due to an over-ambitious perspective of the potential for extracting specific management tools from a predominantly strategic or 'understanding'-focused research program. Strategic research is defined here as that research which will generally not produce a benefit unless further research is carried out. Largely, NEMP has produced (and will produce) knowledge that can be used as a base for further research and, for some projects, for deriving management implications.

It is possible that Australia has an insufficient capacity to design and implement more applied projects to produce useful knowledge for management. This may explain why the program did not receive sufficiently impressive proposals in the more applied fields. Another defence of the strategic orientation of the program is that useful applied research was not feasible until further process understanding and critical knowledge gaps were addressed. These and other issues are addressed as each objective of NEMP is analysed.

Objective 1

The first objective (funding a program to improve the understanding of processes) has been met through this program and the associated strategies. In fact, the first objective seems to have been a principal focus of the program.

The implementation of the second stated strategy was also accomplished – that is, the establishment of a portfolio of projects that met the objective. Whether catchments were chosen where research could be integrated and outputs used by managers is addressed later. Reference committees (the third strategy) were established in most catchments, with some existing committees doubling as reference committees. A formal and ongoing reference committee was not established in the Fitzroy catchment. This was probably due to the fact that there was a limited number of projects in the Fitzroy, at least initially, and landcare and catchment groups in the Fitzroy were not well developed.

Objective 2

The second objective of the program was to develop techniques, including predictive models and decision support systems, to help prevent and manage the impacts of eutrophication. To date, a strong set of predictive models and decision support systems in this vein does not appear to have been established from the program. However, it is possible that in the remaining period of the program some predictive management models and directly applicable management interventions could emerge. Rather than the development of decision support systems and practical guidelines based on the outputs of the NEMP, it is more likely that some general guidelines and principles may be developed. Extracting such guidelines and implications should be a major activity in the remaining period of NEMP and is being encouraged by NEMP management.

Some of the reasons for the second NEMP objective not being fully addressed have already been mentioned. Following is a list of explanations and other qualifications.

(i) In some cases, 'understanding processes' were still required (both within a catchment and across catchments) before management issues could be addressed directly.

(ii) There was conflicting evidence regarding the sources of phosphorus (for example, gully or surface erosion, contribution of fertiliser) which was a critical element in focusing preventative efforts.

(iii) Except for a few projects, project objectives and focus were not in accord with producing practical management guidance.

(iv) Even when some reference to management guidelines were included in project objectives, it perhaps was still optimistic to believe that such could be achieved given the nature of the project design and the principal interests of the researchers.

(v) Projects of sufficient quality and with specific management application were not forthcoming in the calls for projects. This would of course have been a matter of judgement for the Management Committee.

(vi) If (v) were true then this may reflect the capacity of the management agencies and researchers to formulate more applied projects, thus defaulting to the more science-driven projects.

In relation to points (v) and (vi), it would appear that no attempt was made to commission such activity in the management area during the early stages of NEMP. In fact, management information requirements in terms of the then current decision-making and knowledge-base gaps faced by decision-makers were given little specific attention (at least in written form), although stakeholders were involved in the 1994 refinement of priorities and, to various degrees, in the development of projects.

Further, it would appear that the strategies defined to achieve Objective 2 were not all followed by the program. Strategy 1, the identification of management support requirements, and the benefit cost analysis of management techniques at an early stage (Strategy 3) were either not addressed (benefit cost analyses) or only carried out generically or in the last year of the program (identifying management requirements). In essence, the program strategy appeared to be to pursue further scientific understanding (albeit based on key processes and issues agreed by stakeholders) and then interpret how such improved understanding could assist management.

On the other hand, it would appear that strong emphasis (at least in the second half of the program) has been given to emphasising the importance of developing management guidelines. In a few cases, the researchers are not interested in pursuing such activities or feel that such a pursuit requires a major effort and should be the subject of other projects. In some cases, it will be difficult to package NEMP project outputs in a decision support and management framework. This has arisen due to a number of projects being designed primarily to fill scientific knowledge gaps and not to provide specific decision support techniques and management guidelines.

Objective 3

Objective 3 was achieved satisfactorily with all strategies also being followed. However, the effectiveness of communication to achieve immediate impact has been limited more by the material that was available to be communicated, rather than any neglect or failure of communication strategies and activities.

Regarding Strategies 1 and 2, a communication plan was developed for the program and for each focus catchment. A communication plan was also developed for most projects but the depth and how closely each plan was followed varied between projects.

While a newsletter for the program was not specifically developed (Strategy 3 for Objective 3), the program used the *Rivers for the Future* magazine published by LWRRDC for communication about its activities.

The fourth strategy was associated with building linkages with regional and State-wide catchment management bodies and algal coordinating groups. This was, in the main, accomplished through the coordinators within each focus catchment.

The strong support within the program for various workshops (between scientists alone and between researchers and the catchment and water communities) illustrated the implementation of the fifth strategy to meet the communication objective.

3.2 Alignment with priorities set

Table 3.1 classifies the projects into research priority areas. This classification is based on the classification presented on the NEMP web site, but has been adjusted by Agtrans. Projects have been classified according to their major or intended focus. Overall, both classifications were very similar, with only minor discrepancies. Firstly, while projects DAV20 and ANU9 have been classified into Priority B, some of the research in these projects also relates to Priority A. Secondly, while the three projects categorised under Priority C may not directly produce explicit management tools, they had intentions of producing such and therefore have been categorised under Priority C for this analysis. While this analysis indicates that no projects have been funded to address Priority F, projects CLW2 and MDR18 may have implications in this area.

Table 3.2 presents the distribution of funding between priority areas.

Table 3.1: Classification of NEMP projects into research priority areas

Priority A	Priority B	Priority C	Priority D	Priority E	Priority F	Communication and coordination	Other consultancies
MDR17	CWA21	AGS2	CNR2	UWA17		CNR1	AQU3
	ANU9	CEM4		UTA8		CWA18	AQU5
	CWS7	CEM7		UMO36		GMW2	AGT7
	UAD7			CSF1		NDW15	CSU19
	UAD10			UOC12		QNR5	WQT1
	DAV20			CLW2		WRC2	ULN2
	ANU16			MDR18		ANU10	UNS24
	EMM1			CLW16		WRC3	
						QNR10	
						INT2	
						RMM1	

Table 3.2: Proportion of funding for each priority area

Priority area	Number of projects	NEMP funding ($)	% of total NEMP funding	Total funding ($)	% of total funding
Priority A	1	339,000	9.2	648,863	8.2
Priority B	8	926,810	25.3	1,661,634	21.1
Priority C	3	613,936	16.7	1,867,871	23.7
Priority D	1	6,000	0.2	6,000	0.1
Priority E	8	1,175,016	32.0	3,075,854	39.0
Priority F	0	0	0.0	0	0.0
Communications and coordination	11	471,236	12.8	471,236	6.0
Other consultancies	7	140,776	3.8	154,656	2.0
Total	39	3,672,774	100.0	7,886,114	100.0

It may be concluded that the priority areas have been targeted rather unevenly. Priority A was only targeted specifically by one project. Priority D was addressed by only one scoping consultancy with no research projects funded. There was a high concentration of projects within Priorities B and E. These priorities were the sources and transport of nutrients in catchments (Priority B) as well as the factors leading to the initiation and development of blooms (Priority E). There was also a significant amount of funding allocated for Priority C.

In summary, there was a significant imbalance between the resources allocated to each of the six priorities set for the program, with 69% of resources for research supporting priorities B and E. Priority A (bioavailability) received 11% and Priority C (management of sediment nutrient sources) 20%. The other two priorities received practically no support (episodic events [D] and evaluation of effectiveness of actions to manage nutrients [F]).

The program was strongly focused on phosphorus dynamics and chemistry, and lightly focused on the areas of ecology and nitrogen dynamics. It is not clear whether this was due to the relative priority given to each area in selecting projects or to the type and quality of the proposals received. Program Management attempted over a long period to establish a viable project that addressed episodic events (Priority D). The inability to fund such a project was unfortunate as, in some respects, the quantities and timing associated with nutrient exports from land could dominate all attempts of controlling nutrient export through different land uses, management practices and the provision of nutrient export barriers (all subject to study in other R&D programs).

There appeared to be no attempt to develop projects in improved management of nutrients (Priority F).

3.3 Focus catchment approach

The stated principal reasons for adopting the focus catchment approach for part of NEMP funding was to encourage interaction between researchers as well as between the research and catchment and water managers. While these potential benefits were commendable, there was still the danger that this approach could have inhibited process research that may not have been best carried out in one of the focus catchments. This was allowed for in the program structure as there was a generic set of projects that were better located in the laboratory or in another catchment type.

There were some difficulties capturing all potential benefits from the focus catchment approach. Firstly, four focus catchments meant that the resources available for the focus catchment part of the program (only $1.8 million from core funding over four years) was inadequate to support sufficient projects to take advantage of both the potential benefits of critical mass, synergy and meaningful interaction with stakeholders. For example, for most of the program there was only one research project in the Fitzroy (a second one commenced in 1999), with the biomanipulation project in Queensland sited elsewhere and the episodic events project not proceeding. Two or three scientific projects were funded in each of the other three focus catchments.

Secondly, the interaction with stakeholders between the four catchments varied. Interaction towards the end of the program may be more meaningful to both researchers planning further research and to stakeholders seeking implications from research results.

Overall, the focus catchment approach worked reasonably well, with networks being built and increased information flows occurring between researchers. A widening of the issues perceived to be important also occurred in some catchment communities. Catchment groups and managers within focus catchments expect that specific management guidelines will evolve once all projects are completed and results are synthesised.

3.4 Outputs and knowledge generation

Many of the projects produced a range of outputs and outcomes (and potential outputs and outcomes), some of which are described in the individual project summaries presented in Appendix 1. As many of the projects are not yet completed, especially the analysis of data, it is likely that results will provide further outputs and outcomes over the next year.

In general, most projects met their stated objectives, at least in part, and in that regard the overall project performance was quite satisfactory. Due to the nature of much of the research funded, most outputs added to the knowledge bank regarding the development of blooms, and the source and role of nutrients. Some of the research was aimed at clarifying issues that remained controversial at the beginning of the program and, in that regard, some good progress was made. However, direct attribution of the current improved state of knowledge to the NEMP projects is difficult as knowledge-building is cumulative in nature. At worst, NEMP confirmed or refined much of what was perhaps already suspected. At best it has produced further knowledge that can be used as the basis for further research (both applied and strategic). NEMP has also produced some findings that will have management implications and directly lead to policy changes and management interventions.

For example, the program publication *Phosphorus in the Landscape* (NEMP, 1999), emanating from one of the workshops on the sources and transport of phosphorus in Australian landscapes, was mentioned by a number of stakeholders as an output from NEMP. On the other hand, that publication was derived from a workshop in which only two of the 16 participants were active in NEMP projects. While the publication is regarded as a NEMP output, it is uncertain how much of the information synthesised was derived from NEMP research projects. In fact, it would appear that whenever NEMP activities addressed the synthesis of information from all sources, outputs were significant. This supports the notion that a synthesis of all available information on eutrophication would be productive for management.

NEMP is writing a major summary document covering the latest understanding of the causes of eutrophication and algal blooms and the increased management opportunities that have arisen. This document will be disseminated widely and will be a major resource for water managers.

Some of the principal outputs emerging from NEMP so far are:

- the finding that light availability, not nutrients, is the factor controlling algal growth in the Rockhampton barrage of the Fitzroy River;
- the introduction of predatory fish has successfully suppressed cyanobacteria in mesocosm trials;
- the flow management techniques, developed prior to NEMP for nutrient-rich rivers, have been extended to nutrient-deficient rivers;
- the diffuse sources of phosphorus and sediments from catchments will be estimable from geomorphic attributes before NEMP is completed;
- guidelines for reservoir managers have been drafted, based on analysis of long-term data sets from Lake Burrinjuck; no guidelines exist at present and these will allow reservoir managers to manage inflows and outflows in a way that minimises the chance of algal blooms occurring;
- an increased understanding of the role of *Ruppia* in estuaries and the complexity of algal bloom development in Wilson Inlet has been found.

New techniques have also been generated:

- the NIFT and iron-strip methods have been accepted by water quality managers; the latter technique is being used in two laboratories to provide significantly cheaper and quicker assessments of bioavailable phosphorus;
- a standard phytoplankton sampling procedure has been developed, approved by water managers and distributed to laboratories. It will lead to more nationally consistent information on algal blooms in standing waters.

Shifts in understanding have occurred:

- contrary to previous beliefs, large loads of phosphorus can travel through subsoil pathways in a wide range of east Australian soils, thereby bypassing surface interception measures; this has major local management implications;
- nitrogen is equally important to phosphorus in controlling algal growth in the Murray-Darling Basin and possibly elsewhere;
- light, and not nutrients, is commonly the factor that controls algal growth in inland rivers; this has major implications for current phosphorus control strategies and the program is disseminating this result widely;
- the bioavailable fraction of phosphorus is roughly equal from dryland, irrigation and sewage treatment plant sources in the Goulburn River; it had been hypothesised that phosphorus from sewage treatment plants was more available to algae than phosphorus from dryland sources.

In addition, a number of mathematical models have been either developed or refined during NEMP, but their transferability, general applicability and usefulness in anything other than an 'understanding' context is uncertain.

Overall, the complexity of the various factors operating in the development of algal blooms has been increasingly recognised in NEMP. Many projects within the program are not yet completed and the final year of the program will focus on the integration of all project outputs into management guidelines.

It should be noted that the CSIRO's multidivisional program that was completed in 1995 (at the same time that NEMP was commencing) produced the following findings (Davis, 1997);

- flow management can be a practical tool for managing blooms in impoundments on inland rivers;
- nutrient management (particularly of phosphorus) is a more limited tool than was previously believed;
- in both estuaries and rivers, there are significant periods when nitrogen is the nutrient controlling algal biomass;
- sediments can provide a more accessible source of nutrients than does run-off from catchments.

It is interesting to note that there is some similarity between some CSIRO findings and those being claimed by NEMP. To a degree, some of the shifts in knowledge due to NEMP have confirmed or refined previous findings, but there have been significant new findings as well.

3.5 Science quality

(contributed by Roger Croome)

The following is provided in response to a request for scientific and other comment concerning the structure and content of six NEMP projects.

The six projects, selected from the 23 science-orientated projects, were:

CEM7 Management strategies for the control of cyanobacterial blooms in the Fitzroy River barrage;

UOC12 Physical and nutrient factors controlling algal succession and biomass in Burrinjuck Reservoir;

ANU16 Modelling the effects of land use and climate on erosion, phosphorus and sediment movement in the Namoi River;

UTA8 The phytoplankton ecology of Wilson Inlet;

MDR18 Validation of the NIFT assay for identifying nitrogen and phosphorus limitation of phytoplankton growth;

MDR17 Algal availability of phosphorus discharged from different catchment sources.

Appendix 3 presents a detailed evaluation of each of these projects. Comment is provided on each project with respect to its targeting of appropriate issues, overall project design, methodology, representativeness of data and observations, implications of results, and technology transfer. A synthesis of the individual reviews is presented here.

Nature of research

Each project has clear aims or well delineated outcomes. Singly they focus on significant issues within nutrient or algal management; together they comprise an impressive mix of investigative and well targeted research. The six projects fall into three groups, namely:

- short extensions to previous work (ANU16, MDR18);
- determination of factors affecting algal growth within standing waters (UOC12, CEM7, UTA8); and
- the origin and fate of nutrients within rivers (MDR17).

Of the two projects which are continuations of previous work, ANU16 is an extension of sediment or nutrient work in the Namoi Basin and will provide managers with a modelling package to use on their personal computers. It appears to be relatively straightforward, and of considerable value in furthering the aims of the previous study. MDR18 seeks to refine and validate an inventive technique for assessing nutrient limitation within individual algal cells. The work is scientifically acute and has demonstrated the validity of the technique, but broad-scale application of the work is unlikely without considerable additional effort by the proponents.

UOC12 utilises 20 years of physico-chemical and biological data in an attempt to characterise algal dynamics in Burrinjuck Reservoir, and to develop guidelines for reservoir management. CEM7 tackles algal problems in the Fitzroy River barrage via physico-chemical and biological assessment, and then modelling, as part of developing strategies for algal control. Both are comprehensive studies involving experienced researchers and their results are likely to be utilised elsewhere. UTA8 investigates algal and nutrient dynamics in Wilson Inlet, Western Australia, in concert with two other studies (on sediments and macrophytes). It is centred around a doctoral study, which appears to have been an advantage in this particular instance (there has been, for example, greater sampling intensity and focus as the project has progressed).

MDR17 is an inventive explorative study of the relative availability to algae of different phosphorus sources (treated sewage, irrigation return water, agriculture) within the Goulburn system. It is complex and is supported by a scientific advisory committee. It will certainly aid nutrient management decisions within the Goulburn; its ready application elsewhere is less certain, but it does contain a significant modelling component.

Project management

The 'scientific calibre' of the researchers involved in the projects is impressive and each project has been responsibly managed within the constraints experienced. As a group, the projects have proceeded much as might have been expected, given the vagaries inherent in ecological research and the workloads or other activities being pursued by individual principal investigators.

- The one-year MDR18 was successfully completed, but eight months late. This was due to other commitments, technical problems and the need to include an industry workshop.
- The seven-month ANU16 was extended by three months due to the unexpected departure overseas of a key researcher.
- After timely reporting for the first two milestones, the fieldwork within the 32-month CEM7 (and, thus, project completion) was delayed for 12 months due to unusual flow conditions. The delay had the full agreement of industry partners.
- The 27-month UOC12 has not proceeded as expected. The first milestone report was submitted five months late and subsequent work has also been delayed.
- The three-year UTA8 has proceeded well, largely meeting all milestone conditions on time.
- Finally, the three-year MDR17 (due for completion 31 October 2000) was initially delayed by eight months due to difficulties in hiring staff, and then altered slightly to accommodate changes in data needs for modelling, but is now proceeding as originally planned.

Scientific methodology

The basic scientific methodology chosen for each project, whether it be the collection of field and experimental data followed by modelling, the use of supplemented historical data to infer relationships between physico-chemical and biological characters, or the validation of novel scientific techniques using statistically valid laboratory assessment, has been entirely appropriate to the aims of the individual project. Indeed, this is only to be expected given the experience and stature of the researchers involved, giving support perhaps to the publicly-stated policy of one CSIRO Chief of Division to consider the funding of individuals as much as projects.

All the work is technically acute and, in the main, at the leading edge of research within the respective area. Given this, it is considered appropriate that LWRRDC/ NEMP should expect a far greater seating of project proposals within the current literature. One proposal did not mention a single scientific reference and, in others, most references were simply given to demonstrate the proponents' experience in the area of the research proposed. Given the scientifically acute nature of the proposals funded, consideration should be given to the formal inclusion of a review or demonstration of knowledge of the current literature as part of the application process.

Technology transfer

Concerning technology transfer, it is suggested that far greater effort be put into ensuring that existing information is available to catchment managers *now*. Rather than aiming the bulk of resources at individual acute studies with an emphasis on localised benefit, ways in which we can effectively transfer *existing* knowledge to management practitioners should be considered. While this may be less attractive (and perhaps less rewarding) to individual researchers, both approaches are necessary, and the latter requires fostering at this time. Far greater 'on-ground' interplay is required between those having rapid access to scientific knowledge, and those needing to apply it in day-to-day management. It is a difficult area, and may be difficult to justify case-by-case with respect to benefit-to-cost. Nonetheless, thought should be given to fostering activities which give greater encouragement to ongoing, face-to-face communication between researchers and practitioners, during which management problems are teased out and discussed against the scientific knowledge already possessed.

Conclusion

With regard to the work examined in detail here, effective establishment, conduct and progress within each project has been ensured by:

- the well defined structure of project proposal;
- refereeing, negotiation or refinement; and
- milestone reporting.

As well, each project has been set within a program with well defined aims and objectives. The projects reviewed were of high scientific merit and involved experienced researchers of national or international standing producing meaningful results with respect to nutrient and algal management.

3.6 Translation into outcomes

The design and focus of some projects has made difficult the transfer of many outputs into clearly defined outcomes and management implications for individual catchment and water managers.

Nevertheless, there has been considerable effort made by Program Management to ensure implications are drawn out and communication between researchers and stakeholders is enhanced. Further, a significant amount of effort is predicted as results and analyses become available from many of the projects in the fourth year of the program. This effort is to be commended, but it would have been preferable to explicitly define management information needs early in the program.

For example, current activity in at least one project is identifying the information needs and key decision problems of reservoir managers. The standard response of a number of principal investigators when this sequence was questioned was that there was nothing to communicate before results were available. Now some results are available, they are assessing implications for management with more useful and positive interaction. While this may be so, this sequence appears to the reviewer to be limited with interaction required at the beginning, during and at the end of the project.

Management-orientated research is difficult without first reconciling, confirming or further investigating various management positions with regard to a number of knowledge issues. Also, the lack of explicitly investigating management options at catchment and waterway levels early in the life of each project and at the level of the program as a whole, has contributed to some difficulty for some projects in the translation of outputs into outcomes.

This does not mean that the program has failed in its translation of outputs into outcomes. Some of the outputs listed earlier may result in significant management changes in the future.

Outputs from many of the projects have helped to improve the focus of individual land and catchment management groups. Additionally, in some cases, the complexity of systems in which eutrophication and blue-green algae outbreaks are embedded is now better recognised among catchment and waterbody (including estuary) managers. There will be ample opportunity in the remaining period of the program to tease out these implications for management, and Program Management are aware of the importance of this task.

Information produced by the program that is relevant to the development of blooms or the sources and transport of nutrients will require interpretation within other activities aimed at:

- minimising nutrient export off farms;
- improving catchment water quality;
- protecting riparian lands and streambanks, and so on.

Attempts at such integration with other programs in these areas appear to have been restricted to date. This could be a key focus activity for extracting management implications in the last year of the program.

The translation of outputs into outcomes within each focus catchment may be easier than transferring results generically to other non-focus catchments. Attempts were made to ensure outputs from the focus catchments were transferable between catchments and that outputs could be translated according to specific attributes of other catchments. However, this translation may not be possible in many situations as, in many cases, data in the 'transferee' catchment will not be available; also, the complexity of factors operating in each catchment will make any simple transference difficult. Nevertheless this is another activity that should be given more attention in the remaining year of the program.

It is not clear whether the focus catchment approach has hindered in any way the accumulation of 'process' knowledge (and hence transferability) that may have been assembled in the absence of such a framework.

On the other side of the ledger, it is likely that the approach may enhance the translation of outputs into outcomes in the Wilson Inlet catchment through the interest shown by the community in the three NEMP projects. The three projects in Wilson Inlet may result in an improved understanding of the role of *Ruppia* in the estuary, the importance of factors other than the timing and location of opening of the bar, and an increased emphasis on catchment management as opposed to estuary management. It is expected by those in the catchment that knowledge produced from the NEMP will be used in the Wilson Inlet Catchment Management Plan.

Within the Fitzroy there has been good integration of the projects with the Rockhampton City Council and the Department of Natural Resources, but this level of integration may not necessarily have been due to the focus catchment approach. Overall, it is not possible to assess the focus catchment approach in relation to its encouragement of adoption of outputs, without a detailed study of each catchment. If this is considered, it should take place immediately to set the assessment framework and be followed up within two or three years to assess final outcomes, attribution to NEMP, and local and regional benefits.

Likely management changes that may occur within Queensland include the potential inclusion of the blue-green algae component of Project CLW16 in models used in the Queensland Water Allocation Management Plan for the Fitzroy. Also, if CLW2 results in a successful conclusion regarding biomanipulation, there may be significant outcomes for water storage in the south-east of Queensland. More immediately for the Fitzroy, a fine clay will be trialled by Rockhampton City Council to artificially suppress growth when light reaches critical levels defined from the NEMP research.

There has been heightened awareness of the importance of various sources of phosphorus in New South Wales and Victoria. The diffuse sources of phosphorus and sediments from catchments will be estimable from geomorphic attributes before NEMP is completed; management recommendations (based on these results) for individual landscape units will be trialled in the Namoi catchment in early 2000. Regarding the importance of fertiliser phosphorus, it has been confirmed that fertiliser phosphorus is available in significant proportions immediately downstream of land on which fertiliser is applied. Also, it has been confirmed that nitrogen can be the limiting nutrient in some algal bloom developments. As a result of the work on bioavailability of phosphorus from different sources, there may be further implications for the policies associated with upgrading of sewage treatment facilities in New South Wales and Victoria.

A number of projects may produce some general implications for the allocation of resources and focusing of effort within particular dryland catchments regarding nutrient and sediment export from farms and streambanks (for example, dissolved organic carbon [DOC], nitrogen or phosphorus). This may include consideration of the importance of various land uses, various management interventions and best management practices in relation to both farming and riparian management.

3.7 Overall impact

The overall impact of NEMP will originate mainly from a significant contribution to knowledge rather than the production of specific management guidelines or decision support systems. There does not appear to have been many specific new or revised management interventions that have been introduced to date as a result of the program. Neither have there been any specific policy changes that can be attributed directly to the program, according to representatives of the MDBC and some State agencies.

Many projects selected in the program were 'understanding' or strategic research in nature. In many cases, results are likely to be used only in a general sense to focus management efforts in the future, or be used to build more applied research projects. The bias towards strategic research can be explained in part by the environment that existed during the genesis of NEMP.

At the beginning of NEMP there was considerable uncertainty as to whether existing and proposed management actions would be effective in controlling algal blooms. This uncertainty arose from:

- conflicting views on the sources and bioavailability of phosphorus;
- little information on the role of nitrogen and micronutrients;
- limited understanding of stratification and related control measures;
- where and how flow strategies might be used;
- the role of instream sediment sources and their control;
- the importance of episodic events.

In this regard, the NEMP has contributed to improved understanding of processes that will help resolve these uncertainties. There will need to be further investment in more applied research to translate much of this improved understanding to more specific management guidelines.

Although the program has developed a number of alternative management techniques and guidelines, these have yet to be thoroughly tested in practice. There have been strenuous efforts to engage managers and community coordinators in this work, although there have been only a limited number of practical tools delivered to managers at this stage of the program.

It should be recognised that the expectations for specific and relevant management guidelines to be provided in the final year in most of the focus catchment communities are currently very high. The community groups express confidence that their management needs will be met over the remainder of the program.

However, the on-ground impact of the first phase of NEMP is not yet apparent and is not likely to emerge until after the end of the program in June 2000. Any further funding by partners should focus on capitalising on the strategic understanding gained, and trialling and disseminating the new management techniques developed.

So far the linkages to the potential resource allocation impacts do not appear to have been considered by principal investigators other than in a general sense. It is not clear whether the results of the NEMP projects, considered either individually or collectively, can deliver anything other than generalities with respect to priorities and focus in relation to the relative importance of interventions to minimise nutrient exports, key land use and management practices.

There are significant resources being committed to research and assembly of best management practices and means of minimising nutrient and sediment export off farms. As well, nutrient management and water quality strategies are receiving much attention at the catchment level. It is good management practice to minimise nutrient exports into waterways anyway. Whether the type of information being produced by NEMP concerning sources and forms of nutrients can be used in a practical sense by land users and catchment managers remains to be seen.

As there has been little effort put into the feasibility of management interventions, or their cost effectiveness, it is difficult to assess in any way other than generally, what economic impact the additional knowledge produced by NEMP will have. Certainly the knowledge itself will be useful in designing another set of projects that might more specifically address management issues and provide specific guidelines across a range of catchments.

4. Program management

4.1 Strategic planning

The strategic plan developed for the program appears simple yet comprehensive. Given the genesis of the program, the previous involvement of LWRRDC and MDBC in the areas of eutrophication research, and the previous experience of the Program Coordinator with the CSIRO's multidivisional blue-green algal program, a clear and useful plan was not surprising.

It is understood that the plan was developed by the Program Coordinator and Manager in conjunction with the Management Committee. However, it is not clear whether and how the other stakeholders in the program were consulted in its development. Researchers were not specifically consulted in the development of the plan and it is unlikely that those involved in managing land and water from the point of view of reducing algal blooms were consulted. However, the plan was developed after the consultancies and 'refinement' workshop were held so it is assumed that it reflected the views of researchers and stakeholders at that time.

The focus and priorities apparent in the plan did reflect a broader view than that reflected in the projects eventually selected for funding. However, the plan itself may not have been entirely realistic in terms of the goal of reducing the severity and frequency of algal blooms, given the resources available to the program. There does appear to be a discrepancy between the goal set and the demonstrated intent of the program.

It may have been useful to state in the plan a set of criteria against which performance of the program could have been evaluated. The achievement of objectives set, funding against priority areas and an investment analysis have been the primary criteria used in the absence of stated performance criteria.

Overall, the contents and organisation of the plan are commended.

4.2 Priority-setting

The priority-setting process relied on two consultancies and a workshop drawing on researchers and other stakeholders. However, it is uncertain to what extent land and water managers contributed to the development of priorities. It appears that the priorities reflected the scientific uncertainties of the time. Therefore, the priorities were driven by the need to understand how blooms and the system in which they were embedded actually worked, rather than on potential interventions aimed at reducing blooms.

As already mentioned, the thrust to fill these knowledge gaps may be interpreted in at least two ways.

- At the one extreme, insufficient knowledge was held in order to target potential interventions efficiently. For example, critical knowledge was missing in terms of nutrient sources, availability and release of phosphorus from sediments – all vital elements in prioritising management interventions.
- At the other extreme, it may be held that because the two consultancies were conducted by scientists and the workshop was science-dominated (due to the difficulty faced by managers of identifying their needs in a research framework), priorities were therefore naturally science-dominant, rather than management-dominant.

It is likely that both explanations contributed to the make-up of the final set of priorities. Two priority areas mentioned in the long list of priorities (but not reflected in the six priority areas) were socioeconomics and ecology.

If all priorities had been addressed, however, the balance in the program could well have been appropriate to the program goal. It was mainly the selection of projects chosen to address the priorities that created the science bias in the program.

The priority-setting process did not appear to use any economic or potential pay off criteria for selecting the six priority areas, or for allocating resources across the six areas. That is, there was no deliberate assessment or definition of linkages of how successful research and knowledge generated in each area could be translated in terms of a reduction in frequency and intensity of blooms.

4.3 Project selection

There were 110 proposals received for the generic call and 61 for the focus catchment call. The selection of the projects was carried out effectively through a two-stage process. There were a vast number of proposals to select from in the first round for both calls. Some proposals were identified that were of a similar nature and, where appropriate, those researchers were asked to submit joint proposals.

In at least one case, proposers were asked to join together after each full proposal had been developed independently. This was not as satisfactory as attempting to encourage collaboration after the first-round proposals; this latter type of 'marriage' also took place.

Referees' statements were sought in most cases for second-round proposals, and comments passed on to the proposers for potential changes to be made.

It was evident from the minutes of the Management Committee meetings that the Program Coordinator declared an interest in most CSIRO projects that came before the committee.

A significant effort was made by the committee to fund projects in the area of Priority D (effects of episodic events on waterbody ecology). However, despite consultancies and attempts by eminent researchers to develop a project, no projects directly addressing this area were eventually funded.

4.4 Monitoring and evaluation

Accountability of Program Management was excellent both for the management processes used as well as the execution of that management. Requests for variations that arose in the course of research projects were handled professionally and efficiently. In some cases necessary variations were imposed and suggested by Program Management through milestone reporting and reviews that were carried out for some projects and groups of projects. Some projects were established with steering committees.

Monitoring of projects mainly arose through milestone reporting and selected reviewing. The milestone reporting system worked effectively.

Some redirection of projects was made and at least one project was terminated earlier than the original plan for that project.

Many project reports came in late but in most cases the lateness could be explained. In other cases Program Management made significant efforts to redress the situation.

Workshops were usually run by external contractors. The use of consultancies and communication experts reflected a professional approach to management. Many consultancies were used to focus research and to help develop projects in stated priority areas, except for Priority F. Workshops were used as effective communication tools between scientists within and outside NEMP. Other workshops encouraged interaction between scientists and catchment and water managers. The scientific workshops were effective in encouraging debate and focusing research. The community-focused workshops were effective in widening the issue base for those in some catchments and providing information about the projects. Workshops to be held in the latter part of the program will no doubt be of greater value due to the availability of results for discussion.

To date, the Management Committee has averaged five meetings per year (many by telephone), one more on average than originally anticipated in the program plan.

No stakeholders external to the funding bodies (catchment or water managers) were included on the committee. This is somewhat surprising since it was a eutrophication *management* program.

4.5 Involvement of clients and stakeholders

The involvement of clients and stakeholders varied between the projects and the focus catchments. Involvement of clients and stakeholders within the Wilson Inlet projects was quite strong.

There was also a high level of Angling Association involvement in the biomanipulation project, although it was not conducted within any of the focus catchments. Even though there was only one (and more lately two) projects in the Fitzroy catchment, the client interaction was good in terms of Queensland Department of Natural Resources and the Rockhampton City Council. Potential application of the project results from CEM7 regarding maintaining turbidity may occur, as well as those results potentially emanating from the second project (CLW16). The timing and nature of projects in the Fitzroy, and the less developed Landcare and catchment groups in the Fitzroy, meant that ongoing community involvement was limited.

Involvement of stakeholders within the Namoi catchment was difficult to ascertain although at least one useful workshop was held. Strong networking by the coordinator in Goulburn-Broken was evident.

Focus catchments were actually selected on the basis of there being potential for interaction by stakeholders, as well as a number of other criteria. Although most research proposals sited in focus catchments were developed with knowledge of local community representatives, is not clear what impact such consultations had regarding any modification of the research objectives or approach for any projects. It is likely that any impact was minimal with objectives and direction virtually finalised before much catchment consultation took place.

Focus Catchment Coordinators were important in providing a focus for stakeholders, not only in each focus catchment, but also to the wider program of NEMP. The coordinators also provided linkages to policy and management personnel across State agencies.

Overall, the involvement of stakeholders and clients in the operations of the program was as good as could be expected and the efforts by Program Management, in terms of program structure and encouragement of stakeholder involvement, is commendable.

4.6 Interpreting results into management needs

The program has raised awareness generally of the complexity of factors affecting algal bloom development and has raised awareness in catchments regarding nutrient exports. Some catchment and water managers believe that NEMP has confirmed what they suspected and, in that regard, the investment has been rewarding without specific management changes. Final results for all projects are not yet to hand so it is too early to assess in any absolute sense how well the interpretation of results has been achieved. There appears to have been little synthesis of results so far but, as described earlier, this is currently occurring. However, a number of points need to be made:

(i) As already expressed, the original objectives and focus of many projects has not been conducive to interpreting results directly into management needs. Many projects funded will require further research to effect such an objective.

(ii) Program Management has tried particularly hard to ensure that management implications will arise from each project. This effort has not always been rewarding but, as described earlier, it is evident that some management implications will flow from the investment; that is, some of the research results will provide important additional information to catchment and water managers that may influence and enhance decisions that are currently faced.

(iii) Some project managers appear less interested in management implications than others, partly due to the nature of their project and the attitude that the development of management implications will require further project funding, with projects external to the existing research teams. This exemplifies the rather strategic nature of a number of research projects.

(iv) Some of the thinking about management needs and implications of research results is now just commencing in some projects. While this is commendable in itself, the delayed timing of such initiatives is not a desirable situation given the goals and objectives set for the program, and is symptomatic of science-driven R&D.

The real test for the program with regard to interpretation of results will be in the next 12 months when the interpretation of individual project results, and synthesis of results across projects and across focus catchments, will be addressed.

4.7 Communicating results to stakeholders

Efforts to ensure effective communication between scientists and clients and stakeholders was commendable. Four Focus Catchment Coordinators were appointed and communication plans were developed at program and focus catchment level and for many individual projects.

The initial communications plan for the program (NEMP, 1996b) was developed by the Program Coordinator then significantly revised by the Communications Coordinator who was appointed in 1998. Each focus catchment produced a communications plan which, in most cases, was generally followed.

The appointment of coordinators within the focus catchments appeared a worthwhile investment with the coordinators providing effective communication within the catchments as well as facilitating coordination among researchers and, in some cases, between the researchers and the local stakeholders. In most instances, coordinators engendered trust within the community and fostered a positive attitude to the research. Another key part of the communication strategy was the inclusion of stakeholders in the annual meetings.

The adequacy of project communication plans (required by LWRRDC) and actual communication performance at the project level varied, reflecting the diversity of approaches, enthusiasm and interest among the principal investigators.

While the communication strategy probably did as much as it could, its impact was restricted due to:

- the nature of the research funded in the program, and;
- the lack of interest and capacity of some researchers in communicating to the community the linkages between their research projects and on-ground action and management across Australia.

The expectations of stakeholders may not have been explored sufficiently by researchers, especially at the beginning of some projects.

Fact sheets for each of 12 projects were produced early in the life of NEMP, and the remaining sheets for all projects are to be prepared before the end of the program. It would have been of greater value as a communication aid to have the fact sheets for all projects completed much earlier in the program. One coordinator found it difficult to obtain final reports and up-to-date information on projects outside the focus catchment.

There was no specific newsletter produced for NEMP, however, the program used *Rivers for the Future*, a journal produced by the National River Health Program (NRHP), to convey information about the program. This journal was not targeted at catchment managers but in a general sense probably included many of the stakeholders and clients for the NEMP.

Press releases have been used sparingly as a communication mechanism although it is likely that they will be used more frequently towards the end of the program when there are more newsworthy results to communicate.

As already mentioned, workshops were supported strongly. There were two types:

- one for researchers to explore research areas together and also to discuss particular issues and integrate knowledge where some differences existed;
- the second were community-type workshops where the implications of the research were discussed.

A web page (www.nemp.aus.net) was produced in the fourth year of the program. Inspection of the web site in November 1999 showed it contained some valuable information but was not up-to-date. Descriptions of some individual projects appeared the same as in the fact sheets prepared several years earlier. It should be noted that the maintenance of the site can be quite time consuming (McWaters, 1999). It is suggested that, in order to be manageable and useful, the web site should initially target a specific communication purpose and audience. There are plans to list milestone reports on the site. The same policy is being advanced within other LWRRDC programs.

The program enhanced communication among scientists although there was already a strong network (particularly among CSIRO scientists, due to their previous multidivisional program). It did so by strengthening the existing networks and bringing in more players. However, it can still be difficult for scientists outside traditional disciplines, or with different approaches, to attract funding. For any extension of the program, consideration could be given to supporting capacity-building in areas of agreed importance.

4.8 Integration within the program

Integration of effort by researchers within the program was at a high level and was encouraged strongly by NEMP management. In particular, the annual meetings of researchers involved in the program were highly regarded by researchers. The integration of effort was also strengthened by the workshops sponsored on particular topics. These focused ideas and, to a large degree, synthesised the state of knowledge from both within and outside NEMP in a range of areas.

A good degree of cooperation existed with respect to data collection and use of project sites for assistance to other projects.

A higher level of networking among eutrophication researchers has possibly resulted from the program. Some synergy was evident in terms of this networking. The overall capacity in eutrophication research has probably been improved due to closer contact between researchers.

4.9 Integration with other programs

National Program for Irrigation Research and Development (NPIRD)

While in the past there has been minimal attention given to the environmental impact of irrigation systems (and, hence, minimal interaction with NEMP), a recent initiative of NPIRD (in conjunction with the Cooperative Research Centre (CRC) for Catchment Hydrology) has been to establish a set of projects in the area of nutrients and sediments that address environmental impacts and water quality issues. Projects are to be focused in three catchments, two of them similar to NEMP: the Fitzroy and the Goulburn-Broken. The third will be the Ord River in North Australia.

There should be some further integration of NEMP with this part of the NPIRD program and at least with mechanisms for maintaining contact and information exchange between both programs.

Riparian Lands Program

The Riparian Lands Program has funded projects on the ability of riparian buffer strips to trap sediment, phosphorus and nitrogen. Projects are developing guidelines for management (Price, 1999). In addition, the program has investigated the impact of riparian vegetation in reducing streambank erosion. A further important piece of work entails the role of vegetation in producing shade that impacts on the nature of the instream ecosystem. Management guidelines on all of these potential interventions are about to be published (Price, 1999).

It is not clear whether much interaction between NEMP and the Riparian Lands Program occurred but the Manager of the riparian program has not been approached by any NEMP researchers. Whether the respective Program Coordinators have discussed nutrient findings from both programs is also uncertain, but it is probable that little or no interaction has taken place.

National River Health Program

The NRHP had a small set of four projects investigating environmental flows and nutrient and blue-green algal dynamics. Other projects investigating algal issues in estuaries were supported under the 'urban' component of NRHP, managed by the Water Services Association. The NRHP Coordinator has not been contacted by anybody associated with NEMP projects (Davies, 1999). However, some association with the NRHP was evident through NEMP adding value to previous NRHP projects.

Riverine Issues Program of the MDBC

Some of the NEMP project results have been presented at the Riverine MDBC Annual Forums. NEMP outputs have probably had little direct influence on Commission policies but some indirect influence may have occurred through the bioavailability work of Rod Oliver (Lawrence, 1999). The degree of interaction between NEMP and the Riverine Strategic Investigations and Education Program has varied throughout the life of NEMP, with a strong integration in the early days due to the fact that both NEMP Management Committee members from MDBC were in the Riverine Issues Working Group.

Overall, the integration of NEMP with other programs has relied on the LWRRDC Program Managers who oversee activities across all programs.

4.10 National leadership

Previous to NEMP there had been an attempt to coordinate eutrophication research via the CSIRO's multidivisional program. This had encouraged a multidisciplinary approach and exhibited some leadership nationally but was not particularly well integrated with stakeholders. NEMP expanded the scope of the research and provided strong national coordination while attempting to focus the research on critical issues.

NEMP has provided national leadership in a number of ways. Firstly, NEMP has incorporated other research and researchers outside of the program into its workshops and general communications. Secondly, it has introduced stakeholders to a coordinated program in a structured manner, at least in those States in which focus catchments are located. By encouraging networks, NEMP has facilitated information exchange across Australia regarding matters of eutrophication. This information exchange transcends the NEMP projects themselves. The strong leverage obtained within the program is further evidence of national leadership.

One aspect mentioned by several researchers was the lack of a framework within which the overall program can be viewed. Also, it was felt by some researchers that LWRRDC and MDBC could have shown stronger ownership and management of the program.

While the development of the first national research strategy and the encouragement of integration among various parties has been commendable, NEMP has been less successful in leading the initiative on translating research results into management actions and having these management actions adopted by catchment and water managers. Whether the latter is the responsibility of NEMP or of the States and their structures for extending information is debatable, but NEMP has a clear responsibility in the former function and is addressing this responsibility in the last year of the program.

5. Evaluating investment in eutrophication research

This chapter presents information relating to the economic evaluation of eutrophication. Firstly, a discussion and synthesis of previous economic evaluations relating to eutrophication are presented; secondly, an indicative economic evaluation of NEMP is advanced.

5.1 Previous economic evaluations

5.1.1 Life-of-project evaluations

LWRRDC has a program of 'life-of-project' evaluations where a sample of projects are subject to benefit cost analysis at the commencement of each project, with subsequent updating of each analysis every two to three years. There have been four sets of projects evaluated in this manner, with sets of projects initially evaluated in 1993–94, 1995–96, 1997–98 and 1998–99. The first set of projects (1993–94) has been updated twice and the second set (1995–96) has been updated once.

There have been life-of-project evaluations for four of the NEMP projects (one in each set of evaluations). Summaries of those evaluations are reported in this chapter. Also reported in this chapter is a summary of some case studies on productivity and ecological sustainability of the Australian dairy industry, which include some benefit cost analyses of generic eutrophication research, and which were carried out for the Dairy Research and Development Corporation and LWRRDC in 1997.

The following provides a summary of the results of the economic evaluations carried out to date on each of the NEMP projects.

Project MDR18: Validation of the NIFT assay for identifying nitrogen and phosphorus limitations of phytoplankton growth

MDR18 was developed out of an earlier project, MDR8, which developed the NIFT assay, however this project (MDR8) was not part of NEMP. MDR8 was evaluated in the first life-of-project evaluation (1993–94) undertaken by Temtac (McGregor, Harrison & Tisdell, 1994). MDR18 was evaluated as part of MDR8 only in the second update of the evaluation (Harrison et al., 1999). The two projects are analysed together, therefore separate investment criteria are not available for MDR18.

Determining which nutrient is limiting in algal bloom growth can assist in focusing on decreasing the load of the nutrient. The NIFT assay (developed in MDR8) had the potential to provide a simple monitoring tool for directly demonstrating nutrient limitation in natural phytoplankton populations. Project MDR18 was funded within NEMP. This was because the NIFT assay needed validation regarding its consistency of response patterns before it could be used in a widespread fashion.

The principal outcome expected from Project MDR18 is a validation of the NIFT assay test so it can be widely used by State and Federal agencies as well as research groups and catchment management groups. It will be used to identify and monitor nutrient limitations in phytoplankton populations which will enable water managers to have a greater understanding of the role of nutrients in controlling algal blooms.

The potential benefits from the project incorporated into the analyses are:

- cost effective management strategies;
- reduced community costs from reduced incidence of algal blooms;
- reduced costs of water testing.

In the first evaluation (1993–94), which included only MDR8, the evaluators developed a damage function which relates the probability of a bloom event occurring to the damage associated with that event. Assumptions were then made regarding the most likely reduction to the average annual damage value resulting from the research (for example, 0%, 3%, 10%). Costs were estimated from the data relating to the 1991–92 blue-green algae blooms throughout New South Wales. Costs estimated include:

- impacts on water supplies ($2.76 million);
- impacts on recreation and tourism ($10 million);
- impacts on farm animals ($82,440);
- impacts on human health ($500,000);
- administrative costs ($730,000).

These values, along with some other data, were extrapolated to include other States. The total cost within Australia for a 1-in-10-year event was estimated as $20.81 million. Damage functions were developed for three scenarios: worst case, most likely and optimistic.

The same system was used for the follow-up evaluations, the last of which included the costs and improved likelihood of achieving potential benefits resulting from MDR18.

The investment criteria (at a 7% discount rate) for MDR8 and MDR18 are presented in Table 5.1.

Table 5.1: Investment criteria for second update (MDR8 and MDR18)

Criteria	Phase 3
Net present value	$601,900
Internal rate of return	15.1%
Benefit-to-cost ratio	2.4 : 1

The factors by which the potential benefits of the project are diluted in order to obtain the expected benefits are not outlined explicitly in the evaluation. Rather, they are implicit in the net benefits. In the initial analysis the researchers applied a modifier to reduce the potential benefits, which represented the probability of success of the research reaching a successful outcome. The values assumed were:

- a 'worst case' of 60% probability of success;
- a 'most likely' case of 90%;
- an 'optimistic' case of 100%.

These assumptions proved correct, as project MDR8 was successful in producing its research outputs. Due to MDR8 being completed, and MDR18 being more applied in nature, this modifier appears to have been removed for the second update.

Also in the second update, the researchers make the assumption that the investment in MDR18 has significantly increased the likelihood of adoption of the NIFT assay, although the actual adoption rates are expected to remain the same as predicted in earlier analysis. Therefore, included in the net benefits is a risk factor for adoption, however this risk is lower due to the investment in MDR18.

Following this analysis, project MDR18 has now been successfully completed. There are plans for peer acceptance of the work in academic journals and trial adoptions of the technique and associated training in several laboratories. Further NEMP funds are required for this trial to take place. There still remains an acknowledged risk, as indicated in the Temtac analysis, that adoption of the technique is still not absolutely certain.

Project UAD10: Measurement and treatment of phosphorus and carbon subsoil movement

Project UAD10 was evaluated as part of the second set of projects evaluated in 1995–96 by ACIL (ACIL Economics and Policy Pty Ltd, 1997). This set of evaluations was first updated in 1998–99 (ACIL Consulting, 1999).

This project was to complement Project UAD7, associated with the movement of phosphorus through soils, by characterising the total loads and forms of phosphorus and DOC from different soil types. One objective was to assess how gypsum applications could reduce the amount of phosphorus and DOC translocated through soils and the benefit-to-cost ratio of their application. No clear guidelines on this emerged from UAD10. The project was concluded early with a final effort directed at consolidation and communication of results to water managers about the importance of subsurface flows.

The project is now completed and results indicate that gypsum reduced phosphorus movement only slightly in the first season following application. It did, however, reduce the amount of DOC moving through soils by a very significant amount in the first season following application. This indicates that there are unlikely to be benefits from the research relating to phosphorus, however there may be benefits regarding the use of gypsum to reduce the movement of DOC through soil.

The initial evaluation identified three potential benefits of applying lime and gypsum:

- lower fertiliser costs for farmers (due to reduced use of superphosphates);
- a possible spin-off for farmers in lowering acidity;
- off-site environmental benefits.

The evaluation measured the potential net benefits of the research using only the cost savings to farmers. No attempt was made to quantify the off-site benefits.

Table 5.2: Investment criteria for UAD10

	Initial evaluation	Update
Net present value	$2.7 million	$9.4 million
Internal rate of return	29%	30%
Benefit-to-cost ratio	10.3 : 1	23 : 1

The updated evaluation recognised there was a very low probability the research relating to phosphorus reduction would be successful. Instead it valued the benefits due to reduced movement of DOC into waterways by valuing the benefits of improved drinking water through 'willingness to pay' data. In order to make an assessment of the willingness to pay, the results of previous studies were used. Adelaide was used as an example. Assumptions were made which concluded that the average willingness to pay for improved-quality drinking water (to avoid the effects of higher levels of chlorination used to remove DOC) may be $15 per person. Assumptions were also made regarding the net chlorination cost savings of 10% of the current annual chlorine usage, net of the cost of gypsum application. It is not clear how these results were extrapolated in order to calculate the investment criteria. It is also not clear whether the investment criteria were calculated on the basis of Australia-wide benefits, or benefits to specific catchments or lands of specific soil types. The investment criteria for the two evaluations are presented in Table 5.2.

In light of the results regarding phosphorus, the investment criteria for the initial evaluation should be ignored.

In regard to dilution, the researchers indicate they have implicitly included the risk of research success and risk of adoption in their analysis. It is recognised that although the research has been completed, further analysis is required in order to indicate whether the use of gypsum is economic and will be adopted by land users.

The initial analysis assumed the probability of success of the project was 60% and the maximum level of adoption by land users across Australia would be equal to 50%. There is no indication of alternative figures being used in the update, therefore it is assumed they remained the same.

Project CSF1: The interaction of physics, biology and nutrient regimes on the initiation and development of algal blooms

Project CSF1 was evaluated as part of the third group of life-of-project evaluations, undertaken by Sloane, Cook and King in 1997–98 (Sloane, Cook & King Pty Ltd, 1999). This project targets bloom-forming dinoflaggelates and cyanobacterial species from Australian waters. In the initiation and development of algal blooms, the laboratory-based project investigates:

- the importance of physics (in the form of stability and associated gradients in nutrients and physical parameters, and turbulence);
- nutrient ratios; and
- the biology of resting states.

Potential outputs of this project include an increased understanding of the underlying factors controlling algal blooms and a contribution to knowledge associated with management options available to regulatory authorities. This may eventually lead to improved management of waterbodies aimed at decreasing severity and frequency of algal blooms. The evaluators state the users of the outputs will be other research projects, therefore any social and environmental benefits will be indirect.

Project benefits estimated in the evaluation:

- savings in health costs (current cost to Australia, $252,000 per year);
- lower water treatment cost (current cost to Australia, $927,000 per year);
- lower water quality monitoring cost (current cost to Australia, $3.36 million per year);
- lower monitoring and water treatment costs in aquaculture industries (current cost to Australia, $8 million per year);

- tourism, recreation, use or existence values (current cost to Australia, $3.36 million per year);
- total is equal to $15.9 million per year.

The figures above were estimated from various sources, including Temtac's 1993 review of project MDR8. The evaluation assumes a low adoption risk for the project. Adopters in this case include other researchers and research organisations, as well as waterway managers who would adopt resulting management strategies.

The evaluators assume a medium-to-high benefit measurement risk. This refers to difficulty in attributing the identified benefits to this project, as distinct from broader algal bloom research. In order to allow for this, the evaluators assume that research which reduces the incidence of algal blooms in Australia by 50% would have a value of 50% of those current costs outlined above, and further, that 5% of the value can be attributed to this research project. Therefore the expected contribution of benefit from this project would be $397,000. No explicit mention is made of the subsequent cost of additional research required to produce management guidelines, or the cost of applying resulting management interventions.

The investment criteria (at 7% discount rate) are presented in Table 5.3.

Table 5.3: Investment criteria for CSF1

Criteria	Phase 1
Net present value	$3,012,000
Internal rate of return	36%
Benefit-to-cost ratio	7.1 : 1

The attribution of 5% total benefits to one project seems rather high, however the figure is justified in two ways. Firstly, the results of the research are expected to be used in many other NEMP projects, and secondly, the benefits are expected to be experienced Australia-wide.

Project UMO36: Nutrient release from river sediments: Phase II validation and application of sediment-release model

Project UMO36 was evaluated as part of the fourth set of project evaluations, undertaken by Atech (Atech Group, 1999b). The project is the second phase of a previous project (CEM4) aimed at determining whether the *in situ* release of nutrients stored in river sediments is important in lowland river systems such as the Goulburn-Broken and Murray-Darling, compared with external inputs of nutrients. The research is driven by the end product, a computer model (CANDI) to assist river managers in devising management strategies to minimise opportunities for release, if sediment nutrient release proves to be important.

In order to conduct the benefit cost analysis, the evaluators use information and estimates contained in three documents that have been formulated for the management of nutrients in the Goulburn-Broken catchment. These are:

- 'Draft Goulburn-Broken Catchment water quality strategy' (1996);
- 'Catchment management strategy (final)' (1997);
- 'Benefits from reducing frequency of algal blooms in the Goulburn-Broken Catchment' (1998).

Types of benefits estimated in the third document above include:

- recreation within the catchment;
- urban water quality;
- domestic and stock water quality;
- irrigation water quality;
- reduced cost of management;
- environmental benefits;
- downstream benefits (Murray River).

From the above, and other information, it is suggested that Australia will be investing a total of $1.5 billion in activities to reduce nutrients and algal blooms over the next 20 years. It is further suggested that the benefits of this reduction over the next 20 years will be a total of $2.5 billion (both figures in present value terms). The benefits of this project are then estimated as $75–125 million (total benefits over 20 years in present value terms). These figures are estimated by suggesting either a 5% saving on costs (5% of $1.5 billion) or a 5% increase in benefits (5% of $2.5 billion).

Included in this analysis are assumptions regarding the likely high follow-up cost that will be necessary in order for the CANDI model to be effectively transferred and adopted.

The evaluators estimate the probability of success as 90%. This figure seems rather high, however the evaluators justify it in three ways. Firstly, the research is relatively advanced. Secondly, it is a research area of great importance where information such as this is lacking. Thirdly, the costs of follow-up activities have been included in the model, thus increasing the probability of eventual adoption and use of the model.

The investment criteria (at a 7% discount rate) are presented in Table 5.4.

Table 5.4: Investment criteria for UMO36

Criteria	Phase 1
Net present value	\$65–\$105 million
Benefit-to-cost ratio	from 13:1 to 20:1

5.1.2 Evaluation for dairy industry projects

Detailed case studies on a range of prospective natural resource or environmental research areas relevant to the dairy industry were carried out in 1997 (Agtrans Research and Virtual Consulting Group, 1998). Several of these case studies included estimates relating to the costs of eutrophication to the dairy industry and the public. The average cost associated with an algal bloom was estimated from various elements such as lost tourism revenue, reduction in expenditure due to reduced number of visitors and loss in recreation value to tourists and local residents. Also included were the cost of reduced property value of residential land adjoining waterways and the cost to residents of carting water from alternative sources. The average cost of an algal bloom in a waterbody with significant recreational value was estimated to be \$2.45 million.

One case study which used this estimate was 'Reducing phosphorus exports off-farm'. The evaluation recognised that the reduction of phosphorus exports by land users could contribute significantly to a reduction in algal blooms. The analysis quantified the value of reduced incidence of algal blooms to society, resulting from a reduction in phosphorus exports off-farm. Assumptions were made regarding the average number of algal blooms in a region, the relationship between reduction in phosphorus exports and reduction in algal blooms, and the average cost associated with an algal bloom as described above.

The investment criteria for investment in research that reduces phosphorus exports off-farm are shown in Table 5.5.

Table 5.5: Investment criteria

Criteria	
Net present value	\$3.4 million
Internal rate of return	13%
Benefit-to-cost ratio	4 : 1

5.1.3 Synthesis of evaluations and implications

Table 5.6 presents a summary of the investment criteria for the five analyses discussed above.

The investment criteria identified above vary significantly, from a net present value of \$601,900 for project MDR18, to a potential net present value of \$105 million for UMO36. These large differences are most likely attributable to the large number of assumptions which have to be made by researchers due to a lack of information regarding costs and benefits in respect to eutrophication. All of the LWRRDC project evaluators make the specific comment that the analyses are only indicative because information is lacking. Other differences may be due to the assumptions made with respect to expected adoption and the probability of success of the research. In this respect, assumptions can also vary between evaluators.

The other significant problem is determining what level of benefits can be attributed to an individual project. Two of the above analyses have indicated that a 5% reduction in costs is possible from one research project, however, it is believed the results of these projects will feed into other projects and hence have a secondary impact. The evaluators for Group 1 make the comment that valuing the benefits from some NEMP projects in isolation from the suite of projects of which the individual project is part:

> *"may underestimate the value of the research on the premise that the value of aggregate knowledge is worth more than the sum of its component parts." (Harrison et al., 1999)*

5.1.4 Cost of algal blooms

There are clearly difficulties in estimating the costs associated with algal blooms and therefore the benefits that may be gained by reducing the frequency and severity of such blooms. As the summaries above indicate, there have been several attempts to estimate the cost of a single algal bloom event to Australia, as well as the total costs of algal blooms to Australia.

In 1994, Temtac estimated the total cost within Australia for a 1-in-10-year event was $20.81 million. This estimate was based on data relating to the 1991–92 blue-green algae blooms throughout New South Wales, and included estimates of impacts on water supplies, recreation and tourism, farm animals, human health and administrative costs.

Sloane, Cook & King (1999) estimated the total costs being incurred in dealing with algal bloom events across Australia. They found this figure to be a total of $15.899 million per year. Costs included in this estimate are:

- health costs;
- water treatment costs;
- administration and water quality monitoring costs;
- monitoring and water treatment costs in aquaculture industries; and
- tourism, recreation, use/existence values.

The 1997 study by Agtrans Research and Virtual Consulting Group for LWRRDC and the Dairy Research and Development Corporation also estimated the cost of an algal bloom (Agtrans Research and Virtual Consulting Group, 1998). It was assumed the cost associated with a large algal bloom is $6.5 million and the cost associated with a medium algal bloom is $2 million. It was further assumed that 90% of algal blooms are of a medium size, and 10% are of a large size. It was therefore estimated that the average cost of an algal bloom is $2.45 million. This estimate was based on estimated costs associated with several algal bloom events in Victoria.

The most recent estimate of the costs relating to algal blooms is a study undertaken by Atech for NEMP (Atech Group, 1999a). The final draft of the report estimates the total costs of algal blooms to Australia as being equal to $200 million per year.

The estimates above all vary considerably, though comparison is difficult due to the use of different methods and variables. For example, while the Sloane, Cook and King estimate is significantly less than Atech's recent estimate, it is the only estimate which includes costs to aquaculture industries (current cost to Australia, $8 million). Also, most estimates are of costs associated with a single algal bloom event. Difficulty is experienced when trying to extrapolate this figure to Australia-wide costs. Difficulties are due to the uncertainty regarding the number, size, duration and severity of algal blooms occurring across Australia annually.

The economic analysis which follows uses the Atech estimate as a basis for estimating potential benefits, as it is the most recent and most comprehensive estimate to date. Most of the data on frequency and costs were collected from various sources within each State and region. While extrapolations were used, attempts were made to obtain data from each State. Most previous estimates have used the costs associated with a single or several bloom events in either New South Wales or Victoria and have attempted to extrapolate the estimate to the whole of Australia.

5.2 Economic evaluation of NEMP

This section presents an indicative benefit cost analysis of NEMP. It is only indicative because a majority of the research projects undertaken as part of NEMP are strategic in nature. Because of this strategic nature, further research investment is likely to be necessary in order for the knowledge generated to be translated into interventions and management options, and hence, benefits.

Table 5.6: Synthesis of investment criteria

Analyses	Net present value ($m)	Internal rate of return (%)	Benefit-to-cost ratio
MDR18 (and MDR8)	0.6	15.1	2.4 : 1
UAD10	9.4	30	23 : 1
CSF1	3.0	36	7 : 1
UMO36	65 to 105	not available	from 13 : 1 to 20 : 1
Dairy (phosphorus exports)	3.4	13	4 : 1

Table 5.7: Cost of algal blooms in Australia

Source	Cost (per year)
Joint management costs (algal monitoring, alert notifications and immediate response)	$9 million
Costs incurred by extractive users:	
Urban water supply	$35 million
Stock and domestic supply from farm dams	$30 million
Stock and domestic supply from rivers, storages and irrigation channels	$15 million
Irrigation supplies	$15 million
Costs incurred by non-extractive uses (recreation and aesthetics)	$96 million
Total	$200 million

5.2.1 Assumptions

Investment in NEMP

Because the individual expenditures for each project for each year were not available, it was necessary to estimate the total NEMP R&D costs for each year. Budgets were available which indicated the total NEMP funding for each year of core LWRRDC and MDBC funds only. These annual figures were multiplied by the average leverage factor of 1.17 in order to estimate the total program funding per annum. The total investment in NEMP by all parties over all years was $8.7 million.

Potential benefits

As already mentioned in Section 5.1.4, Atech has estimated the total cost of algal blooms to Australia as $200 million per annum. This is the estimate on which the following analysis is based.

For the purposes of this analysis it is assumed that the cost of eutrophication is equivalent to the costs of algal blooms. It is recognised, however, that eutrophication has other impacts besides those that are visible and offensive in the form of algal blooms. Biodiversity and the upset of natural ecosystems are also impacts of eutrophication, as are impacts on the fishing industry. However, there is no attempt made here to place an estimate on the value to society of avoiding these other impacts. It is also recognised that research and management tools which reduce the occurrence and severity of algal blooms may also have positive impacts on other water and land resource issues. Such benefits are also not included in this analysis.

Table 5.7 provides a breakdown of the Atech estimate.

The NEMP R&D program will not necessarily impact on all of these costs. The joint management costs are mostly made up of costs which cannot be reduced by research resulting from NEMP unless blue-green algae are eliminated completely. It is estimated that approximately 80% of this figure is made up of costs associated with monitoring for algal blooms, and with developing contingency plans for responding to algal blooms. The remaining 20% of this cost is associated with alert notifications and other 'one-off' costs associated with the occurrence of an algal bloom. These latter costs do have the potential to be reduced if the frequency of bloom occurrence is reduced. Taking 20% of $9 million, it is estimated that the potential impact of NEMP R&D to reducing the joint management costs is $1.8 million per year.

While none of the NEMP research to date has focused on algal blooms in farm dams, it is recognised that following further applied research, some of the knowledge generated may be adapted for application for farm dams. For the purposes of this analysis however, it is conservatively assumed that the NEMP will have no implications for managing algal blooms at the farm dam level.

Due to the elimination of these two factors, the cost of algal blooms that might be influenced by the NEMP R&D is $162.8 million per year. This potential reduction in cost is taken as the maximum potential benefit that may be derived from NEMP.

The applied program

NEMP will result in further contributions to knowledge, some of which may be used to improve management and reduce the frequency and severity of blooms. It is assumed that the first year of adoption of these improvements will be in the year ending 30 June 2001; that is, the year following the final year of the current NEMP. Benefits from the improved management are assumed to accrue two years after the first year of adoption.

However, in the main it is assumed further applied R&D investment will be required to translate much of the enhanced understanding to implementable management improvements. It is further assumed,

Table 5.8: Assumptions used in investment analysis

	Assumption	Value	Source
A	Discount rate	7% real	Assumed
	Cost assumptions		
B	Total R&D costs for all NEMP projects	$8,653,363 (total cost)	NEMP budgets (core funds multiplied by leverage factor of 1.17)
C	Assumed further four years research, development and extension costs to produce management guidelines before adoption and benefits are realised	$6,000,000 (total cost)	Assumed
D	Costs of implementation	(Included in assumptions re net expected benefits)	Assumed
	Benefits assumptions		
E	Joint costs of algal monitoring, alert notifications and immediate response	$9 million per year	Final draft report, 'Cost of algal blooms' (Atech Group, 1999a)
F	Proportion of these joint costs which have potential to be reduced by NEMP	20%	Assumed
G	Joint costs which have the potential to be reduced by NEMP	$1.8 million per year	E * F
H	Cost to urban water supply	$35 million per year	Atech, 1999a
I	Cost to stock and domestic supply from rivers, storages and irrigation channels	$15 million per year	Atech, 1999a
J	Cost to irrigation supplies	$15 million per year	Atech, 1999a
K	Cost to non-extractive users (recreation and aesthetics)	$96 million per year	Atech, 1999a
L	Total cost of an algal bloom with potential to be reduced	$162.8 million per year	G + H + I + J + K
M	Potential reduction in costs due to NEMP per year	2%	Assumed
N	Potential net benefits per year	$3,256,000	L * M
O	Probability of success	50%	Assumed
P	Expected net benefits per year	$1,682,000	N * O

therefore, that another four years of applied and management R&D will be required following the completion of NEMP in order for additional benefits to be captured.

The level of funding required for these four years of further R&D is assumed to be equal to $1.5 million per year. This figure is based on the approximate average of annual funding for NEMP over the past few years.

Potential reduction in costs of algal blooms due to NEMP

This is assumed to be 2% per annum (cumulative) of the maximum potential benefits ($162.8 million per annum). This estimate is assumed to be a net gain and includes any dilution for less than maximum adoption, as well as any additional costs of implementation of improved management strategies. The 2% is the net cost avoided by the implementation of management interventions ultimately provided by NEMP and actually implemented by catchment and water managers. It is also assumed this 2% per annum relates to the existing potential benefit, and that this potential benefit will remain the same and would not have increased without NEMP or the future R&D investment assumed.

Probability of success

While it is already known that NEMP has been successful in producing useful knowledge and some management implications, there is uncertainty regarding the likely success of the interventions and R&D required for all the assumed benefits to be realised. A 50% probability of success is assumed, reducing the expected benefits to a gain of 1% of the total cost of algal blooms per year.

The assumptions used in the analysis and discussed above are presented in Table 5.8.

5.2.2 Results

Table 5.9 presents the results of the investment analysis. From the assumptions in Table 5.8, the analysis shows the program has a benefit-to-cost ratio of nearly 6 : 1, and an internal rate of return of 27%.

Sensitivity analyses were carried out on several variables. Firstly, sensitivity to a change in the discount rate was considered. Results are presented in Table 5.10 for investment criteria at a discount rate of 4%, 7% and 10%.

This analysis shows that at a 4% discount rate, the benefit-to-cost ratio increases to 8 : 1, while at a 10% discount rate, the benefit-to-cost ratio decreases to only 4 : 1.

Table 5.9: Summary of investment criteria

Criteria	
Net present value	$49.97 million
Internal rate of return	27%
Benefit-to-cost ratio	5.6 : 1

Secondly, sensitivity to a change in the expected benefits was considered by increasing the expected percentage reduction in the costs of algal blooms to Australia. The results of this analysis are presented in Table 5.11.

The analysis shows that if the percentage reduction is increased to 4%, the internal rate of return increases from 27% to 37%, while if costs are reduced by 6%, the internal rate of return increases further to 43%. A break-even analysis was carried out which found that the net present value is equal to zero when the expected percentage reduction in costs is equal to just under 0.4% per annum.

Thirdly, a sensitivity analysis was carried out on the number of years from the final year of NEMP until the first year of expected benefits. These results are summarised in Table 5.12.

This analysis shows that if the benefits from the program were realised immediately following the final year of the current NEMP, the benefit-to-cost ratio increases to 8 : 1. However, if benefits do not begin to be realised until five years after the final year of the current NEMP, the benefit-to-cost ratio decreases to 4 : 1. This demonstrates the value of ensuring that adoption of improved management interventions is as rapid as possible if the investment in R&D is to be profitable.

5.2.3 Conclusion

Overall, the investment criteria and sensitivity analyses indicate that the NEMP should produce significant economic benefits, provided further applied research is undertaken to transfer the knowledge successfully generated so far into management tools. The analyses also indicate that the investment criteria are very sensitive to changes in several of the variables.

It should be recognised that this analysis is only indicative, as much of the information regarding further research and implementation costs, as well as the potential for benefits from the program, has had to be assumed. This analysis has attempted to be conservative by, for example, not including possible indirect benefits of the program to other land and water resource issues.

Table 5.10: Sensitivity analysis for the discount rate

Discount rate (%)	Net present value ($ million)	Benefit-to-cost ratio
4	81.0	8 : 1
7	50.0	6 : 1
10	30.8	4 : 1

Table 5.11: Sensitivity analysis for the expected percentage reduction in the costs of algal blooms to Australia

Reduction in annual costs of algal blooms to Australia (%)	Net present value ($m)	Internal rate of return (%)	Benefit-to-cost ratio
2	50	27	6 : 1
4	111	37	11 : 1
6	172	43	17 : 1

Table 5.12: Sensitivity analysis for the time lag between end of applied research and commencement of benefits

	Net present value ($m)	Internal rate of return (%)	Benefit-to-cost ratio
1 year	72.3	36	8 : 1
3 years	50.0	27	6 : 1
5 years	32.0	21	4 : 1

6. Implications for future research funding

There are a number of implications that arise from this evaluation for both the remaining period of NEMP as well as for any future program aimed at eutrophication and reducing the impact of blue-green algae. As another consultancy is addressing in detail how further research might be organised and orientated, this chapter is quite brief. However, the issues identified as arising from the current NEMP and seen as important for the future are highlighted.

This chapter is divided into two sections. The first section deals with implications for the remaining part of NEMP. The second section deals with implications for research support after the completion of NEMP in June 2000.

6.1 Implications for the remaining part of NEMP

6.1.1 Extract management implications for each project

As already mentioned, there is significant activity occurring in identifying management implications within some projects as final results become available. NEMP management is encouraging such activity strongly and this is to be commended. Workshops being held with water managers will be very useful in assessing the relevance of results to waterway and reservoir management.

With respect to catchment management, those principal investigators who have projects associated with sources and transport of nutrients and sediment should analyse their results in relation to existing research and activities in the focus catchments associated with minimising nutrient export. A general claim being made by some NEMP researchers is that the NEMP results will help to identify priorities for minimising nutrient export off farms. Researchers should assess if, and ensure that, their results are useful to decision-makers as well as other scientists. It is not sufficient to state that the information about sources of sediments and nutrients, and the identification of limiting nutrients (and so on) may be used to prioritise the location and form of interventions. More detail is required regarding the impact of the NEMP results on such priorities and the types of actions and policies that might be important.

6.1.2 Integrate findings across all projects for each focus catchment

Before the end of NEMP there should be a summary statement written for each focus catchment of the aggregate findings relevant to that catchment, and how the information produced from the projects can be utilised in the future. This might be assisted by stakeholder meetings with researchers. In this regard, it is understood that there will be a final workshop in each focus catchment. However, it is desirable that written summaries are provided. Focus Catchment Coordinators should play a role in facilitating such summaries.

6.1.3 Assess potential for extrapolation from findings

Implications identified for each focus catchment should be integrated with findings and implications from generic projects to ensure that generalised guidelines are produced for different types of catchments across Australia. In this regard, recent findings and experience from outside of NEMP should be included. Monitoring and other implications for information needs and data gathering should be identified.

A synthesis of best-bet guidelines for catchment and water managers is an essential output from NEMP. It is likely that this initiative will require an additional budget, as researchers should not be expected to reach this far within their current project funding.

For those projects where models have been developed or refined, principal investigators should be asked to identify:

- the purpose of the model;
- where such models might be useful in relation to specific types of catchments;
- who could use the model;
- what information and resources would be required for the model to be applied by scientists in other projects or by catchment or water managers directly in other catchments.

6.2 Implications for future research funding

6.2.1 Priority-setting

More effort into seeking a better balance between scientific priorities and potential benefits to Australia is warranted. In this regard, priority-setting in future could include the identification of areas where pay offs or benefits could be expected to be highest in relation to lessening the frequency and severity of blooms. Which are the geographic locations, waterbody types and catchment types where a reduction in blooms might provide the greatest benefits? The current Atech study on the cost of algal blooms could provide a starting point for such an initiative (Atech Group, 1999a). For example, the costs associated with bloom development on farm dams is considerable according to the Atech estimate but has not been specifically addressed in the current NEMP.

Priorities should also be influenced by attempting to identify the type and location of likely successful interventions. The scoping of potential management interventions should be an integral part of this priority-setting from the science viewpoint as well as the likely cost-effectiveness and applicability of those interventions across a range of catchments and water systems.

Priority-setting could also involve the community and decision-makers on what are the key aspects and areas on which to concentrate for the purpose of improving the current decisions they face. A start has already been made in this direction from the perspective of reservoir managers. The same initiative would be difficult in relation to catchment management, but in this regard, representatives of other programs working on best management practices and land use planning in relation to natural resource management could make important contributions to priorities.

The identification of information needs from catchment and water managers should not be undertaken merely by inviting representatives to make input at a workshop. The translation of information should be more deliberate and structured and perhaps requires a consultancy study in the same vein as the two scientific consultancies carried out at the beginning of NEMP.

6.2.2 Scoping of management interventions

After NEMP, and before any further investment is made in eutrophication research, preliminary scoping of potential management interventions should take place for both catchments and waterbodies (including water storages, such as weirs and reservoirs).

Results of economic analysis of prospective interventions would be useful in focusing both applied and strategic research in future. Assistance with defining interventions at the catchment level could be assisted by those working in other programs associated with nutrient export. Estimates of the efficacy of interventions at the catchment scale and with respect to 'making a difference' to algal bloom occurrences would supplement information aimed at focusing future research.

For example, one could estimate the reserve of nutrients in sediments and the implications of whether reducing nutrient exports from catchments by certain amounts (either through farming practice changes, use of buffer strips, and so on) is likely to make a difference, given the other perhaps uncontrollable sources of nutrients. If a difference is possible, how many years might it take to demonstrate a reduction in frequency and severity of blooms? These are difficult questions but they need addressing. Would such differences, if they exist, then be overtaken by the expected impacts of episodic events that might make such practices ineffectual for many years?

Benefits other than those derived from reductions in blue-green algae, originating from management interventions aimed at lessening nutrient exports from catchments, would also need to be considered (such as improvements for the fishing industry, biodiversity and the effect on wetlands). Interventions at the catchment level produce impacts only one of which is on blue-green algae.

At a more practical level, interventions (such as sealing the bottoms of reservoirs, increasing turbidity through various mechanisms, flow management and so on) could be screened as to their feasibility, cost-effectiveness and exposed knowledge gaps.

6.2.3 Focus catchment approach

The focus catchment approach used in NEMP was partly successful in producing synergy between researchers and providing scope for interaction between the research and the community. However, if such an approach was to be used in the future, it should be ensured that there are sufficient numbers of projects within each catchment to provide sufficient scope for interaction and synergy. Depending on how the issues in the catchment are defined, it may be preferable to have five or six projects per catchment rather than two or three. If resources are limited this may mean limiting the number of focus catchments (for example, in NEMP from, say, four to two).

One of the key potential benefits from the approach is to engender ownership of the research, and therefore the research findings, to the decision-makers in the catchment. For this to be achieved, considerably more interaction into priority-setting for the catchment (including issue identification and project design) should occur. If this were the case, an improved balance of strategic and management-orientated research might also be developed.

If the program is science-orientated within a management context (as is the current NEMP) and the program strategy is to produce knowledge that is transferable across many catchments, through building knowledge processes and using modeling to extrapolate, then the use of the focus catchment approach may be questionable. In that case, such an approach should be considered against the alternative of carrying out research in selected catchments (one or more) according to which catchments will provide the most information useful for extrapolation to the maximum number of catchments. Such process-type research may have greater prospects for extrapolation.

6.2.4 Ensuring effective communication with catchment and water managers

Whether a focus catchment approach is used or not, the early involvement of catchment managers and water managers in any new program is imperative for two reasons:

- managers can be important in defining the issues and priorities of most concern and can assist in shaping both applied and strategic research;
- research results are likely to be more relevant to decision-makers and therefore the uptake of results more rapid.

Early communication could ensure that:

- the information needs of managers and policy-makers are identified and in a form that is useful to researchers;
- expectations of the R&D program are realistic from the viewpoint of the community and catchment and water managers, depending on the type of program to be funded.

6.2.5 Consideration of an inductive approach

Some attention should be given to a more 'inductive' approach to solving problems associated with eutrophication. While specific knowledge may be critical to advance understanding, it may not be possible to identify the most critical knowledge based on existing scientific understanding. What may be termed inductive experimentation, where the potential outputs may be practical but may not necessarily be achieved, should still provide appropriate 'understanding'-type knowledge that, in the end, may be more relevant to eventual action than testing hypotheses based on previous scientific knowledge.

This possibility of course relies on what and how many variables are monitored during the course of the investigation. A good example of this is the biomanipulation experiment (CLW2) in the NEMP, where the intervention being tested is practical and low cost. If the intervention does not work, there is still considerable knowledge being gathered on ecology of the lakes that will enhance understanding of why the intervention may have failed and provide guidance to what other interventions may be more successful.

While the approach in Project CLW2 has built on some initial strategic research undertaken by mainly one scientist over the past decade, it is likely that other knowledge areas related to blue-green algae development would be well enough developed to postulate management interventions that could be tested. Working against this idea may be the potential higher cost of other intervention experiments. However, it is suggested that this approach be given consideration wherever possible in any future research program.

6.2.6 Integration with other programs

Any future NEMP should interact more closely with other relevant programs operating mainly at the interface between land use and waterbodies. These include the NRHP, NPIRD and the Riparian Lands Program, all managed by LWRRDC. While such programs approach eutrophication from different viewpoints, they all include areas of minimising nutrient exports and nutrient impacts as key objectives. Some of the issues defined in these programs should be highly relevant to any future NEMP. Also, those programs focusing on land use and best management practices (mainly funded by the States and the commodity R&D corporations) may have useful input into a second stage of NEMP. Early interaction is strongly advisable.

Alternatively, it could be argued that a second-stage NEMP could largely remain strategically based, provided that the issues and key strategic information targeted is defined and led by such other programs, most of which are orientated more towards intervention.

With respect to reservoirs and impoundments, this is clearly an area where interventions may be more practical and where information is urgently needed by managers. This area appeared to be given less attention than other areas within NEMP. It is possible LWRRDC sees this area as less 'rural', and therefore less relevant to their charter and more the responsibility of the large agencies responsible for town and city water supply. If this is so, future funding of this area could develop through a partnership approach with new partners such as the Water Services Association.

There is increasing emphasis on water quality strategies across a range of catchments. Eutrophication research should be integrated with such strategies in the future. It is likely that more emphasis on management alternatives and outcomes will be driven by such strategies. Also, it is likely that as the management of environmental flows becomes more accepted, flows will be seen in some circumstances as a means to manage biodiversity as well as blue-green algae.

7. Summary of findings and recommendations

This final chapter is divided into two sections. The first section summarises the key findings of the review. The second section provides some recommendations for the existing NEMP as well as issues that might be considered in developing a further research program related to eutrophication and management of blue-green algal outbreaks.

7.1 Summary of key findings

1. NEMP is characterised by a suite of high-quality science projects that are producing knowledge which will increase the understanding of the factors contributing to the development of algal blooms.
2. The program has also been characterised by very good management and coordination at all levels; that is, by the Program Management Committee, the Program Manager and Program Coordinator, the four Focus Catchment Coordinators, and the administrative and financial management services provided by LWRRDC.
3. Given the limited funding for such a national program, its goals and objectives may have been somewhat over-ambitious. The overall goal of funding research to reduce the frequency and intensity of algal blooms will have been only partly achieved at the end of the program. An improved knowledge base has been established; however, the development of improved interventions that can be readily used by catchment and water managers is likely to be somewhat limited without further effort.
4. The first of the three objectives, that of funding research to enhance understanding, has been achieved. In fact most of the R&D effort within the program was directed at this objective. All strategies developed to pursue this first objective were followed.
5. The second objective, to develop techniques (including predictive models and decision support systems) to help prevent and manage the impacts of eutrophication, is not likely to be immediately and fully achieved. Not all of the strategies set to pursue this objective were followed. The program appears to have made little attempt to comprehensively identify specific information management requirements in the first period of the program (other than perhaps to some degree in the focus catchments) and the intended benefit cost analyses of management techniques at an early stage were not carried out.
6. The reviewers' interpretation of the program strategy is that it was dominated by the objective of producing further scientific understanding and then interpreting how such understanding could assist management. While some client involvement was manifest at the 1994 workshop and in the development of individual projects, the nature of the set of projects that were eventually funded supports the view that the program was driven more by the science than by management needs. It could be concluded that the program was 'science-orientated within a broad management context'.
7. Considerable attention was given to priority-setting at the beginning of the program (two consultancies and a workshop). Both consultancies (for LWRRDC and for MDBC) were carried out by CSIRO scientists. Catchment and water managers attended the workshop in 1994 which was aimed at refining the priorities emanating from the two consultancies.
8. On the other hand, it would appear that strong emphasis (at least in the second half of the program) is being focused on the importance of developing management guidelines. This is commendable in itself, and some guidelines and management implications will emerge from selected projects and groups of projects. However, it may be difficult to package many of the NEMP project outputs directly into decision support and management guidelines.
9. The real test for the program in translating outputs into outcomes and developing management guidelines will be in the next 12 months when the interpretation of individual project results and synthesis of results across projects and across focus catchments will be addressed.
10. The third objective of the program concerned communication of project results to stakeholders. This objective, and the associated strategies, were

pursued vigorously by the program. The strong support within the program for various workshops (between scientists alone and between researchers and the catchment and water communities) was commendable.

11. Explanations for the apparent imbalance of the type of projects funded and the apparent imbalance between strategic and applied research were that:
    - 'Further understanding sources and processes' was still required before management issues could be addressed directly. However, necessary decisions are continually having to be made with respect to reducing eutrophication. Understanding management decisions would appear a necessary element for effective achievement of the goal set for the program.
    - Projects of sufficient quality and with specific management application were not forthcoming in the calls for projects. This would of course have been a matter of judgement for the Management Committee. Given this was the case, this may reflect the capacity of the management agencies and researchers to formulate more applied projects, thus defaulting to the more science-driven projects. The lack of capacity in itself should have implications for capacity and capability-building which might have been considered in the suite of projects funded by NEMP.
12. There was a significant imbalance between the resources allocated to each of the six priorities set for the program with 69% of resources for research supporting Priorities B and E (sources and transport of nutrients [B] and factors leading to the development and initiation of blooms [E]). Priority A (bioavailability) received 11% and Priority C (management of sediment nutrient sources) 20%. The other two priorities received practically no support (episodic events [D] and evaluation of effectiveness of actions to manage nutrients [F]). The program was strongly focused on phosphorus dynamics and chemistry, and lightly focused on the areas of flows, ecology and nitrogen dynamics.
13. The review of past investment analyses for projects associated with eutrophication demonstrated that there are large costs associated with the development of blue-green algae, to both the community at large as well as to specific industries and water users. The investment analyses were hampered by credible data on the cost of algal-blooms (now being improved through a NEMP project), as well as by the assumptions necessary on the linkages from individual research project outputs to the reduction of blooms. Most of the four NEMP research projects analysed within the LWRRDC life-of-project evaluations were strategic in nature and were unlikely to produce results in themselves that could be easily traced to lowering bloom incidence or severity. Nevertheless, results based on the best assumptions available suggested that the return to the project investments were all positive.
14. A benefit cost analysis for the total investment in NEMP was carried out within the present review with assumptions having to be made on the impact that the research could eventually provide, including additional research costs. Using tighter and possibly more conservative assumptions regarding benefits than evident in the life-of-project evaluations, it was estimated that the total investment in NEMP of $8.7 million would provide a net present value of $50 million, a 5.6 : 1 benefit-to-cost ratio and an internal rate of return of 27%.
15. The focus catchment approach adopted in the program had mixed outcomes. Overall it worked well with some synergies between researchers being realised. The extent and nature of interactions between researchers and the local communities varied between catchments and may have been limited in the first few years through the type of research funded. The real test of usefulness of the focus catchment approach will occur in the last year of the program when results and implications are aggregated and synthesised.
16. Overall, there may have been too many catchments selected for the number of projects that could be funded. Also, the advantages of a focus catchment approach may be offset in some respects by the limitations in acquiring and assembling generic process information. While this is not a criticism of the approach in NEMP (as another part of the program was free of focus catchments), further thought may be given in future to the real purpose of a focus catchment approach; in particular, whether it is mainly aimed at community and management ownership of the research, providing

focus and synergy among researchers, or acquiring relevant and critical mass data sets and process models that can be extrapolated across other catchments within Australia.

17. Interaction between NEMP and other LWRRDC programs did not appear to be strong. It is understood that the LWRRDC Board is currently addressing this issue. The Riparian Lands Program has specifically targeted buffer strips, prevention of streambank erosion and shading of waterways as factors contributing to reduced blue-green algal outbreaks. NPIRD is currently developing a suite of projects that address water quality and algal management. It would appear that, at least in these two instances, the contact between NEMP and the respective program has been minimal, other than through the Program Managers. Some association with the NRHP was evident through NEMP, adding value to previous NRHP projects.
18. One of the issues regarding translating outputs into outcomes is that information produced by the program relevant to the development of blooms or the sources and transport of nutrients will require integration within other activities aimed at minimising nutrient export off farms, improving catchment water quality, protecting riparian lands and streambanks, and so on. Attempts at such integration with other programs in these areas could be a key focus activity within the attempt to extract management implications in the last year of the program.

7.2 Recommendations

7.2.1 Recommendations for the remainder of NEMP

1. The development of guidelines and principles for management actions from projects should be a major activity in the remaining period of NEMP and should be encouraged by NEMP management.
2. While the primary objective of the focus catchment approach was not to provide solutions to local catchment issues, there is an expectation by some communities that this will be forthcoming. It is important that a significant effort is made in this endeavour.
3. A stocktake, categorisation and synthesis of models produced or refined under NEMP should be effected. How the models might be used in other research or by land and water managers, together with their data requirements, should be explored in detail.
4. Integration of the outputs of NEMP regarding the implications for other programs would be useful and a small workshop across four or five other relevant programs and NEMP should be considered.

7.2.2 Recommendations for any continuing program

1. Any future program associated with eutrophication should consider scoping studies focusing on management information needs as important inputs to the structure and priorities of the program. Such scoping studies should be carried out before any other projects are funded and should cover:
   - the decisions currently being made by land and water managers that take into account the development of blue-green algal blooms;
   - the scope for interventions at different locations along the water chain (for example, land use and practices, nutrient export, maintaining streambank integrity, flow control, reservoir management interventions, and so on);
   - the potential for cost-effective solutions at different points along the water chain.
2. The balance between strategic and applied research should be given more prominence in developing priorities and selecting projects for future R&D, with a bias in any future program towards more management-orientated or applied research that capitalises on the opportunities provided by NEMP.
3. For all research projects funded in future, there should be stronger definition and expression of the linkages between the potential research outputs and how these outputs will be used. This could be achieved by detailing the type of management and policy decisions that may be assisted by such outputs.
4. A higher level of interaction should be pursued between any future NEMP and other programs associated with interacting processes and strategies such as riparian lands, river health and irrigation. In addition various land-use-based

programs of the commodity R&D corporations (dairy, meat and so on) should be consulted in order to determine where a program such as NEMP can best contribute in terms of information needs at the catchment level.

5. Consideration needs to be given to the argument that small reductions in nutrient exports from land use may not necessarily be effective for many years or perhaps never, given river sediment sources of phosphorus, and episodic events.

Careful consideration should be given as to whether to use a focus catchment approach in future. Such considerations should take into account the major purpose of the program (process understanding, localised case studies, producing management guidelines for all catchments) and the synergies expected (between researchers and between researchers and the community, including personnel of State agencies). If a focus catchment approach is to be used in the future, sufficient numbers of projects within each catchment should be funded to provide sufficient scope for interaction and synergy. This may mean limiting the number of focus catchments.

References

ACIL Consulting (1999), 'Life-of-project impact assessment: Selected LWRRDC projects' (submitted to LWRRDC May 1999).

ACIL Economics and Policy Pty Ltd (1997), *Evaluation of the Impacts of Research Projects Related to Australia's Natural Resources (1995–96 Group: Phase 1)*, LWRRDC, Canberra.

Agtrans Research and Virtual Consulting Group (1998), *Productivity and Ecological Sustainability of the Australian Dairy Industry: Appendices, Detailed Case Studies*, LWRRDC, Canberra.

Atech Group (1999a), 'Cost of algal blooms', draft final report (submitted to LWRRDC and MDBC November 1999).

Atech Group (1999b), *Evaluation of the Impact of Research Projects Relating to Australia's Natural Resources (1998 Group: Phase 1)*, LWRRDC, Canberra.

Davies, P. (1999), personal communication, CSIRO.

Davis, J.R. (ed) (1997) *Managing Algal Blooms: Outcomes from CSIRO's Blue-Green Algal Research Program*, CSIRO Land and Water, Canberra.

Goulburn-Broken Catchment and Land Protection Board (1996), 'Draft Goulburn-Broken Catchment water quality strategy'.

Goulburn-Broken Management Authority (1998), 'Benefits from reducing frequency of algal blooms in the Goulburn-Broken Catchment'.

Goulburn-Broken Management Authority (1997), 'Catchment management strategy (final)'.

Harrison, S.R., Tisdell C.A., Tisdell J.G. and McGregor, M.J. (1999), 'Assessing the impact of research projects relating to Australia's natural resources: Second update in life-of-project evaluations' (submitted to LWRRDC April 1999).

Lawrence, B. (1999), personal communication, MDBC.

McGregor, M.J., Harrison S.R. and Tisdell C.A. (1994), *Assessing the Impact of Research Projects Related to Australia's Natural Resources*, LWRRDC, Canberra.

McWaters, V. (1999), personal communication, NEMP.

National Eutrophication Management Program (NEMP) (1996a), 'Program plan, 1995–2000', LWRRDC, Canberra.

National Eutrophication Management Program (NEMP) (1996b), 'Communications plan', LWRRDC, Canberra.

National Eutrophication Management Program (NEMP) (1999), *Phosphorus in the Landscape: Sources and Transport of Phosphorus in Australian Catchments*, LWRRDC, Canberra.

Price, P. (1999), personal communication, LWRRDC.

Sloane, Cook & King Pty Ltd (1999), *Ex-Ante Evaluation of Selected Research Projects 1997*, LWRRDC, Canberra.

Appendix 1: Individual project summaries

Project CNR1

Project title	The relationship between nutrient (phosphorus) loading and algal growth in aquatic ecosystems	
Principal investigator and agency	Graham Harris, CSIRO and CRC for Freshwater Ecology, Canberra	
Collaborators	Nil	
Funding	NEMP	$18,500
Start date	January 1994	
Finish date	February 1994	
Location	Canberra	
Target audiences	LWRRDC	

Objectives

Preparation of a discussion paper that covers the relationships between nutrient loadings and algal blooms.

Description of project

This consultancy was established to ascertain a base set of knowledge and determine priorities for a potential LWRRDC program associated with blue-green algae.

Potential outputs

A LWRRDC publication containing information on the relationships between nutrient loadings and algal blooms and also identification of knowledge gaps, research opportunities and Australian priorities for research.

Actual outputs

A LWRRDC publication containing information on the relationships between nutrient loadings and algal blooms and also identification of Australian priorities for research.

Priorities included:

- examining the relationships between rainfall intensity, run-off, land use, nutrient concentration, storm flows and phosphorus concentrations;
- making comparative studies of oligotrophic and eutrophic ecosystems;
- making system-level studies of nitrogen and phosphorus cycling in systems of varying residence times;
- examining possibilities of switching water bodies between the 'turbid and cyanobacterial' and the 'clear and macrophytes' states;
- investigating destratification and other physical perturbation techniques (such as flow regulation);
- developing measures of aquatic ecosystem health based on fluxes and ecosystem processes rather than biodiversity should be developed;
- developing a new generation of ecosystem models based on new ecological concepts;
- studying the interaction between climate variability, storm intensity, rainfall, run-off, stream flow, drought, fire and phytoplankton community structure are required.

Potential outcomes and benefits

The paper was to make an input to LWRRDC's decision about whether to establish a separate eutrophication program.

Actual outcomes and benefits

This discussion paper helped shape the NEMP and its priorities. Another consultancy prepared by MDBC also contributed to the genesis of the program.

Project UAD7

Project title	Movement of phosphorus through soils
Principal investigator and agency	David Chittleborough, University of Adelaide (UA); Jim Cox, CRC for Soil and Land Management (CRCSLM)
Collaborators	CRCSLM and Engineering and Water Supply Department, South Australia
Funding	NEMP \$111,250 UA \$ 28,620 CRCSLM \$ 21,000 Total \$160,870
Start date	October 1994
Finish date	July 1997 (final report dated August 1998)
Location	Glen Osmond, South Australia, with field sites in South Australia, Western Australia and Victoria
Target audience	Principally landholders (especially those in Landcare groups); State and regional water authorities

Objectives

(i) To quantify the extent of phosphorus movement through a diversity of soil types.

(ii) To establish the climatic factors (for example, storm intensity, seasonal wetting and drying) which influence phosphorus movement.

(iii) To quantify the effect of soil properties (for example, sodicity, porosity, texture) which influence phosphorus movement through soils.

(iv) To devise a phosphorus movement index to predict the extent of phosphorus movement through soil types based on readily measured soil properties.

(v) To determine the extent to which lime and gypsum reduce the amount of phosphate translocated through the soil profile.

Description of project

The project was focused on defining soil properties that influence phosphate movement and to devise a phosphorus movement index to predict the extent of phosphorus movement through soil types based on readily measured soil properties.

Potential outputs

- A phosphorus movement index for predicting the mobility of phosphorus in soils.
- An appreciation of the role that calcium amendments, principally lime and gypsum, may play in attenuating phosphate movement through soils.

Actual outputs

- Phosphorus mobility in bypass flow is significant in soils with high macroporosity. The importance of macropores in facilitating phosphorus movement was established.
- Development of a good understanding of the factors controlling the vertical movement of both flow and phosphorus through soil profiles from different soil types and positions in the landscape.
- Some of these factors include the influence of prior moisture content on leaching and the position in the landscape where bypass flow is likely to be important.
- Management guidelines (for example, liming, gypsum, rate, timing and method of fertiliser application) based on this knowledge were not developed and some were left to be addressed in Project UAD10.
- The phosphorus movement index and associated modelling was not completed but a strategy for basing it on both the texture of the soil and, importantly, the hydraulic conductivity was suggested.
- The fifth objective, relating to lime and gypsum, was transferred to project UAD10.

Potential outcomes

- Management interventions using the knowledge gained should allow reduction of the amounts of phosphorus in water storages and streams and lead to an improvement in water quality and a reduction in eutrophication.

- A phosphorus movement index can be used as a management and planning tool by environmental planners and soil conservation advisers.

Actual outcomes

- The key to reducing phosphorus contamination of waterways by surface-applied phosphates may lie in reducing rapid transport of phosphorus, paying particular attention to those areas in the landscape where the leaching of phosphorus is known or predicted to be enhanced.
- This may be achieved by a number of strategies which involve a reassessment of irrigation practices and, in those situations where artificial irrigation is not utilised, a reassessment of the rate, timing and method of fertilizer application.
- Adding fertilizer to a pre-wetted soil greatly reduced its transport through the soil profile, presumably due to the increased opportunity for adsorption onto the soil constituents before bypassing flow is initiated.
- Furthermore, applying the required amount of fertiliser at the right time, in small amounts and more often, may prevent the leaching of surface-applied fertilisers into subsurface environments. Although this would be time consuming and expensive, repeat additions of small amounts of fertiliser may only be required in those parts of the landscape where phosphorus movement is known or predicted to be facilitated.

Project UAD10

Project title	Measurement and treatment of phosphorus and carbon subsoil movement	
Principal investigator and agency	David Chittleborough, UA; Jim Cox, CRCSLM	
Collaborators	CRCSLM	
Funding	NEMP	$242,840
	UA	$ 38,400
	CRCSLM	$ 41,650
	Total	$362,890
Start date	July 1995	
Finish date	March 2000 (subsequently revised to August 1999)	
Location	Glen Osmond, South Australia, and trial sites in South Australia and Western Australia	
Target audience	Water managers, land managers, water quality specialists, Landcare groups, soil conservation boards, agricultural industries, technical specialists	

Objectives

(i) To quantify the proportion of phosphorus and DOC moving from soils into streams and water storages by subsurface flow at the hillslope scale.

(ii) To characterise the chemistry, physical and mineralogical properties of the mobile phosphorus and DOC.

(iii) To determine the extent to which lime and gypsum reduce the amount of phosphorus and DOC translocated through soils and the benefit-to-cost ratio of their application.

(iv) To transfer results to Landcare officers and water and land management agencies through meetings, field days and the publication of a brochure.

Description of project

This project was to complement Project UAD7 associated with the movement of phosphorus through soils by characterising the total loads and forms of phosphorus and DOC from different soil types. Some emphasis on how gypsum applications could reduce phosphorus flows was also made, although no clear guidelines emerged. The project was concluded early with a final effort directed at consolidation and communication of results to water managers about the importance of subsurface flows.

Potential outputs

- Description of trial sites, characteristics, instruments and methods.
- Summary of key findings about phosphorus, DOC and colloid fluxes in surface and subsurface flows.
- Description of flow and compositional changes over the subcatchments and the implications of catchment characteristics for discharge of phosphorus, DOC and colloids to streams.
- Description of physical, chemical and mineralogical properties of mobile phosphorus and DOC.
- Scientific and economic evaluation of the use of gypsum to reduce phosphorus and DOC discharges.

Actual outputs

- Improved understanding of phosphorus and DOC and colloid flows in surface and subsurface flows.
- Gypsum reduced phosphorus movement only slightly in the first season following application.
- Gypsum reduced the amount of DOC moving through soils by a very significant amount in the first season following application.

Potential outcomes

- Guidelines for reducing phosphorus subsurface flows.
- Application of gypsum or lime applied to pastures to reduce DOC concentrations in streams and water storages.
- Appreciation by water managers of the importance of subsurface flows as a method of phosphorus export into streams.

Actual outcomes

- Any management guidelines may depend on how long gypsum has an attenuating effect on DOC.
- Unlikely to have produced any specific management guidelines until further work is completed.
- Information may be used in other applied research.

Project CWA18

Project title	NEMP Program Coordinator	
Principal investigator and agency	Richard Davis, CSIRO Land and Water, Canberra	
Collaborators	Nil	
Funding	NEMP	$260,536
Start date	August 1995	
Finish date	June 2000	
Location	All over Australia	
Target audiences	Program management committee, principal investigators of projects, stakeholders in the program	

Objectives

Strategic

(i) To manage the process of identifying program goals and R&D priorities taking into account linkages and overlaps with other LWRRDC programs through the involvement of stakeholders so as to achieve broad acceptance.

(ii) Where appropriate, to undertake or arrange the assessment of policy, economic and social impediments to improved natural resource management in the program area, and identify and suggest implementation of R&D to overcome these impediments.

(iii) To optimise the delivery of program and project outcomes through active communication, ensuring the development of guidelines and regulations (by regulators) based on sound knowledge, and by promoting best management practice in the industry.

(iv) To act as a catalyst to coordinate and integrate research effort in which LWRRDC has an investment in Australia to meet the program objectives.

(v) To approach additional funding partners (in particular the National Landcare Program) with a view to increasing the financial resources, improving national coordination and enhancing the delivery of program outcomes.

Management

(vi) To arrange for seminars, workshops and reviews to define R&D priorities and their ranking as required.

(vii) To monitor progress of projects against objectives, milestones and performance indicators and organise panel reviews of projects.

(viii) To provide advice to the program management committee on scientific policy and other substantive program issues.

(ix) To organise and manage technical working groups and other technical assistance required for the program.

(x) To report on program activities to the program management committee and program funding partners.

(xi) To prepare project schedules in collaboration with the LWRRDC Program Manager for approval by the committee.

(xii) To respond to queries from clients regarding programs and projects and provide assistance where appropriate.

(xiii) To provide executive and secretarial support to the program management committee, including the preparation of agendas and writing and distribution of minutes of the committee meetings.

Technology transfer/communication

(xiv) To organise the implementation of the program communication plan.

(xv) To facilitate the adoption of R&D by rural industries, land and water managers, government agencies, community groups (for example, Landcare) and regulators.

(xvi) To liaise closely with researchers and managers, industry, government and community groups.

(xvii) To communicate the projects and outcomes of R&D to all the program stakeholders via the media, newsletters, papers and other channels as appropriate.

Provision of expert knowledge and skills

(xviii) To provide expert technical knowledge of the program area to the program management committee.

Description of project

The Program Coordinator adds value to the program by injecting another level of management into the program. This assists the smooth functioning and cohesiveness of the program, assists with priorities and integrates projects. In addition, there are many management functions that are performed and this input assists and lessens the workload of the Program Manager.

Potential outputs

As per objectives

Actual outputs

As per objectives

Potential outcomes and benefits

Improved focus, more efficient execution and increased impact of portfolio of projects funded.

Actual outcomes and benefits

Improved focus, more efficient execution and increased impact of portfolio of projects funded.

Project EMM1

Project title	Assisting the NEMP Management Committee identify the major research needs with Priority B – sources and transport of nutrients in catchments	
Principal investigator and agency	Emmett O'Loughlin	
Collaborators	Nil	
Funding	NEMP	$15,633
Start date	July 1996	
Finish date	August 1996	
Location	Across Australia	
Target audiences	NEMP Management Committee	

Objectives

(i) Report on the current understanding of catchment nutrient sources and transport, recommend research topics and clear up remaining questions.

(ii) Identify priorities and activities for research within Priority B – sources and transport of nutrients in catchments.

Description of project

This was a consultancy to assist the committee with priority projects for addressing the area of sources and transport of nutrients within catchments. At the time there was considerable confusion about the processes that produced and transported phosphorus from catchments to waterbodies in different parts of Australia.

Potential outputs

A report with recommendations identifying priority projects.

Actual outputs

A report with recommendations identifying priority projects.

Potential outcomes and benefits

- A key recommendation was that funding should be provided for both CSIRO and ANU projects on further isotopic studies as tracers of phosphorus in catchments, and that a geomorphologist be added to the research team.
- Improved portfolio of projects funded in the area of sources and transport of nutrients within catchments.

Actual outcomes and benefits

Although not all recommendations appear to have been followed, it is likely there was an improved portfolio of projects funded in the area of sources and transport of nutrients within catchments.

Project CEM4

Project title	Modelling and nutrient release from sediments in lowland rivers and storages	
Principal investigator and agency	Phillip Ford, CSIRO Land and Water, Canberra	
Collaborators	Water Studies Centre, Monash University; CSIRO Division of Coal and Energy Technology (CET); Murray-Darling Freshwater Research Centre (MDFRC)	
Funding	NEMP	$220,000
	CSIRO Land and Water	$326,000
	CET/MDFRC	$232,200
	Total	$778,200
Start date	1 September 1996	
Finish date	30 April 1998 (second stage to 2000 has been approved)	
Location	Data for model collected from Fitzroy and Goulburn catchments	
Target audiences	Water management agencies and environmental protection agencies at State and Federal level	

Objectives

(i) Develop a conceptual model of the key microbial and chemical processes involved in nutrient diagenesis in sediments, incorporating the availability (and quality of) organic carbon and of electron acceptor species (that is, O_2, NO_3, Fe(III), SO_4).

(ii) Couple the microbially mediated sediment diagenesis model with a realistic quantitative physical transport model and implement the numerical solution of the resulting coupled partial differential equations.

(iii) From a critical review of the literature, collect values for all parameters required to operate the model under conditions appropriate to Australian waters. Identify cases where adequate parameterisation for specific chemical or microbiological processes is not at hand.

(iv) Determine the missing parameters through judicious laboratory experiments.

(v) Using the model, calculate profiles (and flux rates) of nitrogen and phosphorus species under conditions representative of episodic oxygenation typical of seiching, wind set-up, operation of destratification systems, and intermittent flows.

(vi) Apply the model to calculate fluxes and nutrient concentrations in specific rivers in NEMP focus catchments.

(vii) Document model.

(viii) Disseminate results and transfer technology as appropriate to river managers and other key target audiences.

Description of project

This project will develop the predictive tools to identify the scope and effectiveness of measures for controlling sediment nutrient release based on varying the extent of oxygenation of the sediments. Similar methods will be applied to evaluate the consequences of other management strategies aimed at blue-green algal control such as discharge manipulation from weirs and natural processes such as seiching and wind set-up in reservoirs, which can lead to episodic oxygenation.

Potential outputs

- Improved understanding of the forms and at what rates nutrients are released from sediments in different circumstances.
- Information on how the system can be manipulated to achieve lowered incidence and severity of blue-green algae (for example, pulsed flows).
- An efficient validated tool for predicting nutrient transformations and mass balances in rivers and reservoirs, under conditions of oxygen fluctuations.

Actual outputs

- Modelling work appears to be giving useful results.
- It is possibly time without oxygen rather than the absence of oxygen that controls phosphorus release.
- The nutrient dynamics work needs to be integrated with the results of other studies, notably CEM7, which demonstrates the importance of light controls and the difficulties of reducing nutrients to limiting concentrations.
- Increased understanding of the importance of nutrient releases in the general armory of management tools for algal control.
- At the beginning of the project sediment modelling was seen as a rather esoteric area. Now other institutions are developing skills in this area and applying the general methodology as a way of understanding observations and integrating specific results into more generic frameworks.

Potential outcomes and benefits

Potential use of water depth manipulation (refill and drawdowns) in intermittent weir systems to destratify, and other interventions such as oxygenation or clay application leading to:

- Improved management of rivers and reservoirs leading to reduced incidence and severity of algal blooms.
- Reduction in water use through better understanding of nutrient consequences of pulsed flows.
- Avoidance of unnecessary restricted control on agricultural nitrogen inputs as scope for denitrification defined.

Actual outcomes and benefits

- The potential outcomes listed above may occur in the medium to longer term.
- Serious application of the outputs of the project will not be made in a totally autonomous sense, but more through the integration of these results with quantitative predictions about the behaviour of other elements of the river/weir pool system. Managers will then be able to investigate reasonably confidently the consequences of different flow strategies.
- Regarding the nitrogen issue, while the project has detailed the scale of denitrification, processes which impinge on other types of nitrogen in the water column and their dynamics fell outside the scope of this project and will be important also in assessing this potential benefit.

- A recent approach from a catchment management group suggests that there is a desire to explore the applicability of the work.

Project CWS7

Project title	Retrospective study of nutrient variations in some riverine systems	
Principal investigator and agency	Andrew Herczeg, CSIRO Land and Water, Adelaide	
Collaborators	Nil	
Funding	NEMP	$136,087
	CSIRO	$ 63,590
	Total	$199,677
Start date	September 1996	
Finish date	June 1998	
Location	Lake Alexandrina, Namoi River, Burrinjuck Reservoir, Goulburn-Broken River, Fitzroy River and Wilson Inlet	
Target audiences	Land users and managers, Landcare and community groups, water managers	

Objectives

(i) Review literature on the use of stable carbon and nitrogen isotopes in freshwater and estuarine sediments, and assess its applicability to interpretation of data from the Murray-Darling Basin, Fitzroy catchment and southern Western Australia.

(ii) Analyse C and N isotopes and P/Fe ratios for sediment cores from Lake Alexandrina, Namoi River, Burrinjuck Reservoir, Goulburn-Broken River, Fitzroy River and Wilson Inlet.

(iii) Assess the significance of temporal changes in sources and relative fluxes of organic C, N, P inferred from sediment core data, to that of water column and trophic state over the past several hundred years.

Description of project

Chemical and isotopic compositions preserved in sediments deposited over the past several hundred years can provide valuable insights to the impact of European settlement on changes in sources of nutrients to aquatic systems and their relationship to river health. This information can be used to better target current day nutrient control measures. The project analysed data from existing and new sediment cores from a number of sites. How that information can be included in assessing strategies for reducing the prevalence of blue-green algal blooms has been evaluated.

Potential outputs

- Data for integrated nutrient preservation trends in riverine sediments over the past one to two centuries.
- Information on carbon and nutrient burial rates and their respective sources prior to changes in land use along the river systems.

Actual outputs

- Sediment records in four of the six catchments showed that significant changes in nitrogen sources or dynamics have occurred in the last few decades.
- Carbon sources have only changed in two of the catchments.
- Sedimentary organic material is dominated by aquatic plant material with relatively little terrestrial vegetation.
- No evidence of change in the relative amount of nitrogen fixing to non-nitrogen fixing aquatic metabolisms; blue-green algae do not dominate the total algal population at any of these sites.
- Possibility of increasing nitrogen limitation in some catchments, possibly due to increased phosphorus loadings or phosphorus availability over the past 30 years.
- Increased fluxes of inorganic nitrogen in Lake Alexandrina suggest irrigation drainage and dairying may be responsible.

Potential outcomes and benefits

- Any change in N/P/C ratios over time, along with phytoplankton dynamics, will have implications for management of nutrient delivery from various sources.

- The above may then be used in evaluation of strategies for management of algal blooms, presumably by focusing or not on nutrient supply to waterways.

Actual outcomes and benefits

- Nitrogen fixing organisms (cyanobacteria) have not increased in frequency over time, suggesting that the perception that they are increasing may not hold.
- The catchments exhibiting increasing levels of nitrogen limitation might be interpreted as an increase in phosphorus inputs.
- Nutrient dynamics have been altered, with increases in nitrogen and phosphorus inputs particularly over the past 30 years in several of the studied catchments from intensive industries and sewage outfalls.
- Land clearance throughout the past century may have resulted in some increases in phosphorus fluxes to several catchments, and consequent nitrogen limitation.

Project UNS24

Project title	The role of sulphur in nutrient release	
Principal investigator and agency	David Waite, University of New South Wales	
Collaborators	Nil	
Funding	NEMP	$8,000
Start date	October 1996	
Finish date	December 1996	
Location	All over Australia	
Target audiences	NEMP Management Committee	

Objectives

(i) Collate published and, as far as possible, unpublished information on the role of sulphur in determining nutrient release from freshwater sediments.

(ii) Interpret this information to advise on the extent to which sulphur is likely to be an important factor in nutrient release.

(iii) Identify critical knowledge in understanding the role that sulphur plays (including its sources) and recommend potential research topics.

Description of project

Information on the role of sulphur was collated from the literature, from overseas and Australian specialists, and from an information request to all United Nations' INFOTERRA subscribers.

Potential outputs

Clarification of the role of sulphur in nutrient release from sediments.

Actual outputs

The literature revealed that the mechanisms of sulphate impact on phosphorus release from sediments has now been relatively clearly demonstrated.

Potential outcomes and benefits

Identification of knowledge required in understanding the role of sulphur in nutrient release.

Actual outcomes and benefits

As there was sufficient knowledge already available to understand the mechanisms and involvement of sulphur, the consultancy made other recommendations that could be addressed within project CEM4.

Project CEM7

Project title	Modelling nutrient release from sediments in lowland rivers and storages
Principal investigator and agency	Myriam Bormans, CSIRO Land and Water, Canberra
Collaborators	Central Queensland University (CQU), Queensland Department of Natural Resources (QDNR) and Rockhampton City Council (RCC)
Funding	NEMP $199,936 CSIRO $146,755 QDNR, CQU and RCC $174,980 Total $521,671
Start Date	1 November 1996
Finish date	30 June 2000 (extended from 30 June 1999 due to climatic conditions)
Location	Fitzroy River barrage
Target audiences	QDNR and other water management agencies

Objectives

(i) Establish the role of flow stratification, turbidity and nutrient dynamics in the development and persistence of cynaobacterial blooms in the Fitzroy River barrage by a combination of field measurements and modelling.

(ii) Extend an existing predictive model of stratification and algal growth dynamics in rivers by incorporating nutrient dynamics, and adapt and verify the updated model for the barrage.

(iii) Use the model to investigate and select the most favourable strategies for cynanobacterial control in the barrage.

(iv) Assess the potential of a general applicability of the model to other temperate and tropical rivers affected by cyanobacterial problems throughout Australia.

Description of project

The project is aimed at establishing the relationship between flow, stratification, turbidity and nutrient dynamics in the development and persistence of cyanobacterial blooms. Also, the project is about extending mixing and algal growth models to include nutrient dynamics. In turn, the model will be used to investigate and identify optimum flow management strategies for controlling algal growth.

Potential outputs

- Improved understanding of the causes of cyanobacterial blooms in weir pools.
- Data on how stratification, algal growth and nutrient fluxes behave in the barrage.
- Management guidelines for the Fitzroy River barrage based on the physical manipulation of the stratified water column.
- Extension of such guidelines to other river systems through the use of predictive models.

Actual outputs

- Improved understanding of causes of cyanobacterial blooms in weir pools.
- Useful data sets for light, stratification, nutrients and algae in the barrage.
- Demonstration that nutrients are unlikely to be limiting in the barrage thus ruling out management strategies based on nutrient limitation.
- Modeling outputs for stratification.
- Improved understanding on how light, stratification, algal growth and nutrient fluxes behave in the barrage.

Potential outcomes and benefits

Management interventions via flow or light control to contribute to:

- Prevention of algal blooms or reduced severity of algal blooms.
- Reduced water treatments costs.
- Improved aquatic environment leading to tourism and recreational benefits and, potentially, stock health.

Actual outcomes and benefits

- Demonstration that algal control by nutrient limitation is not possible, thus saving time and resources.
- Specification of flow discharges and duration to achieve turbidity levels required for algal control by enhanced flows.
- Management of Fitzroy River Water has started exploring scope for algal amelioration based on turbidity enhancement. This initiative is based on direct communication between the principal investigator and management.
- 'Understanding'-type research rather than applied research.
- Potential benefits above (management intervention leading to reduced algal blooms) will not be attained from this project by itself.

Project GMW2

Project title	Eutrophication-related coordination in the Goulburn-Broken catchment	
Principal investigator and agency	Pat Feehan, Goulburn-Murray Water, Tatura, Victoria	
Collaborators	Nil	
Funding	NEMP	$20,000
Start date	December 1996	
Finish date	June 2000	
Location	Goulburn-Broken catchment	
Target audiences	Natural resource managers, natural resource users, researchers, environmental interest groups, decision-makers	

Objectives

To undertake coordination and communication activities associated with the NEMP program in the Goulburn-Broken catchment and waterbodies.

Description of project

This project is one of liaison with researchers,community groups and State and local government agencies. The project was intended to deal mainly with dissemination and uptake issues.

Potential outputs

- A communication plan for NEMP activities in the Goulburn-Broken catchment.
- Improved understanding of community and local authorities in understanding and appreciating research projects in the catchment.

Actual outputs

- A communication plan for NEMP activities in the catchment was developed. It needed more information about local communication activities. The outcomes for each activity needed to be described.
- The plan was to facilitate communication and coordination with those stakeholders concerned with managing harmful or undesirable blooms in freshwater and estuarine systems of the lower Murray-Darling Basin and southern Victoria, and to facilitate the operation of NEMP R&D projects in the Goulburn-Broken catchment

Potential outcomes and benefits

Likely quicker and greater extent of adoption of management options that might be derived from the NEMP investment in the catchment.

Actual outcomes and benefits

As for potential outcomes.

Project NDW15

Project title	Eutrophication-related coordination in the Namoi catchment	
Principal investigator and agency	Chris Glennon and Anna Porter, Department of Land and Water Conservation, Tamworth, New South Wales	
Collaborators	Nil	
Funding	NEMP	$20,000
Start date	December 1996	
Finish date	June 2000	
Location	Namoi catchment	
Target audiences	Natural resource managers, natural resource users, researchers, environmental interest groups, decision-makers; specifically, the Namoi Catchment Planning Taskforce was to act as reference group for the NEMP activities	

Objectives

To undertake coordination and communication activities associated with the NEMP program in the Namoi catchment and waterbodies.

Description of project

This project is one of liaison with researchers, community groups and State and local government agencies. The project was intended mainly to deal with facilitating research, and with dissemination and uptake issues.

Potential outputs

- A communication plan for NEMP activities in the Namoi catchment.
- Improved understanding of community and local authorities in understanding and appreciating research projects in the catchment.

Actual outputs

- A communication plan for NEMP activities in the catchment was developed.
- A workshop on eutrophication management research was held in October 1997. The proceedings were published containing key messages and research needs, and proved most useful. This output was good to see and bridged the gap to some extent between users' needs and the research.

Potential outcomes and benefits

Likely quicker and greater extent of adoption of management options that might be derived from the NEMP investment in the catchment.

Actual outcomes and benefits

As for potential outcomes

Project QNR5

Project title	Eutrophication-related coordination in the Fitzroy catchment	
Principal investigator and agency	Peter Thompson, QDNR, Brisbane	
	Collaborators	Nil
Funding	NEMP	$20,000
Start date	December 1996	
Finish date	June 2000	
Location	Fitzroy River catchment	
Target audience	State and national government river management agencies and bodies; researchers (environmental, resource management, biological); water industry administrators (urban and rural water managers, environmental management groups); natural resource user groups; community environmental groups and relevant community action groups (for example, Landcare, catchment groups, Conservation Council); the community in general (including secondary and tertiary students and rural and urban residents); and appropriate staff at QDNR	

Objectives

To undertake coordination and communication activities associated with the NEMP program in the Fitzroy catchment and waterbodies.

Description of project

This project coordinates the projects based on the Fitzroy catchment and assists with communications about the total and individual project outputs in this focus catchment.

Potential outputs

Preparation of a coordination and communication plan to facilitate the operation of NEMP R&D projects in the Fitzroy catchment and assist the dissemination of NEMP outcomes to the Fitzroy and similar catchments.

Actual outputs

- The communication plan was prepared and incorporated into the Program Communication Plan.
- Radio, print and television media coverage, at different levels, for several projects, as well as dissemination of results to user groups via fact sheets and workshops. The projects involved include CEM7, CLW2, QNR10 and CLW16.

Potential outcomes and benefits

Improved communication between principal investigators and end users and dissemination of results to end users and the media will lead to improved use of the knowledge developed through the program, due to increased awareness about the program and projects.

Actual outcomes and benefits

As for potential outcomes

Project WRC2

Project title	Eutrophication-related coordination in the Wilson Inlet catchement	
Principal investigator and agency	Malcolm Robb, Water and Rivers Commission, Western Australia	
Collaborators	Nil	
Funding	NEMP	$20,000
Start date	December 1996	
Finish date	June 2000	
Location	Wilson Inlet	
Target audiences	Researchers, catchment managers, land users and managers, water managers	
Objectives	To undertake coordination and communication activities associated with the NEMP program in the Wilson Inlet catchment and waterbodies	

Description of project

This project is one of liaison with researchers, community groups and State and local government agencies. The project was mainly to deal with dissemination and uptake issues.

Potential outputs

- A communication plan for NEMP activities in Wilson Inlet.
- Improved understanding of community and local authorities in understanding and appreciating the three research projects.

Actual outputs

- A communication plan for NEMP activities in Wilson Inlet was developed.
- A list of achievements shows that innovative approaches were applied to introduce community people to the researchers.

Potential outcomes and benefits

Likely quicker and greater extent of adoption of management options that might be derived from the NEMP investment in Wilson Inlet.

Actual outcomes and benefits

As for potential outcomes

Project CNR2

Project title	Effects of episodic events on aquatic ecology in tropical and subtropical areas: Project scoping consultancy
Principal investigator and agency	Graham Harris, CSIRO Land and Water, Canberra
Collaborators	Nil
Funding	NEMP $6,000
Start date	January 1997
Finish date	February 1997
Location	Subtropical and tropical Australia
Target audiences	NEMP Management Committee

Objectives

(i) Provide terms of reference for a study which would increase understanding of and ability to manage the effects of episodic events on aquatic ecology, particularly algal blooms (with special emphasis on water storages).

(ii) Specify the objectives, approaches and management opportunities arising from the project.

(iii) Suggest appropriate locations to conduct the study and identify links between this project and others occurring either in the Fitzroy catchment or elsewhere in Australia.

(iv) Suggest scientific groups with the capacity to carry out the project and management agencies that would be interested in supporting the work.

Description of project

This project was a short-term consultancy to prepare terms of reference for a study that would address the relationships of episodic events to algal blooms.

Potential outputs

- Specified hypothesis to be tested.
- Objectives of study prepared.
- Experimental design stated.
- Specification of study team and location.
- Management implications.

Actual outputs

As for potential outputs

Potential outcomes and benefits

A third study for the Fitzroy catchment aimed at episodic events and their effects on aquatic ecology.

Actual outcomes and benefits

It was considered that the project, as specified, could not work and instead another project was to be developed by Stuart Bunn. However this did not get off the ground either. Eventually the third project was developed as an extension of CEM7, and this project may consider episodic events to some degree.

Project AGS2

Project title	Nutrients in Wilson Inlet: Are sediments a major source of nutrients for biomass production?	
Principal investigator and agency	David Heggie and David Fredericks, Australian Geological Survey Organisation (AGSO), Canberra	
Collaborators	Western Australian Water and Rivers Commission (WRC)	
Funding	NEMP	$194,000
	AGSO	$212,000
	WRC	$162,000
Start date	1 January 1997	
Finish date	31 December 1999	
Location	Wilson Inlet	
Target audiences	Wilson Inlet Management Authority	

Objectives

(i) (a) Estimate the inventories of dissolved nutrients (N, P and Si) in sediments of Wilson Inlet, and the microbial processes controlling their concentrations and distributions in these sediments;

(b) use the pattern of nutrient concentrations found in porewaters to interpret the biological processes occurring within the sediments.

(ii) Estimate flux of nutrients (N, P, and Si) from bottom sediments to overlying water in Wilson Inlet and assess the importance of this flux as a 'source' of nutrients for plant and algal growth.

(iii) Determine the microbial processes controlling the production and speciation of dissolved nutrients being transported across the sediment water interface. In particular, determine the relative importance of nitrification/denitrification in liberating nitrogen to the water column and estimate the effectiveness of bottom sediments in sequesting the phosphorus mobilised by microbial decomposition of organic matter.

(iv) Identify the most important sources of organic matter to bottom sediments in Wilson Inlet.

(v) Examine the transport of dissolved nutrients across the sediment water interface with particular reference to:

(a) the role of groundwater;

(b) bio-irrigation; and

(c) the intrusion of ocean waters.

Description of project

The project will ascertain if sediments act as a sink or a source for nutrients, and whether sediments are an important source relative to external sources (catchment sources). If sediments are a sink for nutrients, they may continue to act as a sink or conditions could change so that they may release nutrients, decreasing water quality. The project will measure the total amount of dissolved nutrients in sediments, measure release rates and determine what processes control the storage and release of nutrients so that the capacity for Wilson Inlet to accommodate continued nutrient loadings can be assessed.

Potential outputs

(i) Increased understanding of nutrient budgets and biogeochemical cycling of nutrients in a catchment or water body.

(ii) Determination of the major source of organic matter to bottom sediments.

(iii) Assessment of sediments as a source of nutrients.

(iv) Identification of microbial processes operating in bottom sediments.

(v) Better ability to predict system response to management actions by Authority.

(vi) Better understanding of links between land management practices and water quality in the inlet.

Actual outputs

- All outputs listed above will be achieved, except for output (vi) which will only be addressed indirectly.
- Nutrient budget to be developed soon.
- Confirmation that nitrogen is the most limiting nutrient.

Potential outcomes and benefits

- Guidelines for improved land management practices associated with nitrogen sources leading to reduced frequency and severity of algal blooms in the inlet.
- Improved decisions on management of the bar opening.

Actual outcomes and benefits

- Improved decisions on management of the bar opening.
- While an improved understanding of processes will result, no specific intervention guidelines regarding control of nutrients are likely to emerge from this project.

Project ANU9

Project title	Sources and delivery of suspended sediment and phosphorus for four Australian rivers: Part B, Nd and Sr isotopes and trace elements
Principal investigator and agency	Candace Martin, Australian National University (ANU), Canberra
Collaborators	CSIRO Land and Water
Funding	NEMP $116,666 ANU/CSIRO $163,940
Start date	1 January 1997
Finish date	31 December 1999 (extended to 30 June 2000)
Location	Namoi (Bundella Creek and Liverpool Plains) and Johnstone River (Berners Creek) catchments; algae also collected from Fitzroy in conjunction with CEM7 and from Goulburn-Broken in conjunction with Rod Oliver (MDR17)
Target audiences	Resource managers, landholders, Landcare and community groups

Objectives

(i) Identify the natural and anthropogenic (fertiliser) sources of suspended sediments and associated phosphorus using trace elements and naturally-occurring radiogenic isotope (143 Nd/144 Nd, 87 Sr/86 Sr) signatures.

(ii) Assess the relative and absolute magnitudes of the antrhropogenic (fertiliser) and natural fluxes of phosphorus. Relate the fluxes to land use and geologic and geomorphic variability in catchments, in conjunction with Part A (Project CWA21).

(iii) Investigate whether the radiogenic isotope compositions of algae directly monitor the source of bioavailable phosphorus, in conjunction with Rod Oliver.

(iv) Present this information in a form useful to Landcare and community groups and to State and Federal agencies together with Part A.

Description of project

This project will identify whether the dominant sources of bioavailable phosphorus thought to be associated with the increased frequency of algal blooms is derived from fertiliser or from natural sources of weathering and transport of rock, sediment and soil particles to rivers, perhaps associated with increasing erosion. This will be done by analysing intrinsic elemental and isotopic signatures which are useful for tracing topsoil versus subsoil and natural versus anthropogenic sources of suspended sediment and associated phosphorus in rivers. The tracing results will be liked to a geomorphic model which aims to describe the connection of sources to streams. This will be used to estimate the efficiency of sediment delivery from the land to streams at different positions in the stream network. Direct analyses of algae will also be made to assess if bioavailable phosphorus has a different source than total phosphorus.

Potential outputs

- Determination of sources of bioavailable and particulate phosphorus in sediments in waterways.
- Determination of sources of phosphorus utilised by algae (additional part of project).

Actual outputs

- The net sediment deposited in a Namoi reservoir was predominantly derived from the basalts in the catchments. The amount of phosphorus derived from fertilisers was very small (fertiliser was 0.3% of total).
- Similarly for the Johnstone catchment, fertiliser phosphorus appeared to be a minor contributor to phosphorus in stream sediments.
- Technique-wise, the Sr technique may now be used to determine the proportion of the dissolved phosphorus that is sourced from fertiliser.
- Fertiliser phosphorus appeared to be a major contributor to bioavailable phosphorus (dissolved phosphorus) in areas close to the fertiliser source.
- No sediments were derived from the pasture sources.
- Put more specific limitations on phosphorus in sediments from fertiliser sources (<10%) whereas before this study, fertiliser phosphorus was thought to vary from 10 to 30%.
- However, fertiliser phosphorus can contribute up to 80% of bioavailable phosphorus (dissolved phosphorus) in stream locations close to the fertiliser sources, at least in headwater streams.
- Algae do take up the radiogenic isotopes and therefore sources of phosphorus taken up can be determined (not yet analysed).

Potential outcomes and benefits

- Improved management of land use practices by land users and managers, particularly with respect to erosion control and fertiliser use.
- Potential implications for land use and land use practices such as fallowing, overgrazing, agroforestry, use of buffer strips, and so on.

Actual outcomes and benefits

Direct guidelines for management will not be produced as part of the project. However, understanding has been enhanced and more applied projects can be formed on a sounder base as a result.

Project UTA8

Project title	The phytoplankton ecology of Wilson Inlet	
Principal investigator and agency	Peter Thompson, University of Tasmania (UTA)	
Collaborators	WRC	
Funding	NEMP	$ 96,250
	UTA	$ 72,540
	WRC	$213,000
Start date	January 1997	
Finish date	December 1999	
Location	Wilson Inlet	
Target audiences	Resource managers and researchers across Australia	

Objectives

(i) To review and assess the available data base on the physical, chemical (including nitrogen and phosphorus) and biological characteristics of Wilson Inlet.

(ii) To collect additional data on important phytoplankton processes in Wilson Inlet (primary production, nutrient uptake, potential nitrogen and phosphorus limitation of phytoplankton).

(iii) To analyse the phytoplankton dynamics in Wilson Inlet and identify the major processes controlling phytoplankton blooms in this ecosystem.

(iv) To review the suitability of various management options for controlling algal blooms in Wilson Inlet.

Description of project

This project was built in collaboration with the other two projects in Wilson Inlet. Process data was required to understand how the algal blooms might relate to the Inlet's changing physical and chemical environment. Field work is designed to provide both a seasonal characterisation of the phytoplankton dynamics and also to determine the phytoplankton responses to the bar opening.

Potential outputs

- A data base of parameters for Wilson Inlet including spatial and temporal dynamics of temperature, nutrients and irradiance.

- Measurement of ongoing processes such as primary production and nutrient uptake.
- Overall improved understanding will enhance ability to manage the inlet.

Actual outputs

- Improved understanding is being achieved.
- An algal bloom appeared in 1997 which appeared to be nitrogen limited.
- Nutrients released from the sediments some weeks after the bar opening are making it possible for algae to bloom.
- Nitrogen management may be more important then previously thought.

Potential outcomes and benefits

- Management focus will be on intermittent disturbances, such as large-scale mixing, which should be able to be implemented better (for example, timing) if the understanding is enhanced.
- This may mean changing the pattern of the bar opening.

Actual outcomes and benefits

Too early to assess but this project is unlikely to lead directly to specific management interventions.

Project ANU10

Project title	Communication plan for the sediment and nutrient tracing and modelling work in the Namoi Valley	
Principal investigator and agency	Meg Keen, National Centre for Development Studies, ANU, Canberra	
Collaborators	Dr Sue Stocklmayer, Centre for Public Awareness of Science, Australian National University, Canberra	
Funding	NEMP	$3,200
Start date	February 1997	
Finish date	April 1997	
Location	Namoi Valley	
Target audiences	Clients and stakeholders	

Objectives

Develop a communication plan for the sediment and nutrient tracing and modelling project in the Namoi Valley.

Description of project

This project set out to develop a communication plan for the sediment and nutrient tracing and modelling projects in the Namoi valley (MDBC R5061 project). This was to act as a blueprint for the communication plans of other NEMP projects. The communication plan received input from selected stakeholders and researchers.

Potential outputs

The communication plan contained:

- the expected outcomes of the research project;
- the stakeholders;
- communication channels and their effectiveness;
- the communication channel to be used for each outcome; and
- a rationale for the plan so that researchers could amend the plan as the project proceeded and so that other research leaders could develop their own plan.

Actual outputs

As per potential outputs.

Potential outcomes and benefits

Improved communication and transfer of information emanating from Namoi Valley projects.

Actual outcomes and benefits

- Recommendations (for example, tracking progress) are being implemented by another set of consultants.
- Communication is probably more regular and responsive as a result of the plan.

Project UWA17

Project title	Nutrient cycling by *Ruppia megacarpa* and epiphytes in Wilson Inlet	
Principal investigator and agency	Di Walker, University of Western Australia (UWA)	
Collaborators	WRC	
Funding	NEMP	$ 60,000
	UWA	$ 45,000
	WRC	$ 45,000
	Total	$150,000
Start date	February 1997	
Finish date	February 2000	
Location	Wilson Inlet	
Target audiences	WRC, Wilson Inlet Management Authority, Landcare groups	

Objectives

(i) To investigate the nutrient dynamics of the dominant macrophyte *Ruppia megacarpa* and its epiphytes in relation to the nutrient status of Wilson Inlet by utilising:

(a) growth-related requirements;

(b) standing stock (biomass) development and losses due to tissue removal (leaf shedding and erosion);

(c) leakage; and

(d) decomposition.

(ii) To use these nutrient data to determine whether nutrient limitation of primary production in *Ruppia megacarpa* or its epiphytes occurs, either on a seasonal or annual basis.

(iii) To determine the overall contribution of *Ruppia megacarpa* and its epiphytes to the nutrient budget of Wilson Inlet and to determine whether they form major sinks for nutrients, and hence to determine likely outcomes of any further decline in *Ruppia* populations.

Description of project

The project will result in increased understanding of *Ruppia megacarpa* in Wilson Inlet with specific relevance for its management, as it may represent a significant sink for nutrients and may be critical for long-term maintenance of a healthy ecosystem. The study will produce a system scale nutrient budget of *Ruppia megacarpa* which could be linked to other studies of water quality and sediments, to provide a more complete understanding of the fate of nutrients in this system.

Potential outputs

Increased understanding of nutrient cycling in estuaries dominated by aquatic angiosperms.

Actual outputs

Nutrient budgets are being developed.

Potential outcomes and benefits

- The enhanced understanding will lead to a more informed basis for development of effective management strategies and their implementation.
- Results will be used in the development of a comprehensive management plan for Wilson Inlet which may include manipulation of sea water exchange in addition to reductions in inputs.

Actual outcomes and benefits

Too early to assess although unlikely to have specific and direct management implications.

Project MDR17

Project title	Algal availability of phosphorus discharged from different catchment sources	
Principal investigator and agency	Rod Oliver, MDFRC, and Ian Webster, CSIRO Land and Water, Canberra	
Collaborators	CSIRO Land and Water; Department of Natural Resources and Environment, Victoria; Goulburn Valley Water; Goulburn-Murray Water	
Funding	NEMP	$339,000
	MDFRC	$242,019
	Others	$ 67,844
	Total	$648,863
Start date	March 1997	
Finish date	October 2000	
Location	Goulburn River	
Target audiences	Scientific community, water management agencies and catchment management groups	

Objectives

(i) Describe the chemical compartmentalisation and availability for algal growth of phosphorus contained within the discharge from a sewerage treatment plant, an irrigation return drain and an agricultural catchment within the Goulburn-Broken system.

(ii) Describe changes in the quantity of algal-available phosphorus associated with suspended sediments from the different sources under different conditions of supply (for example, different flow rates and in different seasons).

(iii) Measure longitudinal changes in the particulate and dissolved phosphorus concentrations immediately downstream of the three input sources.

(iv) Determine the algal availability of phosphorus in bottom sediments of the Goulburn River downstream of the three discharge points under naturally occurring toxic conditions.

(v) Develop and test a non-specific sediment transport model incorporating particle settling and resuspension, coupled to a phosphorus-speciation model describing transformations between dissolved, particulate and bottom sediment forms of phosphorus, to predict the downstream effects of discharges on streams.

Description of project

This project has the aim of:

- characterising three different sources of phosphorus to the Goulburn River and determining the bioavailability of phosphorus downstream from each source;
- discovering how the bioavailability alters after biogeochemical processing under conditions typical of those in bottom sediments; and
- determining the potential of phosphorus release from bottom sediments and how this might be modified by phosphorus inputs from different catchment sources.

This information will form the basis of a generic model describing phosphorus transport in river systems. An understanding of the movement of phosphorus into particular river reaches or its rate of transfer to downstream sites is necessary in assessing the impact of phosphorus loads on the system. The model should enable the identification of phosphorus accumulation sites (phosphorus loadings) that may be prone to algal blooms.

Potential outputs

- Information on the bioavailability of different sources of phosphorus.
- Information on the effect of biogeochemical processes on bioavailability.
- Information on the phosphorus release from bottom sediments and how it might be affected by phosphorus from different sources.
- A generic model to predict the location of phosphorus accumulation sites in rivers and their influence on algal blooms based on the forms of phosphorus contributed by different sources.

Actual outputs to date

- Forms of phosphorus in discharges from the three sources have been categorised and their bioavailability assessed. This information has been presented in a series of workshops and conferences organised through NEMP, the Australian National Committee on Irrigation and Drainage, Goulburn Murray Water and the CRC for Freshwater Ecology.
- A preliminary model has been developed to describe phosphorus speciation and transport. Validation is continuing using data from several research projects.

Potential outcomes and benefits

- Improved targeting of phosphorus sources for management purposes.
- Improved understanding of phosphorus transport and accumulation in rivers.
- Enhanced capacity to predict impact of phosphorus loads on rivers.
- Eventual reduction in the incidence and severity of algal blooms.

Actual outcomes and benefits to date

Measurements of bioavailable phosphorus loads from the different sources have confirmed the targeting of the nutrient management strategy for the Goulburn Valley.

Project UOC12

Project title	Physical and nutrient factors controlling algal succession and biomass in Burrinjuck Reservoir	
Principal investigator and agency	Ian Lawrence, CRC for Freshwater Ecology (CRCFE), University of Canberra, Canberra	
Collaborators	CSIRO Centre for Environmental Mechanics; CSIRO Institute for Natural Resources and Environment	
Funding	NEMP	$100,000
	CRCFE	$105,248
	Total	$205,248
Start date	3 March 1997	
Finish date	30 June 1999 (extended to 30 September)	
Location	Burrinjuck Reservoir near Yass, New South Wales	
Target audiences	Land use planners and managers, catchment management groups, environmental regulatory groups, wastewater management authorities	

Objectives

(i) Assess the relationship between reservoir inflow, nutrient loading, mixing and drawdown, sediment dessication, phosphorus and nitrogen in the water column and algal biomass, composition and succession, for Burrinjuck Reservoir for the period 1976 to 1996.

(ii) Determine if the primary factors controlling nutrient availability are:

- (a) nutrient loading from river and seepage inflows;
- (b) nutrient losses from discharge and sedimentation;
- (c) nutrient remobilisation from the sediment;
- (d) internal nutrient redistribution due to mixing and flows.

(iii) Determine if the primary factors controlling algal biomass are:

(a) retention time in the surface layer;

(b) levels of available nutrients;

(c) mixing conditions; and

(d) temperature and light.

(iv) Determine if the primary factors controlling algal composition are:

(a) nutrient composition (C/N/P/Si ratios);

(b) euphotic to mixed-depth ratios.

Description of project

This project was to consolidate 20 years of catchment and reservoir data into an accessible form for analysis. Discharges to the reservoir were to be estimated based on historical rainfall and a calibrated export predictive model. The reservoir's water quality and algal responses to events as well as sustained base flow conditions, and to a range of mixing regimes and drawdown conditions were to be analysed. A key aspect is the linking of a catchment nutrient model to a predictive model of reservoir water quality.

Potential outputs

- Improved understanding of water quality and algal response processes.
- Information and criteria for assessing catchment land use and management practices.
- Provision of improved information on the impact of catchment nutrient exports on reservoir water quality and algal biomass and composition.
- Address the role of nitrogen in impacting on water quality and algal processes.
- Guidance on the requirements for treatment of wastewater discharges.
- Assessment of initiative of removing nutrients from Canberra sewage effluent.
- Importance of organic carbon rather than phosphorus noted.
- Workshops held with water managers.

Actual outputs

All potential outputs achieved as planned.

Potential outcomes and benefits

- Improved land management practices through limiting organic carbon exports to waterways (for example, biological oxygen demand levels in wastewater, limiting specific types of agricultural carbon sources).
- Improved reservoir management practices (mixing, drawdown, sediment dessication).

Actual outcomes and benefits

It is likely that this project will not directly produce any specific management guidelines for reservoir or land managers. However, general guidelines and a greater understanding will be provided to managers so that future interventions based on improved knowledge can be developed.

Project WRC3

Project title	Compendium for Wilson Inlet	
Principal investigator and agency	Malcolm Robb, WRC	
Collaborators	Nil	
Funding	NEMP	$20,000
Start date	April 1997	
Finish date	December 1997 (draft submitted January 1999; revised version will be completed late 1999)	
Location	Wilson Inlet	
Target audiences	Wilson Inlet Management Authority and Wilson Inlet Catchment Committee	

Objectives

(i) Describe all existing routine data such as rainfall, stream flow summaries, soil type description, fertiliser application and so on which are relevant to understanding catchment and inlet eutrophication processes and which are collected on a routine basis.

(ii) Document all past and current research relevant to eutrophication being conducted in the catchment including information on project objectives, progress status and location of results or relevant information.

(iii) Condense the data and interpret in the context of eutrophication issues.

(iv) Compile the above data into a compendium designed for regular use by defined target audiences. Address where possible the catchment issues identified in the Narrikup workshop, identifying areas requiring further research, development or extension.

(v) Produce a summary report for general distribution in a format that can be readily updated.

(vi) Discuss these data in the context of basic catchment and eutrophication processes and relate to neighbouring catchments such as the Kalgan, other relevant catchments and work undertaken in the NEMP program.

Description of project

The project will produce a compendium that will be an assembly of all eutrophication or water-related information (published, unpublished and work in progress) in the Wilson Inlet catchment. Focus is on the catchment rather than the inlet.

Potential outputs

Compendium produced and widely distributed within the catchment and among key stakeholders including researchers.

Actual outputs

Compendium nearly completed.

Potential outcomes and benefits

- Concern was originally raised among community members that information and research accumulated for the inlet catchment was not readily available or too difficult to locate.
- The compendium will allow more informed debate concerning management and research priorities within the catchment.

Actual outcomes and benefits

As for potential outcomes.

Project CWA21

Project title	Sources and delivery of suspended sediment and phosphorus to Australian Rivers – Part A, radionuclides and geomorphology	
Principal investigator and agency	Peter Wallbrink and Cathy Wilson, CSIRO Land and Water, Canberra	
Collaborators	Department of Land and Water Conservation (DLWC), New South Wales	
Funding	NEMP	$233,334
	CSIRO	$244,524
	DLWC	$ 44,100
	Total	$521,958
Start date	1 April 1997	
Finish date	31 December 1999 (rescheduled to June 2000)	
Location	Namoi River Basin and Johnstone River (Berners Creek) catchments	

Objectives

(i) Quantify the relative contributions of topsoil and subsoil to the suspended sediment loads in generic landform/use catchments using atmospherically-derived radionuclides (137Ca, 210Pb, 7Be).

(ii) Link radionuclide results to trace element and 143Nd/144Nd, 87Sr/88Sr data collected and analysed by Dr Candace Martin defining natural anthropogenic sources of phosphorus.

(iii) Assess the relative and absolute magnitudes of the anthropogenic and natural fluxes of phosphorus within the generic catchments. Relate the fluxes to land use and geologic and geomorphic variability in catchments.

(iv) Generate a set of rules governing the behaviour of sources of phosphorus within a set of generic landuse/landscape-type catchments.

(v) Develop a landscape analysis technique that relates the dominant sources of sediment and phosphorus to geomorphic attributes in catchments.

(vi) Determine how geomorphic attributes affect the efficiency of delivery of sediment and phosphorus to streams.

(vii) Present this information in a form useful to regional Landcare and community groups and to State and Federal agencies.

Target audiences

Resource managers, landholders, Landcare and community groups.

Description of project

The research will investigate the relative sources of phosphorus delivery to rivers by linking topsoil/subsoil tracing with the phosphorus tracing exercise carried out in ANU9. The tracing results will be analysed in the context of catchment geomorphology, land use and fertiliser management to develop a model which aims to predict sources of sediment and phosphorus to streams from a suite of catchment landscape attributes. The project is closely linked to ANU9.

Potential outputs

- Determination of sources, and relative contributions from these, to particulate phosphorus in sediments in rivers.
- Techniques to estimate sediment and phosphorus delivery at the paddock scale through landscape analysis verified and calibrated using the tracer techniques.
- Method whereby catchment managers and the like will be able to estimate and plan for the impact of changes in land use on phosphorus exports at farm scale.

Actual outputs

- Surface erosion, and thus phosphorus delivery, is the dominant source in the Johnstone River site (where cultivation cropping occurs). Where present, channel erosion dominates on cultivated land in Liverpool Plains.
- Landscape analysis techniques for estimating phosphorus and sediment delivery are well underway.
- Transferable methods for predicting phosphorus and sediment at paddock scale are developed, however understanding requires high resolution topographic data. Knowledge base is restricted to soils developed on basaltic lithologies.

Potential outcomes and benefits

- Improved management of land use practices by land users and managers, particularly with respect to fertiliser application strategies, use of agroforestry, mix of farming practices and so on.
- Potential assistance to decisions on where to focus management interventions at the farm scale, such as limiting fertiliser phosphorus export, gully erosion, changes to fallowing systems, overgrazing and so on.

Actual outcomes and benefits

- Will produce a method to address the potential outcomes above.
- Full implementation of the method at catchment manager level will need to be supported in a separate project.
- Some management interventions may emanate from this project. Interventions that do emerge will be enhanced by additional work in new lithologies and implementation described above.

Project QNR10

Project title	Fitzroy catchment eutrophication compendium	
Principal investigator and agency	Peter Thompson, QDNR, Brisbane	
Collaborators	CQU	
Funding	NEMP	$20,000
Start date	1 May 1997	
Finish date	31 December 1997 (changed to June 1998, then August 1998)	
Location	Fitzroy River basin	
Target audiences	Community, land and water managers, researchers	

Objectives

(i) Describe data collections broadly relevant to eutrophication in the Fitzroy and its catchment. This would include a wide range of water quality and flow data on catchment condition (such as soils, vegetation, geomorphology, land use). It should include frequency, duration and accessibility of the data.

(ii) Describe research projects either completed or underway in the catchment and its waterbodies. Project objectives, contact points, progress and publications should be included.

(iii) Produce the compendium.

Description of project

The project will produce a compendium that will assemble all eutrophication or water-related information (published, unpublished and work in progress) in the Fitzroy catchment.

Potential outputs

Compendium produced and widely distributed within the catchment and among key stakeholders.

Actual outputs

Compendium produced and widely distributed within the catchment and among key stakeholders.

Potential outcomes and benefits

Researchers and local community.

Actual outcomes and benefits

- Has had more application outside of the NEMP program than inside it; requests are still being received from other agencies, tertiary institutions, colleges and local governments.
- QDNR will use it as a base for describing to the Minister what R&D has been associated with the Fitzroy in preparation for a new project.

Project CSU19

Project title	Limiting nutrients workshop	
Principal investigator and agency	Alistar Robertson, Charles Sturt University, Wagga Wagga, New South Wales	
Collaborators	Nil	
Funding	NEMP	$10,000
Start date	November 1997	
Finish date	December 1997 (finalised report delayed until 1999)	
Location	Australia-wide	
Target audiences	Eutrophication researchers and water managers	

Objectives

(i) To organise the limiting nutrients workshop at Charles Sturt University.

(ii) To handle travel, venue, accommodation and food arrangements for the workshop.

(iii) To produce a report on limiting nutrients agreed to by all participants and suitable for publication as a LWRRDC Occasional Paper.

Description of project

The workshop was held to review the current state of knowledge regarding the relative importance of different nutrients and variations in the light environment in controlling phytoplankton population dynamics in freshwaters. The workshop was held in the context that there had been increasing evidence that nitrogen could, in some circumstances, be as important a limiting factor as phosphorus.

Potential outputs

Review of current knowledge written in plain English for managers.

Actual outputs

- Review of current knowledge written in plain English for managers.
- Final report appears to lack specific information for managers.

Potential outcomes and benefits

More informed water managers regarding research findings to date.

Actual outcomes and benefits

As for potential outcomes.

Project MDR18

Project title	Validation of the NIFT assay for identifying nitrogen and phosphorus limitations of phytoplankton growth	
Principal investigator and agency	Rod Oliver, MDFRC, Albury, New South Wales	
Collaborators	Nil	
Funding	NEMP	$27,274
	MDFRC	$ 8,908
Start date	January 1998	
Finish date	January 1999	
Location	Albury, New South Wales	
Target audiences	State and Federal agencies, research groups and catchment management groups	

Objectives

Establish the validity of the NIFT assay for identifying nitrogen and phosphorus limitations in phytoplankton. Specifically:

(i) Confirm for a green alga, a diatom and a cyanobacterium (as representative of the main phytoplankton groups) that the NIFT assay for nitrogen and phosphorus limitation is reliable when the organisms are grown under nitrogen-limited conditions using both nitrate and ammonium as their sole inorganic nitrogen sources.

(ii) Using these three phytoplankton types, demonstrate that prolonged dark incubation does not influence the outcome of the NIFT assay.

(iii) Measure the NIFT responses of a nitrogen fixing cyanobacterium grown without a source of combined inorganic nitrogen.

(iv) Test the suitability of commonly used fluorometers for the NIFT assay obtaining instruments on loan from agencies and manufacturers.

Description of project

Determining which nutrient is limiting in algal bloom growth can assist in focusing on decreasing the load of this nutrient. The NIFT assay had the potential to provide a simple monitoring tool for directly demonstrating nutrient limitation in natural phytoplankton populations. The NIFT assay needed validation regarding its consistency of response patterns before it could be used in a widespread fashion.

Potential outputs

Validation of the NIFT assay test so it could be widely used.

Actual outputs

- The test has now been firmly established but will need testing under real-life conditions and accepted by scientific peers.
- A workshop on nutrient limitation of microalgae in freshwater sponsored by NEMP included the NIFT method as one of three methods to be assessed as to their relevance to the water industry.

Potential outcomes and benefits

- Once validated the test could be used to identify and monitor nutrient limitations in phytoplankton populations, so enabling water mangers to have greater understanding of the role of nutrients in controlling algal blooms.
- An improved ability to assess the effectiveness of controlling nutrient loads to aquatic systems.

Actual outcomes and benefits

- The test has been validated but it is not clear whether any consultants or water authorities have started using the test and, if so, whether they have derived any benefits from its use. However, application of the method in research projects has already influenced concepts of nutrient limitation and algal blooms in Australian inland waters.
- If the reliability of the method can be confirmed in scientific research projects then it may be

incorporated in monitoring programs to assist identification of nutrient influences on algal growth.

- The NIFT assay has provided direct evidence that nitrogen limitation of algal growth occurs commonly in waters of the Murray-Darling Basin. This has significant implications for the species composition of algal blooms and for nutrient management strategies.
- Demonstration of nitrogen limitation using the NIFT assay has increased the research community interest in this nutrient and assisted in stimulating research on nitrogen dynamics by influencing funding agencies.
- Several research groups have shown an interest in using this physiological indicator of nutrient limitation to address specific questions of nutrient transport and supply. As a research tool it is likely to further improve conceptual understanding of nutrient dynamics.

Project DAV20

Project title	Identifying sources of phosphorus in agriculture run-off (Phase 1)	
Principal investigator and agency	David Nash, Department of Natural Resources and Environment (DNRE), Gippsland, Victoria	
Collaborators	Nil	
Funding	NEMP	$15,000
	DNRE	$65,000
	Total	$80,000
Start date	January 1998	
Finish date	February 1999	
Location	Initially Gippsland, Victoria, however as project progressed it became more generic, hence the location became broader	
Target audiences	Land managers and users, downstream water users and waterway managers	

Objectives

(i) Identify biological markers (bio-markers) specific to organic materials, especially soil organic matter, decomposing grass and dung, present in a grazed pasture system.

(ii) Identify which, if any, bio-markers are potentially related to phosphorus losses in agriculture run-off.

Description of project

This project attempts to use chemically unique organic compounds to characterise or fingerprint the sources of phosphorus found in agricultural run-off and stream systems. The identification of bio-markers would have enabled the development and testing of best management practices without the need for expensive and time-consuming field trials. This will enhance the development of best management practices and reduce the off-site impact of grazing systems. Phase 1 focused on the identification of bio-markers, including a literature review, screening tests and speciation of phosphorus forms in run-off. Additionally, the technique will allow phosphorus materials to be compared to other land uses.

Potential outputs

Successful identification of markers that characterise sources of phosphorus.

Actual outputs

- Literature review being published in *Water Research.*
- Characterisation of forms of phosphorus in the run-off and drainage waters.
- A marker was identified as being closely correlated with orthophosphates.

Potential outcomes and benefits

- Improved development of best management practices associated with grazing systems.
- Improved catchment management.

Actual outcomes and benefits

- The second phase did not proceed. It was associated with quantification of the relationship and validation of the technique.

- However, there was a high level of bioavailable phosphorus coming off grazing land and this was measured using the ion chromatography and flow injection detection methods, which were considered novel.

Project INT2

Project title	NEMP Communications Coordinator	
Principal investigator and agency	Vic McWaters, Integra, Ivanhoe, Victoria	
Collaborators	Nil	
Funding	NEMP	$69,000
Start date	July 1997	
Finish date	June 2000	
Location	Across all NEMP projects	
Target audiences	Communities, resource managers and the general public	

Objectives

(i) Develop and maintain a program communication plan

(ii) Assist with preparation of focus catchment and project communication plans

(iii) Undertake program communication activities including:

  (a) liaison with catchment coordinators;

  (b) targeted activities to transfer research results to stakeholders;

  (c) workshops and meetings;

  (d) written and visual material about NEMP;

  (e) general publicity material, including briefing, press releases, world wide web pages and displays.

Description of project

This project concerns overall communication of the program, including focus catchment communication as well as individual project communication. Various plans and activities are being prepared to ensure that results of the program are available and extended to those who may use them.

Potential outputs

- Program communication plan;
- Focus catchment plans;
- Project plans;
- Organising workshops;
- Articles and brochures;
- Web site development;
- Annual meeting for NEMP in December 1998, Western Australia.

Actual outputs

- Program communication plan;
- Some workshops in 1999;
- Articles and brochures produced;
- Web site has been developed and is operational;
- Facilitated meeting in December 1998 (NEMP annual meeting) and focused on implications and applications.

Potential outcomes and benefits

Improved communication and information transfer to users and resource managers so that information is sought out more than before and improved management of nutrient and sediments to waterways and by water managers can reduce the frequency and severity of algal blooms.

Actual outcomes and benefits

As for potential outcomes.

Project CLW2

Project title	Whole-lake biomanipulation for the reduction of nuisance microalgae	
Principal investigator and agency	Dr Vlad Matveev, CSIRO Land and Water, Brisbane	
Collaborators	QDNR	
Funding	LWRRDC	$150,433
	CSIRO	$502,604
	QDNR	$113,000
Start date	February 1998	
Finish date	July 2002	
Location	Lake Maroon and Lake Moogerah, south-east Queensland	
Target audience	Water management agencies and water storage operators	

Objectives

(i) To conduct a long-term whole-lake biomanipulation experiment by changing fish community in a small water storage.

(ii) To perform pre- and post-manipulation analyses of relevant plankton-associated food webs, taking into account seasonal and inter-annual variability.

(iii) To investigate the mechanism of the effect of planktivorous fish on plankton community structure.

(iv) To assess the effect of the manipulation on algal biomass.

Description of project

The effects of the introduction of native piscivorous fish (Australian Bass) on lake and reservoir biomass at one lake site, plus a reference lake, will be assessed. These effects may include the reduction of the population of planktivorous fish which in turn can cause a reduction in total algal biomass. The induced changes in zooplankton community structures will enhance overall grazing on phytoplankton and reduce algal and cyanobacterial biomass.

The project was not based in the Fitzroy catchment due to limited funding and the transport and travel implications of regular monitoring. One reservoir in the Fitzroy was ideal but was sprayed for insect pests which would have been adverse for Daphnia.

Potential outputs

Improved understanding of the functioning of aquatic ecosystems, in particular those of water supply storages and other lentic waters including:

- description of trophic structure of experimental and reference lakes;
- description of model of planktivore-phytoplankton interactions;
- description of estimates of predation rates and selectivities;
- description of pre-manipulation food web structure of experimental and reference lakes;
- description of changes in experimental lake and comparison with reference lake;
- model of the major interactions before and after manipulation;
- reduced levels of gudgeons due to introduction of Australian bass into the lake leading to reduced blue-green algae outbreaks.

Actual outputs

- The first two outputs above have been realised.
- The rest of the potential outputs are also on target to being realised.
- A key output will be the control of gudgeons and impacts on blue-green algae.

Potential outcomes

- Improved management of water resources by means of biological control.
- Reduced frequency and severity of algal blooms in south-east Queensland lakes.
- New protocols for water resource use and consultancy services on how to perform food web analysis and apply biomanipulation.

Actual outcomes

As the results of the project are becoming available, they are being effectively communicated to interested parties, including interstate and international researchers. Therefore, while it is too early for the outcomes to be realised, they are on target to being achieved.

Project WQT1

Project title	Toxic algae workshop	
Principal investigator and agency	Don Bursill, CRC for Water Quality and Treatment	
Collaborators	Water Services Association of Australia (WSAA)	
Funding	NEMP	$7,500
	WSAA	$7,500
	Total	$15,000
Start date	April 1998	
Finish date	April 1998	
Location	Adelaide	
Target audiences	Water storage and treatment managers, natural resource and environmental managers, primary producers and State agencies	

Objectives

(i) To review the status of current knowledge on toxic algae in relation to the implications for water resources, water supply and public health.

(ii) To review the status of current research programs on toxic algae.

(iii) To discuss the implications for food production where irrigation or process waters are subject to toxic contamination and identify sources of research funding.

(iv) To identify research priorities to assist with the resolution of key issues (for example, water supply quality and public health-related guidelines for toxins).

(v) To identify funding sources for research into agricultural and natural resources implications of toxic algae.

Description of project

The impact of algal toxins on public health via drinking and recreational exposure and their significance in contamination of food chains and agricultural products has been identified as a key emerging scientific issue for Australia, with implications for both water industry and agricultural commodity sectors. This was a workshop that covered a range of issues associated with algal toxic research in Australia. The workshop addressed directions for future research and identification of research funding issues.

Potential outputs

The proceedings of the workshop, scoping the various issues and identifying research priorities and funding sources for future research.

Actual outputs

- Proceedings of the workshop which scoped the various issues and identified research priorities and funding sources for future research.
- Confirmation that chlorine is effective in breaking down algal toxins was the highest priority. The question of by-products remains.
- Toxins need to be measured accurately and validation of measurement techniques is required.
- Other areas associated with water supply included animal studies, best practice in reservoir management, development of bio-markers and human studies.
- The use of irrigation water that is affected by toxic algae was a main concern, particularly regarding take-up by plants and animals.
- The impact of toxins on natural systems was among many questions raised with regard to natural resources and the environment.

Potential outcomes and benefits

Improved focus for future research on toxic algae.

Actual outcomes and benefits

Improved focus for future research on toxic algae.

Project CSF1

Project title	The interaction of physics, biology and nutrient regimes on the initiation and development of algal blooms	
Principal investigators and agencies	Susan Blackburn, CSIRO Marine Research, Hobart, and Peter Thompson, UTA, Launceston	
Collaborators	WRC	
Funding	NEMP	$268,743
	CSIRO	$298,047
	Total	$566,790
Start date	July 1996	
Finish date	June 1999	
Location	Wilson Inlet	
Target audiences	Users and managers of water, government departments and agencies	

Objectives

(i) Regulation of resting cyst germination:

(a) To determine the role of the key environmental factors, light, temperature, salinity, dissolved oxygen and nutrient concentration on resting cyst germination of the bloom-forming dinoflaggelate and cyanobacterial species *Gymnodium catenatum* (and *G. impudicum* if verified from Wilson Inlet), *Nodularia spumigena*, and *Anabaena circinalis*.

(b) To establish endogenous dormancy requirements of resting stages of bloom-forming dinoflaggelates and cyanobacterial species (as listed above).

(ii) Nutrient availability:

(a) To determine the role of the relative supply of nitrogen, phosphate and silicate (N : P : Si ratios) and rate of supply on phytoplankton species succession using *G. catenatum*, *Prorocentrum* spp, *Scrippsiella* sp., *N.Spumigena*, *A.circinalis* and *Skeletonema costatum*.

(iii) Interaction of water column stability or turbulence with nutrient gradients (species for this objective as listed in objective [ii]):

(a) To establish the relative importance of light attenuation and sedimentation on succession, particularly with respect to development of cyanobacterial blooms.

(b) To determine the role of water column stratification due to salinity and temperature on the competitive ability of bloom-forming dinoflaggelates and cyanobacteria relative to other phytoplankton groups, both with evenly distributed nutrients and vertical nutrient gradients.

(c) To determine the role of variation in the frequency and severity of physical disturbances (simulated turbulence, natural and man-made) on the viability and competitive ability of dinoflaggelates and cyanobacteria to initiate and develop blooms.

Description of project

This study targets bloom-forming dinoflaggelates and cyanobacterial species from Australian waters. The laboratory-based project investigates the importance of physics (in the form of stability and associated gradients in nutrients and physical parameters, and turbulence), nutrient ratios and the biology of resting states in the initiation and development of algal blooms.

Potential outputs

- Increased understanding of the underlying factors controlling algal blooms.
- Contribution to knowledge associated with management options available to regulatory authorities.
- Assessment of seed beds as initiators of dinoflaggelates and cyanobacterial blooms (compared with vegetative cells in the water column), and the types of physical and nutrient conditions favouring these blooms.

Actual outputs

Unsure

Potential outcomes and benefits

- Improved management of waterbodies aimed at decreasing severity and frequency of algal blooms.

Actual outcomes and benefits

- The project is mainly associated with knowledge generation and therefore unlikely to contribute much in the short term to management options and decisions.
- The proposal states that the work provides fundamental information on which modellers will build predictive management capability, which will require consultation with managers on management costs.

Project UMO36

Project title	Nutrient release from river sediments: Phase II validation and application of sediment-release model	
Principal investigator and agency	Barry Hart, Monash University, Melbourne; Phillip Ford, CSIRO Land and Water, Canberra	
Collaborators	MDFRC, University of Melbourne	
Funding	NEMP	$219,300
	Monash University	$ 54,000
	CSIRO	$131,800
	MDFRC	$ 11,800
	University of Melbourne	$ 6,800
	Total	$423,700
Start date	July 1998 (delayed to October 1998)	
Finish date	March 2000	
Location	Goulburn-Broken River system	
Target audiences	Natural resource managers, in particular water management agencies	

Objectives

(i) Undertake controlled laboratory experiments to measure key kinetic parameters required for the CANDI sediment diagenesis model (focus on temperature, organic carbon load and type, nitrogen and sulphate dynamics, phosphorus adsorption coefficients under anaerobic conditions, bioturbation).

(ii) Undertake an integrated, laboratory- and model-based investigation in the Goulburn-Broken River system (NEMP focus river basin) aimed at quantifying the major release processes operating in these rivers.

(iii) Apply the sediment model CANDI, together with general information on particular river and sediment conditions, to predict the effects on phosphorus and nitrogen release from a range of different management scenarios.

Description of project

This project is the second phase of a previous project (CEM4) aimed at determining whether the *in situ* release of nutrients stored in river sediments is important in lowland river systems such as the Goulburn-Broken and Murray-Darling, compared with external inputs of nutrients. The research will be driven by the end product, a computer model to assist river managers in devising management strategies to minimise opportunities for release, if sediment nutrient release proves to be important.

Potential outputs

- An improved model (original CANDI model developed in Phase 1) with regard to parameters and process understanding. (Note: The project has secured assistance from Dr Michael Harper in developing a simpler sediment model to complement CANDI.)
- Demonstration of the application of the model as a tool assisting river managers to adopt strategies for manipulating nutrient release in lowland rivers and storages, and for predicting the consequences for flow manipulation.

Actual outputs

The CANDI model, developed and implemented in Phase 1, has been extended to include the sorption of phosphorus to amorphous iron oxyhydroxides. This process is thought to be important in controlling the retention or release of phosphorus by sediments in Australian systems. The revised model has been successfully used to reproduce concentration depth profiles of nutrients measured in Lake Nagambie. The revised CANDI has proven a valuable research tool, assisting the project team with the identification of the important parameters and processes-controlling nutrient diagenesis and sediment-water exchange, and providing a framework for the interpretation of experimental studies.

However, the model's suitability as a research tool cannot translate into its routine use by managers to predict nutrient fluxes in river systems. This is largely due to its complexity and the requirement for *a priori* knowledge of a large number of parameters. In recent months the emphasis has switched to developing models of sediment-nutrient processes that incorporate only key processes, and therefore require much smaller parameter sets, but are nevertheless capable of reproducing observed behaviour. These simpler models will be parameterised and validated with data collected during the upcoming field trip, and their development should be complete by March 2000.

Potential outcomes and benefits

- Improved management of flows and nutrients in lowland river systems by predicting nitrogen and phosphorus releases from different interventions (for example, flow manipulation, intermittent oxygenation, changes in sediment loads, reduced phosphorus inputs, reduced nitrogen loads, reduced organic carbon inputs).
- May assist river management agencies to identify those areas and flow conditions where nutrient release from sediments is most likely to occur.

Actual outcomes and benefits

At a NEMP community seminar recently held in Melbourne (La Trobe Research and Technology Centre, 26 October 1999) members of the project team were challenged with a range of questions reflecting the concerns of water managers and community members about algal blooms. We found this workshop very useful in focusing what research is needed to meet community needs.

Additionally, the project team has sought feedback on the usefulness of the project outputs at each of the seminars and talks given over the past nine months.

Project RMM1

Project title	NEMP conceptual model web page	
Principal investigator and agency	Brenda Moon, Reef Multimedia, Victoria	
Collaborators	Nil	
Funding	NEMP	$10,000
Start date	August 1998	
Finish date	September 1998 (extended to February 1999)	
Location	Australia-wide	
Target audiences	Anybody interested in resource management and specifically those associated with the NEMP	

Objectives

(i) Develop a web page for NEMP which links information about research being undertaken across Australia according to the attached brief and in consultation with Richard Davis and Viv McWaters.

(ii) Provide advice on the maintenance and updating of this site.

Description of project

Development of a conceptual model web page for NEMP that concentrated on research being conducted across Australia and which forms a part of the NEMP communications program.

Potential outputs

- Web page as described above.
- Recommendations on maintaining and updating the site.

Actual outputs

- Web page.
- Web page is not up-to-date (November 1999).

Actual outcomes and benefits

Improved communication among researchers and between researchers and the wider community.

Potential outcomes and benefits

Likely to have resulted in improved communication but no information to support such a position.

Project ULN2

Project title	Extending the 'Rivers' Phytoplankton Monitoring' manual to Australian standing waters	
Principal investigator and agency	Roger Croome, La Trobe University, Wodonga, Victoria	
Collaborators	Nil	
Funding	NEMP	$30,276
	La Trobe	$ 6,380
	Total	$36,656
Start date	October 1998	
Finish date	June 1999	
Location	Australia-wide	
Target audiences	Algal workers and water quality/water resource managers	

Objectives

(i) Extend the 'Rivers' Phytoplankton Monitoring' manual to include protocols for monitoring phytoplankton in standing waters.

(ii) Incorporate responses from Australian water managers to the draft manual.

(iii) Bring the manual to production stage.

Description of project

This project concerned the development of a methods manual which assists State agencies and other algal workers in standardising the monitoring of phytoplankton, enlarging it from one concerned solely with rivers to one encompassing all surface waters. The manual covers sampling, fixation, preservation, identification and enumeration of phytoplankton, and recommends procedures for quality control, data storage and occupational health and safety.

Potential outputs

Extended manual published as envisaged.

Actual outputs

- The 58-page manual has been published as LWRRDC Occasional Paper 22/99.
- The manual has been made consistent with the National Protocol for the Monitoring of Cyanobacteria and their Toxins in Surface Waters.

Potential outcomes and benefits

- Reduced errors in phytoplankton monitoring data.
- Comparison of results from different studies more valid.

Actual outcomes and benefits

Likely to be as above but too early to assess.

Project ANU16

Project title	Modelling the effects of land use and climate on erosion, phosphorus and sediment movement in the Namoi River
Principal investigator and agency	Tony Jakeman, Integrated Catchment Assessment and Management Centre, ANU, Canberra
Collaborators	CSIRO Land and Water, Canberra; DLWC, New South Wales
Funding	NEMP $16,000 ANU $22,750 CSIRO $14,000 Total $52,750 The NEMP project (R5061) of which ANU16 is an extension was funded by MDBC from 1995–97 to an amount of approximately $750,000. CSIRO Land and Water contributed in the order of $1 million to R5061 while the ANU contributed an estimated $64,000. The DLWC contributed in-kind data collection and analysis.
Start date	1 December 1998
Finish date	30 June 1999
Location	Namoi River
Target audiences	Land management committees such as the Liverpool Plains Land Management Committee

Objectives

Extension of the NEMP project on sediment and nutrient tracing and modelling in the Namoi Valley.

(i) Complete an instream model of phosphorus and suspended sediment movement in the Namoi River.

(ii) Provide the model to the CWA20 project team and demonstrate its use in Integrated Catchment Management Software (ICMS).

Description of project

A modelling system comprising an upland catchment model and an instream model have been developed at a basin scale. Data on nutrient transport and erosion has been collected through a monitoring network. Water quality data is now available to allow the instream model to be calibrated for the Namoi. Modelling components will be linked to a computer program which will allow stakeholders to assess off-site water quality effects of different land uses.

Potential outputs

- Models of instream suspended sediment and phosphorus transport for major areas of the Namoi Basin including the Liverpool Plains.
- Quantification of the effects of land management on phosphorus and suspended sediment in streams and a greater understanding of the relationship between management and on-site and off-site effects.

Actual outputs

- Quantification of the effects of landscape attributes and management on rill and gully erosion.
- Models developed include STARS which is an instream model to characterise the nature of sediment suspension, re-suspension and delivery in Liverpool Plains catchments.
- Links with the ICMS team were established and outputs were delivered to the ICMS project (CWA20). Also, data sets developed in ANU16 are being made available in CWA20 and thereby delivered to the local Catchment Management Committee. Without these data sets and models, CWA20 would be lacking this 'proving ground'.

Potential outcomes and benefits

- Improved understanding on where to focus in the catchment to reduce sediment and phosphorus exports.
- Understanding of the effects of land management practices on gully and rill erosion.
- The models can be used to characterise spatially the separate and combined effects of climatic events and landscape on sediment and nutrient loads generated in both upland catchments, and by streambank erosion in lowland areas.

Actual outcomes and benefits

- The achievement of potential outcomes stated above will be judged partly through monitoring of CWA20.
- A computer package which assists the quantification of the sources and loads of suspended sediments and nutrients.

Project AQU3

Project title	Consultancy into the cost of algal blooms in selected water-user groups in Australia	
Principal investigator and agency	Peter Dempster, Atech Group, Sydney	
Collaborators	Nil	
Funding	NEMP	$25,000
Start date	June 1999	
Finish date	September 1999	
Location	Australia-wide	
Target audiences	Water users, researchers, water management agencies	

Objectives

To estimate the national cost of algal blooms and to identify the water use groups most influenced.

Description of project

Information regarding the impact of algal blooms upon various sectors of the community and industry is dispersed and embedded within a wide range of information sources. This project will develop estimates of the costs of algal blooms to Australia by assembling information for published sources and eliciting information from water management agencies and other groups.

Potential outputs

- Identification of cost categories.
- Identification of those incurring costs.
- Quantitative estimate of individual cost categories and a national estimate.

Actual outputs

Final report submitted to LWRRDC in November 1999 which achieved the above outputs.

Potential outcomes and benefits

- Greater awareness by researchers, water management agencies and the NEMP Management Committee of the magnitude of costs imposed by algal blooms.
- Potentially useful in cost-sharing solutions.

Actual outcomes and benefits

Likely to be as for potential outcomes.

Project CLW16

Project title	A quantitative basis for setting flows to control algal blooms in the Fitzroy Basin	
Principal investigator and agency	Myriam Bormans, CSIRO Land and Water, Canberra	
Collaborators	QDNR	
Funding	NEMP	$253,016
	CSIRO	$213,091
	QDNR	$ 80,000
	Total	$546,107
Start date	1 October 1999	
Finish date	31 December 2001	
Location	Selected tributaries of the Fitzroy catchment	
Target audiences	QDNR's modelling group (integrated quantity–quality model) supporting the Water Allocation and Management Planning for the Fitzroy River and local management agencies and catchment groups	

Objectives

(i) Extend the previous field and modelling work from the Fitzroy River barrage to quantify the relationships between flow and stratification, water temperature, dissolved oxygen, particle and nutrient dynamics and the onset of algal blooms in selected tributaries of the Fitzroy catchment.

(ii) Adapt and verify the model predicting transport of energy, dissolved and suspended material over large distances, including interconnected weir pools and unregulated river sections.

(iii) Use the model to establish flow scenarios for algal control and oxygenation of bottom waters in linked weir pools and river sections and generate operational rules for setting flow size and frequency.

(iv) Provide the parameterisation between flow and water quality parameters to support the application of the integrated quantity–quality model for setting environmental flows in the Fitzroy River catchment in the context of the Water Allocation and Management Planning.

Description of project

The project builds on the results of CEM7 and will make predictions of the effects of flow changes on key environmental parameters in a series of interconnected weir pools and river sections. These predictions will enable the assessment of opportunities for controlling algal blooms. Modelling outputs will be used in developing guidelines and strategies for manipulating flows to achieve desirable environmental outcomes.

This project builds on the findings of CEM7 where the key role of light availability in the onset of cyanobacterial blooms was demonstrated. Light availability is controlled by the dynamics of the fine particles left after the previous flood. It is argued that flow manipulations can be used when turbidity is declining to control the light climate, as well as the water stratification.

Potential outputs

- Understanding of the relationships between flow size and frequency and environmental parameters such as stratification, water temperature, dissolved oxygen, particle load and light climate, sediment and water column nutrient dynamics.
- Validation of an existing hydrodynamic model, previously untested for a series of interconnected weir pools, so that the model can be used to predict the effect of different flow release scenarios on water quality parameters.
- Development of guidelines for optimal water release and prediction of the size and timing of flows to minimise nuisance algal growth.

Actual outputs

Likely to be as for potential outputs.

Potential outcomes and benefits

Management interventions associated with flows and light interception that may result in:

- decreased frequency of outbreaks of blue-green algae and sediment loads leading to decreased water treatment costs;
- improved aquatic environment leading to tourism and recreational benefits, and potentially stock health;
- improved native fish habitats due to better timing and quantity of flows;
- potential for selling additional water for irrigation due to reduction in size of flows required to achieve environmental objectives such as oxygenation;
- potential for conjunctive use of water earmarked for environmental flows for irrigation purposes.

In addition, models are likely to be used by QNDR as one component of their Water Allocation and Management Planning for the Fitzroy. The Water Allocation and Management Planning aims to define the appropriate balance of water needed to maintain the health of the river system and water that can be stored or withdrawn for consumption. Flow strategies to control algal blooms are important as well as to provide recruitment and habitat for native fish. Water quality is included in the integrated quantity–quality model hydrologic model simulations of stream flow.

Actual outcomes and benefits

Likely to be as for potential outcomes.

Appendix 2: Total funding for individual projects

Code	Title	Total funding ($)
CNR1	The relationship between nutrient (phosphorus) loading and algal growth in aquatic ecosystems	18,500
UAD7	Movement of phosphorus through soils	160,870
UAD10	Measurement and treatment of phosphorus and carbon subsoil movement	362,890
CWA18	NEMP Program Coordinator	250,536
EMM1	Assisting the NEMP Management Committee identify the major research needs within Priority B – sources and transport of nutrients in catchments	15,633
CEM4	Modelling nutrient release from sediments in lowland rivers and storages	778,200
CWS7	Retrospective study of nutrient variations in some riverine systems	199,677
UNS24	The role of sulphur in nutrient release	8,000
CEM7	Management strategies for control of cyanobacterial blooms in the Fitzroy River barrage	521,671
GMW2	Eutrophication-related coordination in the Goulburn-Broken catchment	20,000
NDW15	Eutrophication-related coordination in the Namoi catchment	20,000
QNR5	Eutrophication-related coordination in the Fitzroy catchment	20,000
WRC2	Eutrophication-related coordination in the Wilson Inlet catchment	20,000
CNR2	Effects of episodic events on aquatic ecology in tropical and subtropical areas: Project scoping consultancy	6,000
AGS2	Nutrients in Wilson Inlet: Are sediments a major source of nutrients for biomass production?	568,000
ANU9	Sources and delivery of suspended sediment and phosphorus for four Australian Rivers: Part B, Nd and Sr isotopes and trace elements	280,606
UTA8	The phytoplankton ecology of Wilson Inlet	381,790
ANU10	Communication plan for the sediment and nutrient tracing and modelling work in the Namoi Valley	3,200
UWA17	Nutrient cycling by *Ruppia megacarpa* and epiphytes in Wilson Inlet	150,000
MDR17	Algal availability of phosphorus discharged from different catchment sources	648,863
UOC12	Physical and nutrient factors controlling algal succession and biomass in Burrinjuck Reservoir	205,248
WRC3	Compendium for Wilson Inlet	20,000
CWA21	Sources and delivery of suspended sediment and phosphorus to Australian Rivers: Part A, radionuclides and geomorphology	521,958

continued on page 82

Code	Title	Total funding ($)
QNR10	Fitzroy catchment eutrophication compendium	20,000
CSU19	Limiting nutrients workshop	10,000
MDR18	Validation of the NIFT assay for identifying nitrogen and phosphorus limitation of phytoplankton growth	36,182
DAV20	Identifying sources of phosphorus in agriculture run-off (Phase 1)	80,000
INT2	NEMP Communications Coordinator	69,000
CLW2	Whole-lake biomanipulation for the reduction of nuisance microalgae	766,037
WQT1	Toxic algae workshop	15,000
CSF1	The interaction of physics, biology and nutrient regimes on the initiation and development of algal blooms	566,790
UMO36	Nutrient release from river sediments: Phase II validation and application of sediment-release model	423,700
RMM1	NEMP conceptual model web page	10,000
ULN2	Extending the 'Rivers' Phytoplankton Monitoring' manual to Australian standing waters	36,656
ANU16	Modelling the effects of land use and climate on erosion, phosphorus and sediment movement in the Namoi River	40,000
AQU3	Consultancy into the cost of algal blooms to selected water user groups in Australia	25,000
AGT7	Review of the National Eutrophication Management Program	30,000
AQU5	Scoping study for a National River Contaminants Program	30,000
CLW16	A quantitative basis for setting flows to control algal blooms in the Fitzroy Basin	546,107

Note: Total funding includes funding from LWRRDC/MDBC, the research organisation and third parties.

Appendix 3: Detailed scientific comment on six NEMP projects

Project CEM7

Project title	Management strategies for the control of cyanobacterial blooms in the Fitzroy River barrage
Duration	November 1996 – June 1999 (now June 2000)
Funding	$552,000; NEMP contribution $200,000 (36%)
Principal investigator	Dr Myriam Bormans

Targeted at appropriate issues?

This is a sophisticated yet straightforward study of stratification, nutrient and algal dynamics within a system suffering persistent and predictable problems with cyanoprokaryotes, and subsequent modelling to assist in developing strategies for cyanoprokaryote control.

It is a highly relevant, good quality study being conducted with a multidisciplinary approach and in cooperation with management authorities, ensuring good technology transfer at the site of the particular problem. The previous experience and calibre of the researchers involved will ensure a successful outcome, hopefully one with application elsewhere.

Project design

Previous experience in similar waters has had a major influence on the basic limnological design, which addresses both the spatial and temporal variations inherent in such systems. Model construction also follows that developed elsewhere, ensuring a meaningful outcome for the water of concern. The overall project is well structured – allowing, for instance, minimal disruption (other than time) as a consequence of unseasonal conditions.

Methodology

The involvement of such experienced researchers will always ensure appropriate methodologies are pursued, and this appears to be essentially true for this project. The principal hyoptheses are clearly stated.

A specific enquiry relates to zooplankton. The field measurements are designed 'to fully characterise the physical, chemical and biological environments', and a very large amount of data is being collected to that end. Zooplankton are to be examined during bloom conditions, as algal (and cyanoprokaryote) grazers have been observed, and it is stated there is scope to incorporate zooplankton within the model if their importance during bloom conditions is demonstrated. But it is not clear that the impact of grazing on phytoplankton (and nutrient) dynamics prior to the establishment of blooms has been sufficiently considered.

Response

Any zooplankton observed in the alga samples are recorded. Net tows were done on several occasions. However, no extensive zooplankton monitoring was included due to lack of funding.

Are data and observations representative?

There is always a concern in such studies that the sampling may not be sufficiently representative of the water body as a whole, nor indicate the true association between organisms and their environment over the whole storage. This has been recognised by sampling of a given stretch of the weir pool over a diurnal cycle for both algae and nutrients, but later comment by the researchers on the level of sampling required to adequately characterise the Fitzroy River barrage would be valuable to workers at other sites, especially with regard to the biota.

Implications of results

The study will no doubt lead to limnological manipulation of the Fitzroy River barrage for the amelioration of cyanoprokaryotic blooms. The extent to which the work will have application elsewhere is still to be demonstrated, but the investigators claim the work can be readily adopted elsewhere, provided there are sufficient stratification data (Bormans personal communication to P. Chudleigh).

Adequate technology transfer?

Technology transfer from this project will undoubtedly be highly effective at a local level. The effective transfer of meaningful, acute information to other players within the water industry is less certain. Hands-on participation by selected members of this particular team would no doubt be preferable for application of the work elsewhere.

Summary

A highly relevant, well designed study with a multidisciplinary approach and effective technology transfer, currently delayed due to unseasonal conditions. Successful completion is anticipated with likely application of results elsewhere.

Project UOC12

Project title	Physical and nutrient factors controlling algal succession and biomass in Burrinjuck Reservoir
Duration	March 1997 – September 1999
Funding	$205,000; NEMP contribution $100,000 (49%)
Principal investigator	Ian Lawrence

Targeted at appropriate issues?

This is a study of the physico-chemical and biological factors affecting the biomass and composition of the algal populations of Burrinjuck Reservoir over the period 1976–1996, with a view to developing guidelines for reservoir management. It is acutely targeted at the three principal objectives of NEMP and utilises data from a known problem site subject to management control, at the same time benefiting from several experienced researchers being willing to participate in the project, albeit for a small fraction of their time. It was a very 'coercive' proposal, and continues to arouse interest with respect to what it might achieve.

Project design

The overall design of the project appears sound, with the consolidation of 20 years of data, to be followed by the development of water and nutrient budgets, assessment of algal responses to identified physico-chemical parameters, and the subsequent development of guidelines for reservoir management practices.

However, problems occurred early in the project:

- troubles arose with software and data storage/ manipulation;
- other activities took the time of the principal investigator; and
- meaningful communication activities had to await project outcomes.

Methodology

This is an all-encompassing project utilising an extensive data set and involving respected researchers across the areas of catchment inputs, hydrodynamics and algal ecology.

Currently, it is difficult to gauge the extent to which the project expectations will be met, particularly with respect to the key aspect of scientifically acute (rather than indicative) outcomes concerning changes in algal biomass, composition and succession in response to seasonal conditions and isolated events.

The outcome of the project relies largely on the quality and type of the algal data, and this has not been clearly demonstrated, except to say that the algal data were collected (never more often than fortnightly and at times monthly), and that with respect to quality assurance, 'data quality has already been assessed and validated under NATA registered procedures'. This is unlikely to be true of all the algal data but in any event, an unequivocal statement of the extent, quality and frequency of the algal data would have been appropriate, together with an appreciation of what limitations these might put on the project outcome. A statement of what algal data might have been collected had the project begun *de novo* would also be useful for reservoir managers. The investigators could also provide similar explanations with respect to zooplankton.

There is not a single reference to the scientific literature in the copy of the project proposal supplied, the funding body and referees being asked rather to trust the knowledge and experience of the project proponents. This they obviously agreed to do, but should a demonstration of literature awareness be a formal expectation in such project proposals?

Are data and observations representative?

The study utilises extant information and may suffer from having to use data collected for reasons other than those central to this project, particularly the biological data, a difficult area at the best of times. While this will always be the case in such retrospective studies, the participants could well have been asked to detail more fully in their original application the extent and quality of the data available, enlarging on their statement that it was sufficient to ensure attainment of the project objectives.

Implications of results

The data set itself is (now) a valuable one, and there is no doubt that completion of the project will provide information and tools for application in other waters or catchments. For the benefit of the water industry, a clear statement of the type and extent of data required for effective reservoir management would be helpful.

Adequate technology transfer?

In projects of this sort, it is often 'the doing' as much as the final result which brings benefit to the way in which we manage our waters; that is, the collaboration, knowledge sharing and change in appreciation which comes from interacting with stakeholders. Again, it is difficult to assess the extent to which this has occurred to date in this project, although it is noted that formal knowledge-sharing activities have been delayed pending a more complete understanding of the data.

The intended formal publication of results is noted. Given the calibre of the researchers assisting with the project, the publication of guidelines on reservoir management practices will be extremely valuable in itself.

Summary

A slightly troubled project, initially delayed due to data manipulation and staffing and time problems, now awaiting acute analysis of changes in algal biomass, composition and succession within Burrinjuck Reservoir in response to both seasonal conditions and single events, and then effective technology transfer of project results and their implications. A logically designed and valuable project involving experienced researchers interpreting historical data, hopefully of direct benefit elsewhere.

Project ANU16

Project title	Modelling the effects of land use and climate on erosion, phosphorus and sediment movement in the Namoi River
Duration	December 1998 – September 1999
Funding	\$40,000; NEMP contribution \$16,000 (40%)
Principal investigator	Professor Tony Jakeman

Targeted at appropriate issues?

This is a straightforward extension of a major (MDBC-funded) project on sediment/nutrient tracing/modelling in the Namoi Valley. Funded at \$16,000 only, it is a cost-effective project being undertaken at the Integrated Catchment Assessment and Management Centre, Australian National University, aimed at completion of instream modelling of phosphorus and suspended sediment, and the production of a readily usable personal computer modelling package for use within the Namoi Basin. Key stakeholders believe the previous research in the Namoi to have been of great value, and that this extension will allow 'the work to be delivered in a useful format to the on-ground managers in the catchment'.

Project design and methodology

The extension is logical and relatively straightforward in nature. Time commitment by the principal investigator is substantial. PhD candidate Li Zhang completed much of the prescribed work before departing for Canada, leaving the principal investigator to finish the final report during a three-month extension.

At face value the work appears technically well seated and follows other acute work accomplished by the principal investigator and his colleagues, making it a 'scientifically-safe' as well as cost-effective extension of the Namoi study.

Are data and observations representative?

The instream modelling component of the previously funded project was developed using water quality data for the Murray and Murrumbidgee Rivers. Part of the reason for granting an extension was that sufficient water quality data have now become available from the Namoi system.

Implication of results

The degree to which the work will be relevant elsewhere cannot be easily discerned from the project outline/ submission. When the opportunity is given to detail expected benefits, the proponents are quite certain about benefits with respect to the Namoi Basin, but are less definitive concerning the benefit of the work nationally. However, the proponents are confident that the flow model component of the work has national application, and the catchment component will be useful west of the Divide in New South Wales and Victoria, provided relevant data exist (Jakeman personal communication to P. Chudleigh). Incorporation of the work into the ICMS package (CWA20) will ensure widespread application of the methodologies.

Adequate technology transfer?

Continued stakeholder support suggests that consultation has been ongoing, that the project is of very real value within the Namoi system, and that adequate technology transfer will occur. This project extension itself is aimed in large part at effective technology transfer.

Summary

A good quality, cost-effective extension of an existing project, validating the models developed with recently acquired data from the catchment in question, and facilitating technology transfer via a readily usable personal computer modelling package. The flow model component of the work has application nationally, and the catchment component has application through substantial areas of the Murray-Darling basin.

Project UTA8

Project title	The phytoplankton ecology of Wilson Inlet
Duration	January 1997 – December 1999
Funding	$382,000; NEMP contribution $96,000 (25%)
Principal investigator	Dr Peter Thompson

Targeted at appropriate issues?

This is an innovative study of the phytoplankton ecology of Wilson Inlet in Western Australia, and is to include a review of management options for algal bloom amelioration within that system. It is being conducted in parallel with NEMP projects on the inlet by Heggie (AGS2 on sediments/nutrients) and Walker (UWA17 on macrophytes/nutrients), with sufficient coordination in field and experimental work to produce an overall nutrient budget (Robb, WRC). It is targeted at a problem area, with substantial involvement by local water and management authorities.

Project design

The overall project design was no doubt influenced by the principal investigator's experience in assessing nutrient/phytoplankton dynamics in the Swan estuary. It is logical and well structured, being constructed in part to suit the requirements of a doctoral study by candidate L. Twomey.

Methodology

The original statement of R&D methods indicated rather infrequent field trips to assess primary productivity and nitrogen uptake, and suggested parallel (infrequent) WRC sampling for phytoplankton and water quality characters. (A subsequent milestone report indicated historical weekly sampling of phytoplankton.) It is not clear from the material provided how this project was refereed, but it would be interesting to know what comments were made to the proponents concerning the frequency of sampling, which at face value appeared too low.

It is to be expected that methodology and techniques will change during a project undertaken while satisfying the needs of a doctoral study. In this case, the structuring of the work as a PhD project appears to have been an advantage, as any changes appear to have enhanced rather that detracted from the central theme of this study (for example, changes in the sampling frequency and assessment of both phytoplankton and nutrients, and the additional sampling of the microphytobenthos, which may be oxygenating the surface of the sediments and restricting the flux of phosphorus and ammonium).

Are data and observations representative?

The proponents have added significantly to their data collection as the study has progressed, ensuring a more representative assessment of their study site. The extent to which the observations made are representative of other like systems is yet to be demonstrated.

Implications of results

Phytoplankton biomass within Wilson Inlet has been found to vary substantially over the period 1995–97 and, in common with other such systems, to increase overall with increasing nitrogen loading. However (unlike the situation prevailing in the Swan estuary) experimental work in 1997–98 indicates that nitrogen levels are not markedly in excess of growth requirements at any time. The implications of these findings within future management options is yet to be explored, but may lead to a future focus on nitrogen management within this system.

Given the overview role and active participation of the WRC, it is expected that the results of this project will be successfully integrated with those of Heggie and Walker, and will be fully utilised in assessing and developing management options for the inlet, via the WRC and the Wilson Inlet Management Authority. The extent to which the work can be applied elsewhere is less certain, given the variability known to exist between individual estuaries. Nonetheless, successful intervention in Wilson Inlet would provide further evidence of our ability to manipulate such systems, and the general principles (if not specific findings) will be relevant elsewhere.

Adequate technology transfer?

Technology transfer at the local level is assured via the WRC, who will be responsible for 'communication of the work with the community through media releases, public meetings, active observation of the work underway and written materials'. The methods by which wider transfer will be accomplished (other than through the scientific literature) are not as well defined, with general rather than specific references being made to other stakeholders and problem areas.

Summary

A well constructed project aimed at assessing the phytoplankton component of Wilson Inlet, satisfying the needs of a doctoral thesis in addition to those specified by NEMP. It is proceeding as required, but being significantly enhanced as the work progresses. Results are highly relevant to a local management problem, but their application elsewhere is less certain.

Project MDR18

Project title	Validation of the NIFT assay for identifying nitrogen and phosphorus limitations of phytoplankton growth
Duration	January 1998 – September 1999
Funding	$36,000; NEMP contribution $27,000 (75%)
Principal investigator	Dr Rod Oliver

Targeted at appropriate issues?

This is an extremely acute, laboratory-based project which followed on from project MDR8 (which pre-dated NEMP) and concerns refinement and validation of a technique for determining whether either nitrogen or phosphorus is limiting the growth of a particular algal population. The NIFT technique takes advantage of the fact that chlorophyll fluorescence occurs within individual algal (and cyanoprokaryote) cells if they are supplied with an agent that is limiting their growth.

The identification of which nutrients may be limiting algal growth has application in applied surface water management, particularly given the current Australian focus on integrated catchment management, and nutrient minimisation within surface waters.

Project design

Logical and well pursued, leading to a satisfactory completion of the project.

Methodology

The extension of MDR18 to this project was invited by LWRRDC/NEMP and may not have undergone the usual perusal by referees. Were referees given the chance to point out potential problems with respect to the culturing of *Aulacoseira* for instance, no doubt a frustrating and time-consuming issue within the project may have been avoided via peer review. Also, did any industry referee have the chance to comment on the likelihood of the technique being taken up within monitoring/assessment programs (a major stumbling block as it turns out), and what approach might be taken to enhance this?

The technical aspects of the project were acutely executed, despite initial problems in establishing appropriate algal cultures, and later in maintaining culture room facilities. Standard culturing techniques were used, and replication was utilised to ensure the validity of results.

Implications of results

The protocol is a complex one for everyday use. Even during this validation study, the proponents found unexpected results with respect to the utilisation of nitrogen. It was expected that cells utilising nitrate-N would show a NIFT response if either nitrate-N or ammonium-N was added (as cells utilising nitrate-N convert it to ammonium-N before use), but that cells utilising ammonium-N would show a response to ammonium-N only. This was not the case – *Microcystis* growing on nitrate-N responded to ammonium-N but not to nitrate-N, and *Microcystis* growing on ammonium-N responded to both nitrate-N and ammonium-N! Nevertheless, the NIFT technique can be used to distinguish whether a particular suite of algae is being growth-limited by either nitrogen or phosphorus, and has already been important in reassessing our view of the role of nitrogen (as opposed to phosphorus) in limiting algal growth in our surface waters (Oliver, personal communication).

Will NIFT be taken up by the water industry, for example in routine monitoring or to identify the relationship between nutrient availability and algal growth prior to the occurrence of an annually predictable bloom in a particular water, or at the peak (or just after) of such a bloom? Time will tell, but its uptake will depend on:

- conceptions of its complexity and the need for careful interpretation on a site-by-site basis;
- the need to process samples immediately (that is, in less than two hours);
- the availability within this timeframe of a suitable (non-portable and relatively expensive) fluorimeter;
- the unwillingness of agencies to incorporate into their monitoring/assessment programs techniques which may be more expensive (time, materials, expertise) than their current practices, or techniques that have not been fully validated and accepted elsewhere (leading to legal problems if the data are contested, for instance).

Nevertheless, the technique is potentially a powerful one, with a good possibility of application, especially in discrete studies of known problem sites.

Adequate technology transfer?

An industry workshop held in August 1999 included a presentation on the NIFT assay, and identified many of the problems inherent in having it taken up as a routine assessment tool. One of these was concerned with technology transfer itself, in that water resource agencies are unlikely to utilise it fully until it is published and accepted, and has been demonstrated as an effective tool in algal population interpretation. This remains a challenge for the proponents over the next few years.

Summary

A scientifically acute, well constructed laboratory study with implications for the way in which we formulate and implement nutrient management strategies. Soundly conducted and very successful as a project, but it is suspected there is quite some distance to travel before there is ready acceptance and implementation of the technique for other than selected discrete investigations of individual problem waters.

Project MDR17

Project title	Algal availability of phosphorus discharged from different catchment sources
Duration	March 1997 – October 2000
Funding	$650,000; NEMP contribution $340,000 (52%)
Principal investigator	Dr Rod Oliver

Targeted at appropriate issues?

This is an intriguing study of the proportion/amount of phosphorus available for algal growth within water entering the Goulburn system from a sewage treatment plant (at Shepparton), a major irrigation return drain (Rodney Main Drain), and an agricultural catchment (via the Acheron River), and how that bioavailability changes within the receiving water immediately downstream of each input. Significantly, the original proposal has changed to now include the developing and testing of a sediment transport/phosphorus model (with Webster) which will predict the downstream effects of individual discharges.

In their project proposal, the proponents claimed that previous uncertainty in nutrient management has followed from lack of knowledge of phosphorus speciation, and suggested a 20-year saving of $18 million within the Goulburn catchment as a result of their work. No doubt they now see (with the inclusion of the sediment transport/nutrient model) significant additional benefit elsewhere.

Project design

The overall project design originally focused equally on three inputs (treated sewage, irrigation return, catchment). The need to accommodate the modelling component, and the resource constraints which followed, forced changes which threatened the outcome with respect to downstream work at two sites, directing the work more to the sewage treatment input (which could always be relied on to produce data suitable for model development, the results for the other two sites being less definitive [Oliver, personal communication]). The project was then redirected once more so that each site was treated equally. As a consequence, a component of the project concerning oxic/anoxic field observations and laboratory experiments (originally stated as satisfying an important knowledge gap) was deleted.

Project design has thus been modified and remodified over time, albeit in a scientifically responsible manner and in response to resource issues and the advice to include modelling. The overall design remains well structured and logical, and will no doubt ensure meaningful outcomes.

Methodology

Unexpectedly, little characterisation is given of the three study sites – likely variation in the Rodney Main Drain for instance, or the type and present/future operation and discharges of the Shepparton sewage treatment plant, but it is noted that they were ‘proposed sites only’ in the original application, and were only a few of the sites which had been discussed with catchment managers as being appropriate (Oliver, personal communication).

Several innovative and recent methodologies are employed within the project, including:

- iron-oxyhydroxide strips to desorb phosphorus within individual suspended particle samples;
- experimental development of phosphorus adsorption-desorption isotherms; and
- *in situ* ‘peepers’ to measure vertical profiles of interstitial phosphorus and oxygen in the bottom sediments.

Method development has also been important within the project, particularly in regard to sedimentation rates of different sized particles within the load carried by the river (Oliver, personal communication).

Both the project and the individual methodologies used within it are technically complex, but there is demonstration of clear understanding by the proponents in both the project proposal and milestone reports. There is additionally a scientific advisory committee to ensure logical progression, support and technical advice.

Are data and observations representative?

Three discrete sites have been chosen for study to exemplify inputs from sewage treatment, irrigation return and dryland agriculture. There is nothing to suggest they are not representative of the chosen activities, and their very magnitude (at least for the sewage treatment plant and the Rodney Main Drain) ensures their examination is appropriate to management within the Goulburn system. As with many sewage treatment plants, the one at Shepparton is moving towards off-river disposal, but the results from this particular discharge are important to the development of the sediment transport/nutrient model.

Implications of results

The proponents identify significant monetary benefits in terms of more effective targeting of nutrient management within the Goulburn system. Benefit outside the catchment would be most likely to result from the dryland agriculture and irrigation drain work, and development of the model (present policy and practice is to remove sewage inputs from surface waters in any event). On the one hand, the results of the dryland agriculture and irrigation inputs may not be sufficiently representative of those in other catchments to be of great benefit, given that considerable variation in nutrient type and availability would be expected between individual irrigation return drains in areas of different crops, soil types, fertiliser application and so on. (The proponents recognised this in part when they said in the original proposal that one of the factors which would demonstrate the success of this project would be 'the initiation of similar studies in other catchments'.) On the other hand, the addition of model development to the project has given it wider application within Australia.

Adequate technology transfer?

Goulburn-Murray Water has been a key supporter of this project, the Water Quality Coordinator – Goulburn-Broken (and the local NEMP coordinator) has a close association, and local catchment management groups are kept informed. Sufficient technology transfer within the local area is assured. Wider transfer at catchment management level is less certain.

Summary

A rather complex project which has been re-modelled as resource implications of desirable project additions have appeared. Scientifically acute, and supported by an advisory committee. The project will be of direct benefit to local catchment managers via clearer identification and fate of individual algal-available phosphorus sources within surface waters. Meaningful application of the research results to other catchments is less certain, but the project has been modified to include the development of a sediment transport/nutrient model which can be used to predict the downstream effects of discharges to any river or stream.