Evaluation of the

National River Health Program

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1. Executive Summary

The National River Health Program (NRHP) is a nationally coordinated and collaborative program between the Department of Environment, Sports & Territories (DEST) and the Land & Water Resources Research Corporation (LWRRDC). The NRHP has in progress a variety of research programs to improve the science involved in assessing river health and environmental flow requirements in Australia. This review provides an evaluation of the program covering its aims, scope, and effectiveness, and recommendations on post-program adoption strategies and on the role of DEST in the future of the program. The NRHP is an important national initiative. Through its provision of the technological tools and information for the effective allocation of water for the environment the NRHP plays a key role in the implementation of the recommendations of the COAG Water Industry Reforms. In addition, by providing the biological monitoring tools for the assessment of aquatic ecosystem health the NRHP has made substantial progress towards achieving the ANZECC recommendation of the use of biological indicators for the protection of aquatic ecosystems. To date the NRHP has been effective in ensuring a coordinated response by the states for the development of a national approach to monitoring river health. The NRHP has been effective in meeting its goals to date and it is recommended that NRHP receive further funding to ensure that the technologies developed are effectively adopted by the water industry. However, further attention needs to be paid to the following areas:

- Development of a strategic framework for environmental flows R & D
- Increased communication with all participants and with the water industry through such avenues as more detailed and frequent newsletters and focussed workshops.
- The development of formal ISO standards and implementation methods for quality control and quality assurance for biological water quality programs.
- Establishment 2 new R&D sub-programs to support the current environmental flows program.
    - (i) R&D on water delivery for environmental allocations
    - (ii) R&D on the social and economic aspects of environmental flows

1.1 Summary of Recommendations

1.1.1 Program definitions

- *In order to maintain a clear focus on its goals of improving the health of Australian riverine ecosystems, the NRHP should adopt the following definitions of ecosystem health:*
  - *For Australian ecosystems, riverine ecosystem health should be defined as the state of an ecosystem, ranging from pristine to highly degraded, and with the level of anthropogenic impact defined in terms of deviation from the pre-European state.*
  - *A healthy ecosystem is one that has excellent biological integrity as defined by Karr and Dudley (1981),* i.e. *the "ability of an aquatic ecosystem to support and maintain a balanced, adaptive community of organisms having a species composition, diversity, and functional organisation comparable to that of natural habitats within a region".*

- *The NRHP should adopt the following definition of its scope:*
  - *The scope of the NRHP is the development of tools, technologies, management methods, and criteria for the measurement of riverine ecosystem health and for achieving desired states of riverine ecosystem health.*

1.1.2 Environmental flows

- *Develop a framework for Environmental Flows R&D & Implementation.*

- *Undertake an assessment of the application and evaluation of existing methods of determination of environmental flows.*

- *Establish 2 new R&D sub-programs to support the current program.*

  (i) R &D on water delivery for environmental allocations

  (ii) R &D on the social and economic aspects of environmental flows

1.1.3 Program communication

- *With respect to the MRHI there needs to be increased communication between the researchers involved in the R & D Projects and the State and Territory Programs, such as through a more detailed and frequent newsletter than currently exists.*

- *With respect to the MRHI there needs to be increased communication between those involved in the State and Territory Programs. This would facilitate a national approach to the program. In addition, success of the program would be rapidly communicated, thereby promoting continued support from state agencies.*

- *Greater communication with the water industry needs to be developed, particularly given the larges changes in organisation structures and of personnel that it has recently experienced.*

- *There is some overlap between the NRHP with other programs (e.g. LWRRDC, National Riparian Program) which needs to be explored.*

- *If the MRHI program is to continue, there needs to be an ongoing commitment to technology transfer and education programs and these programs need to be tailored to the particular needs of each state*

- *There should be an on-going role for environmental flows information packages which are updated regularly and form part of a continuous education program for water managers and scientists.*

1.1.4 Program quality assurance and quality control

- *It is recommended that laboratories participating in the NRHP develop standard methods for the collection, enumeration, and identification of macroinvertebrates and that the NRHP assist in the development of National Standards.*

- *To facilitate the above recommendation, the NRHP Management Committee should fund a scoping study (from existing unallocated funds) on the development and implementation of formal ISO standard QA/QC programs for the MRHI.*

1.1.5 RIVPACS ownership and development

- *Until the States develop the appropriate expertise, the initial development and management of the RIVPACS model should be centralised at the CRC-FE at the University of Canberra or at either of AWT's Ensight or Water Ecoscience Divisions.*

1.1.6 Future funding

- *Funds for environmental flow monitoring systems should be made available to ensure authorities undertake rigorous programs and which share some common elements. This will enable an evaluation of many river systems which may result in information not available from single studies with limited focus.*

- *There needs to be a continued Federal commitment to fund the continuation of the NRHP to the turn of the century to ensure the widespread adoption of the NRHP technologies.*

1.1.7 Program administration

- *It is recommended that greater assistance be provided to Dr Davies in the form of an extra subprogram manager or managers. This will be essential if the program is extended.*

- *If the NRHP is to receive further funding, it should be continued to be managed through the program management committee involving LWRRDC.*

- *Dr Peter Davies recommendations for future directions of the NRHP provide a well-considered basis for the development of the second phase of the NRHP and with the exception of the funding of R & D into long term ecological processes, should be adopted by DEST*

- *The overall management of the NRHP appears to be effective and if further funding is provided to continue the program it may be most efficient to continue with the existing management arrangements through DEST*

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2. Introduction

2.1 Background

The Monitoring River Health Initiative resulted from a commitment by the then Prime Minister, Paul Keating, in his December 1992 Statement on the Environment. This program was subsequently incorporated into the National River Health Program (NRHP) which is a nationally coordinated and collaborative program between the Department of Environment, Sports & Territories (DEST) and the Land & Water Resources Research and Development Corporation (LWRRDC).

Monitoring and assessing river health has been recognised as an important factor in managing rivers across Australia. Several water and environment management agencies in Australia and elsewhere have implemented significant biological and water quality monitoring programs and the NRHP has supplemented these programs. In addition, the NRHP has begun a variety of research programs to improve the science involved in assessing river health and environmental flow requirements.

The NRHP is now in its second year of operation and DEST has contracted Water Ecoscience P/L to undertake an evaluation of the program. The evaluation, which is detailed in this document, consists of the following components:

- A review of the aims and objectives of the program
- An assessment of the scope, effectiveness and efficiency of the program components in the light of this review
- Recommendations on post-program adoption strategies and on the role of DEST in the future of the program

2.2 Objectives of the NRHP Evaluation

Principally, this report aims to provide an objective evaluation of the National River Health Program in relation to meeting its objectives which are as follows:

- to monitor and assess the health of Australian rivers;
- enhance the management of river flows, water allocation and water use to ensure the sustainability of river and floodplain ecosystems;
- encourage active management to improve the health of Australia's rivers, based on a sound understanding of key ecological and hydrological processes;
- evaluate the effectiveness of river management actions at a national scale.

The report also assesses the appropriateness of the Program in:

- developing scientific water quality programs;
- investigating environmental flow requirements of Australia's rivers.

A secondary objective of the report is to provide a preliminary assessment of the effectiveness and efficiency of the Program.

The explicit terms of reference for the consultancy are to:

- Review the extent to which the current goals and objectives of the NRHP have been progressed;
- Review the adequacy and relevance of the current aims and objectives of the NRHP with particular regard to the Council of Australian Governments Water Reforms, the draft National Water Quality Management Strategy and the Commonwealth State of the Environment Reporting;
- Review the current scope of the NRHP projects to ensure they adequately address environmental flows and bio-monitoring research and development needs of Australia's water managers;
- Review the State and Territory bio-monitoring program and the development of the RIVPACS model for Australian rivers;
- Provide advice on post-program strategies to ensure the adoption of tools, protocols, and methodologies developed by the NRHP.

2.3 Overview of NRHP

2.3.1 Program Structure

The NRHP is an integrated program that has developed as a joint exercise between representatives of the Department of Environment, Sport and Territories (EPA and Environment Strategies Directorate) and the Land and Water Resources Research and Development Corporation (LWRRDC). Dr Peter Davies has been appointed as National Co-ordinator to facilitate the program with executive support provided by LWRRDC. The program was developed into its present form after the Prime Minister's Statement on the Environment of 21 December 1992, where $70m of funds dedicated to improving the health of Australia's rivers were announced. One of the programs to be covered by these funds was the Monitoring River Health Initiative (MRHI) which was to have several components, including biological monitoring of rivers by States and Territories, the development of biological indicators of river health and investigations into the environmental flow requirements of rivers. To assist in the administration of the MRHI and to coordinate the research within an existing scientific research framework, DEST involved LWRRDC. Already in existence under LWRRDC were environmental flow projects and other initiatives relating to river health. By integrating the MRHI and LWRRDC

programs, the National River Health Program (NRHP) was established, with its administration and management through a Management Committee comprising representatives from DEST (EPA and Environment Strategies Directorate) and LWRRDC. Thus, within the NRHP there are projects that address general river health, those investigating the environmental flow requirements of rivers, and the MRHI (Fig. 2.1). The MRHI can be further divided into a number of sub-programs or components.

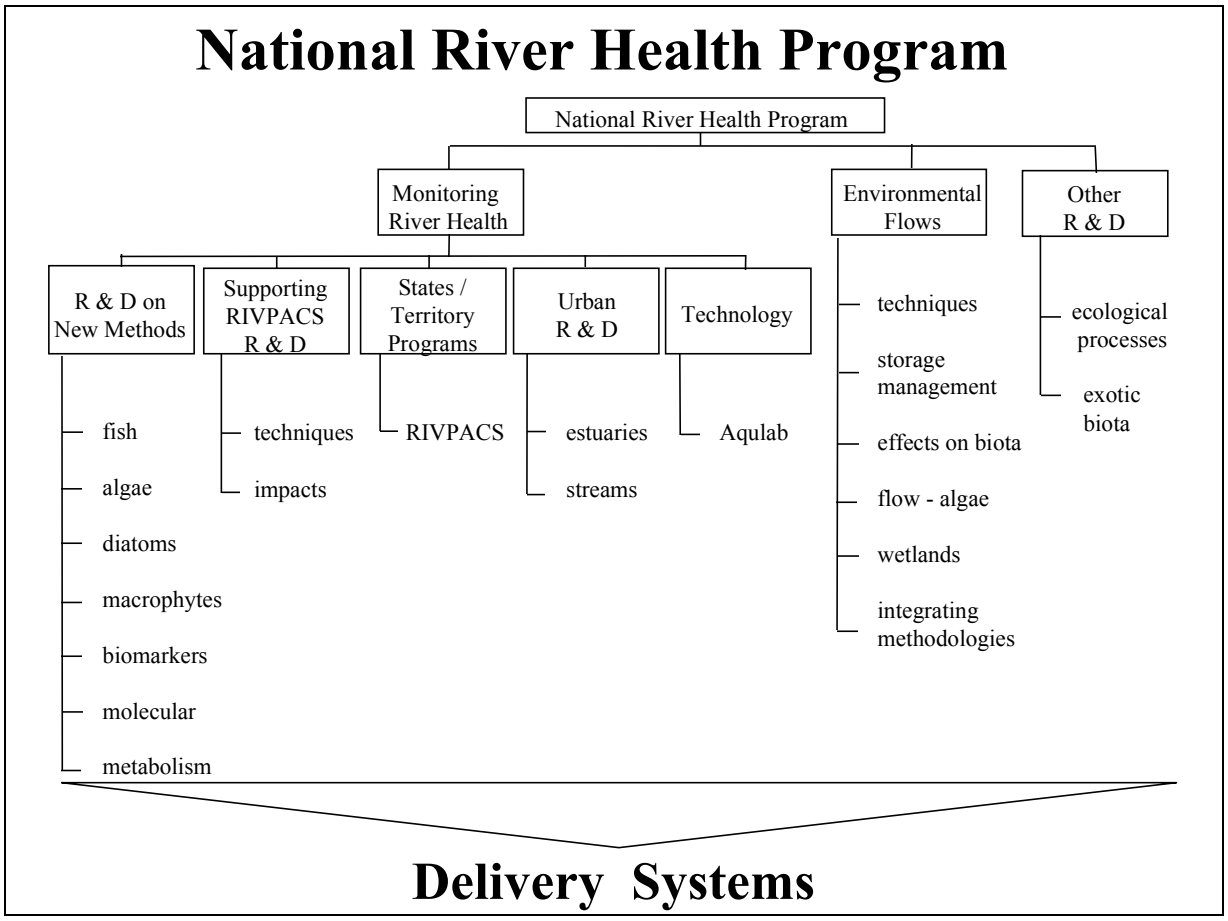

Figure 2.1 Schematic diagram of NRHP structure.

On May 26th 1994, a Project Management Agreement was signed which established LWRRDC as an agent to administer the program. The Program Management Agreement between DEST, CEPA, and LWRRDC allows the parties to combine funding and provides both DEST and CEPA with cost savings and efficiencies by using LWRRDC's well established research and development, administrative, and reporting processes. The Agreement authorises the Management Committee to approve projects and to ensure that projects satisfy the Program goals and objectives.

The financial contributions for the financial years 1993-94 to 1997-98 from the NRHP sponsors are currently $3.1 million from LWRRDC, $2.5 million from DEST, $2.25 million from CEPA and almost $0.5 million in interest (see appendix)

2.3.2 Monitoring River Health Initiative (MRHI)

The MRHI has four sub-programs that differ in scope and degree of progression (see below). The largest of the sub-programs is the Rural Program which incorporates the State and Territory Programs and rural R & D Projects. These latter projects are designed to support and refine the methodology and results from the State and Territory Programs. The term 'rural' is used in the present report to distinguish the biological monitoring and research under this program from that being conducted in the Urban Program. It should be recognised, however, that some biological monitoring under the State and Territory Programs is being conducted in urban areas.

The Urban Program is the second largest sub-program under the MRHI and incorporates urban stream and estuarine bioassessment. The third program is the Decision Support/Delivery Systems Program which will facilitate the transfer of technology from researchers to users. The Technology Program, the fourth component of the MRHI, is a small specialised program designed to demonstrate and facilitate the uptake by the water industry of the Aqualab remote automatic water quality monitoring unit.

2.3.2.1 State and Territory Programs

The water industry has developed a general recognition that there is a need for biological monitoring in addition to the physical and chemical measurement of water quality, to provide sufficient information on which to base management decisions that affect river health. Physical and chemical measurements only give an indication of one component of a river's health at an instant of time. In contrast, biological monitoring uses, as the basis of assessment, biota that integrate a variety of physico-chemical factors (*e.g.* pollutants, riparian zone health) over a period of time. The use of biological monitoring, therefore, gives a more accurate assessment of a river's health than otherwise would be available.

In September 1993 two reports were commissioned to investigate biological monitoring. The Environmental Protection Agency commissioned the Cooperative Research Centre for Freshwater Ecology to establish core indicators, while Professor Angela Arthington from Griffith University undertook a report for LWRRDC to establish R & D priorities. Both reports recommended the use of macroinvertebrates as biomonitors. As a result, the NRHP Management Committee proposed that the most appropriate manner in which to establish an Australia-wide biological monitoring program was the development of a River Invertebrate Prediction and Classification System (RIVPACS) similar to that which has been successfully developed in the UK. State and Territory agencies were to carry out the biological monitoring (the State and Territory Bioassessment Protocol), with ongoing refinement of RIVPACS through supporting R & D projects (see below).

The State and Territory Agencies (see Table 2.1) commenced sampling early in 1994. Since that time, each State and Territory has been conducting biological monitoring, using macroinvertebrates

identified to family level, and measuring a variety of physico-chemical parameters. The methodology they have adopted is that outlined in the *River Bioassessment Manual* which was developed by Dr Peter Davies (the NRHP Coordinator) with the assistance of the NRHP Management Committee.

Table 2.1: Agencies conducting biological monitoring as part of the MRHI State and Territory Programs

State/Lead Agency	Project Manager
N.T. Power and Water Authority	Mike Lawton
S.A. Department of Environment and Land Management	Phil Suter
ACT Department of the Environment, Land and Planning	Peter Liston
Victorian Environment Protection Authority	Lisa Dixon
Tasmanian Department of Primary Industries	David Fuller
NSW Environment Protection Authority	Russel Cowell
Queensland Department of Primary Industries	Peter Thompson
W.A. Department of Conservation and Land Management	Stuart Halse

2.3.2.2 R & D Projects (Rural Program)

While the core activity of the MRHI has been the development and support of the State and Territory Bioassessment Protocol and the development of the RIVPACS bioassessment tool, another important part of the initiative (approximately 50 % of funds) has been the establishment of R & D projects that support RIVPACS. The R & D projects fall into four categories, ranging from research aimed at refining the RIVPACS methodology, to research that will facilitate the interpretation of results.

There are four projects that directly support RIVPACS with research on specific aspects of the RIVPACS process. These projects include: Evaluation of biological assessment for RIVPACS modelling; Temporal variability of macroinvertebrate communities in Australian streams; Testing alternative approaches for linking habitat variables with site classifications in a RIVPACS model; and interpreting the output of the National River Bioassessment Protocol to support management decisions.

There are six R & D projects that directly support the RIVPACS process, such as increasing the scope and quality of taxonomic information available on macroinvertebrates. These projects include: Quality assurance and control for the MRHI program; Development of an interactive key to families of Australian aquatic macroinvertebrates; Rationalisation of voucher collections and keys for selected families of Trichoptera; Taxonomy of immature of selected families of Ephemeroptera and Trichoptera; Illustrated key to the nymphs of the Australian Ephemeropteran families - Caenidae, and Baetidae; Taxonomy of the nymphs of the Australian Plecoptera.

There is a group of six projects that assess alternative bioassessment tools to macroinvertebrates, such as diatoms. These projects include: River bioassessment using fish community structure;

Evaluation of attached diatoms for assessment of river health; Evaluation of attached diatoms as a tool in riverine bioassesment using artificial substrates; Development of a phytoplankton bioassessment protocol for Australian rivers; Macrophytes as indicators of ecosystem health; and Assessment of river health by the measurement of community metabolism.

Four projects are aimed at relating changes in macroinvertebrate communities to specific changes in water quality. The projects involve both field and artificial stream studies and include: Relating lowland river macroinvertebrate community composition to water quality; Macroinvertebrates as monitors of river health in the tropics; *In situ* testing of water quality; and Relating river macroinvertebrate communities to specific changes in water quality.

2.3.2.3 Technology

Under the MRHI a single technological project has been funded to demonstrate and facilitate uptake by the water industry of the Greenspan 'Aqualab' remote automatic water quality monitoring unit. The project is being managed by the NSW Department of Water Resources under a Steering Committee and is testing the Aqualab instrument under a wide variety of conditions, ranging from sub-alpine waters to arid-zone waters, sewage effluent and saline waters.

2.3.2.4 Decision Support Systems/Delivery Systems

There is $400K of funds to go towards decision support systems. These funds are currently uncommitted.

2.3.2.5 Urban Program

The urban program of the MRHI is jointly funded by the EPA and LWRRDC and is being overseen by the Water Services Association of Australia (WSAA) through the Urban Water Research Association of Australia (UWRAA) which is constituted under WSAA. WSAA's Executive Director, Dr John Langford, is acting as Project Director. Recent major changes in the structure of urban water authorities and therefore in the personnel representing UWRAA's members has impeded the development of the program. Recently, there has been progress in this area with the appointment of a program co-ordinator (Dr Jean Jackson) and calls for expressions of interest and project proposals.

The urban program includes streams and estuaries affected by runoff and discharges from urban areas. Priority research projects in both urban streams and estuaries have been identified in consultation with researchers, and project outlines have been written on the basis of the proposed priority areas. At this stage the titles of the proposed projects within the program are as follows: Basic decision support system for management of urban streams; RIVPACS for urban streams;

DIPACS (Diatoms Prediction and Classification System) for urban streams; sediment chemical composition-fauna relationships in urban streams; classification of estuaries; literature review of estuarine health topics; estuarine health assessment using benthic macrofauna; and estuarine eutrophication models.

2.3.3 Environmental Flows

Eleven projects investigating the environmental flow requirements of rivers and their associated floodplains are currently being funded, with $0.5 million in funds still to commit. The projects that have been funded range from research into the water requirements of plants on floodplains to the impacts of hydrological disturbance on stream communities. The title of the projects funded are as follows: Water requirements for plants of floodplain wetlands - Gwydir test case; Water requirements for plants of floodplain wetlands; Setting target river flows for the prevention of cyanobacterial blooms; Modelling the dynamics of blue-green algae in relation to river flow; Critical flow and population development of the cyanobacteria *Anabaena* and *Microcystis* in the Murray-Darling River system; Impacts of hydrological disturbance on stream communities; Impact of critical flow events on biota in regulated streams; Time share flooding of aquatic ecosystems - strategy assessment; Integrating environmental and irrigation water allocation under uncertainty; and Ecological basis for river habitat and in-stream flow management.

2.3.4 Other Initiatives

Under the NRHP several reviews have been initiated in order to prioritise R & D projects in a number of key areas. Dr P.S. Lake (Monash University) reviewed the R & D requirements in ecological processes for the improved management and monitoring of Australia's rivers. Professor Angela Arthington (Griffith University) reviewed the R & D requirements in exotic aquatic biota for the improved management and monitoring of Australia's rivers and Professor Barry Hart and Dr Duncan Veal (Monash University) reviewed the use of microbial indicators in river health. Associate Professor Doug Holdway (Royal Melbourne Institute of Technology) has reviewed the R & D requirements in "Biomarkers" for assessing key river impacts and aspects of river health.

From these reviews priority R & D has been finalised in the areas of microbial indicators, the impacts of displaced and exotic species, and ecological processes. A project to prepare a book on environmental assessment, design and monitoring protocols has recently been approved. The former research area has $375K of funds to commit.

3. National River Health Program Evaluation

3.1 Scope of the NRHP

To define the scope of the National River Health Program more precisely, we need to focus on the use of the term 'Health' in the NRHP title. In this context health refers to river health, or more broadly, riverine ecosystem health. According to Steedman (1994), the term health when applied to ecosystems is an idea which is comprised of a class of phenomena. Ecosystem health is a symbol for a complex set of ecological realities; it is a condition that cannot be measured or monitored directly (Steedman 1994). Ecosystem health, therefore, is a vaguely defined term and so the objectives of the NRHP are also somewhat vaguely defined. This may be appropriate for describing the broad direction of the program, however, each objective needs to be linked to a series of more precisely defined goals. Such goals are recommended in the following section. In this section we focus on the scope of the NRHP.

For Australian ecosystems, we define ecosystem health as the state of an ecosystem, ranging from pristine to highly degraded, and with the level of anthropogenic impact defined in terms of deviation from the pre-European state. Our definition is pragmatic in that it ignores the significant impact on the landscape of Aboriginal Australians. This is done on the basis that post-European occupation impacts on the landscape have been far more rapid, intensive and widespread. The extent of deviation by an ecosystem from the pre-European state can be defined by comparison to pristine or near pristine ecosystems, using appropriate biological criteria. By our definition, a healthy ecosystem is one that has excellent biological integrity as defined by Karr and Dudley (1981), *i.e.* the "*ability of an aquatic ecosystem to support and maintain a balanced, adaptive community of organisms having a species composition, diversity, and functional organisation as comparable as practicable to that of natural habitats within a region*".

Given this definition of ecosystem health, the scope of the National River Health Program is broad and covers the more recent concept of water quality embraced in the ANZECC[1] Australian Water Quality Guidelines for Fresh and Marine Waters (ANZECC 1992). Traditionally water quality referred to the chemical state of natural waters, however, in recent years use of the term has been broadened to cover a range of biological and ecological parameters which may collectively indicate ecosystem health. For example, the ANZECC guidelines list criteria for the protection of aquatic ecosystems including those for toxicants, physico-chemical and biological factors. These factors are affected by larger scale phenomena such as river flow and catchment management and therefore it is appropriate that such phenomena are covered in the scope of the NRHP.

A precise definition of the scope of the NRHP is, therefore, the development of tools, technologies, management methods, and criteria for the measurement of riverine ecosystem health and for achieving desired states of riverine ecosystem health.

[1] ANZECC - Australian and New Zealand Environment and Conservation Council

3.2 The state of environmental management of rivers in Australia prior to the NRHP

3.2.1 Water quality monitoring

A recent review of water quality monitoring in Australia (Aquatech 1995) concluded that it was relatively well organised, although there was scope for significant improvement in some areas. The report, which was based on questionnaires sent to monitoring organisations across Australia, did not address the scope of the various monitoring programs in light of ANZECC guidelines, however, some information was provided on the techniques used for monitoring. This information is useful in gauging the level of adherence to ANZECC guidelines; in particular those relating to biological monitoring. The majority of programs used physical, chemical, and microbiological techniques to determine water quality (Aquatech 1995) but only around 19% made use of biological monitoring techniques.

The protection of aquatic ecosystems is one the key components of the Australian Water Quality Guidelines (ANZECC 1992) and this is strongly underpinned by biological monitoring. According to the guidelines; "Biological water quality must become an essential tool of resource managers responsible for protecting aquatic ecosystems, as only biological techniques can demonstrate that the integrity of the ecosystem is being maintained". It is clear then, that at the time of the survey, only 19% of water quality monitoring programs were attempting to assess ecosystem health or integrity.

Norris and Norris (1995) discuss the reasons why they feel that little biological monitoring has been conducted in Australia. These are:

1. A lack of coordination and direction from national or state agencies;
2. A lack of funding to undertake studies using biota because of the perceived cost and because of a lack of understanding among those responsible for resource allocation about the efficacy of biological approaches;
3. A lack of biological guidelines to apply in biological monitoring;
4. A scarcity of freshwater ecologists with interests in this area;
5. A prosaic approach to innovation, largely because of restricted training opportunities; and
6. A reluctance of biologists to accept or even test overseas approaches often discounting them with the argument the 'Australia is so different'.

Even amongst those organisations that make use of biological monitoring, it is not clear that it is being used effectively. This problem is recognised in the ANZECC guidelines (ANZECC 1992) where the authors point out that biological assessment techniques are in an early stage of

development in Australia. It is clear that many of these problems are now being addressed by the NRHP through the MRHI.

3.2.2 Environmental flows

Flow management has been recognised as an important issue for many years, however, despite this recognition the issue has been not clearly defined. Ryan (1991) defined "Environmental Flows" as those that are provided to enhance natural processes' dependant on the flow regime. However, various other authors (*e.g.* Hart *et al.* 1989, MDBC 1993, Arthington 1994) have suggested that flows may be used for other purposes such as dilution flows for salinity, nutrient or algal problems. This latter definition should be considered a consumptive use rather than a flow that will directly benefit the environment. In some cases, flows released to prevent or break up an algal bloom in late summer may harm the ecological conditions of a river system.

Numerous conferences have been held over the last decade in Australia (6 over the last 5 years) that have focussed on Environmental Flows or substantially dealt with the subject. Furthermore, many papers have been published as a result of these workshops (120+) and other related work (23+). This tally is most likely incomplete and does not include the substantial literature that has been generated overseas during the past 30 years.

No agreement exists in the scientific literature or community in terms of what are appropriate environmental flows, how they are determined and how they are delivered! This remains the central issue for the practical application of environmental flow studies and the implementation of environmental flow allocations in Australia.

3.2.2.1 Determining environmental flows

Many techniques for determining environmental flows have been reviewed and suggested for use in Australia (see Tunbridge 1980, Richardson 1986, Anderson & Morison 1988, Kinhill 1988, Gan & McMahon 1990, Gippel *et. al.* 1991, Arthington & Pusey 1993, Arthington 1994, Gippel & Stewardson 1995). However, none have been universally accepted or widely trialed.

The approaches adopted overseas for instream flow determinations have included the Tenant Method (Tenant 1976), flow duration curve analysis (Stalnaker & Arnette 1976), transect analysis (Stalnaker & Arnette 1976), available habitat methods (Wesche 1973), Instream Flow Incremental Method (IFIM; Bovee 1982, Milhous *et al.* 1984), Holistic method (Arthington & Pusey 1993, Arthington 1994) and the expert-panel method (Cahveroche & Sabaton 1989; Swales *et al.* 1994). All of these methods involve an assessment of a number of environmental features (or part thereof) such as existing flows, habitat or biological requirements of instream biota. The biological basis for most methods used overseas has been criticised because of the lack of direct evidence for relationships

between flows and biological processes (Mathur *et al.* 1985, Shirvell 1986, Orth 1987, Orth & Leonard 1990).

These techniques have been extensively applied and critically evaluated in the USA leading to the refinement of many techniques, exploration of new ideas and some adaptive management. More importantly, from a management and conservation viewpoint, environmental water allocations have been made to many river systems in the USA as a result of these environmental flow studies.

Little application or evaluation of environmental flow techniques has been undertaken for the Australian situation other than on a theoretical basis (but see Richardson 1986 and Swales *et al.* 1994). Those allocations which have been made, have been without the benefit (or otherwise) of these formal techniques.

The determination of the environmental flow requirements for a system is clearly dependant on the type of river system under consideration, the habitats present, target biota, water quality considerations, its regional location as well as special management considerations such as environmental problems (*e.g.* algal blooms, salinity, *etc*.).

This variety in the rationale or purposes for environmental flows is probably the major reason why there has been little agreement on a standard method and little adoption or application of any environmental flow methods.

3.2.2.2 Delivery of water for environmental flows

Scant attention has been paid to how environmental flows can actually be delivered. Many logistical problems in delivering environmental flows exist in regulated river systems because of natural and irrigation channel constraints, natural and man-made barriers and other demands and storage problems. In unregulated systems where diversions are the main form of abstraction, restriction policies are the only effective measure for preventing impacts to the key elements of the flow regime. Furthermore, closer liaison and co-operation between river engineers, hydrologists and ecologists is required in determining and allocating water for the environment.

3.2.2.3 Determining Social & Economic Costs & Benefits

Social and political considerations are important as they will either limit or facilitate the allocation of water for environmental purposes. Furthermore, the economic evaluation of both water use by the environment (together with transmission losses) and benefits as a result of providing Environmental Flows is another important factor in the final decision making process. A strategic approach to the social, political and economic factors is yet to be developed by either government or researchers.

A number of papers (Malcolm; Alexandra; Syme & Nancarrow; Musgrave & Kaine; Dudley; Wonder) in the Pigram & Hooper (1994) proceedings of the "Water Allocation for the Environment" workshop all address this issue. However, each of these papers point out that their results, to date, are based on a small and limited research base.

Environmental flow allocations (as distinct from environmental flow requirements) are often made as a result of social or political decisions without the benefit of ecological research. The recent allocation of 100GL of water for the Barmah-Millewa Forests, on the Victorian-New South Wales Border, was made as a result of community concerns that water allocation was necessary for the forests' well-being. However, supplies were limited and large allocations would impact severely on available water for consumptive use. The 100GL allocation was not based on the extensive ecological and hydrological studies that have taken place in the forest over recent years (Maunsells 1992, Ward 1991, Ward *et al.* 1992). However, the application of this research can now assist in the definition of the actual delivery mechanisms and strategies necessary to have the best environmental result from this allocation.

3.3 Approaches to monitoring river health in other countries

3.3.1 United States

In the United States, the US Environmental Protection Agency (EPA) has recently focused on biological integrity for assessing the condition of surface waters and documenting the success of water resource restoration and protection (Jackson and Davis 1994). In 1994 the US EPA released a Strategic Plan aimed at guiding planning, resource allocation, and decision-making for the ensuing five years (US EPA 1994). The plan is centred on seven major principles, two of which relate to biological integrity: Ecosystem Protection and Strong Science and Data. This plan is much broader in scope than the Australian NRHP in that it covers both land and water systems, and State of the Environment Reporting. The objective of the Ecosystem Protection principle is "to upgrade (the US EPA's) ability to protect, maintain and restore the ecological integrity of the nation's lands and waters, including human health, urban areas, and plant and animal species" (US EPA 1994). To accomplish this, the Strategic Plan states the US EPA must:

1. Identify stressed and threatened ecosystems;
2. Define environmental goals;
3. Develop and implement an action plan;
4. Measure progress and adapt management to new information over time; and
5. Identify tools and support that can be provided at a national level

By comparison the current Australian NRHP seeks only to address points 2 and 5. The remaining points are addressed by different programs and mechanisms in Australia.

The objective of the second principle, Strong Science and Data, is to ensure that the United States' environmental policies are based on the best available science and information.

The US EPA is currently focussing its efforts on the development of indicators of biological integrity. An intergovernmental task force has prepared position papers on 1) criteria for the selection of indicators, 2) use of ecoregions, reference conditions, and index calibration, and 3) use of a range of indices (termed 'metrics' in the US) for describing ecological conditions. These indices are becoming more widely used in the US since they were expounded in US EPA publications (*e.g.* Plafkin *et al*. 1989). This is the major difference between US and Australian approaches to biological monitoring in that although the NRHP is funding some research on indices (*i.e.* Dr Bruce Chessman's signal index), these are only a minor component of the NRHP. The type of biological monitoring targeted by the NRHP is the development of tools and methods for the prediction of the taxa (*i.e.* invertebrate species or families) expected at a site assuming little or no human impact. The difference between the observed set of taxa at the site and the predicted set is a measure of the state of ecosystem health of the site. The predicted set of taxa is developed using a statistical model which uses information stored in a database containing records of the taxa collected at a few hundred unimpacted sites across a state or geographic region. By comparison, the US approach has been criticised by Norris (1995) for its inability to define an ideal state of ecosystem health in a statistically defensible fashion. In particular, the lack of within-site replication of samples means that individual sites (*e.g.* an unimpacted site and a potentially impacted site) cannot be compared with any confidence that differences might have resulted from anything other than chance (Norris 1995).

3.3.2 United Kingdom

In England, Government Policy for water quality is the responsibility of the Department of the Environment and the management of rivers, canals, and estuaries in England and Wales is undertaken by the National Rivers Authority (NRA). The NRA is a regulatory authority formed in 1989 from the Rivers Units of ten regional Water Authorities (NRA 1991) after their water supply and sewage functions were privatised (Wright 1995). The management of rivers in Scotland and Northern Ireland is undertaken by separate authorities which are not further discussed here. The NRA has no single Australian equivalent; the nearest Australian entities being State and Territory Water Resource Departments and Regional Water Authorities. The NRA spends approximately £3.4 Million on Water Quality R & D per annum (NRA 1994) covering all aspects of water quality including a program on biological assessment. Of particular relevance to the Australian NRHP is the further

development of the UK RIVPACS computer model being undertaken by the British Institute of Freshwater Ecology (IFE) on contract from the NRA (NRA 1994). RIVPACS is one of the major biological assessment tools used in the UK and is now in its third phase of development which will see an increase in the number of unimpacted reference sites (used to give the model its predictive capacity) to over 700. The idea for RIVPACS was conceived by scientists at the IFE (formerly the British Freshwater Biological Association) in 1977, and since then the IFE has undertaken most of the model's construction and development. In 1990, 8796 sites were surveyed, throughout the UK, most on three occasions, and assessed for biological condition using the RIVPACS model (Wright 1995).

3.3.3 Other countries

A recent European Communities symposium (Newman *et al.* 1992), provided an overview of the different approaches used to measure river water quality in Europe. At the time of the symposium it was apparent that many European countries had water quality monitoring programs based on EC Directives which specifically targeted either harmful substances (*e.g.* heavy metals, pesticides *etc*.) or microbiological indicators of sewage contamination (*e.g. E.coli etc*.). Newman *et al.* reported that there was a growing recognition amongst EC member states that such directives were too precise and to protect the aquatic environment in this way would require thousands of Directives with specific substances allocated specific maximum concentrations. In addition, such Directives ignored the possibility of synergisms or antagonisms between different toxicants. A new EC Directive was proposed that considered the protection of the ecological quality of surface waters. The draft Directive is to take into account natural geological, climatic, and physical water quality conditions, and the measurement is to be one of intactness of the aquatic biological community or representative indicators of it.

The main elements of the proposal are (Mandl 1992):

- a target of high ecological quality for all surface waters;
- a monitoring system and an inventory of discharges and of diffuse sources;
- programs in order to reach the target fixed;
- the implementation by Member States of the measures contained in the program;
- public information and involvement;
- a reporting system;
- a committee to be created to help the implementation of the Directive.

This ecological Directive has much in common with the ANZECC water quality guidelines although its stage of development appears to be considerably behind that of the Australian guidelines.

Despite the early stage of development of EC-wide guidelines, some Member States have recognised the need to address the biological and ecological aspects of water quality (most notably the UK).

However, Newman *et al.* (1992) stated that there were "almost as many methods of measuring and interpreting the biological integrity of an aquatic community as there were biologists measuring it". A brief overview of these methods is given in Newman *et al*. The only national program reported was that of Ireland, where a national biological river quality classification scheme has been operating for 20 years (McGarrigle *et al.* 1992). The Irish system is based on indices tabulated by expert ratings of the pollution tolerance of various riverine invertebrate taxa. With the exception of the UK, the methods generally rely on an expert assessment of the value of various indices and are similar to the US approach to ecological water quality assessment. Consequently, the criticisms of the US approach by Norris (1995) apply to most of the European water quality assessment programs.

More recently, at his presentation to the second NRHP Workshop in Canberra in May 1995, Dr Roger Sweeting of the UK National Rivers Authority commented that several European countries have either begun trials with RIVACS type assessment techniques or are considering such an approach. This is most likely due to the important feature of the RIVPACS technique which is its ability to statistically define an ideal state of ecosystem health.

In summary, despite the diversity of approaches to water quality assessment in Europe, with the major exception of the UK and to a lesser extent Ireland, the state of technique development is similar to that of Australia before the implementation of the NRHP, with a diversity of techniques in use. Consequently, the European approach to ecological water quality monitoring (again, with the exception of the UK) provides only a limited amount of material from which to draw useful ideas for constructing an appropriate methodology for Australia.

3.4 Adequacy and relevance of current NRHP aims and objectives

3.4.1 Council of Australian Governments water reforms

The Council of Australian Governments (COAG) is an intergovernmental committee that meets periodically to coordinate State and Federal activities and initiatives on a wide range of issues. At its meeting on 8-9 June 1993, COAG asked that a Working Group, under an independent chair, prepare a report for its next meeting containing a strategic framework for the efficient and sustainable reform of the water industry (COAG 1994). The Working Group reported back to COAG in February 1994. Apart from identifying issues such as improved pricing policy, infrastructure upgrading, wise economic use of irrigation water, and clear institutional responsibilities, the Working Group also reported the need for governments to focus on widespread natural resource degradation which has an impact on the quality and/or quantity of the nation's water resources.

COAG (1994) endorsed the Working Group's strategic framework and agreed to its implementation. The sections of the framework of most relevance to the NRHP review are detailed below:

- **COAG water resource policy in relation to water allocations or entitlements**
  - States should give priority to formally determining allocation or entitlements to water, including for the environment as a legitimate user of water
  - Allocation of water to the environment should occur with regard to work being undertaken by ARMCANZ and ANZECC
  - Environmental flow requirements, wherever possible, will be determined on the best scientific information available and have regard to the inter-temporal and inter-spatial water needs required to maintain the health and viability of river systems and groundwater basins
  - Arrangements are to be made by 1998 to balance water resource use in relation to river systems that are currently overallocated or stressed
  - Jurisdictions to consider establishing environmental contingency allocations which provide for a review of allocations after five years
  - Where significant future irrigation activity or dam construction is contemplated, in addition to economic evaluations, assessments will be undertaken to ensure that the environmental requirements of river systems can be adequately met

- **COAG water resource policy in relation to the environment**
  - Member governments should support ARMCANZ and ANZECC in their development of the National Water Quality Management Strategy, through the adoption of a package of market-based and regulatory measures, including the establishment of appropriate water quality monitoring and catchment management policies and community consultation and awareness.

- **COAG water resource policy in relation to water and related research**
  - Member governments should give higher priority to the research necessary to progress implementation of the strategic framework, including consistent methodologies for determining environmental flow requirements, and
  - act to ensure greater coordination and liaison between research agencies to more effectively utilise the expertise of bodies such as the Land and Water Resources Research and Development Corporation, the Murray-Darling Basin Commission, and other State and Commonwealth organisations.

Clearly, the COAG objectives relate strongly to the Environmental Flows component of the NRHP. *Given the still early stage of development of environmental flows technology and management in Australia, and the strong COAG support, there is a clear need for continuing research in this area.*

3.4.2 National Water Quality Management Strategy

In response to the deteriorating quality of Australian waters, ARMCANZ and ANZECC are co-operatively developing the National Water Quality Management Strategy (NWQMS). The policy objective of the NWQMS is *to achieve sustainable use of the nation's water resources by protecting and enhancing their quality while maintaining economic and social development.*

To achieve this objective, the environmental values of water resources need to be clearly defined and protected from degradation (ANZECC 1992). ANZECC considered five environmental values in its development of national guidelines:

- Ecosystem protection (both inland and marine), including protection of waters used for shellfish and fish production and by wildlife;
- recreation and aesthetics;
- raw water for drinking water supply;
- agricultural water;
- industrial water.

For the purposes of the NRHP review, we are concerned mainly with the first environmental value; ecosystem protection. Apart from setting guidelines for certain physico-chemical variables and for concentrations of particular toxicants, ANZECC (1992) has also recommended the use of biological indicators of water quality to be used in the protection of aquatic ecosystems stating that "Biological water quality must become an essential tool of resource managers responsible for protecting aquatic ecosystems, as only biological techniques can demonstrate that the integrity of the ecosystem is being maintained. However the development of biological assessment techniques applicable to the protection of aquatic ecosystems is in its infancy in Australia". ANZECC were, therefore, unable to recommend specific values for any biological indicators.

Within a month of the release of the ANZECC Australian Water Quality Guidelines in November 1992, the Prime Minister released his Statement on the Environment which incorporated funding for the Monitoring River Health Initiative. Subsequently, the NRHP was formed and the program committee chose biological monitoring as a major focus using a state of the art technique - RIVPACS. As a result, the NRHP has made substantial progress towards achieving the ANZECC recommendation of the use of biological indicators for the protection of aquatic ecosystems.

3.4.3 Commonwealth State of the Environment Reporting

One of the Department of Environment, Sport and Territories (DEST) priority activities is to undertake reporting on the state of Australia's environment. The purpose of State of the Environment (SoE) reporting is to document changes in Australia's environment (CEPA 1992). The most useful SoE reports for Australia would contain both environmental statistics and indicators of trends in

environmental conditions (CEPA 1992). As noted in the ANZECC water quality guidelines biological techniques are the only techniques that can demonstrate that the integrity of the ecosystem is being maintained. Hence the development of biological monitoring tools for the assessment of aquatic ecosystem health by the NRHP clearly assists DEST in its national SoE reporting requirements. SoE reporting is also imperative to assess the effectiveness of the COAG water reforms.

3.5 A critical review of the National River Health Program

3.5.1 Current state of awareness of NRHP among potential users

As part of the evaluation of the program over 150 questionnaires were sent to water authorities and various agencies who are responsible for river management. The questionnaires were designed to ascertain the extent of knowledge of the NRHP by those in the position to utilise its outcomes. Information pamphlets about the program were enclosed with the questionnaires so that those who were unaware of it prior to being surveyed could comment on its applicability to river management. People were asked the following:

1) Prior to receiving the questionnaire, whether they had heard of the National River Health Program.

2) If they had heard of the program, were they aware of its expected outcomes and their application to natural resource management.

3) From their understanding of the program, could they use its outcomes.

4) In the future would they use the RIVPACS or environmental flow research.

5) Would they be interested in the future to fund the development of a local RIVPACS type program.

The manner in which the responsibility for river management differs between states (*e.g.* in New South Wales some councils are responsible for river management, in Queensland water authorities often have this responsibility, whereas in Tasmania the water authorities predominantly deal with water supply only) meant an uneven number of questionnaires were sent to each state. The majority of the questionnaires were sent to Queensland, New South Wales and Victoria, with relatively few sent to Western Australia, South Australia, Northern Territory, Tasmania, and the Australian Capital Territory. As a result, there was a low number of responses from these latter states and, therefore, they are not discussed further in any detail.

It was found that in NSW and Victoria that the majority of people surveyed had heard of the NRHP (Table 3.1). Of those who had heard of the program in these two states, 67 % in NSW and 69 % in Victoria were aware of the expected outcomes and their applicability to natural resource management. In Queensland, however, a majority of the respondents had not heard of the program although those aware of the program, in general, were familiar with its outcomes. In NSW and Victoria 82 % and 84 %, respectively, believed that they could use the outcomes of the program,

with only 45.5 % of the respondents from Queensland believing this to be the case. Of those who felt they could use the outcomes of the program it was environmental flow research that they believed was most likely to be used. However, in NSW and Victoria there is considerable support by water authorities and agencies to fund the development of local RIVPACS. This is not the case in Queensland.

These results suggest that there is considerable interest and support of the program in NSW and Victoria by those in a position to utilise its outcomes. Such support is likely also to be present in Queensland if the program was better understood, as those aware of the program prior to the present survey supported it in a similar manner to the other states. The different level of understanding of the program between states highlights a need for promotion of the program to be tailored to the manner in which river management responsibility is conducted in different states. A general Australia wide promotion of the program, that assumes that all states operate in a similar fashion, increases the likelihood that potential users of the program outcomes will not receive information that contains appropriate explanations on how it can assist in addressing river management issues.

Research into environmental flows enjoys good support in all states and demonstrates the importance of this issue to managers who are trying to meet the competing demands of water resources for human use and the environment. In general, it appeared that the greater interest in the outcomes of environmental flow research compared with RIVPACS was not a reflection of the lesser importance of this latter issue, but due to a poor understanding of what the RIVPACS offers natural resource managers. The seemingly more complex nature of the RIVPACS research, including its cryptic name, appears to obscure the potential usefulness of its outcomes to natural resource managers. Thus, there appears to be a need for greater communication of the RIVPACS part of the program.

Table 3.1: Results expressed as percentages of returned questionnaires from each state (n), however, as some questionnaires were incomplete, responses to questions do not always add up to 100%. Question numbers refer to those listed above. The results of question 2 were expressed as a percentage of the number of respondents in question 1 that had heard of the program prior to the survey.

Question	Response	SA (4)	NSW (11)	QLD. (22)	VIC. (19)
1. Knowledge of NRHP	Yes	75	91	32	68
	No	25	9	68	32
2. Knowledge of NRHP objectives	Yes	100	67	83	69
	No	-	33	17	21
3. Can you use the outcomes?	Yes	100	82	45.5	84
	No	-	9.1	36.4	-
4a. Could you use RIVPACS/	Yes	50	72.7	41	63
	No	25	-	59	26.3
4b. Could you use the Environ. flows technology?	Yes	100	91	54.5	89.5
	No	-	-	50	10.5
5. Would you be prepared to fund local RIVPACS development?	Yes	50	63.6	23	52.6
	No	25	9.1	77.3	47.4

3.5.2 Monitoring River Health Initiative (MRHI)

3.5.2.1 Current Issues

During the present evaluation of the NRHP researchers conducting the State and Territory Programs and R & D Projects were contacted to investigate what they believe are the current issues affecting the success of the NRHP. The general response from those contacted was that the NRHP was an important initiative that was making a substantial contribution to increasing the understanding of river health in Australia. A number of comments were made raising concerns about, and making suggestions for, the future direction of the program. These comments have been summarised into four categories below. The section on NRHP communication has been included in the recommendations of this review. The other sections were considered to be minor issues, or there are already plans to address them within the NRHP.

3.5.2.1.1 State and Territory Programs

- There is concern over the divergent manner in which the methodology used by different states and territories has developed.
- There is a need for QA/QC methodology. Different states and territories have recognised the need for QA/QC component within the program, and have been considering or implementing QA/QC. Without a national approach to this issue there is the risk that the approaches taken will diversify.
- There is a need for a critical evaluation of the research that is being conducted.

3.5.2.1.2 RIVPACS/alternative models

- There are some concerns over the applicability of the RIVPACS model in Australia, given the geographic and climatic variability of Australia compared with that of Britain where the approach was initially developed. This concern is focussed mainly on tropical northern Australia.
- The family level of taxonomic identification is considered inadequate by a number of researchers, who argue that important information is being lost by not identifying macroinvertebrates to the lowest possible taxonomic level that is currently possible.
- Others are concerned that the push by some researchers for species level identification ignores the need for simple cost effective methods that can be used by less experienced field staff.
- Alternative model development may require further funding to develop a better understanding of key areas (*e.g.* early life history of fish, macrophytes) and provide a useful alternative approach in the advent of RIVPACS being unsuccessful.
- There is concern that the supporting R & D Projects are running concurrently with the State and Territory Programs, given that the projects are designed to support the State and Territory Programs.

3.5.2.1.3 Support of the program

- Although the co-ordination of the program has been good, as the program develops there is likely to be a need for a full-time co-ordinator or further support of the current part-time position.
- There is concern that the direct commissioning of projects may reduce the chances of having the best qualified people to conduct the work.
- There is a lack of trained, qualified staff in some states.

- A lack of long-term federal funding commitment to the program is causing two main problems. First, uncertainty of funding results in trained personnel being lost from the program; and second, without a federal commitment of funds, state funding may not be forthcoming.

3.5.2.1.4 Communication within the program

- *There needs to be increased communication between the researchers involved in the R & D Projects and the State and Territory Programs, such as through a more detailed newsletter than currently exists.*
- *There needs to be increased communication between those involved in the State and Territory Programs. This would facilitate a national approach to the program. In addition, success of the program would be rapidly communicated, thereby promoting continued support from state agencies.*
- *Greater communication with the water industry needs to be developed, particularly given the change of personnel that it has recently experienced.*
- *There is some overlap between the NRHP with other programs (e.g. LWRRDC National Riparian Program) which needs to be explored.*

3.5.2.2 Quality Assurance and Quality Control.

Some concern has been expressed by participants in the NRHP about the need for adequate quality assurance and quality control procedures. Some steps have already been taken under the NRHP to ensure a measure of quality assurance for the State and Territory programs, however, these are very preliminary. Experience in the routine use of RIVPACS by the National Rivers Authority in the UK has shown that third party proficiency testing plays an important role in ensuring that reliable, high quality data is produced. Organisations that provide such services in Australia include Standards Australia, NATA (National Association of Testing Authorities) and Lloyds Register. These agencies work under the framework of the Joint Accreditation System for Australia and New Zealand (JAS-ANZ) (see Fig. 3.1).

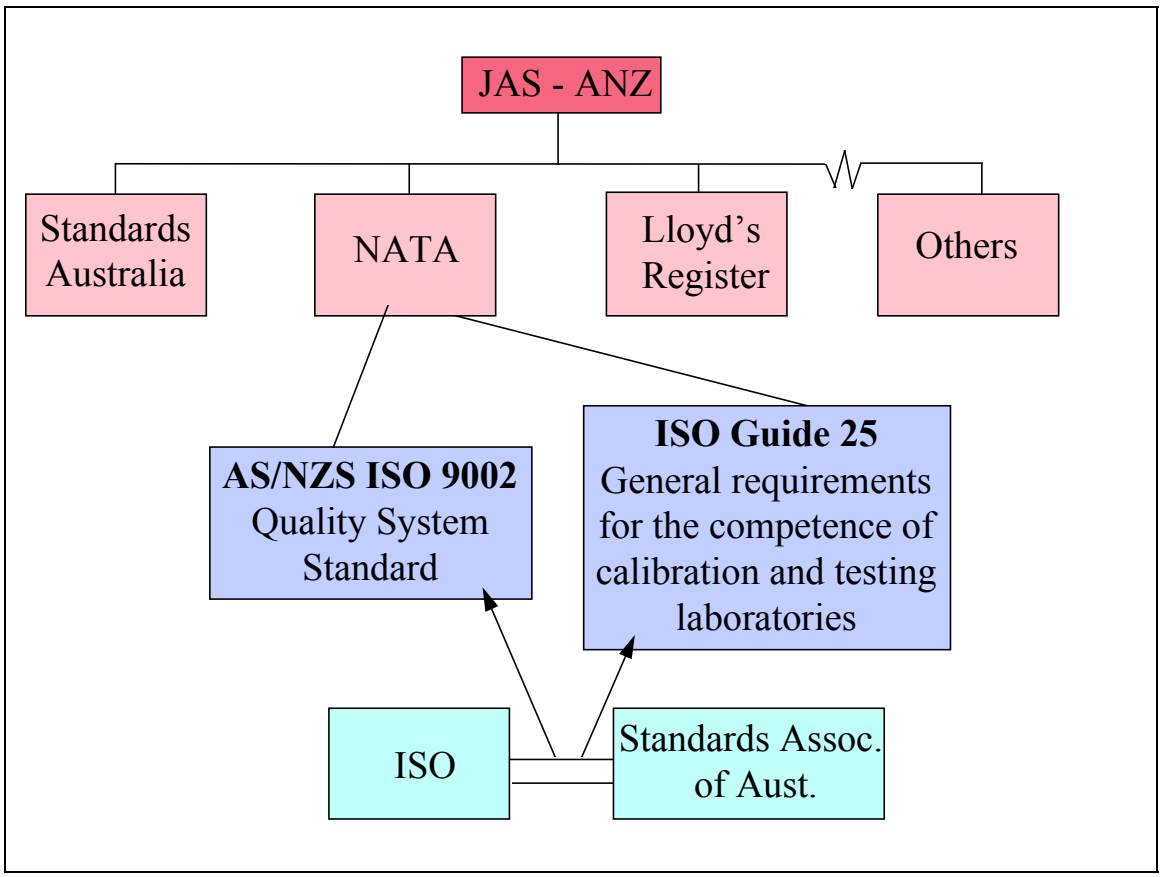

Figure 3.1. Quality Management Systems for Australian Laboratories.

The development of regular biological monitoring programs which will eventuate from the NRHP will require monitoring organisations to seek certification of their quality system and possibly accreditation (or registration) for their laboratory methods (a formal recognition of competence). Organisations participating in the NRHP that wish to gain formal third-party registration for the enumeration and identification of benthic macroinvertebrates or other organisms need to seek accreditation under the NATA requirements for Biological Testing (or the comparable standard of other accreditors). Biological testing comes under the ISO (International Standards Organisation) Guide No. 25. For the purposes of accreditation, biological testing may be divided into a large number of different categories. A generalization of these categories is listed in Table 3.2. No laboratories in Australia have any form of third party accreditation for macroinvertebrate sampling, identification, and enumeration and only a few have achieved accreditation for phytoplankton and zooplankton testing (*e.g.* Water Ecoscience P/L). No laboratories participate in regular interlaboratory proficiency testing. In the absence of formal accreditation, laboratories should have a Quality Management System certified to AS/NZS ISO 9002, which entails that they adhere to a series of written procedures and methods for any analytical determination and also for overall laboratory management.

Table 3.2. Summary of types of biological testing for inland waters undertaken in Australian Laboratories and state of standard method development.

Type of testing	**Source of testing**	**Reason for testing**	**Waters**	**State of development for laboratory testing in inland waters***
Microbiological	water supply	public health	inland	very good
Phytoplankton (including most blue-green algae & dinoflagellates)	water supply, environmental waters	public health, ecosystem health	inland & marine	medium (some labs with NATA accreditation)
Benthic microalgae	environmental waters	ecosystem health	inland & marine	medium/poor
Chlorophyll-*a*	water supply, environmental waters	public health, ecosystem health	inland & marine	medium
Macroalgae	environmental waters	ecosystem health, contamination, conservation	inland & marine	poor
Macrophytes	environmental waters	ecosystem health, contamination, conservation	inland & marine	poor
Zooplankton	environmental waters	ecosystem health, contamination	inland & marine	medium/poor
Benthic macroinvertebrates	environmental waters	ecosystem health, contamination, conservation	inland & marine	poor
Fish	environmental waters	ecosystem health, contamination, conservation	inland & marine	very poor

* virtually all testing for all biological components of marine and estuarine waters is in a poor state of development

It is recommended that laboratories participating in the NRHP develop standard methods for the collection, enumeration, and identification of macroinvertebrates and that the NRHP assist in the development of National Standards.

3.5.2.3 MRHI R & D Projects: Scope

The key issues in relation to the MRHI are:

1. the level of taxonomic resolution;
2. the level of temporal variability of Australian macroinvertebrate communities;
3. the development of cost effective, field sampling, and sample processing and statistical analysis techniques;
4. the development of appropriate quality assurance and quality control standards for field sampling, sample processing, and database management;
5. the evaluation of novel and alternative techniques of biological water quality assessment.

The NRHP management and technical advisory committees have recognised these issues and allocated funds to support R & D projects in these areas. Although the level of R & D support for issues 1, 2, 3 and 5 appears appropriate at present, further funds need to be allocated to issue 4. The current QA/QC project for the MRHI state & territory program is in the form of a third party proficiency assessment program managed by Mr John Hawking of the Murray-Darling Freshwater Research Centre at Albury. Proficiency testing may also be by interlaboratory sample exchanges mediated by an independent third-party agency such as NATA or Standards Australia. In the long-term this approach may involve less expense than the current approach, however, there is currently no national forum for the development of systems to implement such an approach. A proposal was recently put to the NATA national water quality subcommittee by Ms Anne McNeill of Water Ecoscience to convene the meeting of a new biological water quality assessment subcommittee. This committee would provide an appropriate forum for developing national standards for biological monitoring of river water quality and the organisation of inter-agency proficiency testing programs and accreditation to appropriate ISO standards. It is also important to note that proficiency testing is only one part of a QA/QC program (see section 3.5.2.2) and appropriate standards and quality systems also need to be developed for sample processing and database management. *The NRHP Management Committee should fund a scoping study (from existing unallocated funds) on the development and implementation of formal ISO standard QA/QC programs for the MRHI. An indicative cost for the scoping study would be $8000 to $10,000.* This would provide a clear direction for future quality assurance and quality control programs for biological water quality assessment.

3.5.2.4 Technology

Under the MRHI a single technological project, managed by the NSW Department of Water Resources, has been funded to assess the utility of the Greenspan 'Aqualab' remote automatic water quality monitoring unit. It is envisaged that this instrument may be best utilised in gaining short periods (*e.g.* two months) of intensive physico-chemical water quality data at remote locations (*e.g.* north western NSW). This data could then be used to calibrate conditions at the site with less remote sites. Water quality conditions at the remote sites could then be predicted on the basis of water

quality at the less remote sites. The two key issues are the instrument's reliability and the cost of maintenance in comparison to routine monthly sampling by Water Resources staff or contractors. Another use of the instrument is in the surveillance monitoring of acid sulphate soils.

Even with state of the art self-cleaning and calibrating technology, remote water quality monitoring devices will need at least monthly or two-monthly maintenance. The only economic gain they offer over the routine manual monthly sampling currently conducted in most state water quality monitoring networks, is the provision of daily or hourly data. With the present technology it is envisaged that they would be deployed in special situations (such as those mentioned above) where existing methods are inappropriate. The development of reliable and cost-effective remote water quality monitoring units are therefore an important part of the NRHP since these devices fill the gaps in the coverage offered by conventional water quality monitoring methods.

3.5.2.5 Decision Support/Delivery Systems

There are currently $400,000 of funds earmarked for the development of information delivery and decision support systems (DSS's) for the NRHP. These funds are currently unallocated. The use of DSS software in integrated catchment management has increased in recent years (*e.g.* the CSIRO Catchment Management Support System, and several Adaptive Environmental Assessment and Management [AEAM] catchment nutrient models in Victoria) and the utility of DSS's is now widely accepted by regional water authorities in Victoria and to a lesser extent elsewhere in Australia. This component of the NRHP, although yet to be developed, has the potential to be of major importance in ensuring that the results of biological water quality sampling are used effectively and efficiently. It is important that clear goals are developed by the NRHP technical advisory committee for the type of decision support systems they wish to see developed and their expected output.

It is noted here that the current administrative structure of the NRHP (see Figure 2.1) does not include a DSS component for the Environmental Flows subprogram, yet this is an area where DSS's could prove most valuable. It is likely that this is an oversight in the production of the figure, nevertheless, it should be recognised that some DSS and Delivery System funds will be required for environmental flows issues.

3.5.2.6 Urban Program

The Urban Program is an important part of the NRHP. Urban streams represent a special subset of the national river and stream system. Most are very degraded physically, chemically and biologically, and require a separate set or subset of indicators and tools to be developed. Estuaries are also important because most major urban areas in Australia are situated on estuaries. Our knowledge of Australian estuaries is less well-developed than for our rivers and streams and therefore the focus of the estuarine projects in the Urban Program on preliminary classification and evaluation projects is appropriate. The urban stream component should be viewed in a similar light and the focus of the program on preliminary classification and evaluation is also appropriate. For example, some urban streams are so degraded physically (*i.e.* concrete stormwater channels) that their is little

point including them in biological water quality assessment programs. Consequently, the development of an urban stream classification system (project S1) is an important first step in identifying which streams and stream sections to include in monitoring programs.

3.5.3 Environmental Flows

The main issue facing the Environmental Flows R&D Program of the NRHP is its lack of a structured framework. There are no clear program goals and it is not clear that all the necessary research questions are being addressed. Part of this problem is due to the later inclusion of existing environmental flows R&D projects into the NRHP and part is due to the early stage of development of the science & technology of environmental flows. As noted earlier, despite considerable research effort in Australia and overseas, little consensus has been reached on the uses for environmental flows and the technologies which are most appropriate.

To find a resolution to this problem, we have assessed the main needs of the users of environmental flows R&D, evaluated which of these are adequately met by the stated objectives of the R&D projects already in the EF Program of the NRHP, and then recommended actions to bridge the gap and therefore establish a more complete R&D program.

3.5.3.1 Users Needs

The users of the information generated from environmental flows research are mainly water authorities and environment managers. These groups have considerable immediate and long-term requirements for information regarding river and floodplain ecology to meet their environmental management responsibilities. This has recently risen in importance due to the corporatisation of the water industry (and now increasingly the environment industry as well) which is occurring throughout Australia. The significant impact of this has been the de-skilling of these agencies and a narrowing of their focus on core activities. Furthermore, the increased importance of the economic value of water in storage means that these authorities are now more reluctant to "experiment" with releases or allocate water to non-commercial clients (*e.g.* the environment).

The information needs of water managers are best summarised in terms of short-term needs (repackaging of information) and long-term needs (R&D), these are:

- Short-term Needs (Information Repackaging)
  - Packaging of Current Information
  - Definition of Environmental Flows
  - Development of a Framework for R&D and Implementation

- Long-term Needs (R&D)
  - Determination of Environmental Flows
  - Delivery of Environmental Flows
  - Determining the Social & Economic Costs & Benefits

3.5.3.1.1 Packaging of Current Information

The main immediate need is for presentation of ecological information in a way which can influence the management of water and other natural resources. We currently have a good understanding of many of the broad ecological processes which are environmentally important, and although it is incomplete, it could be applied to improve our current management of rivers and associated systems. This is not research, *per se*, however, innovative ways need to be found to effectively communicate this information which includes mechanisms which allow the information to be updated as new outcomes arise from on-going R&D.

3.5.3.1.2 Definition of Environmental Flows

While the definition itself is not particularly important, it is important that some common understanding of what the each party means when they use the term "environmental flows", and in particular, how will these flows be used. The resolution of this issue will solve some of the underlying conflicts which have held up the practical application of environmental flows and prevented consensus on what are appropriate techniques for determining environmental flows.

3.5.3.1.3 Development of a Framework for Environmental Flows R&D and Implementation

The resolution of the main uses and therefore a rationale for an environmental flows research program will enable the establishment of a substantial framework to assess and direct research proposals for future funding. A new method of establishing a framework for Environmental Flows R&D is required, as previous methods (conferences & workshops) have not been successful.

3.5.3.1.4 Determination of Environmental Flows

The determination of environmental flows is critical to the sustainable management of our river systems. Four major elements are necessary to provide information and technology to enable accurate determinations, these are:

1. Impacts of Flow Changes (natural & man-made)
2. Application of Existing Methods
3. Development of New Methods
4. Demonstrations of Ecology/Habitat/Flow Relationships

3.5.3.1.5 Delivery of Water for Environmental Flows

The delivery of water for environmental flows is central to their effectiveness. However, many logistical problems in delivering environmental flows exist in regulated river systems because of natural and irrigation channel constraints, natural and man-made barriers, demands and storage problems. Modelling and on-ground works - both of which will require research and development - may be necessary to facilitate the actual delivery of water to desired locations. Other areas which relate to the delivery of environmental water include the transmission losses along rivers, across floodplains, etc; the hydrodynamics of floodplain forests; and the multiple uses of environmental flows.

Research in these areas will require a concerted effort using a multi-disciplinary approach with river operation engineers, hydrologists and ecologists collaborating to achieve results.

3.5.3.1.6 Determining the Social & Economic Costs & Benefits

Social and political considerations are important as they will either limit or facilitate the allocation of water for environmental purposes. Furthermore, the economic evaluation of both water use by the environment and benefits as a result of providing Environmental Flows is another important factor in the decision making process. Research and development in the area of the social and economic aspects of environmental flows is required to assist the *allocation* process. The biological and hydrological information from R&D alone will not be sufficient to translate environmental flow *requirements* into environmental flow *allocations*. Nonetheless, the social and economic research must be closely aligned with the scientific research as listed above.

3.5.3.2 Needs met by the NRHP Environmental Flows Program

The stated objectives of the projects which have been funded under the NRHP were examined to assess the extent to which they covered the above user needs (Table 3.3). No assessment of whether the projects were actually meeting these objectives has been undertaken as this was beyond the project brief.

This assessment very clearly demonstrates that the current program only substantially addresses the ecological and hydrological aspects of environmental flows as well as exploring new methods of environmental flow determinations (point 4). Despite the excellent coverage of this broad need, only two or three projects will apply existing methodologies. This is a significant omission as these existing methodologies have resulted from over 30 years of research and have not been systematically tested or evaluated under Australian conditions (see section 3.2.2.1). It is likely that, at the very least, an evaluation of existing techniques will lead to a better understanding of the requirements of alternative methods for assessing environmental flow requirements.

Only two projects (CWN11 and GRU10) will provide repackaging of current information, but these will concentrate on aquatic vegetation and fish in Queensland. Therefore, there is a need to provide similar information on other components of the ecosystem (flows, fish, invertebrates, birds, microbes, *etc*).

Another important aspect of environmental flows relates to the investigations and modelling of the practical delivery of water for environmental flows. This is only partially addressed in two projects ((HEC1 & VCB1).

The remaining user needs which require addressing include of a definition and agreement on the uses of environmental flows, an integrated R&D framework and social and economic research. None of these are addressed by the current program.

Table 3.3: Matrix of User Needs and Current NRHP Environmental Flows R&D Projects

User Needs	Projects (LWRRDC Code)									
	GRU10	AWT3	HEC1	UMO23	VCB1	CWN11	UNE22	ACW1	CWN10	CEM2
1. Packaging of Current Information										
2. Definition of Environmental Flows (Agreement on uses of Environmental Flows)										
3. Development of a Framework for R&D and Implementation										
4. Determination of Environmental Flows										
a. Impacts of Flow Changes (natural & man-made)										
b. Application of Existing Methods						*partially*				
c. Development of New Methods										
d. Demonstrations of Ecology/Habitat/ Flow Relationships										
5. Delivery of Water for Environmental Allocations			*partially*		*partially*					
6. Determining the Social & Economic Costs & Benefits										

3.5.3.3 Bridging the Gap - Environmental Flows R&D and Implementation

The Environmental Flow Program of the NRHP has made a substantial start in addressing the user needs for scientific information concerning environmental flow determinations. Indeed, if all the projects addressing new environmental flow methods are successful, Australia will be placed at the leading edge of this research.

However, other defined needs are poorly addressed, and this deficiency will prevent the practical application and implementation of environmental flow recommendations. These deficiencies can be rectified by the provision of funds to undertake some short-term projects to provide information for managers and other funds to stimulate R&D in specific areas. Four major projects (both short- and long-term projects) are indicated in priority order below, although all are regarded as essential for the success of the Environmental Flows R&D Program.

1. Develop a framework for Environmental Flows R&D & Implementation.

A new method of establishing a framework for Environmental Flows R&D is required as previous methods (conferences & workshops) have not been successful. One option would be to establish a small focus group of researchers, managers (water & environment), and policy analysts. This group would undertake a number of tasks: (1) define environmental flows and uses of different types of releases; (2) undertake strategic consultation with key stakeholder groups to gain agreement on point (1) above and refine user needs; and (3) use the first two tasks to establish a broad strategic framework for environmental flow R&D and implementation.

2. Develop an information packaging project to provide managers with current information to assist with natural resource management.

A call for a project (or projects) which will develop information packages which will assist water managers in understanding the environmental needs of the systems they manage, as well as those which assist researchers and environment managers understand the operational issues and constraints. This information transfer will result in improved and more directed R&D as well as faster adoption of recommendations from this research. Innovative communication media should be used and multidisciplinary project teams with ecological, hydrological and communication skills are required for a successful result.

3. Application and evaluation of existing methods of determination of environmental flows.

The establishment of a project which applied a suite of existing techniques to a practical situation would allow an evaluation of these techniques and a demonstration to water managers. In addition, it would provide information for current R&D projects seeking to develop new environmental flow techniques which may improve the outcomes of these projects.

4. Establish 2 new R&D sub-programs to support the current program.

(i) R&D on water delivery

The actual delivery of water for environmental flows is central to their effectiveness, a factor often neglected when environmental flow studies are being conducted. Discovering and solving logistical problems will require investigations, computer modelling (resource allocation, system restraints) and possibly on-ground works and design (to modify systems to meet new requirements). This type of work will require research and development as traditional engineering techniques may not be suitable or existing techniques may require supplementing with new techniques. Certainly, this type of research will require a multi-disciplinary approach using river operation engineers, hydrologists and ecologists.

(ii) R&D on the social and economic aspects of environmental flows

Social and political research will highlight the factors which may limit or facilitate the allocation of water for environmental purposes. Economic R&D will enable techniques for the evaluation of the costs of water used by the environment and benefits as a result of providing environmental flows. Research and development in the area of the social and economic aspects of environmental flows is required to assist the allocation process. Significantly, this research must not be done in isolation, but closely aligned with the scientific environmental research already underway and in the planning stage.

4. Future of NRHP

4.1 NRHP funding

The future direction and development of the NRHP is highly dependent on the future of DEST funding. In the absence of continued DEST funding it is unlikely that the program could continue. In addition much of the momentum developed nationally, particularly in the MRHI would be lost or at least greatly diminished. It is clear from discussions with the representatives of the Lead Agencies involved in the MRHI in each State, that the States would be reluctant to commit the significant funds which are needed for the continued development of the RIVPACS model. The RIVPACS development is yet to yield any results so that if funding support should cease before the implementation of the model, State agency staff would be unable to demonstrate any progress to senior managers. In this climate the staff may be unable to convince their superiors that further funding for biological monitoring is warranted, particularly in a competitive funding environment.

In view of the recommendations of the COAG water industry reform Working Group, it is clear that the NRHP plays a critical role in the meeting of Australia's technology needs in environmental flow management. The MRHI component of the NRHP is also crucial in providing the technological tools required to fully implement the ANZECC water quality guidelines for assessment of ecosystem integrity. For these reasons and for the need to maintain the momentum developed by the NRHP in creating a national awareness of how riverine ecosystem health can be assessed and managed, *there needs to be a continued Federal commitment to fund the continuation of the NRHP to the turn of the century to ensure the widespread adoption of the NRHP technologies.*

4.1.1 Ownership of RIVPACS at a National and State level

An important issue that arose out of the second NRHP workshop in May 1995, was the future National ownership of RIVPACS. There is substantial concern amongst scientists involved in the NRHP nationally, that there is a lack of expertise in the State agencies to undertake the initial development and testing of the RIVPACS model. As mentioned above, in the UK, RIVPACS model development is managed and coordinated by the National Rivers Authority, who contract the Institute of Freshwater Ecology (IFE) to undertake the technical aspects of model development. In the UK the IFE occupies a role in relation to the Government, similar to that of the CSIRO Division of Water Resources in Australia. However, despite the fact that the Division does have some freshwater biologists in its employment, none are trained in, or have a demonstrated research interest in, river ecology, particularly with respect to macroinvertebrates. The only organisations with significant experience in either ecological statistics or macroinvertebrate and river ecology are the Co-operative Research Centre for Freshwater Ecology (CRC-FE) at the University of Canberra and Australian Water Technologies (AWT) Ensight (Sydney) and Water Ecoscience (Melbourne) Divisions. *Until the States develop the appropriate expertise, the initial development and management of the RIVPACS model should be centralised at the CRC-FE at the University of Canberra or at one of AWT's Divisions*. These organisations could set up the model on the Internet with a World Wide

Web site which would allow the States to download the latest versions of software when necessary. Contractual arrangements for the national management of the RIVPACS model should be managed through DEST.

4.2 Program Organisation and administration

Dr Peter Davies, the NRHP coordinator is employed 50% of his time to run the program. Although Dr Davies has done an excellent job, some of the participants in the program believe that the demands of the program have become so great that it will be difficult for him to adequately manage it. This situation will be exacerbated if the program is extended. *It is recommended that greater assistance be provided to Dr Davies in the form of an extra subprogram manager or managers. This will be essential if the program is extended.*

The current program structure has proven to be very effective in ensuring all the major components of the NRHP are addressed. The provision of R & D project management capabilities by LWRRDC has meant that there is a considerable body of experience available to ensure that the program is managed effectively. This has clearly been the case with the current program and *in the event of the program being extended, it should be continued to be managed through the program management committee involving LWRRDC.*

Dr Peter Davies has outlined his view of the strategic directions for the NRHP at the NRHP Strategic Directions Workshop held in September 1995 (see Table 3.4). *These recommendations provide a well-considered basis for the development of the second phase of the NRHP and with the exception of the funding of R & D into long term ecological processes, should be adopted by DEST.* Although important to the long term management of the Nation's rivers, this latter component needs a clearer framework and tangible goals before it is considered for funding. It may also be better managed through a separate program. Since much of the research would be of a relatively pure nature, partnership funding between agencies such as LWRRDC, various CRC's, and the Australian Research Council should be considered.

Table 3.4: National River Health Program future directions and estimated cost as proposed by Dr Peter Davies.

Program	Proposed Project	Funding required	Time period (years)
Monitoring River Health Initiative	First National RIVPACS assessment of river health and further reference site sampling	$6m	4
	First RIVPACS and DIPACS assessment	$0.75m	4
	Further taxonomic work	$0.5m	3
	Central site for RIVPACS model custodianship and development (seed money)	$0.3m	3
	Integration of RIVPACS output and developing diagnostic interpretation	$0.2m	2
	Further evaluation/integration of Waterwatch	$0.5m	3
Environmental Flows Program	'Building Block' exercise	$0.5m	2
	Training in IFIM	$0.2m	2
	Development of hydraulic modelling	$0.3m	2
	Development of wetland approaches	$0.3m	3
	Relationships between channel form and flow	$0.5m	3
	Biological responses to changing flow regimes	$1.2m	4
Microbial Indicators	Training in new techniques	$0.25m	3
	Microbial river health assessment demonstration	$0.5m	3
	New microbial technique development	$0.2m	3
	Links between changes in microbial and other biological communities	$0.2m	3
Ecological Processes	Establishment of several long-term multidisciplinary process-orientated R & D studies	$5m	7-10
Total		**$17.4m**	

4.3 Post Program Adoption Strategies - general

4.3.1 MRHI

According to budget plans supplied by Dr Peter Davies, there is currently, $450,000 of uncommitted funds earmarked for technology transfer under the MRHI. This includes $100,000 for a Video and demonstration tour, $150,000 for pilot studies, $150,000 for a comparative Waterwatch-MRHI study and $50,000 for the calibration of RIVPACS with other river health assessment techniques such as the 'State of Rivers' habitat assessment and the CRES/ANU river classification methodology. These initiatives will be important for the adoption of the technology. A particular issue identified in this study is the need to educate potential users on the value of RIVPACS and its output. Across Australia, the level of awareness amongst water resource agencies of the utility of RIVPACS was low, whereas the need to have better environmental flows technology was well understood. Although the program is reasonably well known in Victoria and New South Wales, this is not the case in Queensland. *If the MRHI program is to continue, there needs to be an ongoing commitment to technology transfer and education programs and these programs need to be tailored to the particular needs of each state.*

Although perhaps beyond the scope of this review, the adoption of the methods and tools being developed through the NRHP will be facilitated in each state if the state environmental regulatory agencies require industries, including water management agencies, to comply fully with the Australian Water Quality Guidelines (ANZECC 1992). The protection of aquatic ecosystems is one of the key components of the ANZECC guidelines and this is strongly underpinned by biological monitoring. The NRHP will provide the tools to meet these requirements.

4.3.2 Environmental Flows

The outcomes of Environmental Flows R&D can be implemented as the program progresses. The new projects suggested in section 3.5.3.3 include development of information packages for water managers so that they can improve their current environmental management practices. *There should be an on-going role for these information packages which are updated regularly and form part of a continuous education program for water managers and scientists.*

Much of the progress in the field of environmental flows is likely to come about through adaptive management. The experimentation which will be undertaken will occur, by necessity, on single unreplicated river systems with the need for substantial pre- and post-manipulation data sets. *Funds for monitoring systems should be made available to ensure authorities undertake rigorous programs and which share some common elements. This will enable an evaluation of many river systems which may result in information not available from single studies with limited focus.*

4.4 Role of DEST in NRHP

As a national program, the NRHP obviously needs to be administered through a Federal Government Department or federally convened council with members from each State and Territory and the Federal Government. The recommendation of which federal department or agency that should be responsible for this is beyond the scope of this review. There does appear, however, to be a need for greater coordination at the federal level of water-related environmental issues. For example, the issue of environmental flows could be considered of great relevance to DEST, the Australian Nature Conservation Agency (ANCA) and the Department of Primary Industries and Energy.

Despite these concerns, the overall management of the NRHP appears to be effective and if further funding is provided to continue the program it may be most efficient to continue with existing management committee arrangements involving DEST and LWRRDC.

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APPENDICES

- NRHP BUDGET - 31st DECEMBER 1995

- SAMPLE QUESTIONNAIRE FORMS