Research and development needs for river restoration in Australia

Report to the National River Health Program Management Committee of the Land and Water Resources Research and Development Corporation, Canberra

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Published by:

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

Publication data:

'Research and development needs for river restoration in Australia' by Ian Rutherfurd, Anthony Ladson, John Tilleard, Michael Stewardson, Sarah Ewing, Gary Brierley and Kirsty Fryirs, Occasional Paper 15/98.

ISSN 1320-0992

ISBN 0 642 26728 6

Typesetting: Mastercraft, Canberra

Printing: Communication Station, Canberra

November 1998

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Acknowledgements

This project was initiated by Dr Nick Schofield (LWRRDC), and we thank him for his patience and assistance. We are also indebted to Bobbie Heath of LWRRDC and John Molloy (CRCCH) for managing the administration of the project with good humour!

We would like to thank the following people for contributing to the development of this report, both by reading drafts, and by constructive discussions: David Perry, Phil Price, Sam Lake, Chris Gippel, Barry Hart, Brian Finlayson, Ross Hardy, Sandra Brizga, John Koehn, Bob Newbury, Jane Doolan, David Outhet and Rebecca Bartley; among many others.

We thank the many stream managers and catchment management officers around Australia who replied to a questionnaire regarding stream rehabilitation R&D needs in their regions.

We also sent out a request for contributions over the email list of the Australian Society of Limnologists and received valuable replies. Many thanks to the people who made contributions.

Best regards

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SECTION 1

Summary of report

This is a report on research and development needs for stream restoration in Australia. The report was prepared by the Cooperative Research Centre for Catchment Hydrology (CRCCH) and attempts to provide information required for the development of a national stream restoration program by the Land and Water Resources Research and Development Corporation (LWRRDC), Canberra.

Stream restoration (as defined below) is the manipulation of the physical and hydrological character of a stream with the intention of returning some, or all, of the streams original physical and ecological values. Since it is usually impossible, in all but the rarest cases, to restore the original condition of an Australian stream, we use the term 'stream rehabilitation' throughout the document.

Current Situation

In Australia, stream rehabilitation is a developing area of endeavour. Although there are good examples of stream rehabilitation projects, there is considerable scope for enhancement and development of stream rehabilitation practice. To date, stream rehabilitation in Australia typically exhibits:

1. goals that are narrow, unclear or unrepresentative;
2. inadequate communication amongst and between practitioners, researchers and managers;
3. poor recognition of the multi-disciplinary nature of the task;
4. inadequate use of professional resources and knowledge;
5. poor evaluation of the effectiveness of works or activities.

The future

This report outlines some proposals to help overcome these problems, with particular emphasis on the resources and approaches available to LWRRDC to implement these proposals. The aim of the proposals is to develop stream rehabilitation as a recognisable area of expertise that:

1. is clear about its goals and how to apply them to river rehabilitation projects;
2. draws effectively on a wide body of knowledge from the relevant sciences including stream ecology, geomorphology, hydrology, and engineering;
3. is able to apply this knowledge successfully to rehabilitation of streams throughout Australia, and;
4. is able to learn and improve by monitoring the success of Australian and international stream rehabilitation activities.

Background

Since European settlement, many Australian streams have been modified to provide regular water, reduce flood damage, and to limit inconvenient erosion and sedimentation. Catchments have been cleared and urbanised and riparian areas degraded. Many of these changes have been made to meet the utilitarian demands of society, often at the expense of the environmental values of streams. The extent of environmental degradation in streams since European settlement is now recognised in reports such as the National State of the Environment Report 1996.

The demand for more environmentally oriented stream management is growing and there is a new enthusiasm to rehabilitate our streams. This is reflected in funding from the Natural Heritage Trust (NHT) of over $90 million over five years, that is aimed at improving water quality, physical condition and the ecological health of Australia's river systems. This money will be at least matched by funds coming from state and local governments. Successful outcomes from the expenditure of all of this money and enthusiasm will be enhanced by a focused effort to improve our understanding of the needs and processes of good stream rehabilitation in the Australian context.

This report:

Following the terms of reference, this report:

1. Details a holistic framework within which stream rehabilitation should be conducted which encompasses the bio-geographic variation across Australia;
2. identifies sound, sustainable stream rehabilitation techniques world-wide and recommends a strategy for their promotion and demonstration in Australia;
3. describes stream rehabilitation projects in Australia, the organisations involved and the status of these projects;
4. recommends a process for identifying which stream rehabilitation concepts and techniques would be worthy of future research;
5. recommends how the stream rehabilitation sub-program within LWRRDC can be most effectively interfaced with the NHT, in particular in the sense of providing sound, sustainable techniques for onground works; and
6. identifies other organisations that may wish to partner this sub-program.

Scope of this report

Restoring our streams involves providing environmental flows and improved water quality, improving catchment condition, improving the condition of riparian zones, and physical improvement of the stream channels themselves (eg. fish passage, habitat, stability, low sediment loads etc.). Research into all of these activities falls within the National River Health Program. This report is concerned predominantly with the last of these issues: **improving the physical and ecological condition of stream channels in Australia**. In general these activities can be summarised as returning some of the original structural and hydraulic complexity to stream systems so that they can sustain complex ecological communities. Typical structural activities under this umbrella would be revegetation of channels, re-introduction of large woody debris, construction of artificial habitat structures, manipulation of the bed and banks so as to improve ecological condition, and removing barriers to fish passage. Other key issues, such as environmental flows, are covered in other LWRRDC reports.

It is important to emphasise that this document is not a comprehensive review of the basic research required for successful stream rehabilitation in Australia. This task was not in the terms of reference. Although we have compiled a list of research needs in Appendix 6, this is not a comprehensive review. A thorough review of research needs should be completed, but we would stress that this research must sit within a conceptual framework that is provided by this report.

SECTION 2

General principles that should guide stream rehabilitation in Australia.

The following points cannot be described as 'actions' for LWRRDC, but they provide some guiding principles (lessons if you like) from past practice and international experience, that should be considered in developing a stream rehabilitation program.

- Stream rehabilitation is about attempting to restore the physical, hydrological, hydraulic and biological complexity of stream systems in an effort to develop sustainable ecosystems—it is not just about having stable, attractive streams.
- It is unlikely that we can ever restore any Australian streams to their original condition.
- Protecting the remaining pieces of stream that are in good condition should almost always take precedence over attempts to rehabilitate damaged reaches. This principle applies at a national scale meaning that resources may need to be expended in remote regions where there is no apparent human benefit.
- Stream rehabilitation is a subset of catchment management. Streams cannot ultimately be rehabilitated in isolation from improvement in the condition of the catchment.
- It has taken us nearly two centuries to reduce our streams to their present parlous state—it will take at least as long to rehabilitate them. We must look upon stream rehabilitation as taking decades, rather than years, to accomplish.
- For the time being, we recommend concentrating Australia's comprehensive stream rehabilitation efforts to smaller streams in which there is a good chance of success, and in which variables can be controlled and measured. Rehabilitation of large streams is likely to be so expensive and problematic that efforts should be restricted to flow and water quality issues. Obviously there will be exceptions to this principle, where simple changes to a large stream can produce great ecological benefits, or where the publicity value of the project may outweigh the technical challenges.
- The main reasons for failure of stream rehabilitation projects are, poor definition of project objectives, wrong diagnosis of the real problem in a stream, or failure to consider the catchment context of works. The easiest part of a stream rehabilitation project is the selection of the tools to fix the problems in the stream (eg. particular structures), yet this is often the issue that attracts most R&D attention. Again, often the main impediment to stream rehabilitation can be social and political factors rather than poor understanding of what to do.
- Stream rehabilitation efforts should target the 'limiting variable' for recovery first. In most cases you would check variables in the following order: water quality, hydrology, hydraulics, interaction with the floodplain, and habitat condition.
- All stream rehabilitation projects must have some evaluation of success, and a few selected projects must be rigorously evaluated so that we can have a high level of confidence in the outcomes. Few projects have been evaluated in the past.
- One of the key advances that can be made in stream rehabilitation practice in Australia at present is the development of well evaluated 'flagship' projects that attempt to rehabilitate long reaches of stream. These projects must be a focus of research.

- Australian streams and their biota are different in many ways from Northern hemisphere streams. Physical differences, as well as political and resource differences, mean that we must evaluate international experience critically.
- Stream rehabilitation requires input from many previously disparate disciplines and groups. Because stream rehabilitation is a young and evolving activity, communication and interaction between these groups is poor. Stream rehabilitation is yet to develop as a mature discipline.

SECTION 3

Suggested priority tasks for LWRRDC

Table 1 on page 6 sets out the tasks that we would recommend LWRRDC do to encourage stream rehabilitation in Australia, and the order that they do could do them in. We acknowledge that LWRRDC has limited resources. LWRRDC's role is to provide information to the industry, encourage targeted research, act as a coordination agency between the states, and raise the profile of the issues around stream rehabilitation. LWRRDC may also be able to influence the distribution of resources under programs (such as the Natural Heritage Trust). Thus, most of the following activities will have to be achieved by funding research projects that will then act as a basis for action by other agencies, eg. state agencies or management authorities. To this end it is essential that any end-users of the research are included in the research from the outset, wherever possible. Other opportunities for LWRRDC to 'lever' rehabilitation outcomes with limited resources are discussed throughout the document.

Not all recommended action are included in the table. See specific sections of the main report for a full list of actions.

We have attempted to prioritise the tasks on the basis of importance, as well as on returns for effort. You will note that the highest priority tasks (after developing the structure of the program) relate to identifying and preserving reaches of stream that are still in good condition. This is much more cost effective than rehabilitating damaged streams.

Key recommendations for LWRRDC

During the process of addressing the above issues we have developed a series of recommendations that are documented in the main body of the report. *Our key general recommendations are listed here. More specific recommendations, actions, and approaches, are suggested within boxes in the body of the report.* In summary we recommend that LWRRDC facilitate R&D that will:

1. clarify stream rehabilitation goals;
2. use the best available scientific and technical information in stream rehabilitation practice;
3. develop basic and applied research that will assist with the practice of stream rehabilitation
4. encourage monitoring that will allow us to learn from the success and failure of stream rehabilitation projects; and
5. improve communication about stream rehabilitation.

We propose that these recommendations be implemented through a National River Restoration Reference Panel. This panel, resourced and appointed by LWRRDC, would have a full-time National River Rehabilitation Coordinator to develop and implement the strategies described below. In addition, specific advances can be made by interfacing directly with the NHT process.

Clarify stream rehabilitation goals

This report and appendices reveal a need for the goals of stream rehabilitation activities to receive some careful attention. Appendix 1 presents the advantages of being clear about stream rehabilitation goals, Appendix 3 calls for clear 'problem definition' as part of stream rehabilitation projects, and Appendix 7 comments on the desirability of detailed 'needs assessments'.

Table 1
Tasks for LWRRDC in establishing a research and development program for stream rehabilitation in Australia (the tasks are roughly ranked in order of priority)

Tasks	Magnitude of the task (1 large to 5 small)	Discussed in this section of the document:
1. Employ a person to coordinate the program	5	10
2. Appoint a national stream rehabilitation reference panel (SRRP) to advise on LWRRDC's R&D program	4	10
3. Ensure close coordination between environmental flow research programs (eg. the River Health program under Environment Australia) and this stream rehabilitation program.	4	11
4. Develop a proposed research strategy for the program that can receive wide consultation.	4	10
5. Identify and preserve stream reaches that remain in good condition.	2	4, 10
6. Encourage research into approaches to preserve remnant reaches of stream that are in good condition (both legislative, administrative and physical).	4	4, 10
7. Urgently review the successful and proposed NHT projects (or other stream projects carried out nationally) to identify projects that could provide vehicles for research and evaluation. Provide **extra** funding for these projects so that they can be redesigned as stream rehabilitation experiments in association with qualified scientists.	2	6, 10
8. Encourage the establishment of key 'flagship' stream rehabilitation projects to act as both trial and demonstration projects, and to act as a focus for research and publicity.	2	6, 10
9. Investigate existing state and federal legislation that influences stream rehabilitation to see whether sufficient legislative power exists to rehabilitate streams. Also consider the application of international legislative models to Australia.	4	8
10. Review existing guidelines and practices for works and activities in and around streams that will impact on stream condition (eg. road culvert design). The aim is to prevent continuing damage to streams while we are busy trying to fix them.	3	5
11. Update the Guidelines for Stabilising Waterways (Standing Committee on Rivers and Catchments 1991) to include broader ecological considerations.	3	10
12. Develop tools that will assist managers to plan successful stream rehabilitation projects (including tools that allow managers to predict the impact of change to variables at different scales)	1–2	5, 10
13. Develop a training strategy based on existing knowledge (eg. Brierley catchment approach, stream rehabilitation manual, etc.).	4	5, 10
14. Develop secondment system where officers from state agencies are identified as stream rehabilitation project officers and are seconded to LWRRDC projects	4	10
15. Establish a *stream rehabilitation clearing house* to act as a nerve centre for the industry	4	10
16. Review international work in stream rehabilitation (physical, biological, administrative and legal).	4	7
17. Encourage and sponsor visits by international experts in all aspects of stream rehabilitation	5	7

In short, the goals of stream rehabilitation, which involve ecological sustainability, and bio-diversity, are very much secondary goals on the agendas of most stream management agencies. Flooding, water quality, water quantity, and erosion are the dominant goals of stream management in Australia today. Ecological issues are much discussed in strategy plans, mission statements, and policy speeches, but they are seldom central to the allocation of resources. This is true at national, regional, catchment, reach and site specific scales.

A key conclusion of this report is that perfect knowledge about how to rehabilitate stream systems will not help much if bio-diversity and geo-diversity are not considered valuable goals of management in their own right. How does LWRRDC encourage this fundamental change in perspective and priorities amongst catchment managers, politicians and other decision makers? We recommend the following:

1. encourage 'flagship' demonstration projects that can catch the public imagination and so gradually change the management priorities (see Section 10)
2. investigate existing Australian legislation to see if it reflects broader stream rehabilitation objectives (Section 8);
3. examine examples of *international legislation* that could provide ideas and approaches for Australia (Section 6).
4. instigate *training*, as described in the report, that will change manager's perception of what is possible in rehabilitating streams (Section 10);
5. provide *training* for state and regional assessment panels in assessing NHT proposals (Section 10); and
6. develop *planning frameworks* that adequately reflect broader ecological goals when goals and objectives are set in strategic planning for stream management (Section 10).

The other key issue about goals is that most stream rehabilitation work across the country targets the reaches of river that are in the *worst* condition. Stream rehabilitation should usually be protecting the *best* reaches of stream first, followed by reaches that threaten these good reaches, and so on. LWRRDC should ensure that its research emphasises the identification and preservation of stream reaches that remain in good condition, as much as the traditional emphasis on the worst reaches of stream (Section 5).

Make use of the best available scientific and technical information

Stream rehabilitation is a multi-disciplinary activity that requires input from a range of scientific fields including geomorphology, hydrology, and stream ecology. It also draws on engineering skills for design and construction as well as skills in community consultation, land management and planning. In common with other areas of natural resources management, encouraging exchange of information between disciplines is a key to efficient and effective outcomes.

The following recommendations are made to encourage use of the best available information in stream rehabilitation projects.

- Establish a clearinghouse for the collation and dissemination of national and international information about stream rehabilitation (Section 10).
- Use the results from evaluations of projects, along with expert input, to develop, document and promote Best Practice in stream rehabilitation. This would lead to progress in stream rehabilitation guidelines (Section 10).
- Continue to develop and publish guidelines for stream rehabilitation. These would make use of existing publications and build on work that has already been published by LWRRDC (Section 10).

- Develop integrated approaches to planning stream rehabilitation projects that incorporate the best aspects of the existing suite of planning tools (Section 5).
- Continue the practice of supporting visits by international scientists and practitioners, but include visits by senior managers with strategic experience and successful community motivators. Trial and critically evaluate international approaches to stream rehabilitation where appropriate (Section 7).
- Undertake a review of the international stream rehabilitation scene, especially in N. America and Europe (including science, legislation, and administrative approaches). Document implications for Australian stream rehabilitation activities (Section 7).
- Undertake a thorough review of research and development requirements amongst leading practitioners, scientists and managers. There are numerous R&D requirements for stream rehabilitation, and many of these relate to a basic understanding of stream ecology and physical processes (particularly outside of coastal South-Eastern Australia and Murray–Darling Basin). There is also equal need for work on the social, legislative, and political aspects of the stream rehabilitation process (Section 5). Some ideas are listed in Appendix 6.

Develop basic and applied research to assist with the practice of stream rehabilitation

We have identified four basic areas requiring research in stream rehabilitation:

1. problem recognition (planning approaches, setting goals objectives and priorities, methods for measuring benefits, project evaluation protocols, legislation, administrative structures, community);
2. basic and applied research into ecological and physical processes in streams ;
3. approaches to technique selection (methods to select appropriate rehabilitation strategies including decision support systems and development and communication of guidelines); and
4. stream restoration techniques (eg. guidelines for establishing vegetation, techniques for improving physical habitat, alternatives to willows for erosion control).

Appendix 6 lists some projects under each of these headings. A variety of consultative approaches are described that would increase the number of projects described in Appendix 6 (Section 7). In terms of priorities, we would emphasise the first two of these research groups as needing the most research at present.

It is fair to say that we do not, at present, have the basic knowledge to predicably reconstruct naturally functioning and sustainable stream systems. Even after many decades of this type of work overseas, the same conclusion can be drawn. Without doubt the major advances can be made by effective and rigorous monitoring of rehabilitation projects (see next section).

Learn from stream rehabilitation activities

Learning from the successes and failures of national and international projects will be important in improving the quality of stream rehabilitation work. Effective evaluation of stream rehabilitation projects is rare. Major advances in stream rehabilitation in Australia are likely to come from the experience and evaluation of a few comprehensive stream rehabilitation projects across the nation, rather than from many small projects.

1. Select and sponsor major stream rehabilitation projects to develop as fully planned and evaluated *demonstration projects* (Section 10). This would preferably involve the rehabilitation of the majority of a catchment rather than short reaches of stream and could be done in conjunction with other funding agencies. There are many organisations that could be partners with LWRRDC in this work, particularly amongst urban stream management agencies (Section 11).

2. *Add value to NHT projects*. There are major R&D opportunities within the NHT process. By coupling NHT projects with research activities (eg. design and evaluation) LWRRDC can make major advances in stream rehabilitation. Using the NHT project proposals, identify a range of project types in different regions and develop a hierarchy of projects that are sponsored to carry out evaluation. This hierarchy of projects should include sufficient coverage of stream problem types, and geographic regions that it produces general results that are applicable nation wide (Section 10,11).

3. Ensure that stream management projects that have a stream rehabilitation component are *reviewed* by a broad range of people, with a wide range of expertise before onground work begins. This would ensure that the projects realise their full potential. To this end, :LWRRDC could establish *accredited review teams* around the country.

4. Work with other funding agencies such as NLP and NRMS to encourage effective evaluation of stream rehabilitation projects. Another requirement is the development of evaluation procedures and protocols that are appropriate for the full range of stream rehabilitation projects (Section 10).

Improve communication about stream rehabilitation

Currently there is little information exchange about stream rehabilitation in Australia. Improving communication in this field is major opportunity.

It is recommended that LWRRDC develop a communications strategy for stream rehabilitation. Suggested activities include the following.

1. Establish training programs in stream rehabilitation. These programs would be based on guidelines and best practice.
2. Develop a register of rehabilitation work undertaken across the country to act as a basic database for future projects.
3. Establish an exchange program between Australian institutions and agencies, and selected international sites.
4. Initiate and publicise a national prize for stream rehabilitation (the ‘River Health Prize’).
5. Publish simple guidelines (eg. a pamphlet) of the basic features required for an acceptable stream rehabilitation project proposal
6. Identify situations in which management practices of other agencies that impact on streams damage streams (eg. field manuals for road construction recommend culvert designs that stop fish passage)

Implementing these recommendations

We have considered the mechanisms for implementing the strategies described above and recommend the following two proposals to LWRRDC as key actions to promote development and adoption of best practice in stream rehabilitation in Australia.

First, we suggest that LWRRDC initiate and sponsor a few major stream rehabilitation projects in Australia. These would be experimental projects, on small to medium sized streams, that would be cooperative ventures with many organisations. They would demonstrate best-practice in planning, evaluation and execution. These would serve as flagship projects that would transfer technology, but most importantly, they would capture the imagination of the country.

Our second suggestion is that LWRRDC sponsor the establishment of a National Stream Restoration Reference Panel to provide a focal point for the development and dissemination of knowledge of stream rehabilitation practice nationally. The objectives of the panel would be to:

1. clarify stream rehabilitation goals and promote development and application of rigorous needs assessment for setting the goals of stream management projects;
2. facilitate use of the best available scientific and technical information in stream rehabilitation practice;
3. encourage monitoring so that we can learn from the successes and failures of stream rehabilitation projects; and
4. improve communication about stream rehabilitation amongst and between practitioners, researchers and managers.

The panel would be expected to use the recommendations of this report as guidelines in the achievement of its objectives.

We propose that the panel would be small (say four members) and multi-disciplinary; appointed and financed by LWRRDC and supported by a full-time national river rehabilitation coordinator. An alternative to this structure is to appoint a panel of stream rehabilitation experts from each state (as is found in the present Riparian Zone Program Steering Committee). This would ensure the critical interaction between state agencies, practitioners and researchers.

The full-time national river rehabilitation coordinator would report to the reference panel. The coordinator would be responsible for developing and implementing strategies under the direction of the panel, and may also manage the stream rehabilitation clearing house (alternatively this job could be contracted out).

Specific interfaces with the NHT

The NHT program provides a major opportunity for progress in the fledgling stream rehabilitation industry in Australia. LWRRDC should take advantage of this opportunity by influencing the NHT process. We have mentioned the option of developing core projects within NHT, but are not blind to the difficulties of influencing the State and Regional Assessment Panel process. A related approach is to :

1. Provide training and tools that can be used by the state and regional assessment panels to assess the merits of various projects. Influencing those panels is a way to influence the NHT process.
2. Develop scientific reference panels that can assist in reviewing NHT proposals.

Which streams to rehabilitate?

Given the limited resources for stream rehabilitation in Australia, and the high cost of this type of work, it would probably be unwise to attempt the general rehabilitation of large streams. Whilst it is highly desirable in the long term to rehabilitate a stream like the Murray River, this would be likely to sap the limited resources of the nation for this type of work. This is especially true when there is little guarantee of success. At this stage we would recommend concentrating our efforts on streams of manageable size, where a large proportion of the stream length can be treated, response times are short (decades?), and it is possible to measure results and control variables. Also, we would recommend concentrating on low to moderate energy streams that are easier to manage.

Whatever scale we work at, it is important to realise that stream rehabilitation is a long process. We cannot expect results in a few years. Thus, stream rehabilitation requires a commitment of decades from the government, the community, and from researchers. Gaining political and public support for projects of this duration is a fundamental challenge for LWRRDC.

Introduction to the main report

This is a report to the National River Health Program Management Committee of the Land and Water Resources Research and Development Corporation by the Cooperative Research Centre for Catchment Hydrology and the Centre for Environmental and Applied Hydrology. The report addresses research and development needs in river rehabilitation in Australia.

Since European settlement, Australians have modified the few streams of this driest of inhabited continents to provide regular water, to reduce flood damage, and to limit inconvenient erosion and sedimentation. Many of these changes have been made to meet the utilitarian demands of society, often at the expense of the environmental values of streams. The extent of environmental degradation in streams since European settlement is now recognised in reports such as the National State of the Environment Report 1996. It is clear that in many cases the ecological integrity and diversity of our stream systems has suffered. Today we are embarking on a new endeavour—the *repair* of some of the environmental damage that we have done to our streams. Unfortunately there is limited knowledge and experience in the environmental rehabilitation of Australian streams.

Over the next five years the Federal government program, the Natural Heritage Trust (NHT), will inject $260 million into catchment management initiatives. More than $90 million of this money will be directed at projects that aim to restore the ecological and physical condition of Australian rivers and streams. This amount of expenditure will be at least matched by expenditure by state governments, catchment management agencies, and urban stream managers. The Land and Water Resources Research and Development Corporation (LWRRDC) is responsible for providing research and development (R&D) related to Australia's water resources and stream systems. The purpose of this report is to advise LWRRDC on some aspects of the R&D required for stream rehabilitation in the context of the large expenditure of NHT money, and the growing interest in stream rehabilitation generally.

Scope of the report

This report addresses the following six tasks described in the project brief:

1. Describe a holistic framework within which stream rehabilitation should be conducted which encompasses the bio-geographic variation across Australia;
2. Identify sound, sustainable stream rehabilitation techniques world-wide and recommend a strategy for their promotion and demonstration in Australia;
3. Describe stream rehabilitation projects in Australia, the organisations involved and status;
4. Recommend a process for identifying which stream rehabilitation concepts and techniques would be worthy of future research;
5. Recommend how the stream rehabilitation sub-program within LWRRDC can be most effectively interfaced with the NHT, in particular in the sense of providing sound, sustainable techniques for onground works;
6. Identify other organisations that may wish to partner this sub-program.

At the beginning of the document we also include an additional discussion about what stream rehabilitation is.

Implications of each section for LWRRDC are contained in boxes throughout the text. In the same boxes are recommended ***ACTIONS*** for LWRRDC to take, along with some suggestions on how to implement the action included as a **METHOD** section.

What is research and development?

The following definitions are in this report.

1. Research into stream rehabilitation is any activity that helps us to better understand how and why things are the way they are, how and why things happen, or how, why and when to apply particular rehabilitation techniques.

2. Development is transforming that knowledge into a form that can be applied in decisions and active management. It is important to emphasise that useful R&D can come from many quarters, not just from universities and research institutes.

Data collection is not, of itself, research or development. Collection of information must be done within the framework of a measurable objective or hypothesis (eg. a doubling of fish numbers within five years) to constitute R&D.

Structure of the report

Several people have contributed to this report. Each of the six tasks described in the project brief has been addressed in one or more appendices provided by team members. The key arguments have then been crystallised into this synthesis document. Although the summary reflects the contribution of the authors of the appendices, not all of the contributors necessarily agree with everything in the synthesis. Thus, responsibility for content and omissions in the summary remain with the principal authors.

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Synthesis and recommendations	Synthesis	Ian Rutherfurd Tony Ladson John Tilleard	CRCCH, Monash Univ CEAH, Univ of Melbourne CRCCH, Univ of Melbourne
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Framework for sediment management	Appendix 2	Gary Brierley Kirsty Fryirs	Macquarie University
Framework for stream rehabilitation design	Appendix 3	Michael Stewardson	CRCCH, Univ of Melbourne
International experience in stream rehabilitation	Appendix 4	Ian Rutherfurd	CRCCH, Monash University
Current rehabilitation projects in Australia	Appendix 5	Ian Rutherfurd	CRCCH, Monash University
Process to identify R&D needs	Appendix 6	Tony Ladson Ian Rutherfurd	CEAH, Uni of Melbourne CRCCH, Monash University
Approach to ensure success of onground works	Appendix 7	Sarah Ewing	CEAH, Univ of Melbourne
List of contacts in stream rehabilitation	Appendix 8		

What is stream rehabilitation?

Stream rehabilitation is part of total catchment management. Stream rehabilitation aims to re-establish elements of the original physical complexity (eg. substrate, pools and riffles etc.), hydraulic complexity, hydrological complexity required to sustain appropriate biological systems in the long term. In many cases, this is only possible if catchment condition does not compromise the condition of a stream reach.

The size of the task

Even if it were desirable, it would be impossible to return all Australian streams to their original condition. Here are some statistics that provide a snap-shot of the condition of our streams.

1. A review of Victorian streams found that 27% of all Victorian streams were in 'poor to very poor' condition (as judged by a range of environmental indicators), with 65% of streams in cleared areas being in this category (Mitchell 1990). This represents 17,000 km of streams.

2. Over 36% (135 km) of the length of streams in the Maroochy River in Southern Queensland are categorised as being in very poor to highly degraded condition using the 'State of the Rivers' methodology (Anderson 1993).

3. Up to half of the available aquatic habitat in the coastal catchments of SE Australia has been obstructed by artificial barriers (Harris 1984). In Victoria over 2,500 barriers to fish movement have been identified (O'Brien 1996)

Stream rehabilitation in practice

Throughout this report we emphasise that the key constraint to the recovery of sustainable stream ecosystems is often well defined goals. Thus it is important that we define clearly what we mean by the various terms used to describe this type of work. Throughout this document we have used the term 'stream rehabilitation', whereas, 'stream restoration' is more commonly used in the United States. The US National Research Council (1992) argues that to ***restore*** an aquatic ecosystem, all functions and structural characteristics must be considered and that the ***fundamental goal of stream restoration is to return the stream to a condition that resembles its natural state as closely as possible***. It is recommended that the term 'restoration' should be applied only to those activities directed to rebuilding an entire ecosystem. According to National Research Council (1992), restoration projects

1. are self-sustaining,
2. do not manipulate elements in isolation,
3. seek to re-establish the pre-disturbance aquatic functions and related physical, chemical and biological characteristics,
4. are likely to involve reconstruction of antecedent hydrological and morphological conditions, and biological manipulations including revegetation, and
5. address the causes of degradation.

Whilst it would be ideal to truly 'restore' our streams it is much more likely that we can return only some elements of the pre-disturbance condition. Such partial restoration should be described as 'rehabilitation'. The terms 'enhancement' and 'creation' should be used to describe projects that aim to provide a higher quality ecosystem rather than recovery of the pre-disturbance state (Brookes and Shields 1996). 'Enhancement' is the improvement of isolated structural or functional attributes. Creation is the 'birth' of an entirely new ecosystem.

The following examples illustrate the distinction between river enhancement, rehabilitation and restoration.

1. Increasing the availability of pool habitat through the use of some artificial structure that causes bed scour is an example of habitat **enhancement**.

2. Re-instating pre-disturbance woody-debris volumes in a channel subject to ongoing flow regulation and flood control is an example of river **rehabilitation**.

3. Environmental flow management, wetland management, revegetation of streambanks and fencing are all likely to be required for **restoration** of a lowland river ecosystem subject to regulation.

Because stream restoration is so difficult to achieve, this document concentrates upon stream *rehabilitation*, and uses that term.

What stream rehabilitation is not …

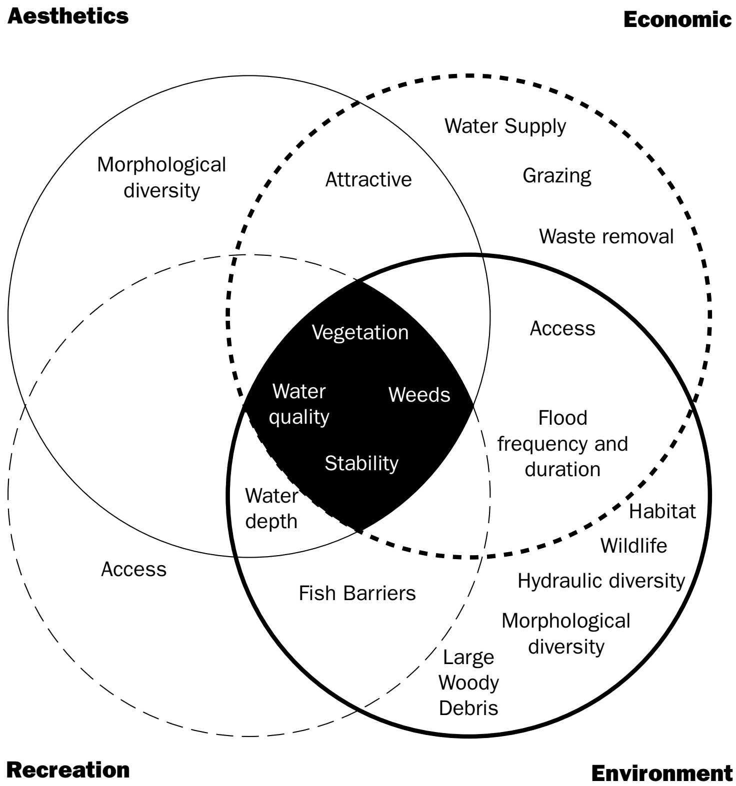
It is important that rehabilitators, and LWRRDC, are very clear about the purpose of rehabilitation work. To do this we need to consider what stream rehabilitation is not. There are four basic goals that drive most stream management work in Australia (Figure 1). Management attempts to maintain or improve:

1. ecological/environmental values (eg. physical habitat for organisms),
2. economic production and economic security (eg. reducing loss of farm production from flooding and land loss),
3. aesthetic values, (eg. stream beautification), and
4. recreational values (eg. water skiing, fishing, swimming).

There are many ‘components’ that make up each of these ‘values’ and many of these components are shared between the four basic goals (Figure 1). Thus, water quality, water depth, revegetation, fish, weeds, and stability are usually relevant to all of the goals, but to different degrees. Although the fundamental goal of stream rehabilitation is to protect and improve environmental values, other goals may be advanced in the process. For example, a stable stream is advantageous for both farm production and stream ecology. But absolute stability (eg. full rock lining) will often not advance environmental recovery. Again, some people will take the view that a ‘rehabilitated’ stream should look clean, manicured and somehow ‘English’. In reality, in Australia, an ecologically desirable stream will probably look ‘messy’ and unmanaged. This may not fulfil the goals of land managers who take pride in a property that looks clean and organised. Fishermen may see good trout stocks as a measure of a healthy river, and a goal for management. Trout are an exotic fish, so we do not see improving trout stocks as being a goal for rehabilitated streams.

Note that most stream management work in Australia is dominated by the activities *that are common to all four of the goals* shown in Figure 1, that is: stream stabilisation, water quality, revegetation, and weed control. This is because these activities, understandably, have the widest appeal to government and community groups. It is important to emphasise that concentrating on these ‘overlap’ areas does not always further environmental goals. Stream rehabilitation is about ecological sustainability and it is important that this primary goal is not diluted by always pursuing the easier ‘overlap’ goals.

Figure 1
The four basic values for which streams are managed with their shared and un-shared components.



Implications and actions for LWRRDC

1. As a manager of R&D in the water industry, it is critical that LWRRDC is very clear about the goals and objectives of projects that it supports. There is no doubt that pursuing economic security type goals for stream management will deliver some ecological benefits, but this type of project should not masquerade as a stream rehabilitation project if it does not lead to more general ecological benefits.

2. Since most of the work that goes on in streams in Australia is for erosion control (see Appendix 5) a key task for LWRRDC is to ensure that this work is done in such a way that it leads to maximum environmental benefit.

3. A critical implication of taking an 'ecological' perspective to stream management is that preservation of streams that remain in good condition becomes a higher priority for funding than does patching-up the most damaged section of a stream (discussed below).

- **ACTION**: LWRRDC should support research that attempts to identify areas for preservation as well as research into repairing damaged reaches. (Methods to achieve this are discussed later)

- **ACTION**: LWRRDC should decide at a policy level the features of a project that would identify it as being true stream rehabilitation as opposed to local erosion control. Some central features would include:

  Any works should treat the problems of a reach and not a point (thus protecting a single eroding bank must have clear justification, or be part of a broader strategy)

  Any works should produce a sustainable improvement in the physical and ecological function of the stream

We now address the six specific tasks identified in the consulting brief.

A holistic framework for stream rehabilitation

The Task: What is a holistic framework within which stream rehabilitation should be conducted which encompasses the bio-geographic variation across Australia?

(See Appendices 1, 2 and 6 for detailed discussion of this question)

This question does not relate only to stream rehabilitation R&D, but more specifically to all stream rehabilitation activities. We understand this question to mean “how can LWRRDC assess the adequacy of stream rehabilitation proposals in general”? This assessment must take place within some framework.

We would argue that an adequate framework for stream rehabilitation must incorporate two elements:

1. a rigorous planning framework.
2. a physical framework (that assists managers to identify the correct priorities and actions in a catchment)

Planning framework

Appendices 1 and 2 describe planning frameworks for stream rehabilitation projects.

Hierarchy of stages in a river rehabilitation project

For a river rehabilitation project to be successful and effectively targeted there is a hierarchy of stages to be negotiated. These are represented in Figure 2 below.

1. Developing goals and measurable objectives.
2. Understanding the constraints that prevent the goals and objectives from being achieved .
3. Selecting the most appropriate strategy to address goals and objectives.
4. Detailed design and specification of techniques to implement the strategy.
5. Implementing works or activities.
6. Evaluating the performance of the project
7. Maintenance or follow up activities.

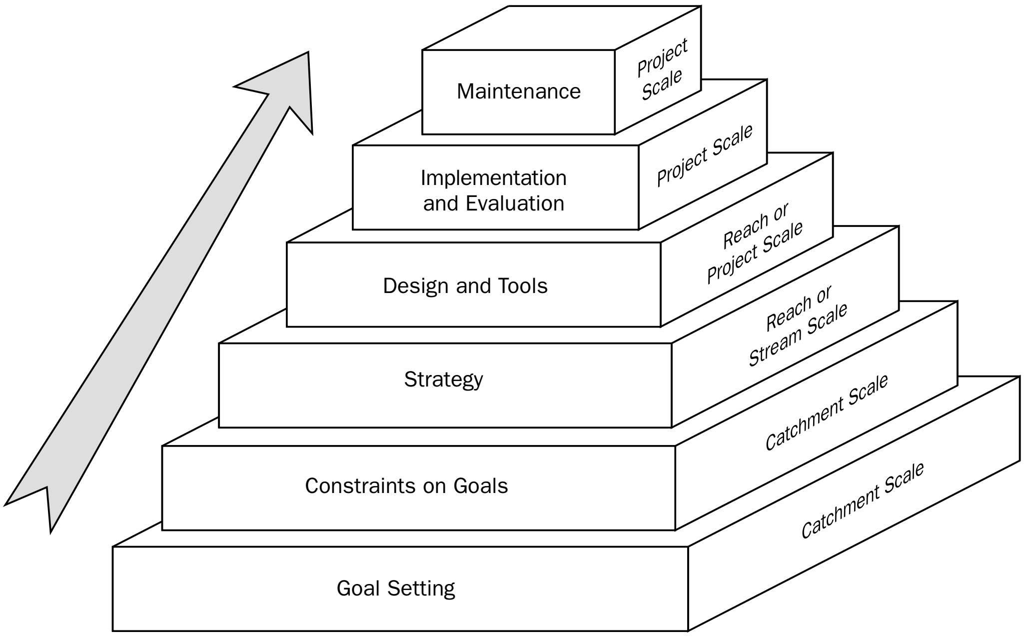
Considerations of scale

This hierarchy applying to stages in time is parallelled by a similar hierarchy that relates to space.

1. Goals and objective setting for river rehabilitation should commence at a catchment or regional scale.
2. Understanding of constraints must similarly reflect a catchment wide perspective.
3. Strategies will relate to rehabilitation programs for whole streams or to substantial stream reach or community scales.
4. Detailed design will have a reach or project focus or relate to small communities of stakeholders.

5. Implementation is at the site by site level involving individuals or small groups of stakeholders.
6. Evaluation, maintenance and follow up are more likely to apply within a site or to individuals.

Figure 2
The 'foundations' of stream management. Managers must work up the pyramid to reach the goal!



Stream rehabilitation projects must address all seven temporal steps in a rigorous way using best practice techniques, and incorporating a needs assessment which identifies the project as a high priority within the catchment or region. The strategy developed must similarly reflect an understanding of the stream processes at the site or reach, and the consequences of the work on upstream and downstream reaches.

Leaving aside administrative problems, international experience (described below) has shown that the main reason for failure of stream rehabilitation projects is, first, poor definition of project objectives, wrong diagnosis of the real problem in a stream, or failure to consider the catchment context of works.

The planning framework is informed by the physical framework.

Implications and actions for LWRRDC

Stream rehabilitation can fail at any of the steps shown in the process above. NHT projects must be adequate at each step of the process. The main implication for LWRRDC is that R&D must be carried out at each level of this hierarchy—not just at steps 4 and 5 which are the design and implementation stages which usually attract the bulk of the work. In a later section we suggest that the most important R&D requirement are at the top level of this process—at the point at which one decides on objectives and identifies the problem.

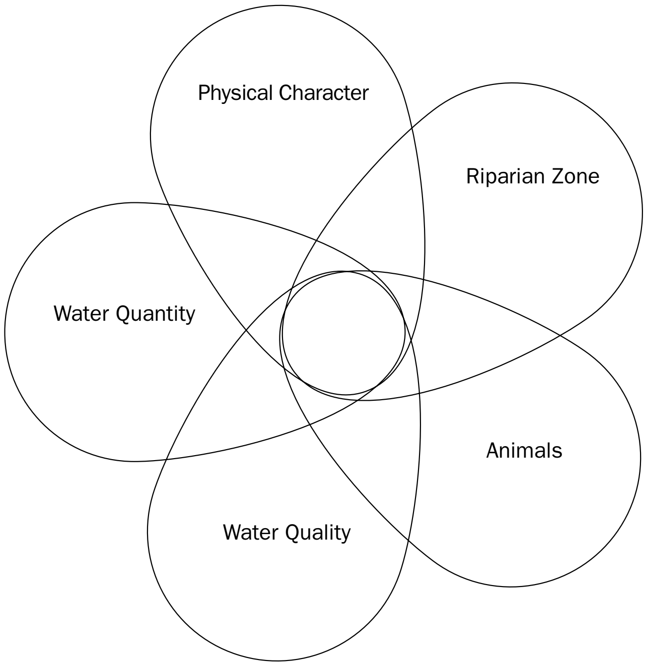
We must emphasise that in many cases the most difficult aspect of stream rehabilitation is not solving the problem, but identifying the underlying cause of the problem! This difficulty can only be overcome by (a) better understanding of the basic functioning of our stream systems (b) better dissemination of what we already know about how our stream systems function (c) better understanding of society's goals and expectations of streams.

Physical framework

A physical framework for stream rehabilitation simply makes sure that you understand enough about your stream to be able to know (a) what the key problem (not symptom) is (b) whether the problem will solve itself (c) what else is happening in the catchment that could affect your plan.

There are five interacting elements that define stream condition (Figure 3) These include the physical character of the stream (ie. the shape and size, sediments, large woody debris etc.) the quantity and quality of water, the condition of the land adjoining the stream (the riparian zone), and the diversity, population and type of creatures living in the stream.

Figure 3
The five key elements of stream health



Stream rehabilitation must include all of these elements, although this report concentrates upon the physical component of a stream (especially emphasising its physical stability, morphology, and physical habitat).

There are several approaches presently available that describe the physical condition of streams in a catchment, and provide guidance on stream rehabilitation. These methods include the following:

1. Geomorphic catchment characterisation (Brierley and Cohen 1996)
2. State of the Rivers methodology (QLD) (Anderson 1993)
3. Index of Stream Condition (Vic) (DNRE 1997), the
4. Rivercare approach (Northern NSW) (Raine and Gardiner 1995)
5. Foreshore condition approach from WA (Pen 1994)
6. Newbury stream analysis approach (Newbury and Gaboury 1993)
7. Rosgen stream classification (Rosgen 1996)

Note that none of these approaches, on their own, is sufficient to develop an ecologically based rehabilitation strategy for a stream. But they all provide essential elements of the process.

Stage 1: Characterisation of the catchment and reach

Depending upon the goals of the management, managers should consider the following measures:

1. Map the catchment and plot basic geomorphic characteristics (eg. long-profile)
2. Map all 'point' influences (eg. dams, extraction sites, tributary inputs etc.) as well as landuse types.
3. Define stream segments (usually defined by changes in long-profile) as the second level of management
4. Describe basic stream hydrology as a basis for design (flood frequency, flow duration)
5. Define management reaches
6. Describe history of the catchment (eg. clearing, channel change, extraction)
7. Describe the condition of reaches using a selection of the tools listed above (this may involve measuring cross-sections to develop a hydraulic geometry for the catchment as described by Newbury (1993).
8. Extent of point impacts identified (eg. downstream extent of impact from a dam)
9. Describe biological variables (biological populations and diversity), and relevant physical variables (eg. water quality, changes to hydrology), and assess which of these could be limiting the stream ecology.
10. Change in the condition of reaches over time combined with an assessment of the impact of change in one reach with change in another reach (by combining points 4 & 5) (for sediment, a key tool for exploring the 'trajectory' (or recovery) of a stream system is the catchment characterisation procedure described by Gary Brierley and Kirsty Fryirs in Appendix 2).

Stage 2: Prioritisation

Once there is an adequate description of the condition of streams in a catchment, then the next step in the framework is to explicitly priortise the reaches, point impacts, or problems for attention. Where the aim of the management is rehabilitation of some biological values (eg. a specific fish species) then the manager would consider the variables in the reach that *limit* the recovery of the species. The variables may be water temperature, predation, habitat availability etc. The manager would then treat those variables as a priority. The manager would also prioritise the reaches for attention on the following basis.

Priority One: Discontinuous threats that threaten remnant or refuge reaches

The greatest value for both effort and money can be achieved by maintaining the condition of high quality reaches. Priority one issues are therefore to address *discontinuous* problems such as headcuts, or point sources of low water quality, that threaten the future environmental value of the remnant reach.

Priority Two: Remnant or refuge reaches (threatened reaches)

Ensure the preservation of all reaches that are in unusually good condition, or contain endangered organisms, or act as corridors between important habitats.

Priority Three: Threatening reaches or point-impacts

These are *entire reaches* that have problems that could threaten the integrity of the remnant or refuge (Priority 1) reaches. Examples would be: upstream reaches delivering large volumes of sediment or poor water quality; or downstream barriers to fish migration.

Priority Four: Linking reaches

Where a reach in poor condition lies between two priority one reaches, then you can get good value for money by rehabilitating the 'linking' reach.

Priority Five: Impeded recovery reaches

These are the reaches that are in poor condition but their natural recovery is limited by something. An example would be a reach that has a good natural source of seeds to the site, but grazing always limits regeneration of riparian vegetation. Simply fencing the site off will produce good results.

Priority Six: Moderately damaged reaches

These are reaches that are damaged by human impact, but have good potential to recover at reasonable cost.

Priority Seven: Basket-case reaches

These are reaches that are in very poor condition, that do not threaten other reaches, but have little chance of recovering themselves over time. An example would be a low-slope, low energy, incised stream that cannot cut a new course (Brookes 1987). These reaches need intervention to recover.

Priority Eight: Basket-case reaches with hope

These are the reaches that are in very poor condition, do not threaten other reaches, and have some chance of recovering themselves with time. Examples may be the high-energy reaches, close to the mountain front, that tend to get damaged by large floods (although these may get bumped up the priority if their instability threatens downstream reaches).

Implications and actions for LWRRDC

1. A well planned stream rehabilitation project will usually incorporate most of the elements discussed here (whatever its bio-geographical position). In particular there should be a structured process of planning and catchment description that includes a rigorous approach to prioritising reaches and problems for treatment.

2. There are several tools available for describing stream condition (eg. Index of stream condition, state-of-the-rivers), but none of them on their own are presently sufficient to describe the condition of streams for stream rehabilitation. An R&D requirement is to develop *integrated management tools* that will allow successful assessment of the cause of problems on a stream, as well as successful implementation of the project. An alternative is to develop a methodology that will assist people to know when to use a particular approach.

- **ACTION**: Develop planning and assessment tools that integrate the best aspects of the existing approaches for stream rehabilitation. Alternatively, commission a short study that will develop a decision making approach that will help managers to know when to use a particular approach.

3. It should be clear how priorities have been set in catchments for stream rehabilitation. Where the objective of the work is stream rehabilitation, then preserving existing streams in good condition should be the highest priority. We believe that such preservation should also be reflected in R&D priorities. The recent federal Wild and Scenic Rivers project identified the major large streams with outstanding values, but it did not identify *reaches* of otherwise modified streams that remain in good condition.

- **ACTION**: Ensure that an appropriate proportion of LWRRDC research is directed toward identifying streams and stream reaches that are of high ecological quality.
- **METHOD**: If LWRRDC is involved in funding, for example, inventory type work, or a needs assessment (as recommended later) then LWRRDC should emphasise the importance of preservation in this work)
- **ACTION**: Fund research to develop approaches to preserve and protect remaining high-quality reaches of streams
- **METHOD:** There are many novel approaches to preserving remnant assets (eg. international methods applied to preserving remnant resources in the developing world, economic incentives, legislation, etc. *The full suite of possible alternatives should be explored in a piece of commissioned research.*

Can international experience of river rehabilitation help meet Australia's R&D needs?

The task: Identify sound, sustainable stream rehabilitation techniques world-wide and recommend a strategy for their promotion and demonstration in Australia

Appendix 4 provides a brief summary of the present research situation in N America and Europe. It also includes a discussion of the unique character of Australian streams in relation to international work. The review draws the following conclusions.

Some lessons from international projects

Certain developments appear to have greatly assisted the stream rehabilitation community in the Northern hemisphere

1. Large integrated projects (eg. UK River Restoration Project, Kissimee River Project in Florida, Danube restoration in Germany (Kern 1992), Demonstration in Erosion Control Project in Mississippi) are examples of such projects. These large projects lead to major changes in public perception, and appear to be a very successful trigger for more wide-spread adoption of principles. An Australian example of a similar project is the Clear Paddock Creek project in Sydney (Frost, Wiese, Schaffer and Bewsher 1997).
2. Despite the last point, there is a growing recognition that rehabilitating large rivers may be too great a challenge at present (see discussion in Gore and Shields 1995). This reflects the great, and cumulative modifications made to these streams over centuries, the limited opportunities for change (eg. flood and flow constraints) and the huge cost involved (eg. the plan to return salmon to the Rhine River (Salmon 2000) is expected to cost (over 10 years) the equivalent of the entire German national budget for one year). Major advances have been made in improving water quality in large streams (eg. the Thames in London).
3. Geomorphically based approaches to stream rehabilitation (eg. Newbury, Rosgen, Montgomery, Bavarian models) have expedited a large amount of rehabilitation work—largely because they empower non-geomorphologists to make decisions about what is wrong and right with streams. There is, of course, debate about the use of such classifications (eg. Miller and Ritter 1996).
4. Strong environmental legislation (eg. US Federal Endangered Species Act, Danish Water Resources Act, Canadian Fisheries Act) have triggered major phases of stream rehabilitation work in these countries. The controversy surrounding many applications of this legislation (eg. the Kissimee River project) suggests that the legislation is pushing rehabilitation rather than reflecting general public opinion.
5. Major advances have been made in rehabilitating streams in the USA and Northern Europe following the development of a large range of ***bio-engineering tools.*** These tools incorporate local vegetation directly into engineering structures. Examples are fascines and 'living' riprap (see Gray and Sotir (1996) for a full description). Unfortunately, most of these designs rely on cuttings of willows, poplars and other exotics that are no longer favoured in Australia (Ladson, Gerrish, Carr and Thexton 1997).

We can learn some other lessons directly from international experience.

1. Some of the engineering and geomorphic results are directly comparable (eg. incised streams)
2. Some of the approaches developed overseas (eg. stream classifications, hydraulic habitat methodologies) can be modified directly for our use.
3. Piecemeal management of habitat, without also considering the catchment context, is doomed to fail. In practice, this means that the projects failed because (a) the habitat element that was fixed was not the problem anyway (eg. may have been water quality or downstream barrier to fish) (b) the function of the works was damaged because of sediment inputs from upstream (c) the works were poorly designed.
4. Direct historical reconstruction of streams has often been unsuccessful because the new channel was not designed with regard to contemporary (ie. larger) run-off and sediment yields. The lesson is very clear: we must design artificial channels in relation to present hydrology and sediment loads not in relation to pre-historic/natural conditions.

What is common between Australian and international projects?

1. Projects tend to be piecemeal and treat short reaches of stream in isolation
2. Until very recently there has been very little long-term evaluation of stream rehabilitation projects, except in terms of fish numbers
3. There are many examples of habitat manipulation works doing more harm than good (Frissell and Nawa 1992).

Where we need to be cautious in applying experience from the Northern Hemisphere

Most of the stream rehabilitation literature that we read comes from a limited range of settings in the Northern hemisphere. The Australian stream manager should be aware that this literature is based on a set of premises that may well be less relevant to Australian streams. These are some of the premises.

1. Often the detail of Northern hemisphere projects is of little value to us because it deals with the specific requirements of salmonid fish. Thus, international information is often of little value in defining problems in Australian streams, but it is useful for finding general approaches and defining solutions.
2. Intense and costly management of Northern hemisphere streams is justified by a boutique fishing industry. There is no such industry in Australia, so rehabilitation must often be justified on purely environmental grounds.
3. Intense habitat enhancement is also justified in the Northern hemisphere by the large resources and population available per unit of stream length, and the small length of stream that remains in good condition (ie. each unit of stream restored is worth relatively more than in Australia).
4. In the Northern hemisphere, the streams to be restored are often textbook-type streams with morphology formed by a specific range of flows and sediment loads. Many Australian streams do not fit this textbook model.

5. Northern hemisphere streams can be stabilised by 'bio-engineering' structures that incorporate cuttings of willows and other softwoods. These species are no longer encouraged in Australia so we must use slower growing vegetation species, and develop our own stream stabilisation techniques.

In mentioning these contrasts with Northern hemisphere streams we are not suggesting that we can learn nothing from them, because Australian streams are so different. This is obviously not the case. We simply emphasise that all Northern hemisphere experience should be evaluated critically.

General implications of International work

1. *We should be cautious about the scale of project that we embark on.* Whilst it is tempting to attempt the rehabilitation of large stream systems, international experience has shown the huge cost and the massive constraints on such projects. We recommend concentrating on flow and water quality issues in large streams, and concentrating in-stream rehabilitation to small and medium sized streams that are of a manageable size.

2. *Australian stream rehabilitation projects may take longer to show signs of success than an equivalent stream in the Northern hemisphere.* Low stream power and low sediment yields in Australia combine to limit the capacity of streams to 'recover' from human disturbance. For example, incised streams take many years to recover because there is often limited sediment to form a sinuous channel in the bed. The same may be true for stream ecology. The biological response of a system to rehabilitation may be subtle and slow. This means that we should not expect our projects to show results in the same time as we find international projects being completed.

3. *Northern hemisphere pre-conceptions about 'habitat' may not be appropriate in our streams.* Northern hemisphere models of ideal stream habitat (often based on salmonid fish) may not be appropriate for Australian streams in which, for example, the original condition may well have been a chain-of-ponds and not a pool-riffle system. In many streams, large woody debris may be of more importance than substrate composition, for example. Many models of hydraulic habitat from the Northern hemisphere will be useless in say the Darling or Fink Rivers.

4. *Much Northern hemisphere rehabilitation work concentrates on channelised streams.* Whilst many Australian streams are also channelised, we must not assume that this is the only type of stream that requires rehabilitation. Other Australian stream types may be equally in need of rehabilitation.

5. *We should not necessarily expect to spend as much money on projects as they do in the Northern hemisphere.* Whilst the huge cost of some of the elaborate stream rehabilitation projects in N America and Europe is daunting, we should not necessarily look to these projects as models for the way we should do our rehabilitation. In some cases they have more money to spend (per-unit stream length), stronger legislation, and a boutique fishing industry. This provides a motivation for projects that we cannot match in Australia. The great majority of our rehabilitation must often be justified on more general environmental and bio-diversity grounds.

To conclude, overseas experience with restoring streams provides numerous excellent principles and concepts that can be used in Australia. However, we should not adopt these approaches uncritically. We should be very ready to develop our own approaches that are appropriate to our unique environment. Many of the most important lessons that we can learn from international experience relate to legislation, general approaches, concepts, planning, methods of stream analysis etc., rather than direct rehabilitation methods.

Implications and Actions for LWRRDC

1. From international experience, integrated projects that treat long reaches of stream, or a whole catchment, may be the most effective way to encourage stream rehabilitation projects, and to encourage adoption of methods. However, it is probably wise at this stage to concentrate on small and medium sized streams that are more likely to yield good, measurable, results.

- **ACTION**: support the development of 'flagship' experimental projects that can command a high profile (see recommendations below regarding large projects). For now, concentrate on small and medium sized streams (wadeable streams) rather than large complex systems.

2. Geomorphologically based approaches to stream rehabilitation appear very successful in triggering stream rehabilitation projects.

- **ACTION**: LWRRDC should **continue support** of geomorphologically based approaches to stream rehabilitation, and encourage wide dissemination of the techniques.
- **METHOD**: Dissemination could be encouraged by making application of such techniques mandatory as part of NHT or NLP proposals)

3. Strong environmental legislation is a powerful stream rehabilitation incentive internationally.

- **ACTION**: LWRRDC should **commission** some research into the character and effectiveness of international legislation in encouraging stream rehabilitation and explore whether similar legislation would be appropriate in Australia.

4. The exotic vegetation types used in many of the Northern hemisphere bio-engineering tools are not acceptable throughout most of Australia. It is important that similar tools are developed using indigenous Australian species.

- **ACTION**: LWRRDC should **support** research that develops bio-engineering techniques incorporating Australian vegetation species.
- **METHOD**: This work could be carried out in cooperation with LWRRDC's National Riparian Zone Project, but would require cooperation between engineers and botanists, as well as field trials. Evaluation methods used overseas could be used.

A strategy for promoting desirable international practices in Australia

The Task: recommend a strategy for the promotion and demonstration of desirable international practices in Australia

In general there is not a great deal of international influence on the practice of stream rehabilitation in Australia at present, often because of uncertainty about the application of alien approaches. The critical aspect of such transfer is (a) that appropriate information is transferred, and (b) that it is transferred effectively.

Ensuring appropriate information is transferred

It is tempting to grab the latest fad technique or concept from overseas and apply it to Australian streams. This may not always lead to good outcomes. Appropriate techniques can be identified by close evaluation of trials, or by early review by a technical panel.

Implications and actions for LWRRDC

- **ACTION**: **Initiate** research that evaluates and documents existing practice and research overseas so that we can mine the most useful material and avoid the inappropriate material. This will be more efficient than the present piece-meal approach where everything from overseas is automatically no good, because it is not relevant to our streams, or the other view, that if it comes from the Northern hemisphere it must be better.
- **METHOD**: Contract a critical review of international stream rehabilitation literature. This must include an assessment of the legislative and administrative underpinning for the work (this part of the review may have to be completed separately by environmental lawyers?). This assessment of international work could be carried out in concert with the later recommendation to develop a specific list of R&D required for stream rehabilitation in Australia. In addition, the clearing-house discussed later would provide a forum for rapid dissemination of any evaluation of techniques.

Methods of transferring international information

Some methods of international exchange are already taking place successfully in Australia.

1. The visits by Bob Newbury, in particular combining training with real, on-the-ground projects, appear to be particularly influential. These workshops have galvanised many local groups into action. Such visits can be relatively cheap and should be encouraged. However, it would be good if these visits included managers and others who have examples of successful management and administration of stream rehabilitation projects (also legislation) in Australia. Often this will provide very useful material for us. A recent visit by Professor Jim Gore (Florida State University) has also been influential.

2. There are numerous international Internet sites dealing with stream rehabilitation. It is not clear how these influence practice at present, but they have the potential to provide rapid access to international experience.

Implications and actions for LWRRDC

- **ACTION**: Continue to **sponsor** visits by international experts, but expand the program to include successful managers, community motivators, and legislators.
- **METHOD**: International transfer could be efficiently encouraged by developing a visiting Fellowship program.
- **ACTION**: Encourage the rapid collection and dissemination of relevant international information.
- **METHOD**: Establish a **clearing house** for stream rehabilitation information that can rapidly assimilate and circulate relevant information. This suggestion is discussed in more detail on page 41.

Other options

1. Develop exchange programs between management agencies (some programs already exist between universities) (eg. Mr Wal Hader of the NSW Department of Land and Water Conservation, spent an influential period working with the Bavarian government in 1990).
2. Much of the international experience needs to be meshed with the general 'technology transfer' suggestions made later in this report.
3. Benchmark our stream rehabilitation practice with other organisations around the world.
4. Establish international best practice in stream rehabilitation practice

Existing river rehabilitation projects in Australia, the organisations involved and status

The task: Describe stream rehabilitation projects in Australia, the organisations involved and the status of these projects.

Appendix 5 provides tables of projects that we know are taking place in Australia now, and some further discussion.

The problem in reviewing activities across the continent is defining what stream rehabilitation is (see Figure 3 on page 19). Many activities on streams can be carried-out for many different reasons, and there may be an incremental (even inadvertent) stream rehabilitation outcome. For example, much of the early river and gully stabilisation work carried out across the nation led to some marked improvements in stream ecological condition. For example, construction of large rock riffles on an incised stream in NE Victoria produced permanent pools that were found to be teeming with native fish (Paul Brown, Victorian Department Natural Resources and Environment, pers. comm.). If enough works were done (as they were in, say, the Hunter River system in NSW) then there can be some catchment wide benefits. These works, however, were really designed to reduce loss of land and assets, and reduce flood levels, not to re-establish stream bio-diversity. Of course, for our purposes here, it does not matter what the intention of the works were, if they did rehabilitate the stream, then that is all that matters.

However, the reality is that it is very rare to find a stream project whose ***principle*** aim is the rehabilitation of stream ecology, bio-diversity and general health. Our conclusion from a cursory review of projects in Australia is that work in streams is primarily motivated by stability and flood issues, but with lip-service given to ecological issues, usually by incorporating vegetation into the project design. In urban areas, aesthetics is the additional dominant objective of work. In some cases this approach can lead to sustainable ecological improvement, but this is often a matter of luck rather than design.

We make the following general points about the type of stream rehabilitation work being carried-out in Australia at present:

1. There has been a great increase in the amount of work being justified on vaguely ecological grounds, although in practice, stream works in Australia are still justified primarily by utilitarian rather than ecological goals (usually erosion control). Nevertheless, the signs are hopeful that ecological condition will, within the decade, become an acceptable goal, in its own right, for stream management work.
2. Almost without exception, the emphasis of Australian stream management continues to be on fixing and stabilising the reaches of stream with the worst problems instead of emphasising the protection of the remnant reaches that are in good condition.
3. Where work is motivated by ecological motives, recreational fishermen are often pushing the project.

4. Many works in a catchment are now coordinated through a catchment management plan, however, these almost always target erosion and flood issues as priorities, and emphasise working on the worst problems first rather than preserving the best remnants.
5. Most planning emphasises the tools for fixing problems, with goals and objectives being only vaguely defined.
6. The dominant stream rehabilitation activity in Australia is bank revegetation
7. Most money is being spent on urban streams rather than rural streams. These are often the streams with least potential for successful ecological rehabilitation.
8. Coordination and communication between agencies and groups tends to be poor. This is particularly shown at the local level of NLP projects. It should not be necessary for every catchment group to go through the same learning process in doing stream rehabilitation projects (for example, in terms of structures and approaches that do and don't work).
9. We have seen few projects that are evaluated in such a way that they can provide information to other managers.

What projects are there in which the primary motivation for the work is ecological? One example is the proposed rehabilitation work on the Snowy River below Jindabyne in which the original stream morphology will be restored. Another is the Clear Paddock Creek 'Restoring the Waters' project in Sydney, in which an urban concrete drain is to be re-meandered and returned to a roughly natural state (Frost, Wiese et al. 1997). Various demonstration projects within the LWRRDC riparian zone project are essentially aimed at ecological rehabilitation. There are, no doubt, numerous local projects across the country that are increasingly emphasising ecological goals. Examples are the many projects across SE Australia now that are using the original 'chain-of-ponds' morphology as a target for stream works.

There are other large projects in which ecological values are given prominence. These are attempting to develop catchment scale, integrated projects with reasonably well defined ecological goals. Some examples would be the integrated plans for the Torrens and Inman Rivers in the Mt Lofty Ranges in SA, although these are yet to be implemented.

Implications and actions for LWRRDC

Most of the recommendations throughout the rest of the report relate to the perceived short-comings in Australian stream rehabilitation. These relate to establishing ecological end-points as acceptable goals for stream rehabilitation, emphasising preservation as much as restoration, poor communication and poor evaluation. Actions to address these issues are discussed in other 'action' boxes.

SECTION 9

A process to determine R&D needs in stream rehabilitation

The Task: Recommend a process for identifying which stream rehabilitation concepts and techniques would be worthy of future research

Please see Appendix 6 for detailed lists of suggested research.

It was not the brief of this section of the report to actually identify specific areas of research required for stream rehabilitation, but instead to discuss how this research can be identified. Nevertheless, Appendix 6 identifies some areas of research based on contributions made from many quarters during this review.

It is clear that R&D is not just required on stream rehabilitation **techniques** but on the full range of processes that make up a stream rehabilitation project including problem recognition, goal setting, allocating priorities, developing scientific understanding of problems, and technique selection. We recommend that R&D be couched in terms of this type of hierarchy rather than being discussed in terms of disciplines, as it usually is.

Identifying the research needs in stream rehabilitation requires three steps. The first is to identify the questions that need to be answered, the second is to prioritise the questions, and the third is to determine who does the research and where it is done. This last is a particular problem because different places have different problems that are locally relevant. LWRRDC must be concentrating upon the larger, general questions with the most general application, or the greatest conceptual value.

We believe that we have made some headway on identifying research gaps in Appendix 6. But there are certainly many other areas of potential research, particularly in the many areas outside the expertise of the authors. One way to identify these areas is by asking people what should be researched. This consultation process could include telephone surveys and questionnaires. It would also be desirable to hold a workshop with key participants. Key stakeholders that could be canvassed include:

1. scientists;
2. management agencies;
3. the community;
4. the irrigation industry;
5. water supply authorities;
6. recreational interests including fishers and kayaks, and
7. other river users.

Some key contact groups are identified in Appendix 8.

Such a consultative process would provide some input, but in our experience may not be an effective method to focus people’s minds. Often people will not want to put their favourite research idea into the ring because they want to do it themselves. Others will be reluctant to participate in a ‘bureaucratic’ process.

Another approach to identifying research ideas is more confrontational. The National Stream Rehabilitation Reference Panel (which should consist of people from a range of disciplines and backgrounds) would determine the areas of research and their priority. Appendix 6 could provide a start for this process. The list of research areas (or even specific topics) would be widely circulated with the statement “these are the areas of research that will be supported by this LWRRDC program, and this is their priority, unless you can convince us otherwise”. Consultation would then take the form of submissions from interested parties, either supporting the list, or more likely vehemently defending their area of interest that is not represented, or of low priority. We believe that this approach would focus everybody’s minds most effectively. At the end of the day it would be up to Reference Panel and LWRRDC to set priorities.

Setting the research priorities is probably the hardest part of the process. We have argued already that priority should be given to the larger, conceptual issues and basic understanding of systems, rather than on tools for management. However, this will not always be the case. In some cases the goals and nature of the problem are well known, it is just tools that are required. An example of this is the need for stream bio-engineering techniques in Australia.

The final issue is how this research should be carried out. Should it be done in a scatter-gun approach where small projects are spread across the country, or in large coordinated research projects focused on a few research groups? Another alternative is to sink large resources into a few large ‘demonstration/research’ type projects with long lead times, but narrow geographic focus. Each of these approaches has its merits. Another (complementary) approach that we support is to learn all that we can from evaluating existing and developing rehabilitation projects. Thus, researchers would join with practitioners in designing and evaluating projects together. Ideally this synthesis could be carried out through the NHT process. However, we are aware that rigorous research and evaluation has not been the main goal of the NHT process. Thus, we recommend that LWRRDC provide some resources and encouragement for developing these research projects as soon as possible—before the impetus of the NHT process is lost. Coordination with the NHT is the subject of the next section.

Supporting a targeted group of stream rehabilitation projects will also be an effective way to identify R&D needs. In the planning of the project it will quickly become clear what needs to be know to advance the project, and specific questions can then be investigated.

It is critically important that the consultation process is national in perspective. This is because stream rehabilitation is based on the underlying premise of improvign bio and geomorphology-diversity.

Implications and actions for LWRRDC

Broad consultation is required to identify the broad range of R&D required for stream rehabilitation. Possibly the most efficient way to get this consultation is to confront people with the LWRRDC priority list and ask them to respond.

- **ACTION**: Develop, through the Stream rehabilitation reference Panel and LWRRDC officers a priority list of research and development (possibly using ideas in Appendix 6 as a beginning) that will be used as your priority list unless persuaded otherwise. Then circulate for comment. Ensure that each submission is treated seriously, and that it is clear that LWRRDC is willing to be flexible
- **ACTION**: Use conferences as opportunities to consult effectively (for example the up-coming Australian Stream Rehabilitation Conference (Adelaide, February 1999).

  Supporting onground projects through the NHT will also be an effective way to identify R&D needs.

SECTION 10

Interfacing the LWRRDC stream rehabilitation sub-program with the NHT

The task: Recommend how the stream rehabilitation sub-program within LWRRDC can be most effectively interfaced with the NHT, in particular in the sense of providing sound, sustainable techniques for onground works

This is one of the most important questions discussed in this report, and there are several parts to our answer.

These are our main conclusions:

1. If the goal is to provide sound, sustainable techniques for onground works, then this can best be achieved by making sure that those onground works are carried out within a planning framework that sets clear goals. It is at the strategic 'goal-setting' level that projects tend to fail, rather than at the level of technique selection. Once managers know the problems and their underlying causes, and have clear goals for their management, the techniques to use are often a simpler problem. Furthermore, LWRRDC should be attempting to influence that goal-setting process within the NHT by assisting with a 'needs' assessment process.
2. The most effective interface between the LWRRDC sub-program and the NHT process will occur where the sub-program actually uses the NHT projects to develop a hierarchy of stream rehabilitation projects that double as research and development exercises. Probably the most effective interface will occur within a few, large, stream rehabilitation demonstration projects. Such projects will produce onground results that will be very effective at influencing other projects.
3. The other aspect of the interface between LWRRDC and the NHT is the development of an effective technology transfer process (both for existing knowledge, and for future R&D). This should involve accredited training, and a communication strategy that includes some form of clearing-house of stream rehabilitation information.
4. There are opportunities for seconding extension officers from government agencies to develop extension material in collaboration with LWRRDC. It is important that people be given time out from their organisations to do this detailed work.

Thus, we discuss this question in terms of three areas:

1. How LWRRDC can reduce the failure of stream rehabilitation projects, and NHT projects in particular;
2. How LWRRDC can most effectively interface with the NHT process by developing partnership projects; and
3. How LWRRDC can develop an effective technology transfer strategy to ensure effective 'interface' with the NHT projects.

How LWRRDC can help the NHT provide sound, sustainable, effectively targeted onground works

(See the comprehensive discussion in Appendices 1 and 7)

Recall that in the framework section we identified the following seven stages in a stream rehabilitation project:

1. Developing goals and objectives.
2. Understanding the constraints that prevent the goals and objectives from being achieved.
3. Selecting the most appropriate strategy to address goals and objectives.
4. Detailed design and specification of techniques to implement the strategy.
5. Implementing works or activities.
6. Evaluating the performance of the project
7. Maintenance or follow up activities.

A stream rehabilitation project can fail at any of these six stages even if the other stages are completed successfully. Consider the common case of a project that has ignored stage 1. At completion, many of the stakeholders may feel that the project has been a failure simply because it was never clear exactly what it was trying to achieve. For example, a specific fish species is successfully returned to a stream reach, but the reach still looks pretty ugly, with some bank undercutting. The undercutting and messy logs in the river are seen as desirable for the fish, but as ugly to some landholders who did not really appreciate what the end-point of the project would be.

So in these seven stages, where are the major R&D barriers to effective stream rehabilitation projects in Australia?

Maximum return from R&D will come from tackling the highest order issues (problem definition, priority, objective and goal setting). If there is a problem at stage 1—goal setting and problem recognition—then that should be sorted out before doing any R&D at the lower levels. Getting the correct approach high up the hierarchy means that more projects are positively influenced. R&D at lower stages, such as technique or implementation, will only ever affect the outcome of a limited number of projects. Only if a particular stream rehabilitation project is a priority and the scientific understanding is sufficient, will it be appropriate to research new stream rehabilitation techniques.

Developing catchment wide or regional stream management goals (stage 1) is currently a barrier to progress. Achieving an acceptable balance between utilitarian and environmental objectives for rivers is a topic of current debate. But even within the rehabilitation context, goals and objectives are usually unclear: are we managing this river as a trout stream, for native fish, for general ‘naturalness’, for recreation, etc?

Stage 2 provides the knowledge to support the stream rehabilitation goals and analyse and evaluate stream rehabilitation strategies. Current poor understanding of physical, chemical and biological processes can hinder success of stream rehabilitation projects.

Where stage 2 is able to provide a good understanding of the constraints to achieving the goals, stage 3 (strategy development and selection) may not present a barrier. But if there is insufficient understanding at stage 2, strategy selection becomes difficult. For instance, if a manager does not understand the underlying processes, then he/she will choose between high intervention and low intervention strategies, on site or off site works, social or engineering approaches, entirely based on what he/she is familiar with.

Getting it right at the strategic level has the potential to produce more successful outcomes than getting it right at a single site. Improvements in our abilities to set appropriate objectives, understand the problems and choose the right strategies have the potential to profoundly influence stream rehabilitation progress in Australia. Improvements in designing and implementing works or activities can also have a positive impact but there is less scope for improvement and a smaller sphere of influence.

Adequate professional advice is already available at stages 4, 5 and 7 to assist with design, implementation and maintenance of stream rehabilitation activities. That is not to say that advances cannot be made in these areas, but in general, practice lags well behind knowledge in this area, so the issue is more one of communication than of research. While stages 4, 5 and 7 tend to attract the most interest in stream rehabilitation R&D, the emphasis should be on trials, monitoring and sharing of experience. These issues are taken up later in this section.

Proactive or reactive management

River management, and river rehabilitation in particular, needs to move beyond problem driven management. It needs to be proactive in determining river conditions that are desirable. It then needs to implement a range of reactive recurrent activities, together with proactive strategic activities, that are designed to avoid problems occurring. At present most stream management is based on reactive, localised band-aid solutions. In other words, river management should aim to manage systems rather than treat symptoms. To do this successfully, we need to set clear goals for rivers at scales of catchment, reach and site. To achieve this, we need to see a move away from problem based reactive management, toward objective based proactive management.

Setting goals for rivers—an R&D need

How should we set goals for river management? How should we set goals for river rehabilitation? These are two key research questions.

This issue has been addressed to an extent within the various attempts at ‘strategic planning’ for river management that have been undertaken (and are currently being undertaken) in the various States. Despite a range of approaches, there is no common view on how to go about this multi-objective planning process. The techniques vary from the purely qualitative to the excessively quantitative but regardless of the apparent rigour; all the approaches ultimately rely on the particular value system of the assessor. (A discussion of a multi-objective planning approach used in Victoria is provided in Appendix 7 by Dr S. Ewing, and summarised below).

The lack of reliable practical processes for setting river management and river rehabilitation goals at a regional or catchment level presents a major R&D challenge. A practical method must take account of community expectations and aspirations, and economic implications, as well as being credible through good science. Yet the process must allow sufficient pragmatism and be sufficiently broadly based to ensure that compromises can be reached across catchments.

An example of the benefits of having clear management goals is the Heritage River legislation enacted in Victoria in 1984. Under the legislation reaches of stream can be classified as Heritage Rivers. This status means that not only must they be managed so as to preserve the declared reach, but reaches up and down stream must also be managed so that they do not threaten the declared reach. Because the management goal is simply and explicitly stated, the management becomes efficient and effective.

Needs Assessment: How to ensure that NHT projects are effectively targeted

How can LWRRDC assist the NHT process to effectively target its work? A recent review concludes that the NHT required a needs assessment and that LWRRDC could contribute to this. That point is supported by the following comments.

Under the NHT program, funding is allocated according to priorities identified in catchment or regional plans. In general, preference is given to projects which are part of a strategic land, water or vegetation management plan. Whether or not NHT funding is allocated to river rehabilitation projects, therefore, depends largely on whether a need for river rehabilitation has been identified at a regional level and, if so, what order of priority has been allocated to the issue *vis-à-vis* other resource management issues in the region.

This then begs the question of how regional priorities are identified. For example, do current planning and priority-setting processes have access to adequate information to inform the planning process at a regional level ? How can R&D inform this assessment and priority setting process ?

Needs assessment

As noted in a recent report by the Australian National Audit Office (ANAO 1997), a key factor in value-for-money program delivery is a rigorous assessment of needs to ensure that the projects which receive funding are those with the maximum likelihood of achieving their objectives. However, a comprehensive assessment of needs was not undertaken as part of the design of the National Landcare Program (NLP) and, more importantly, has not yet been done for the NHT. The pending needs assessment that is being completed as part of National Land and Water Audit may provide some useful information, but it is not targeted specifically at the NHT program. In the meantime, NHT funds will continue to be allocated in the absence of reliable, comprehensive, information. ANAO notes that *local knowledge* is often the basis of project applications and the regional assessment process.

The ANAO has found that recommendations of priorities through the regional and state assessment panels (RAP/SAP), which decide on project applications to the NHT are 'often based on intuitive judgements, rather than any robust needs assessments' (ANAO, 1997: 39). Of particular concern is the absence of hard data on environmental needs and priorities, which clearly has implications for resource allocation to river rehabilitation projects. ANAO also notes a concern of conservation groups, that there is a potential for systematic bias against biodiversity-oriented projects at the RAP and SAP levels, since the information and expertise on the panels is often skewed in favour of agricultural interests.

The ANAO found clear indication that greater scientific rigour is required in assessing needs under the NHT. It has recommended that DPIE and Environment Australia:

> *"consider options for further developing and applying strategic research from bodies such as the Land and Water Resources Research and Development Corporation to the needs assessment process of the NHT" (ANAO, 1997: 47).*

In the absence of a comprehensive assessment of needs for programs under the NLP/NHT umbrella, other approaches being developed to assist RAPs and SAPs in setting priorities. One approach, being developed in Victoria by the Victorian Catchment and Land Protection Council (VCLPC) and the Department of Natural Resources and Environment (DNRE), is Multi-Criteria Analysis, a more objective and rigorous processes of setting priorities for natural resource management in Victoria. For a brief outline see Appendix 7.

We recommend that LWRRDC should play a major role in setting priorities for stream rehabilitation nationally through the NHT process.

Implications and actions for LWRRDC

- **ACTION**: **Initiate** research that will develop practical and flexible methods for developing multi-objective goals for stream management. Stream rehabilitation would then sit within the broader framework of stream management. This research would also include methods for prioritising streams or stream reaches for rehabilitation at national, state and regional levels.

- **METHOD**: Appendix 7 describes some needs analysis approaches being used in Victoria. The outcome of the National Water Audit may also prove helpful. In general, there is a large amount of information available at a state level about a hierarchy of needs, but this needs to be incorporated into a planning framework that includes preservation as well as repairing damaged streams.

Setting goals and objectives, however, requires trade-offs to be made. Addressing many of the large-scale stream rehabilitation issues in Australia such as environmental flows will result in winners and losers, for example, providing more flow for fish is likely to result in less flow for irrigators. Unfortunately the costs of stream rehabilitation projects are often easier to quantify than the benefits. Effective stream rehabilitation requires more than new techniques—these will not halt the over-exploitation that degrades streams.

Effective stream rehabilitation will require clarity about goals and objectives for rivers and the institution of new regimes to better manage the natural resource. This is being partly addressed through the COAG agreement on water resources. The economic benefits of the COAG agreement are widely acknowledged but the environmental benefits are less clear. An R&D need here is to identify costs and benefits of stream rehabilitation projects that allow for appropriate trade offs. This research needs to be at the policy level.

Implications and actions for LWRRDC

- **ACTION**: **Initiate and collate** research on identifying costs and benefits of stream rehabilitation projects.

- **METHOD**: This work could be collated within the stream rehabilitation 'clearing house' as discussed below.

Providing tools for the NHT selection process

We have described here and in Section 1 above, what we consider are the key elements of a successful stream rehabilitation project. But how do we ensure that projects like these will be successful in the NHT process. One effective way to achieve this is to provide more formal guidance to the NHT project selection process. When the Regional and State Assessment Panels sit down to review the NHT projects how do they know whether a project is a priority, is well designed, or whether it will lead to sustainable ecological improvement? Furthermore, how will they know if, with just a small change, the project could be dramatically improved? We have already suggested that we need more fundamental assessment of needs, but we must also provide tools that these panels can use to assess the adequacy of the *design* of the proposed projects.

Implications and actions for LWRRDC

Review the NHT selection process to determine if there are opportunities for LWRRDC to ensure that viable, well designed projects are selected. In particular investigate whether there are opportunities to provide training to NHT assessment panels, and a preliminary scientific review of the NHT proposals.

- **ACTIONS**: Here are three possibilities for assisting the NHT panels in their assessment of projects:

  1. Include an initial level of review which includes a panel of managers and scientists who could objectively assess the structure of the projects, whether the projects could really achieve what they suggest, and whether the project's evaluation procedure is likely to work.

  2. Alter the NHT application forms so that they (in some way) cover the steps described in the framework section above.

3. Provide the NHT assessment panels with **training** and simple **checklists** for assessing the NHT proposals in relation to several criteria.

Review the NHT selection process to determine if there are opportunities for LWRRDC to ensure that viable, well designed projects are selected. In particular investigate whether there are opportunities to provide training to NHT assessment panels, and a preliminary scientific review of the NHT proposals.

The need for evaluation

Determining whether projects are successful and effectively targeted requires that they be evaluated. Unless the goals of the project are clear, evaluation can't be carried out. Following implementation, a selection of NHT projects should be evaluated to ensure that stated objectives are met. An R&D need is to develop appropriate evaluation procedures. Lake (1994) recommended that an evaluation protocol be developed for stream ecology research, and we understand that this is being completed by Dr Barbara Downes (University of Melbourne) for stream ecologists. However, we need a comparable document that is appropriate for stream managers to assess the success of their own projects, in terms of measuring changes to the physical character of the stream, as well as realistic ways to measure ecological change. A draft protocol has been prepared for the Stream Rehabilitation Manual, and this could form the basis of such an evaluation approach.

We do not only need tools that will help to evaluate the physical and ecological performance of projects, but equally an approach to evaluate the institutional and social arrangements surrounding the project. What arrangements assisted or hampered the project? Without this type of evaluation we will find down the track that we are only improving our technical expertise and not our understanding of some of the broader issues that surround stream rehabilitation.

Implications and actions for LWRRDC

- **ACTION**:
  Initiate research on robust evaluation procedures for stream rehabilitation projects that can be applied in several project types (eg. community projects).

  Commission a report that develops methods that community groups and others can use to evaluate the (a) physical and ecological outcomes of stream rehabilitation projects (b) the social and institutional arrangements for stream rehabilitation.

  Establish evaluation as an essential component of LWRRDC funded stream rehabilitation projects and advise the NHT to do likewise.

How LWRRDC can most effectively interface with the NHT process by developing partnership projects

In the above section we have discussed problems of evaluation and technology transfer in developing effective stream rehabilitation projects. We believe that one of the most important ways to solve these problems is to actually carry out and evaluate some stream rehabilitation projects. We noted in reviewing Australian and international work that there has little evaluation of stream rehabilitation work that is motivated by efforts to rehabilitate stream ecology. The NHT could provide an excellent vehicle to initiate such evaluation. International experience also suggested that large, multi-disciplinary projects (such as Kissimmee River in Florida (Toth 1996)) are one of the most effective ways to promote stream rehabilitation activities.

Implications and actions for LWRRDC
(Note: This is one of the highest priority tasks for LWRRDC)

- **ACTION**: LWRRDC should use the NHT funded projects as a major vehicle for research and development.
- **METHOD**: A hierarchy of projects covering specific stream problems and specific regions of Australia should be selected from the NHT proposals (or groomed especially for the NHT bids), and receive extra funding from LWRRDC to cover (a) a detailed project design (such as the framework described above) (b) project evaluation (to varying levels of confidence). This approach would provide two major benefits. First, it would link managers, practitioners and scientists in projects. Second, it would provide a more comprehensive approach to the rather piecemeal research that sometimes occurs now.

  These highly rated projects would be of various sizes, to ensure that some produce rapid results. But it is critical that there are at least a few that are large, integrated projects that are seeking to rehabilitate long reaches of stream, and preferably whole catchments. **Such large, integrated projects would serve as high profile flag-ships for stream rehabilitation nationally**. These projects would be carried-out in cooperation with research institutions, government agencies, and community groups. LWRRDC's role would be particularly in coordination and funding of the planning and evaluation component.

  We appreciate that this recommendation would be difficult to carry-out because of the process involved in prioritising NHT bids through Regional and State Assessment Panels. However, there may be some ways to use these panels to help select the key projects. Ask the panels to nominate a certain number of projects for special LWRRDC status, then select the core projects from these.

  We emphasise again the importance of this recommendation. There is a danger that we shall learn little from the NHT projects if we do not incorporate evaluation and project planning into the process. It is our experience that most NHT funding recipients would welcome such input from scientists and experienced managers—but they need the extra funding to implement the evaluation.

How LWRRDC can develop an effective technology transfer strategy to ensure effective 'interface' with the NHT projects

Much of the knowledge required for effective stream rehabilitation already exists. One of the major impediments that we see to effective stream rehabilitation is the poor communication within the industry at all levels. Different state agencies are not aware of practices in other states. Our impression on reviewing the projects described in the National Landcare Program is that many of the projects are targeted at testing designs and concepts that may already have been found to fail elsewhere. In addition, the emphasis remains firmly upon local stream stabilisation rather than more broadly based ecological approaches as described in the framework section of this report. In short, we appear to learn slowly as an industry and this is a core impediment to the effective use of NHT money.

The following table suggests some methods for getting people to apply new knowledge, ranked in order.

Table 2
Some methods for persuading people to apply new knowledge

Training method	How to do it
1. Get the target group to demonstrate the truth of something to themselves by working cooperatively on the research themselves.	Have managers, and proponents of projects, working cooperatively with researchers, to evaluate NHT projects.
2. Force people to apply information by including the information in industry standards and government policy. Provide incentives for people to use information.	eg. Make it a condition of NHT funding in this type of project that certain planning criteria area used (eg. the framework described above).
3. Force people to learn the information by making training a pre-requisite for their job	eg. accredited training. If you don't have the training, you don't get the job.
4. Tell people about the results and hope they will adopt them	Make it easy for people to get information that they need, and to hear about new developments.

LWRRDC can make advances at each of the levels described in the table, and we discuss some possibilities here.

Have the target group convince itself of the truth

In the research section above we suggested that LWRRDC should exploit the NHT projects to get some good research and evaluation done. Doing this would also have fundamental benefits in training. Having participants in a project rigorously evaluate the performance of their own project is a powerful learning tool. This would particularly be the case if scientists, managers, and the onground workers, were all involved in the evaluation.

Implications and actions for LWRRDC

- **ACTION**: **Establish** a hierarchy of projects for evaluation. The justification for the evaluation is for the education of those involved as well as a quest for knowledge.

Developing industry standards

Establishing some industry standards gives people confidence to use techniques and approaches. For example, the Victorian Guidelines for Stabilising Waterways (Standing Committee on Rivers and Catchments 1991), or the Brisbane City Council's guidelines for urban stream rehabilitation (Conrick and Ribi 1996) encourage practitioners to try techniques. Consultants are hesitant to apply new, risky methods unless they have been sanctioned in some way. For example, Dr Sandra Brizga, a consulting geomorphologist, told us that she would be recommending methods for returning large woody debris to stream channels if there was some form of industry standard that described how it should be done. This sanction spreads the risk taken by consultants in condoning new techniques.

It is our assessment that there would be a rapid acceleration in the application of novel, ecologically sound, rehabilitation techniques if they were sanctioned by some formal process. This sanction, of course, relies upon good evaluation and testing which has not been done for many rehabilitation techniques such as remeandering streams, returning timber to streams, or designing solutions to fish barriers. Thus, a logical outcome of evaluation work should be a decision whether a particular approach or method should be sanctioned, and for what circumstances.

Implications and actions for LWRRDC

- **ACTION: Establish** a National River Rehabilitation Reference Panel (NRRRP)
- **METHOD**: Such a reference panel would provide some of the services that would be provided by a professional body in a more mature industry group. However, stream rehabilitation is in its infancy as a multi-disciplinary discipline, and many of the following recommendations relate to this early stage of its development. The panel would be appointed by LWRRDC and would have a full-time National Rehabilitation Coordinator who would report to the panel (see clearing house recommendation below).
- **ACTION: Review and rewrite** the Guidelines for Stabilising Waterways ((Standing Committee on Rivers and Catchments 1991) (the nearest thing we have to a national standard for in-stream work) to include information on stream rehabilitation techniques.
- **ACTION**: **Develop** a process whereby best practice designs and approaches in stream rehabilitation can receive professional sanction.
- **METHOD:** At present there is no obvious professional body who could provide this type of accreditation. We envisage that the NRRRP would evaluate and sanction various practices, perhaps through a publication series. For example, the NRRRP could be responsible for rewriting and updating the Guidelines for Stream Stabilisation (discussed below). Such publications provide de-facto professional sanction and credibility.

Accredited Training

The stream rehabilitation industry is a complex, multi-disciplinary industry requiring a complex range of skills. As we have just stressed above, a stream rehabilitation project can fail at any point in the process, between defining the problem, to driving the excavator. Many of the professionals in the industry are trained in one discipline, but then are expected to make decisions relevant to other areas (eg. engineers making decisions about ecology). This is inevitable. However, the industry is now at the stage where it would profit enormously from a structured, training program. This program will be most successful if it incorporates accreditation (eg. certificates, diplomas, degrees, postgraduate degrees etc.) and this accreditation is recognised by the industry. Ideally, the accreditation would become a pre-requisite for entry into the industry.

It is not a trivial task developing such a program in such a diverse and multi-disciplinary industry, but this cause would be much advanced if LWRRDC took a strong lead in the area.

Implications and actions for LWRRDC

- **ACTION: Develop** an accredited training strategy for the stream rehabilitation industry that recognises the national diversity of the industry, and the need for training at all levels.
- **METHOD**: The NRRRP could provide sanction for such a training course, which would probably be coordinated through a single university but possibly with distance education components. Attempts have been made in the past to set-up such courses by the River Basin Management Society, and they could be a good starting point for the design of the course.

Disseminating existing and new information

(a) An Industry Journal

The stream management industry is strongly state focused. Research and experience moves slowly between catchments, let alone across state borders or between different disciplines. At present, if one group makes an advance that they would like to let others know about, or if some international work should be publicised, there is nowhere to publish that information.

It is interesting to see the LWRRDC newsletter Rip-Rap growing to cover a whole range of topics outside of its original brief, which was riparian vegetation. This is happening because it is filling a role as broader trade journal related to environmental rehabilitation of streams generally. We believe that there is a definite market for some form of trade journal that fills the niche between a Rip-Rap type newsletter and academic journals, but that reflects the unique problems of rehabilitating Australian streams.

Implications and actions for LWRRDC

- **ACTION: Encourage** the development of a journal or publication that would assist in dissemination of information and experience related to stream rehabilitation

- **METHOD**: The stream rehabilitation industry is probably not large enough to sustain its own trade journal, but it could coordinate with other organisations. For example, the Australian Journal of Soil and Water Conservation, published by the Soil and Water Conservation Association of Australia, recently ceased publication but it is now planning to be re-published in a different format. This may be an appropriate vehicle for a trade journal with some start-up funds.

(b) A National Clearing House

Another important contribution (in concert with the journal above), would be some sort of clearing house of information about stream rehabilitation. It is this 'information broking' role that is missing in much of the water industry in Australia, and is required as a link between LWRRDC, researchers and the onground works. One possibility is to fund a single person within an institution to be responsible for maintaining a 'national stream rehabilitation clearing house'. They would play several roles.

- Manage the above journal (not necessarily edit it)
- Maintain a clearing house of material relevant to stream rehabilitation (perhaps through a formal library) Examples would be—books, obscure articles, photos, videos, etc. that are not easily accessible to the average manager.
- Keep up with the latest developments around the world and Australia, via library information, Internet, and by acting as a clearing-house for any work/info done around the country.
- Develop an Internet site to disseminate this information nationally
- Maintain a compendium of stream rehabilitation projects undertaken in Australia: where they are, type of stream, type of works, successes and failures, lessons etc., to serve as a data-base for others to learn from. In general the stream management industry has been quite slow to learn from each other. Such a compendium will become more important as the NHT process rapidly increases the number of projects undertaken.

A typical application would be where a new Landcare group in SA want to undertake an NHT project on their wide, sandy granite stream. There first step would be to contact the 'stream rehabilitation centre', for the latest techniques for rehabilitating this type of stream, and other examples of this type of work across the country. This sort of system would be most successful when combined with a stream classification system that allowed some characterisation of the problem reach and catchment.

Implications and actions for LWRRDC

- **ACTION: Establish** a national clearing house for stream rehabilitation that would act as a conduit for information and examples.

- **METHOD**: This position could be filled by the National Stream Rehabilitation Coordinator (mentioned above). The position would require extra funding to get established.

Identify organisations that may wish to partner this sub-program

The Task: Identify other organisations that may wish to partner this sub-program

Table 3
Identifies groups who may share LWRRDC's interest in stream rehabilitation

Group	Potential interest as partners?
New generation of catchment based organisations with power to rate the catchment.	*These organisations will do the works as well as plan them—strong prospects for cooperation.*
• Mt Lofty Ranges (SA) (Torrens, Onkaparinga Rivers)	Have large rating base, well developed catchment management structures and plans.
• New Catchment Management Authorities in Victoria (CMAs)	Only formed in 1997—still not entrenched in a set program, and open to new ideas. CMAs have their own substantial rating powers.
Non-rating catchment groups • NSW Total Catchment Management Groups • QLD River Improvement Trusts	Not well funded, but a direct conduit to community activity.
Urban authorities/corporations • Sydney Water • Melbourne Water • Brisbane City Council, and equivalents in other capital cities and regional centres.	Urban management authorities are probably the best funded stream management organisations in the country. Although LWRRDC concentrates on rural issues, these urban bodies actually have lots of rural streams in their care. They are also, in our experience, 'hungry' for research in this area. See comment below regarding infrastructure maintenance.
State river management agencies	*Lower potential for research partnerships, but some potential for applied (tactical) research.*
• Qld Dept. of Natural Resources • NSW Dept. Land and Water Resources • VIC Department of Natural Resources and Environment • TAS Dept. of Primary Industries and Fisheries • SA Dept Environment Heritage and Aboriginal Affairs • WA West Australian Water and Rivers Commission • Murray Darling Basin Commission	These agencies are involved in the NHT process, and are the core advisory/extension group for this type of work. The capacity of many of these groups to do research themselves has been eroded in recent years.
Corporatised water authorities • Goulburn–Murray Water etc. Victoria	The newly corporatised rural water authorities may support work in stream rehabilitation so as to reduce or meet their environmental flow requirements (see comment below).

Group	Potential interest as partners?
Federal Agencies • Environment Australia • Dept. Primary Industries and Energy	These departments may have resources for projects of national significance. Critical that LWRRDC develop coordination with Environment Australia in their environmental flow program.
Industry Groups • Sugar industry groups • Dairy industry groups • National Farmers Federation • Water Authorities (Urban and Rural) (eg. Aust. Water and Wastewater Association) • Australian Coal Association Research Program	Industry groups have a strong vested interest in developing clean, green images. Stream rehabilitation is a very saleable item (eg. see the success of Operation Platypus in Victoria—large corporate sponsorship!). Another example is influence of sugar industry on acid sulphate soil research. The Coal industry, for example are involved in numerous stream channel diversions.
Conservation groups • Australian Conservation Foundation • Environment Victoria • Wilderness Society • State Conservation Councils • Local 'Friends of ' and similar groups	Good opportunities for involvement in demonstration projects (witness ACF involvement in the Clear Paddock Ck project in Sydney, and the general interest in the rehabilitation of Lake Pedder).
Research groups • Cooperative Research Centre for Catchment Hydrology • Cooperative Research Centre for Freshwater Ecology • Griffith University Centre for Catchment and In-stream research, and • other research organisations …	LWRRDC should target research groups as potential partners, especially when they have resources in their own right, such as Cooperative Research Centres, and other centres.

Projects of a specific type could be targeted to agencies at different levels. Projects of general national significance can be targeted, for example, at Environment Australia (eg. a review of international stream rehabilitation experience). Large demonstration/evaluation projects could comfortably be targeted at a consortium of groups (eg. state agencies, catchment boards etc.).

Impetus for stream rehabilitation projects will come from several places, including the following two.

1. Over the next few decades there will be an increasing maintenance costs in channelised streams, particularly in urban streams. As concreted, piped and channelised streams age, managers have to decide whether to rebuild them, or manage their decline. We know that this is a major issue in Sydney, Melbourne and Brisbane. Thus we must be ready to suggest rehabilitation as a low maintenance option for these channelised streams. LWRRDC would find major allies in urban management agencies.

2. With corporatisation of the water sector, and the apportioning of water rights occurring in several states (eg. the ‘WAMP’ process in Qld), there may be pressure from dam owners to maximise the environmental benefits of environmental flows by altering the character of the stream rather than alter the amount or timing of flows. That is, by altering the form and structure of the stream you can achieve greater environmental benefits with the same flow. Thus, there may be opportunities for water authorities to partner stream rehabilitation projects with LWRRDC.

General conclusions to this section

1. There is little question that well designed, vertically integrated research (ie. incorporating organisations who will use the outcomes, with researchers and government departments) produces the best technology transfer results. In such integrated projects, the research gets done, but as importantly, the people involved are convinced of the results. We recommend a series of large, integrated projects (see above).
2. There are many groups interested in stream rehabilitation across Australia, and many of these have a funding base quite different from LWRRDCs (eg. local government, catchment rated groups, urban managers, water authorities). Thus, there should be good opportunities for raising matching funds on projects.
3. Ageing and deterioration of old channelised and drainage systems will provide a major opportunity for stream rehabilitation, particularly in urban areas. Already there is good evidence that the urban stream managers could be the major impetus for stream rehabilitation in Australia. These urban authorities could also be the major source of partnership funding for LWRRDC.

Implications and actions for LWRRDC

- **ACTION**: **Pursue** jointly funded projects with the organisations listed in Table 3. LWRRDC’s role in projects would be in coordination, motivation, and matching funding. Emphasis should be given to interdisciplinary demonstration/flagship projects wherever possible.
- **METHOD**: The NHT process may be a vehicle that can be used to initiate such cooperative projects. The Clear Paddock Creek project in Sydney is an example of such a flagship project.

Concluding comments

Rehabilitating streams is a new discipline in Australia. Its underlying premise is that we can return some of the basic ecological and physical values of our streams. This represents a fundamental change in the way we see our streams, and such a change cannot happen quickly. Many of the R&D requirements in this area stem from the fact that it is a new area of work, combining information from many disciplines that themselves have imperfect knowledge (particularly in the unique Australian environment). There is also the added complication of attempting to change the way land and water resources are used at a property level. Thus, many of the R&D needs in stream rehabilitation relate to transforming a loose collection of ideas into a recognised industry group with journals, accredited training, accreditation methods, and clear goals. LWRRDC can play a key role in accelerating this process by implementing some of the recommendations suggested in this report.

APPENDIX 1

Ensuring stream rehabilitation works carried out under NHT funding are successful and effectively targeted

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This paper discusses the research and development that is required to ensure that onground stream rehabilitation work funded by the Natural Heritage Trust (NHT) is successful and effectively targeted.

Context

Hierarchy of stages in a river rehabilitation project

For a river rehabilitation project to be successful and effectively targeted there is a hierarchy of stages to be negotiated.

1. Developing goals and objectives.
2. Understanding the constraints that prevent the goals and objectives from being achieved.
3. Selecting the most appropriate strategy to address goals and objectives.
4. Detailed design and specification of techniques to implement the strategy.
5. Implementing works or activities.
6. Maintenance or follow up activities including evaluation.

Consideration of scale

This hierarchy applying to stages in time is parallelled by a similar hierarchy that relates to space.

1. Goals and objective setting for river rehabilitation should commence at a catchment or regional scale.
2. Understanding of constraints must similarly reflect a catchment wide perspective.
3. Strategies will relate to rehabilitation programs for whole streams or to substantial stream reach or community scales.
4. Detailed design will have a reach or project focus or relate to small communities of stakeholders.
5. Implementation is at the site by site level involving individuals or small groups of stakeholders.
6. Maintenance and follow up is more likely to apply within a site or to individuals.

Failure of river rehabilitation projects

Failure at any one of these levels is likely to result in a river rehabilitation project having a less than optimal outcome even if all the other stages are completed successfully. For example, consider the (frequent) case where stage 1 has been ignored or is unsuccessful, that is, the goals for rehabilitation are unclear. In that case, even if we understand the problem, select the appropriate technique, design, implement and maintain any works or activities correctly, the project is likely to be considered a failure at least by some stakeholders because of disagreement about goals. Similarly being clear about goals, having adequate understanding of a problem and selecting appropriate activities may still result in project failure if there is not correct implementation. Further examples of failures at each of these levels, are provided in Table 4.

Existing state of play

Where do the main barriers exist to successful stream management in Australia?

Adequate professional advice is already available at stages 4, 5 and 6 to assist with design, implementation and maintenance of stream rehabilitation activities. That is not to say that advances cannot be made in design, implementation and maintenance; but in general, practice lags well behind knowledge in this area, so the issue is more one of communication than of research.

1. Design and specification of stream rehabilitation works (stage 4) is not a major barrier to stream rehabilitation success although the sources of sound, well balanced advice are relatively scarce and not well spread geographically. The key issue is to obtain appropriate advice.

2. At the implementation stage (stage 5) it may be necessary to provide training or employ skilled workers. The key issue here is communication of best practice through guidelines or courses. This communication problem is certainly one that needs to be addressed, and possibly by LWRRDC.

3. Recognition of the need for a maintenance stage (stage 6) is sometimes lacking. The key is to plan for maintenance early in the project to make sure there are sufficient funds available for it to be carried out when necessary.

While stages 4, 5 and 6 tend to attract the most interest in stream rehabilitation R&D, the emphasis should be on trials, monitoring and sharing of experience.

The early stages of the hierarchy present the greatest barriers to progress. In the simplest of terms, if we know what it is that we are trying to achieve, it is (comparatively) straightforward to get there. Stages 1, 2 and 3 are the hard ones: stages 4, 5 and 6 are (relatively) mechanistic.

4. Developing catchment wide or regional stream management goals (stage 1) is currently a barrier to progress. Achieving an acceptable balance between utilitarian and environmental objectives for rivers is a topic of current debate. But even within the rehabilitation context, goals and objectives are usually unclear: are we managing this river as a trout stream, for native fish, for naturalness, for recreation, etc?

5. Stage 2 provides the knowledge to support the stream rehabilitation goals and analyse and evaluate stream rehabilitation strategies. Lack of understanding of physical, chemical and biological processes can currently hinder success of stream restoration projects.

6. Where stage 2 is able to provide a good understanding of the constraints to achieving the goals, the stage 3 strategy development and selection may not present a barrier. But if there is insufficient understanding at stage 2, strategy selection becomes difficult. For instance choosing between high intervention and low intervention strategies, on site or off site works, social or engineering approaches reduces to a decision based on familiarity if the understanding is not there.

Research and development needs

How can research and development reduce the risk of failure at each of these levels? The above view of the 'state of play' suggests that the main research and development needs occur in stages 1, 2 and 3. Examples are provided in Table 4.

Furthermore, it is useful to consider where the maximum return from R&D effort is likely to accrue. Again this favours a focus on the strategic level represented by stages 1, 2 and 3 above. This is simply because getting it right at the strategic level has the potential to produce more successful outcomes than getting it right at a single site. Improvements in our abilities to set appropriate objectives, understand the problems and choose the right strategies have the potential to profoundly influence stream rehabilitation progress in Australia. Improvements in designing and implementing works or activities can also have a positive impact but there is less scope for improvement and a smaller sphere of influence.

River rehabilitation as a subset of river management

River *rehabilitation* goals at a regional or catchment level are a subset of broader river *management* goals. River rehabilitation objectives cannot be set without consideration of the compromises that might be imposed by other sets of values and other expectations for the river.

Proactive or reactive management

River management, and river rehabilitation in particular, needs to move beyond problem driven management. Good river management will not just be reacting to perceived problems. Good river management will be proactive in determining river conditions that are desirable and then implementing a range of reactive recurrent activities together with proactive strategic activities that are designed to manage situations in the long term that might not yet be problems. A continuation of the current emphasis on problem driven management will encourage localised bandaid solutions. The aim of river management should not be to treat isolated problems at individual sites, but to understand the system, the pressures and problems, and to implement broad strategies that move the river toward a future condition that meets the agreed aspirations of a range of stakeholders.

River management should aim to manage systems rather than treat symptoms. To do this successfully, we need to set clear goals for rivers at scales of catchment, reach and site. To achieve this, we need to see a move away from problem based reactive management, toward objective based proactive management.

Setting goals for rivers—an R&D need

How should we set goals for river management? How should we set goals for river rehabilitation? These are two key research questions.

This issue has been addressed to an extent within the various attempts at 'strategic planning' for river management that have been undertaken (and are currently being undertaken) in the various States. Despite a range of approaches, there is no common view on how to go about this multiobjective planning process. The techniques vary from the purely qualitative to the excessively quantitative but regardless of the apparent rigour; all the approaches ultimately rely on the particular value system of the assessor. (A discussion of a multiobjective planning approach used in Victoria is provided in Appendix 7 by Dr S. Ewing).

The lack of a reliable practical process for setting river management and river rehabilitation goals at a regional or catchment level presents a major R&D challenge. A practical method must take account of community expectations and aspirations, and economic implications, as well as being credible through good science. Yet the process must allow sufficient pragmatism and be sufficiently broadly based to ensure that compromises can be reached across catchments. For example, it may be appropriate to allow a section of river to degrade in one area in order to maximise naturalness somewhere else.

The selection of 'Heritage Rivers' in Victoria provides an example of successful goal setting. Following detailed investigation and consultation, the Land Conservation Council (1989) nominated various heritage rivers and natural catchment areas to be managed and protected. These recommendations were passed into law through the Heritage Rivers Act (1992) which restricts land and water uses and requires the preparation of management plans. Any stream restoration activities in these areas must comply with these plans and with the Act.

The Goulburn River downstream of Eildon dam in Victoria provides an example where distinct goals may be appropriate in different reaches. Operation of the dam has resulted in reduced temperatures and decreased flood frequency which has "alienated the section of the river between Eildon and Seymour (138 km) from habitation by native fish species" Gippel and Finlayson (1993) argued that it may more pragmatic to manage this section for recreational fishing of introduced species rather than supplying the environmental flows and reservoir destratification that would be necessary to provide for native fish. In compensation, the natural habitat value of the rest of the river could be protected or rehabilitated where necessary. This recommendation contrasts with the actions of the Victorian Government that has recently moved to increase environmental flows despite the water being too cold to allow spawning of native fish (Gippel 1997).

Negotiating trade-offs—an R&D need

Setting goals and objectives requires trade-offs to be made. Addressing many of the large-scale stream rehabilitation issues in Australia such as environmental flows will result in winners and losers—providing more flow for fish is likely to result in less flow for irrigators.

Key issues in setting goals and objectives are the valuing of environmental improvements and the problems of uncertainty. It seems easier to quantify the costs of stream rehabilitation than the benefits. For example, consider the provision of environmental flows. Reducing flows to irrigators results in a well-defined cost to a well-defined group. The group is likely to politicise their problems and there will be pressure for compensation or scrapping of the rehabilitation project.

The benefits of environmental flows are much less clear. It is generally not possible to accurately quantify the expected environmental improvement and there is not a clear benefiting group. The easy way out is to spend more money on environmental flow R&D rather than actually implementing environmental flows. Blame for the lack of action can then be placed on the unavailability of suitable techniques rather than our inability to reach an appropriate trade-off between environmental and utilitarian values in setting goals for the river.

Policy level R&D

Many of the issues of stream restoration are analogous to the problems of managing 'common property' such as those outlined in 'The Tragedy of the Commons' (Hardin 1968). Common property tends to be over exploited. In the case of streams, this over exploitation is what leads to many of the problems that need to be addressed through stream restoration. New stream restoration techniques won't halt the over-exploitation as the pressures that degrade streams will continue. Effective stream restoration will require clarity about goals and objectives for rivers and the institution of new regimes to better manage the natural resource. This is being partly addressed through the COAG agreement on water resources (Pigram et al. 1994; ARMCANZ 1995; Working Group on Water Resource Policy 1994 & 1995). The economic benefits of the COAG agreement are widely acknowledged but the environmental benefits are less clear. For example (Bjornlund and McKay 1995) find there are some benefits but argue that other instruments are also required to address environmental problems. Further R&D at this policy level should be supported by LWRRDC.

The need for evaluation

Determining whether projects are successful and effectively targeted requires that they be evaluated. Unless the goals of the project are clear, evaluation can't be carried out. Following implementation, a selection of NHT projects should be evaluated to ensure that stated objectives are met. An R&D need is to develop appropriate evaluation procedures.

Ensuring NHT works are successful and effectively targeted

Given these problems how can we make sure NHT works are successful and effectively targeted? The key is to R&D the highest stage first. If there is a problem at stage 1—goal setting and problem recognition—then that should be sorted out before doing any R&D at the lower levels. If a particular stream rehabilitation project is a priority and the scientific understanding is sufficient, only then will it be appropriate to R&D new stream rehabilitation techniques.

Maximum return from R&D will come from tackling the highest order issues first. The higher up the hierarchy that we get it right, the more outcomes are successfully influenced. R&D at technique or implementation stage can only ever affect a limited number of outcomes. Focusing R&D at the highest possible level will have the greatest influence so it is very important to concentrate at the problem definition, priority, objective and goal setting end of the stream restoration problem.

Works on the ground will be successful and effectively targeted when all the higher stages are addressed, that is, when we are clear about the goals, when the scientific understanding is sufficient and when the appropriate technique is selected and specified. Works proposals in NHT applications could be reviewed in light of this hierarchy of requirements. Only those proposals that meet all requirements should be funded. Applicants should be specific about the goals of their proposals, which could be for a river reach, a whole river or a catchment. They should also explain the understanding of the problem, technique selection, and how the design, implementation and maintenance will be carried out.

Table 4
R&D needs to ensure that stream rehabilitation projects carried out under NHT funding are successful and effectively targeted.

Stage of stream rehabilitation project	Possible reasons for project being unsuccessful or ineffectively targeted	Example	To avoid the works being unsuccessful:	Example of R & D needs
Developing goals and objectives	Disagreement about vision or objectives for the river system or conflict between goals.	River regulation effectively delivers water for irrigation but cold water releases from dams reduce native fish populations. Are multi-level offtakes warranted or is that an expense that can not be justified?	Seek community input in articulating overall goals for rivers. Develop procedures to allow optimal trade-offs between competing demands.	Participative techniques for setting goals and objectives about rivers.
Understanding the constraints that prevent the goals and objectives from being achieved	Wrong problem is addressed	Habitat, which is in poor condition, is improved in an attempt to increase fish numbers but the over-riding problem is poor water quality.	Thoroughly investigate and understand the problem to be addressed. Use professional advice and scientific input.	Scientific research into physical, chemical and biological stream processes.
Selecting the most appropriate strategy to address goals and objectives	Inappropriate technique selected. Appropriate technique not available.	Gabions (wire baskets) used to control bank erosion in a gravel bed stream. Gravel erodes the wire and the gabions fail.	Use guidelines and professional advice to select appropriate techniques	R&D to find better techniques
Designing and/or specifying techniques to implement the strategy	Inappropriate design or specification	Inappropriate tree species selected. Erosion control works not designed to withstand high flows.	Use professions to specify or design works or programs.	No R&D needs, the key is to obtain competent advice.
Implementing works or activities	Poor construction/ Implementation. Appropriate materials are not available.	Trees aren't watered in at planting, tree guards not place effectively.	Use trained staff or contractors to implement works on the ground	No R&D needs, Just do it. The main issue is to ensure effective communication through published guidelines and training.
Maintenance or follow up activities	Inappropriate maintenance or no maintenance	Fences damaged during floods are not repaired allowing stock damage to a plantation.	Plan and budget for regular and emergency maintenance.	No R&D needs, Just do it.

APPENDIX 2

River rehabilitation research and development needs: a holistic, catchment-based approach

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Introduction

Australian rivers are part of highly modified landscapes in which human activities are dominant (CSIRO 1992).

- Our efforts at river rehabilitation cannot realistically aim to reconstruct landscapes of the past.
- River management strategies that emphasise the need for 'stable' channels are unlikely to be sustainable in either ecological or economical terms.
- Rivers should be managed as integrative, functional systems, working with their natural range of behaviour at differing positions within catchments.
- At any particular site, the linkage between channels and their adjacent floodplains, in terms of transfer of water, sediment, organic matter, nutrients, etc., needs to be maintained.
- River rehabilitation strategies must operate within a catchment-based, holistic framework, linking land and river management.
- Unless river structure is appropriate for differing landscape settings (and/or differing positions in catchments), other aspects of river condition (eg. vegetation, riverine ecology, etc.) are unlikely to be managed effectively.

The procedure outlined in this document assesses the character and behaviour of rivers throughout a catchment, and examines the downstream linkage of river processes (ie. how upstream parts of the catchment impact downstream, and vice versa). River styles are identified for differing landscape settings, based on assessment of channel geometry, channel planform, and the assemblage of geomorphic units that comprises differing reaches of the river. Insights into river evolution are used to predict likely future river structure. Working within the catchment framework, target conditions for river rehabilitation programs are determined for differing river styles.

As rivers demonstrate remarkably different character, behaviour and evolutionary traits, both between- and within-catchments, the same rehabilitation strategy will not necessarily work for similar problems at differing sites. The procedure is based on the premise that adopted target conditions for river rehabilitation must replicate the natural variability in river structure inherent to the Australian landscape. In other words, our strategies for river rehabilitation are likely to be most efficient and most cost-effective if they work with the existing boundary controls within which the river operates. Hence, we aim to replicate the 'natural' character of rivers for equivalent landscape settings, maximising the potential for rivers to self-adjust, and reducing the need for ongoing reactive management. Less impacted sections of river are used to guide the target conditions for river structure in more degraded sections of the catchment which operate under a similar set of controls.

A geomorphic approach to catchment characterisation

The proposed catchment-based framework for river rehabilitation provides a modified, Australian alternative to the procedure outlined by Rosgen (Rosgen 1996). Among the significant attributes of the Rosgen (1994; 1996) approach are:

1. it evaluates river behaviour from its appearance.
2. it assesses the relative stability of differing river types. Likely shifts from one type to another are outlined. Assessment of relative degrees of degradation aids identification of likely future patterns of adjustment.
3. it identifies sediment and hydraulic relationships for each river type.
4. it has the potential to be linked to ecological assessments.

Limitations of the Rosgen (1996) approach include:

1. The approach is static, and does not explain river behaviour, or place river behaviour within an evolutionary context.
2. The framework is site (or reach) specific, and does not explain relationships between reaches within a catchment context.
3. The approach focuses on channel conditions, with relative disregard for their associated floodplains.
4. The suite of river types needs to be extended to encompass the range of landscape settings (eg. the escarpment, low relief plains, etc) experienced in Australia.
5. When deviations from the given forms arise, practitioners have no basis upon which to explain why these types are different and what target conditions to aim for in river rehabilitation strategies.

The proposed framework takes the advantages of the Rosgen approach, works on its limitations, and develops a new approach working within an Australian context (although the procedure is generic). The framework represents a geomorphic approach to river characterisation within a catchment, viewing rivers as the sum of their channels and adjacent floodplain. River character and behaviour are assessed at four interlinked scales: catchments, landscape units, river reaches, and geomorphic units (cf. Frissell, Liss, Warren and M.D. 1986, Naiman, 1982 #2831, Figure 10.1)

The adopted approach effectively dissects a catchment, characterising 'styles' of river behaviour for differing landscape units. The distribution and connection of river processes are explained in terms of catchment-scale boundary conditions (eg. geology, slope, human disturbance, vegetation cover, etc), which determine topography, material character and water availability. This results in a range of form/process associations within each reach, indicated by the assemblage of geomorphic units.

Adjustments to channel and planform geometry provide the critical evolutionary perspective with which to interpret changes in the assemblage of geomorphic units which comprise each river reach. These insights, along with an inventory of sediment availability along river courses, provide a basis to predict likely future river structure.

Application of the procedure

There are five stages in the application of the catchment characterisation procedure (Table 5):

Table 5
Stages in application of the catchment characterisation procedure

Stage 1	**Data compilation (description and mapping)**
(i)	• derive catchment boundary conditions
(ii)	• determine landscape units
(iii)	• assess river character
Stage 2	**Data analysis**
(i)	• define and interpret river styles
(ii)	• explain the character and behaviour of river styles in the contemporary system
(iii)	• assess river history
Stage 3	**Predict likely future river structure**
Stage 4	**Prioritise catchment management issues**
Stage 5	**Identify target conditions or river rehabilitation, based on determination of suitable river structures for each river style**

Stage One: Data compilation

Assessment of catchment boundary conditions

Information compiled at this stage is restricted to larger scale catchment analysis. The following steps are undertaken:

1. Check background literature on the catchment, along with historical and archival information.
2. Using 1:25,000 maps and the most recent equivalent scale air photographs, produce a catchment base map showing the river network and subcatchment boundaries.
3. Determine various morphometric parameters for each subcatchment (such as catchment areas, stream lengths, relief ratios, drainage densities, etc).
4. Plot stream longitudinal profiles.
5. Produce catchment-scale maps showing geology, soils, vegetation coverage and type, land use and rainfall distributions. A GIS approach may be optimal.
6. Summarise available discharge data.

Designation of landscape units

Landscape units are readily identifiable topographic features with a characteristic pattern of landforms. They are differentiated on the basis of physiographic setting (landscape position), and morphology (elevation and slope). Examples include tablelands, uplands, escarpment, base of escarpment, rounded foothills and lowland plains. These features are mapped at 1:100,000 scale by identifying distinct breaks in slope along longitudinal profiles.

River reach analysis

On the basis of channel planform, channel geometry and the assemblage of geomorphic units (instream, channel-marginal and floodplain), river reaches are identified for each landscape unit. At selected sites within each river style, cross-sections are surveyed to map the assemblage of geomorphic units (eg. bars, levees, backswamps, etc.). Sediment analyses are completed for each geomorphic unit.

In future applications of the procedure, when there will be an inventory of river styles at-hand (cf. (Rosgen 1996), river reaches will be characterised as river styles from the outset.

Stage 2: Data analysis—interpretation of river behaviour and evolution

Identify river styles in each landscape unit

River reaches are differentiated into river styles for each landscape unit. This assessment is based on the assemblage of geomorphic units, bed material character, number of channels, lateral stability, etc, as well as the capacity of the river to supply, temporarily store (ie., transfer) and accumulate materials. Hence, the differentiation of river styles is based on assessment of their form (ie. river structure) as well as their function (ie. the range of biophysical processes).

Characterise and explain river behaviour for each river style

River character and behaviour in each landscape unit are analysed in terms of catchment-scale boundary conditions. The key to explanation of river character and behaviour lies in determining controls on the spatial pattern of geomorphic units, and how this has changed over time. These are summarised initially for each reach, then analysed in relation to landscape units. Previous work has shown that variability in slope and valley confinement are likely to be the key controls on river character.

Assess river evolution

Analysis and explanation of contemporary river character provides a benchmark condition for assessment of channel changes. Historical air photographs are used to determine the character and extent of river adjustments over the past few decades.

Downstream pattern of river styles

The downstream pattern of river styles assesses the process linkages between differing parts of catchments, analysing reach to reach and tributary to trunk stream relations. From this, those parts of catchments which have contributed most significantly to channel changes are isolated, and sites which are most sensitive to future disturbance are determined.

Stage 3: Prediction of likely future river character

Prediction of future river structure is contingent on a solid understanding of controls on contemporary river character. Three strategies are used to provide insight into likely future river behaviour:

1. The downstream pattern of river styles, and changes to this pattern, are used to outline likely future river behaviour (cf. Rosgen (1996).
2. Upstream sediment availability is used to infer potential downstream changes in river character.
3. Various principles of contemporary river character are related to existing geomorphic theory (eg. catchment area to channel geometry, pool-riffle spacing, etc.) and insights are used as a basis for prediction of likely future channel adjustments.

Stage 4: Prioritisation of catchment management issues

Effective, long-term river management strategies must balance our efforts at river conservation and rehabilitation within a catchment framework. Many sites will need ongoing management, such as removal of weeds, replanting, or, in more extreme circumstances, shifting sediment accumulations or channel realignment.

Proactive (or pre-emptive) management strategies are the most effective means of river conservation. Once adjustments are set in motion following disturbance, a phase of accelerated change may commence. This stage may be almost uncontrollable without inordinate, impractical expense. As Newson (1992) comments, "It is generally recognised that a river basin which is physically destabilised, through natural or human perturbation of its morphological and sediment transfer elements, is extremely difficult to stabilise through management intervention". The most effective strategy in these situations may simply be one of waiting for the system to regain some sort of balance before adoption of physical intervention strategies. Hence, identification of those parts of catchments that are relatively undisturbed, or represent sensitive sites for future disturbance, are key areas for landscape preservation. Retaining the present condition of these areas is considered the first priority in best management practice.

Various geomorphic principles can be used to prioritise site by site rehabilitation within a catchment framework

1. Underlying causes of erosion and sedimentation problems need to be assessed, so that the sites of instability and associated sources of sediment or accumulation zones can be prioritised. In a number of cases in South-Eastern Australia, management responses will be conditioned by differing phases during the passage of sediment slugs. Responses will vary at differing catchment positions.
2. In general, approaches to changing river structure are best applied from upstream to downstream, as responses triggered at one place must work their way through the system. Eventually, our aim is to achieve a river which is sufficiently resilient to cope with such upstream disturbances.
3. As a general rule, bed level issues need to be addressed before lateral (bank) instability problems, as base level adjustment is the natural precursor to headcut development and subsequent lateral expansion of the channel (Schumm, Mosley and Weaver 1987).

Stage 5: Identification of suitable river structure for Rivercare Planning

Among the many challenges in river rehabilitation in Australia is the need to determine appropriate river structures that provide suitable habitat for the flora and fauna of Australian riverine ecosystems, in the light of changes that are taking place within these systems. It is now widely recognised that channel geometry and vegetation associations must be appropriately reconstructed before sympathetic rehabilitation of riverine ecology will occur (Newbury and Gaboury 1993). The key components of river structure include:

1. channel width and alignment (or planform);
2. diversity of geomorphic units, whether instream, at channel margins, or on the floodplain;
3. bed substrate variability and associated textural variability in banks and on the floodplain;
4. ensure channel–floodplain connectivity is maintained, and
5. riparian vegetation associations.

Our efforts in channels must be balanced by our efforts on floodplains, ensuring that essential linkages are maintained. Appropriate plans must balance concerns for river stability (and associated sediment transfer) while providing suitable aquatic and riparian habitat.

Using procedures outlined in this document, specification of river structure at differing problem sites (ie. the target condition for our efforts at river rehabilitation) is based on assessment of river style from a less impacted section of a catchment which has similar boundary conditions.

Target conditions for each river style must be designed and evaluated within an integrative, catchment perspective. The most appropriate river rehabilitation strategy for a similar looking problem may vary from subcatchment to subcatchment, based on slope, confinement, critical bank height, etc. These geomorphic circumstances must be appraised to determine where minimally invasive vegetation management strategies are likely to work, and what kind of vegetation strategies must be used at differing positions in the catchment (eg. toe revetment versus graded banks, etc). Alternatively, the procedure provides pertinent data to determine where more conventional engineering solutions are required. Consultation with hydraulic engineers and riverine ecologists is required to identify suitable river structures for differing erosion/sedimentation problem sites.

Implementation of the procedure

The outlined framework is open-ended, and never intends to be all-inclusive. Among the many prospective difficulties that will be faced is the consistency in application of the procedure, as differing practitioners with different background skills may face difficulties in interpreting differing river styles and associated controls on river behaviour. The range of identified river styles in Australia is very limited, and considerable expertise and experience are required to characterise and explain the geomorphic behaviour of additional styles.

At this stage, the approach requires a field-based geomorphologist with an ability to 'read the landscape' to effectively apply the procedure. With time, as the designation of river styles becomes more established, it will be increasingly easy for non-geomorphologists to apply the procedure, especially if they have received some initial training in the approach (cf. Rosgen-style workshops). These training sessions could be linked directly to management workshops on river rehabilitation techniques, demonstrating the suitability of differing responses for erosion and sedimentation problems at differing positions in catchments.

Application of the procedure would be best achieved within a hierarchical framework in terms of technical support and advice. In this framework, if the field operator cannot resolve an issue relating to a river style, the regional technical officer is approached for advice. If the problem cannot be resolved, the regional manager is consulted. Beyond this stage, the Head Office could be contacted, or the problem could be contracted out to external consultants (ie. river researchers within universities or private agencies).

Working within the NSW Rivercare framework, implementation of the catchment characterisation procedure for river rehabilitation is a three stage operation, entailing:

Stage 1 Data compilation by researchers

Stage 2 Transfer of data to Rivercare and Landcare officers. Researchers work with technical staff within DLWC (typically the regional river engineer) to determine appropriate river structures for each reach within the catchment.

Stage 3 Communication of non-technical data by TCM, Rivercare and Landcare officers to the community, in a collective effort to implement the management plan for each reach.

This three stage implementation procedure requires consensus among researchers, managers and local facilitators (Rivercare Group, Landowners, etc) on underlying controls on the nature of channel adjustments, and their linkage within the catchment.

Finally, the State Agency (DLWC) would commission auditing procedures on a decadal basis.

Summary

In geomorphic terms, the proposed procedure:

1. is generic and open-ended, and can be used to provide a baseline survey of river character and condition for any catchment
2. explains the within-catchment distribution of river forms and processes in context of system evolution
3. is used to identify and characterise river styles for differing landscape settings
4. assesses linkages between differing river reaches, demonstrating how changes in one part of a catchment have impacted elsewhere, over what time frame
5. provides a predictive basis to assess future river character and responses to disturbance, based on assessment of sediment storage along river courses.

Variability between catchments is determined by:

1. Their differing assemblages of landscape units
2. The differences in river behaviour that may be evident for individual landscape units.

In terms of geomorphic links with river ecology, the proposed procedure:

1. determines the physical template of a river at differing positions throughout a catchment, providing a framework to assess habitat availability along river courses
2. assesses changes in river structure over time, thereby showing how habitat availability has changed
3. provides a basis to determine suitable river structures to support viable habitats along river courses
4. provides insights into ecosystem functioning, through relationships to the character and distribution of riparian vegetation, thereby influencing organic matter processing within river systems
5. can be used to guide selection of 'representative' sites in programs to monitor river condition.

Ecological considerations are evaluated in terms of the character and distribution of geomorphic units that comprise each river style. This assemblage of geomorphic units constrains habitat availability and hence the capacity for ecosystem functioning. Efforts at river conservation must operate at this habitat scale, appreciating controls on the assemblage of geomorphic units in relation to channel geometry and planform scales, and catchment characteristics that determine flow and sediment interactions.

In terms of river management, the proposed procedure:

1. can form the biophysical basis for the development of Catchment Management Plans
2. helps to develop proactive, rather than reactive, management strategies, more effectively prioritorising resource allocation to management issues

3. can be used to identify river management problems at differing positions within a catchment, based on an understanding of why the problem is occurring
4. can be used to prioritise sites for river conservation and rehabilitation
5. enables realistic 'target conditions' to be determined for river rehabilitation programs, based on geomorphological understanding of river processes
6. ensures that site-specific strategies are linked within a reach and catchment-based 'vision'
7. provides baseline data for assessing the viability of river management works (ie. whether engineering strategies are required, or whether soft-engineering approaches will suffice)
8. provides a basis for river auditing procedures (see (Kondolf and Micheli 1995).

Acknowledgments

Much of this work has emerged from LWRRDC Project MQU1, coordinated by Gary Brierley.

APPENDIX 3

A framework for stream restoration design

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Introduction

There are many documented examples of failed restoration attempts and much criticism of the ad hoc approach to the design of stream environmental improvement projects. Criticisms mainly focus on poor definition of project objectives and a lack of understanding of the nature of stream degradation. However, a rigorous engineering design should include both problem definition and exploration. By following an engineering design procedure, the problems of past restoration efforts may be avoided. In this discussion, a design framework is developed for the case of stream restoration projects. Particular emphasis is given to how problems may be defined and explored. The application of engineering design principles will improve the likelihood of successful stream restoration in Australia.

A holistic framework for river restoration should include the social, political, economic, administrative, strategic planning, design, physical, chemical, and biological aspects of the restoration process. Each aspect or dimension has several elements. For example; the physical dimension includes benthic, water column, riparian and floodplain environments; the economic dimension could include economics at the scale of individual farms, regions, states or the nation; and the design dimension could include the steps of an engineering design problem. To be truly holistic, the framework should include all processes that lead to restoration and characteristics of the stream system that determine its response to management efforts. All components of this holistic framework have a role in determining the outcome of stream restoration efforts in Australia.

This discussion deals primarily with the design dimension and is intended to be applicable to a single or series of restoration projects in a wide range of physical settings. This design framework provides the steps that need to be taken to achieve successful restoration. For the purposes of this discussion, the other dimensions of stream restoration could be considered as the context in which the design framework must be used. This context includes stakeholder attitudes, funding arrangements, administrative arrangements, strategic planning, management history, local land and water resource use and the biological, physical and chemical characteristics of the stream. Aspects of the context are described in other sections of this report.

The design framework

The standard steps for Engineering design are:

1. Recognition of problem,
2. Definition of problem,
3. Exploration of problem,
4. Search for alternative proposals,
5. Decision-making, and
6. Specification and communication of solution.

Three further components may be added to provide an adaptive design process,

1. Implementation of the solution,
2. Evaluation of the outcomes, and
3. Maintenance and modification.

A discussion of the first five steps is given below for the case of stream restoration design. By breaking the design process into these components we can identify the information required for a stream restoration project. In some cases this information will not be available and further research and development is required. Thus, the value of further stream restoration research and development may be identified in terms of its contribution within the design framework.

Recognition of problem

There is increasingly perceived to be a need to maintain or enhance the health of aquatic ecosystems in Australia and worldwide. It is this need which provides the stimulus for stream restoration projects. Stream 'ill-health' can be recognised in a number of ways. Local residents who appreciate the ecological value of a stream and have some familiarity with the stream environment over a period of time may recognise that a problem exists. Anglers are particularly well equipped to recognise stream 'ill-health' having some understanding of aquatic habitat. Alternatively a monitoring program using the Index of Stream Condition (Ladson et. Al. 1997) or some other measure of stream health can be used to detect problems. It should be remembered that a problem will most likely be recognised by its symptoms and that the full nature of the problem may not be appreciated at first.

Defining the problem

Once recognised, it is necessary to define the problem. If this step is not undertaken, restoration efforts are likely to be limited to treatment of the symptom. For example, local residents may identify the problem by a declining population of a favoured angling or threatened fish species. If there is no discussion of the problem definition, the design solution may be to enhance the habitat of this particular species. Such solutions may be at the expense of other aquatic species or fail to address the underlying cause of stream degradation. The end result is unlikely to be the restoration of an aquatic ecosystem. A good problem definition will allow the restoration designer to consider the wide range of possible solutions available. Two key elements that define a design problem are the project objective and scope.

Project Objective

In order for a restoration project to be successful it is critical that all stakeholders clearly understand the aim of the project (Osborne 1993). Consequently, all users, managers, landowners and scientists need to be involved at some level to share ownership of the project and to ensure long-term maintenance, support and monitoring. However, there is no universally accepted definition of the term 'stream restoration' (de Waal, Large, Wade, Gippel and Darby 1997). The National Research Council (1992) argues that to restore an aquatic ecosystem, all functions and structural characteristics must be considered and that the fundamental goal of stream restoration is to return the stream to a condition that resembles its natural state as closely as possible. It is recommended that the term 'restoration' should be applied only to those activities directed to rebuilding an entire ecosystem. According to (National Research Council 1992), restoration projects

1. are self-sustaining,
2. do not manipulate elements in isolation,
3. seek to re-establish the pre-disturbance aquatic functions and related physical, chemical and biological characteristics,

4. are likely to involve reconstruction of antecedent hydrological and morphological conditions, and biological manipulations including revegetation, and
5. address the causes of degradation.

Stream management efforts that manipulate aquatic elements in isolation or do not attempt to re-establish the pre-disturbance condition should not be described as restoration. The term 'rehabilitation' is more appropriate for projects that seek to re-establish elements of the pre-disturbance condition in isolation. The terms 'enhancement' and 'creation' should be used to describe projects that aim to provide a higher quality ecosystem rather than recovery of the pre-disturbance state (Brookes and Shields 1996). 'Enhancement' is the improvement of isolated structural or functional attribute. Creation is the 'birth' of an entirely new ecosystem.

To illustrate the distinction between river enhancement, rehabilitation and restoration the following examples are provided.

1. Increasing the availability of pool habitat through the use of some artificial structure that causes bed scour is an example of habitat **enhancement**.
2. Re-instating pre-disturbance woody-debris volumes in a channel subject to ongoing flow regulation and flood control is an example of river **rehabilitation**.
3. Environmental flow management, wetland management, revegetation of streambanks and fencing are all likely to be required for **restoration** of a lowland river ecosystem subject to regulation.

The choice of objective whether it is stream restoration, rehabilitation, enhancement or creation should be made explicitly. For restoration or rehabilitation an approximate point in time must be selected to develop criteria for restoration (National Research Council 1992). If enhancement of stream health is the objective or a new ecosystem is to be created, a definition of stream health must be adopted as the design criteria.

Project Scope

One aspect of the scope of a project is the extent of the reach to be restored. This does not mean that design solution should be restricted to activities in this reach. Solutions such as source control of nutrients, environmental flow management or elimination of barriers to fish passage may be implemented at some distance from the project reach. The identification of a project reach should be the result of catchment-wide strategic planning.

Constraints may be imposed on the project to protect non-ecological uses of the stream such (eg. flood conveyance or water supply). These constraints should be specified as part of the problem definition. It is likely that such constraints will prevent 'restoration' as defined be (National Research Council 1992). In such case, 'rehabilitation' should be adopted as the objective.

Exploration of the problem

Once a problem has been defined the designer asks "where do we start to look for a solution?". However, before identifying solutions, it is necessary to explore the problem and identify the key issues. If sufficient information is available this process should lead to an understanding of the underlying nature of the problem. Without this understanding, solutions may not address the cause of degradation and as a result only offer a short-term improvement in stream health. Three different techniques for analysing stream degradation are discussed below. Limitations of each method when used in isolation can be overcome if they are used in combination to direct restoration design efforts.

In reality, solutions will be proposed after a preliminary exploration of the problem leading to a more and focused exploration of particular issues. In this way problem exploration and the search for alternative solutions are carried out simultaneously. However, it is important that preconceptions of the design solution do not restrict the range of options actually considered.

Identifying Habitat Deficiencies

In many instances, stream habitat degradation is thought to have proceeded to the point where one or more limiting factors have contributed to a decline in aquatic species populations (Beschta, Platts, Kauffman and Hill 1994). The first stage in a habitat enhancement program is to identify the main limiting factors for the faunal groups under investigation (Swales 1989). The habitat enhancement program is then aimed at modifying and recreating these factors usually with the aid of instream structures (Swales 1989; Beschta, Platts et al. 1994). Identifying habitat deficiencies will also direct the focus of stream rehabilitation efforts.

The three critical habitat needs of aquatic biota frequently addressed by enhancement strategies are: (i) substrate quality and distribution; (ii) availability of cover; and (iii) hydraulic conditions (Gore and Shields 1995). Substrate is the inorganic particles, stony material and organic debris of the channel bottom. Cover refers to instream and overhead features, which provide: protection from high current velocities; concealment for both predator and prey fish species; and shading from direct illumination (Swales and O'Hara 1980; Gore and Shields 1995). Cover may also be important in determining fish behaviour, particularly with regard to territoriality (Swales and O'Hara 1980). Some life-stages of aquatic fauna have been found to show preference for specific hydraulic conditions, often defined by velocity, depth and bed shear stress. A change in the distribution of hydraulic conditions in a stream is likely result in a change in the stream's species assemblage. For this reason, habitat enhancement efforts may aim to restore hydraulic components known to be critical habitat for a certain faunal group.

This habitat-based approach has been widely applied in the United States. In some cases it has been shown to be unsuccessful. For example, a review of over 1,200 stream restoration projects in Oregon revealed that early stream restoration efforts concentrated largely on creating pools for summer fish habitat. Recent research has shown that for many Oregon streams, pool habitat is not necessarily the factor limiting fish productivity and the focus for restoration of streams in Oregon is now the provision of cover as refuge for young fish during high winter flows (Andrus 1991).

The habitat enhancement approach requires that habitat requirements for the species at different life-stages have been established (Hey 1992), and that factors currently limiting productivity are correctly identified (Hicks 1994). It is also possible that efforts to enhance the habitat of a limited faunal group may ignore, or have a detrimental effect on, other members of the aquatic community (National Research Council 1992). Even when expertly done, modifications intended to maximise habitat may result in symptomatic treatment of perceived defects from the perspective of one or a few fish species. Current stream restoration practices are rarely based on sufficient knowledge of the physical-habitat requirements of the biota (Borchadt 1993).

A key characteristic of productive streams is habitat diversity (Gorman and Karr 1978; Wesche 1985). Hicks (1994) argue that the impact of restoration efforts must be considered in the context of the fish community and not just a single species or age-class. For this reason, many projects are now attempting to create a variety of habitat conditions that will potentially benefit all fish species and ages. The object of these restoration projects is frequently termed 'habitat diversity', although this term is rarely defined.

Comparison with Physical Templates

Successful river rehabilitation designs must often re-create hydraulic conditions at a range of spatial scales from the broad catchment scale to the scale of individual organisms and bed particles (Newbury and Gaboury 1993). However, the design parameters for fluvial processes, site-specific hydraulics, and aquatic organisms have defied complete analysis, particularly at the finer scales. (Newbury and Gaboury 1993) propose that the more complex habitat characteristics can be reproduced in a rehabilitation design by mimicking the natural materials and dimensions of the stream. This can be achieved by reference to the pre-disturbance condition of the project site or the current condition of nearby lightly disturbed sites (Kondolf and Downs, 1996; Brookes and Shields, 1996). The best habitat enhancement efforts imitate the geomorphology of a reference channel in the hope that natural restoration of biological integrity and water quality will follow (Osborne, et al., 1993). The reference reach not only provides morphological dimensions that can be mimicked at the project site, but can also guide rehabilitation measures that appear to be sustainable (Kondolf, Vick and Ramirez 1996).

A catchment-level analysis can be used to identify suitable references and rehabilitation sites (Kondolf and Downs, 1996). A reference reach should be stable, have a relatively natural channel with a relatively high conservation value, and be preferably close to the project site. If rehabilitation is the objective, the reference reach should resemble the pre-disturbance project reach. Generally, as stream order increases, a catchment offers fewer alternative reference reaches. As a result of this and the widespread impact of rural developments in lowland areas, locating suitable reference reaches for lowland and higher-order rivers is problematic.

Some channel characteristics can be designed using empirically derived regime and hydraulic geometry formulas. This approach is particularly appropriate for design of average channel dimensions (ie. mean bankfull width and depth) in stable single-channel sand- and gravel-bed streams (Shields, 1996). Newbury (1993) suggests using the relation between mean pool-riffle spacing and bankfull width, reported by Chang (1988) for alluvial and bedrock streams, to locate riffles when the project reach has been channelised. In this way, geomorphological relationships can be used to scale and locate fluvial features which create diverse habitats (Sear, Darby, Thorne and Brookes 1994) or rehabilitate the natural channel form. However, more detailed aspects of the design, potentially important for fish habitat, such as riffle or pool geometry, are best estimated from surveys of riffles at undisturbed sites. In addition, the use of empirical hydraulic relationships outside the geographical area for which they were developed is questionable (Brookes and Sear 1996).

Consideration of Fluvial Processes

The geometry of a river channel is the result of the processes of erosion and deposition operating both locally to produce scour and fill, and more generally within the catchment to define longer-term channel evolution (Sear, 1996). An understanding of fluvial processes is not explicitly required for either habitat enhancement or river rehabilitation. Indeed, the resources required for a complete understanding of the unique geomorphological setting of a rehabilitation project may not be available. However, the degree to which rehabilitation projects are self-sustaining will be largely determined by their compatibility with the dominant fluvial processes determining channel (Sear 1996) The use of a stable reference channel as a guide to design is more likely to result in a stable channel form. However, instability or structural failure may occur if an important difference in the morphological controls operating at the reference and project sites is overlooked.

Channel morphology adjusts over a wide range of time-scales to changing water and sediment discharges (Richards 1982; Church 1992) A change in these controls rarely produces an immediate response but instead initiates a change or sequence of changes, which may extend over a long period of time (Brookes, 1992). Medium-term channel adjustments are often 'forced' by human activities such as flow regulation, channel management, land use changes and land drainage (Richards, 1982; Brookes, 1992). Channels typically pass through transient states before achieving a new equilibrium (Richards, 1982).

Sustainable design of river rehabilitation schemes must involve, at the feasibility stage, some consideration of the trends in sediment delivery to the design reach and an appreciation of the morphology associated with these loads (Sear, 1996). The detail of information required will depend on the sensitivity of the river system to changes in morphology, sediment load and hydrology and the accuracy required for design. A catchment-level analysis can be used to determine the site's larger spatial and temporal context, especially the geomorphological setting and controls (Kondolf and Downs, 1996). Such an analysis is likely to combine an audit of catchment data, reconnaissance surveys to determine the current condition of the channel and consideration of the history of the channel based on readily available sources. Project designs that consider the current processes controlling channel geometry and the effects of future trends in sediment supply are less likely to require costly maintenance.

Discussion

The difficulty with the habitat enhancement approach, whether considering habitat of a single life-stage or a range of habitats, is that the limiting factors contributing to the decline in fish populations must be correctly identified. The problem can be overcome to some extent by replicating detailed aspects of natural channel geometry and materials of a stable reference reach known to provide suitable habitat. Using this reference approach, the restored channel will have a stable form if the patterns of discharge and sediment delivery are similar in both the project and reference reaches. In some cases it may be possible to use the project reach in its pre-disturbance state as the reference template if sufficient historical information is available.

The uncertainties in the projection of future stream behaviour following habitat manipulations and the lack of fisheries expertise have undoubtedly contributed to the steady deterioration of fish habitat and fisheries. Beschta et al. (1994)) and Sear (1994) argue that many habitat enhancement projects focus on physical habitat components in isolation rather than taking a broader perspective based on an understanding of the causes of degradation. Kondolf and Downs (1996) observe that planning and design is often focused on a specific reach, in many cases without a sound understanding of a site's larger spatial and temporal context, especially the geomorphological setting and controls. Projects that fail to consider current trends in sediment delivery and the dominant fluvial processes in the project reach are more likely to require costly maintenance, or fail to achieve their intended goal.

It is recommended that all three methods discussed above; habitat deficiencies, comparison with templates, and the consideration of fluvial processes, should be considered for rehabilitation designs. Indeed, although the degree of their importance may vary, all components should be considered regardless of whether the project objective is to restore, rehabilitate or enhance the degraded project reach. These analyses will identify

1. habitat deficiencies that must/should be addressed by the rehabilitation design,
2. changes in the physical character of the channel as a result of any disturbances, and
3. the dominant fluvial processes controlling channel morphology at the present time, in the past (prior to any disturbance) and in the future (over the life of the project).

A restoration design that accounts for all issues identified during these analyses is more likely to be successful in the long-term.

Search for Alternative proposals

Once the problem has been examined using the techniques described above, solutions can be proposed. A variety of techniques are available for stream restoration (Table 6). Reviews of restoration, rehabilitation or enhancement techniques have been prepared by studies both in Australia (Stewardson, White, Gippel, Finlayson and Tilliard 1997) and overseas (Swales and O'Hara 1980; Wesche 1985). The list given in Table 6 is not comprehensive but identifies a hierarchy for the techniques. It is likely that techniques will need to be adapted for a particular problem. Techniques with some potential are those that address the issues identified during the problem exploration and are within the scope of the project.

Table 6
Hierarchy of stream restoration techniques

1. **Environmental flow management**
2. **Floodplain management**
3. **Water quality management**
4. **Vegetation management**
5. **Channel management**
   - ➢ Introducing woody debris
   - ➢ Introducing or removing sediment
     - ◆ Riffles
     - ◆ Chutes
     - ◆ Boulders
     - ◆ Sand extraction
   - ➢ Construction of artificial structures
     - ◆ Weirs
     - ◆ Deflectors
     - ◆ Submerged vanes
   - ➢ Re-shaping channel
   - ➢ Allowing for fish passage

Decision-making

No systematic method is currently available to select the optimum restoration design. Experience of these techniques in Australia is limited and their performance characteristics may not be available. Some questions to ask when selecting a solution include:

1. Are the proposed solutions compatible with fluvial process occurring at the moment and over the life of the project?
2. Are the solutions self-sustaining?
3. How much do the solutions cost?
4. Do the solutions address all the issues identified during the problem exploration?

Non-structural solutions should be favoured. Structural methods should only be used to initiate or enhance natural processes. The reasons for selecting a particular solution should be explicitly stated in project documentation.

Research Priorities

Funding should only be provided for stream restoration projects that adopt a rigorous design process such as the one described above. If steps in the design process are omitted, a restoration project is unlikely to succeed and opportunities to learn from it may be missed. The above design process requires considerable effort in reviewing and documenting design information. We are at an early stage in stream restoration efforts in Australia. A few large case-study projects should be established in strategic areas to facilitate this initial stage. Once completed and comprehensively documented, further projects will be able to draw on the experience of these case-study projects. As a result, restoration efforts will become considerably more efficient and further experience can build on a sound body of knowledge. This approach was used successfully in Canada to develop the rehabilitation methods described by Newbury and Gaboury (1993).

Baseline and post-construction monitoring programs should be established for the case-study projects to evaluate their success. The evaluation program should guide maintenance and possibly re-design of the restoration sites. This process will provide an opportunity to adapt restoration techniques drawn form the international literature to Australian conditions.

The design framework described above identifies the technical information required to carry out a restoration design. Research and development of methods to facilitate the production of this information is likely to improve restoration efforts. The technical information required for restoration design includes:

1. Methods of monitoring stream health
2. The habitat requirements of aquatic and riparian species
3. The physical characteristics of undisturbed streams
4. Methods of identifying the past, current and future processes controlling channel morphology
5. The performance of stream restoration techniques
6. Methods of evaluating project performance

APPENDIX 4

Identify where sound, sustainable stream restoration techniques are located world-wide and recommend a strategy for their promotion and demonstration in Australia

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This section provides the following information:

1. Types and locations of stream rehabilitation work around the world
2. Lessons to be learned from this work in Australia
3. Dangers of unquestioningly applying international practice to Australian streams.

Stream rehabilitation in the Northern Hemisphere

Note that we are not considering issues of environmental flow allocation in this discussion.

Brookes (1996), Kern (1992) and de Jong, (1994) provide useful reviews of stream rehabilitation in Northern Europe. There are many reviews of stream rehabilitation work in North America, but a good summary is provided in National Research Council, (1992). Stream rehabilitation in the Northern hemisphere is dominated by efforts to return fish (and usually salmonid fish) to channelised streams. Most of the literature on stream restoration relates to streams that have been straightened, desnagged and often deepened. For example, about 98% of all the streams in Denmark have been channelised (Brookes, 1987), as have 96% of lowland streams in Britain (Brookes 1990) and a similar proportion would probably be channelised in all of the lowland countries of Europe. Thus, with such a large proportion of their streams fundamentally modified, it is understandable that they embark on such detailed and painstaking restoration efforts on individual streams. It does not follow, however, that Australian streams should be managed in the same way.

The most impressive progress has been made in Denmark following the passing of the 1982 Watercourse Act which provides protection for streams, but also encourages ecological rehabilitation, with provisions for finance (Hansen 1996). This Act has led to several major re-meandering and wetland projects. Trout are the favoured fish species, and a massive impetus for stream work. Habitat modification with small structures, as well as modifying culverts are the major stream rehabilitation activity. This work is labour intensive, small scale and very expensive. Only tens of kilometres have been treated since 1982, but most of this has been successful ie. leading to increased trout numbers. A major impetus for this type of work has been the ageing of the drain systems, and the high cost of repair balanced against falls in productive use of the low lying areas anyway.

Another justification for stream rehabilitation in Denmark is the pollution filtering effect of natural floodplains.

Restoration work appears to take place at two scales: small projects on channelised streams, and huge projects aimed at rehabilitating large stream systems. The largest planned restoration projects in Europe are taking place on the Rhine and the Danube (Kern 1997). These are massive projects planned to cost many billions of dollars. The major measure of success is to return salmonid fish to the streams. Examples of smaller, but still ambitious projects are the two reaches in the UK and one in Denmark that are being restored and monitored in a large project covering between 3 and 12km of stream. This work is being pushed along by a non-profit company called the River Restoration Project. This company consists of scientists and managers. The demonstration projects are funded for $2.5 million (Australian) by the European Economic Community as well as industry. Works completed with initial seed funding has attracted more funding, so the projects continue to grow.

The situation in the United States is very similar to that in Europe. There are numerous small projects aimed at fish around the country, with a few major projects, foremost of which is the Kissimmee River project in Florida (Toth 1996).

1. There has been little monitoring, or rigorous evaluation of stream rehabilitation projects in Europe, with the exception of Denmark. Here the project success is measured in trout numbers. There are few examples of long-term monitoring of entire biological systems in North American rehabilitation either, with the exception of projects that assess fish numbers (Prof. Jim Gore, Personal Communication).

2. Several of the large projects that have re-meandered channelised streams have not been successful because the design has been based entirely on historical reconstructions of channel dimensions. Because the hydrology and sediment loads in the catchments have changed over time, these historical reconstructions have proven too small, and have been overwhelmed with sediment. The lesson for Australia is that we must match channel design to contemporary catchment hydrology and sediment yield.

What can we learn from Northern Hemisphere experience?

A century of experience in physical manipulation of habitat in North America and Northern Europe lead to the following lessons.

1. Manipulation of habitat is illusory without controlling catchment processes that cause the problem.
2. Re-establish the hydrological connection between streams and floodplains wherever possible (eg. remove unnecessary structures and embankments)
3. Establish an advisory service for stream rehabilitation
4. A major impetus (and argument) for stream rehabilitation in Europe is the cost of repairing ageing infrastructure. In the next few decades much of the ageing channelised urban stream system in Australia will require repair. This is the moment to argue for rehabilitation, either through managed deterioration of the channelised streams, or direct intervention (eg. remeandering).
5. The strongest impetus for stream rehabilitation work is strong legislation that drives public opinion rather than following it.
6. Large demonstration projects tend to galvanise research and public enthusiasm, however, attempts to restore large streams present enormous problems (Gore and Shields 1995). .

What can't we learn from Northern Hemisphere experience?

We should be wary of uncritically applying Northern hemisphere models of stream rehabilitation to Australian conditions. The following is a list of some of the fundamental differences between Australian streams and most of the Northern hemisphere streams on which most research is based.

Physical contrasts—Australian streams have relatively:

1. Low relief
2. High flow variability
3. High sensitivity to erosion in alluvial settings
4. Low sediment loads/bedload transport rates
5. Unique channel morphology
6. Relative absence of systems dominated by lateral migration—dominance of vertical accretion/avulsion/anabranching
7. Absence of (natural) braided streams
8. Chains-of-ponds as dominant original condition of many upland streams
9. Problems with application of concepts of dominant discharge (eg. downstream decreasing channel dimensions)
10. Salinity

Biological contrasts—Australian streams have:

1. different riparian and macrophyte vegetation:
   - hardwoods that do not grow from cuttings
   - denser timber and smaller channel sizes leading to higher densities of distributed large woody debris
2. Unique Australian anastomosing arid zone streams
3. low levels of nutrients resulting in low rates of Gross Primary Production by world standards
4. (pre-European) absence of species of salmonid fishes.
5. impoverished fish fauna by world standards for a continent of its size (having between 190–200 freshwater species in 39 families. The low richness of South-Western streams is also apparent in the native fish fauna with only about 13 species in eight families.
6. unusual fish migration patterns
7. biota of our many intermittent streams are well adapted to extremes of flow conditions
8. dominated by sodium and chloride compared with calcium, magnesium and bicarbonate in other streams

Differences in the motivation for stream rehabilitation in the Northern hemisphere

Much more money and resources are expended on rehabilitating streams in the USA and Europe than in Australia.

The Kissimmee River restoration project in Florida is expected to cost $US 14 Billion! Rehabilitation of the Rhine (project Salmon 2000) is expected to cost the equivalent of the entire German gross domestic product for one year over the life of the project.

We emphasise that here stream rehabilitation is defined as modification of streams with the sole or principle goal being to return a stream to a more natural state. Why is it that more money is spent in these countries? The answer is that there is stronger motivation driven by legislation, by the salmonid fishing industry, and the magnitude of the damage.

1. ***The magnitude of the damage.*** In many countries the streams have been so intensively modified that they demand intensive rehabilitation. For example, over 95% of streams in Denmark and Britain have been channelised. As a result, the great bulk of the literature and experience in these countries is related to intensive rehabilitation of small channelised streams. There are many channelised streams in Australia too, but it is not the only problem type.

2. ***The major motivation: Salmonid fish*** Without doubt the major motivation for stream rehabilitation in the Northern hemisphere is salmon, trout and other salmonid fish. The recreational and commercial fishing of salmon in North America is a multi-billion dollar industry. Huge expenditure on rehabilitating streams is justified by the size of this industry, especially in California, the Pacific North-West of the USA, and Western Canada. Even though fishing in rivers is a huge industry in Australia as well, much of this fishing is devoted to exotic species (such as trout) and There may be some exceptions to this such as with bass fishing, and some other premiere species such as Murray Cod, Trout Cod and Barramundi. Although fishing groups are amongst the most active proponents of stream rehabilitation, and have begun several projects in Australia, we cannot see the native-fish fishing industry supporting huge rehabilitation projects such as we see in North America.

It is inescapable that the major motivation for stream rehabilitation in North America and Europe is missing in Australia. In general, fish conservation and general environmental values, will be a much stronger motivation for restoration of Australian rivers than will fishing.

1. Because increased fish numbers is the goal of most stream rehabilitation in North America much of the rehabilitation work is done on streams that would be considered to be in pretty good condition by Australians. That is, many streams that are important for salmonid spawning are in fair condition, but they may lack important habitat features. Thus, there is a strong emphasis on habitat enhancement as the dominant rehabilitation activity.

2. ***Stronger legislation and litigation*** The impetus for stream rehabilitation often appears to stem from compliance with a particularly forward thinking piece of legislation. In Denmark this has been the Watercourse Act 1982. In the USA it has been the federal Endangered Species Act, and the Clean Waters Act amongst others. The litigious character of North American environmental decision-making means that there are often huge resources made available for stream restoration, either as a result of legal settlements, or in order to avoid them. For example, the Zuni Indians of New Mexico were offered a settlement of $US25 million dollars by the US government in a law suit over the development of arroyos (ie. large valley floor gullies). The money was to be used to restore these large incised streams. Again, in the United States, dam owners are often compelled to release environmental flows. For example, the Bonneville Power Company was forced to forego $US450 million of hydro-power generation each year from the Snake and Columbia Rivers (NW USA) because they have been required to provide a particular environmental flow for salmon spawning under the Federal 'Endangered Species Act' (Michael Quick, pers. comm.). By contrast, in Australia, environmental flows are usually provided as grudging favours, or in response to weaker legislation.

3. ***Resources available for rehabilitation*** Australia has much fewer resources per unit of stream channel than, for example Denmark.

Implications of the differences between streams in Australia and the Northern hemisphere for Australian stream rehabilitation

Most of the stream rehabilitation literature that we read comes from a limited range of settings in the Northern hemisphere. The Australian stream manager should be aware that this literature is based on a set of premises that may well be less relevant to Australian streams. These are some of the special differences that you should be aware of.

1. *Consider catastrophic channel changes* Although background stream erosion rates tend to be low, streams can be subject to large magnitude floods that can destroy rehabilitation projects. The reaches of streams that are susceptible to such changes can sometimes be predicted.

2. *Do not assume that the morphology of your stream fits the classical model of an 'equilibrium' stream* It may sometimes be unwise to assume that the morphology of a stream is in equilibrium (which is usually a presumption with many stream rehabilitation approaches). Instead, the stream could be moving toward, or away from, equilibrium. For example, the stream could be gradually being abandoned as a developing anabranch captures flow, or the reach of stream could be recovering from a major flood several years ago.

3. *It is likely to take longer for an Australian stream to recover than for an equivalent stream in the Northern hemisphere.* Low stream power and low sediment yields in Australia combine to limit the capacity of streams to 'recover' from human disturbance. For example, incised streams take many years to recover because there is often limited sediment to form a sinuous channel in the bed. The same may be true for stream ecology. The biological response of a system to rehabilitation may be subtle and slow.

4. *What is 'habitat' in our streams?* Northern hemisphere models of ideal stream habitat (often based on salmonid fish) may not be appropriate for Australian streams in which, for example, the original condition may have well have been a chain-of-ponds and not a pool-riffle system. In many streams, large woody debris may be of more importance than substrate composition, for example.

5. *The importance of refuges and continuity* In stream systems with highly variable flows, and with migrating fish, the importance of refuge pools, and clear movement of fish up and down the stream, is of critical importance.

6. *The channelised stream model* We have seen that a large proportion of stream rehabilitation work in the Northern hemisphere is concentrated on channelised streams. Whilst many Australian streams are also channelised, we must not assume that this is the only type of stream that requires rehabilitation. Other Australian stream types may be equally in need of restoration.

7. *Should we use Northern hemisphere projects as a model?* Whilst the huge cost of some of the elaborate stream rehabilitation projects in N America and Europe is daunting, we should not necessarily look to these projects as models for the way we should do our rehabilitation. In some cases they have more money to spend (per-unit stream length), stronger legislation, and a boutique fishing industry, that all provide a motivation for projects that we cannot match in Australia. The great majority of our rehabilitation must often be justified on more general environmental, and bio-diversity, grounds.

8. *Are all Northern hemisphere stream rehabilitation techniques appropriate for Australia?* No. In particular, the huge range of 'bio-engineering' tools, that rely on cuttings of willows and other softwoods, are not available to us—or at least must be modified for our vegetation.

To conclude, overseas experience with restoring streams provides numerous excellent principles and concepts that can be used in Australia. However, we should not adopt these approaches uncritically. We should be very ready to develop our own approaches that are appropriate to our unique environment. Many of the most important lessons that we can learn from international experience relate to legislation, general approaches, concepts, planning etc., rather than direct rehabilitation methods.

APPENDIX 5

Some stream rehabilitation work already being undertaken in Australia

Task: Describe stream restoration projects in Australia, the organisations involved and status

How we answer this question relates to how one defines stream restoration. Most stream stabilisation projects lead to some ecological improvement, and this is usually one of the goals, along with aesthetic and stability goals. Thus, we could potentially list all of the thousands of waterway projects taking place across Australia that have very mixed goals. Instead what we have looked at a subset of projects funded under the National Landcare Program to get a feel for the range of stream projects taking place. We then list the other projects in each state, that we know of, that emphasise rehabilitation outcomes.

National Landcare Program (NLP) sample

Out of 340 Landcare projects in NSW listed in the published NLP compendium, 44 of them (13%) are related specifically to stream rehabilitation (Table 7). This does not include the many 'gully control' projects, unless they were closer to streams than gullies.

All of these projects involve improving the stability of streams. Five of the 44 projects mention revegetation as an end in itself, but none of the projects is justified entirely on the grounds of ecological rehabilitation, although some do mention improved water quality as a goal. It is our experience that, nationally, there are only a few projects that are not primarily concerned with stability. There is considerable scope for managing streams to improve ecological values at the same time that they are stabilised. In the future we would expect to see an increase in the number of ecologically motivated projects targeting things such as barriers to fish passage, defining buffer strips for riparian zones, remeandering, or cutoff-reinstatement.

Table 7
National Landcare Program projects in New South Wales concerned with stream management

No	Project No	Stream rehabilitation objective
1	930028	Investigate and demonstrate a range of innovative, low-cost techniques that farmers can apply to stabilise streambank erosion, and thereby reduce siltation in the lower catchment.
2	930047	Construct demonstration site to stabilise stream bank erosion Information relay to landholders concerning stream bank erosion
3	930080	Rehabilitate selected sites to improve the amenity of the waterway (Throsby Creek)
4	930082	Demonstrate a range of gully erosion control measures suitable for use in the catchment
5	930108	Adoption of demonstrated techniques towards erosion control/prevention
6	930130	Survey of properties to monitor and record erosion types including streambank erosion
7	931413	Control and reduce riverbank and gully erosion Rehabilitating eroded river banks and gullies Reducing siltation and turbidity in local streams
8	931425	Stabilising river banks from erosion
9	931427	Identification and trialing of native species for streambank stabilisation
10	931431	Prepare a river management plan
11	931434	Stabilise creek erosion
12	931437	Demonstrate a cost-effective way of stabilising eroding stream banks in the Manning Catchment
13	931438	Improve water quality in Bobin and Dingo Creeks
14	931439	To reduce streambank erosion and improve stream water quality by providing off-stream water for stock
15	931443	Coordinate an informed and well-planned method of stabilising both the water course and stream embankment
16	931444	Develop a plan to treat problems including: stream bank erosion, uncontrolled flow, damage to public utilities and creek vegetation
17	931445	Creek realignment, shaping to reduce erosion and meandering, debris removal
18	931467	Prepare a management plan for Budjong Creek to report on stability, erosion, vegetation, denuded areas, and sources of pollution.
19	931717	Demonstrate a number of erosion control techniques on a badly eroded section of Gunns Creek
20	932280	Reduce erosion into Wilpinjong Creek by development of a coordinated drainage scheme
21	932284	Collect information on bank collapse and erosion to determine priorities for action
22	932288	Construct bed control structures and revegetate areas along Minnamurra River
23	932304	Provide conceptual designs of remedial works that will stop further land loss, degradation and resultant siltation of Brogo River.
24	932314	Achieve a reduction in gully erosion by controlling the momentum of drainage flow in heavy rains by lining the bed with brick rubble to provide a solid base, thereby allowing nature to take its course in revegetating the gully downstream.
25	932331	Develop and execute a plan, which combines riparian zone management and streambank erosion control to combat the degradation of Bombay Creek.
26	932375	Demonstration and investigation of river bank stabilisation methods within the group's area including cost-effective methods of river bank stabilisation, experimenting in use of different materials and varied plant and tree species.
27	932381	Stabilise streambank and anabranch erosion along Coxes Creek
28	932385	Repair the badly degraded stream bank on Bulga Creek
29	932387	Obtain and disseminate improved stream bank erosion control practices and techniques.
30	932388	Demonstrate to landholders low-cost streambank erosion control measures by conducting a demonstration site in the Moonan Flat area.

Table 7 (continued)
National Landcare Program projects in New South Wales concerned with stream management

No	Project No	Stream rehabilitation objective
31	942072	Improve the environment and quality of the Bobin, Bulga and Dingo Creeks. Survey and map bank erosion, gravel build-up, island forming, rectify bank erosion
32	942076	Investigate causes of bed erosion in the Cockburn River which has deepened by up to 3 m in recent years
33	942205	Management the riparian zone in a coordinated, integrated way.
34	950020	Address the causes of severe streambank erosion problems based on understanding of catchment processes.
35	950021	Attack and treat problems and enhance Bannockburn Creek, a tributary of the Macintyre River
36	950026	Raise landholders' awareness of stream degradation problems and enable them to identify problem areas. Provide technical assistance and assist with implementation of management strategies to slow or reverse degradation.
37	950028	Develop a river management plan to address streambank erosion and related problems such as the loss of streambank vegetation along with excessive vegetation and build-up of gravel in the channel itself.
38	950029	Identify and assess problem areas and develop a management plan for improvement of the riverine corridor as well as developing a greater community awareness of environmental issues.
39	950031	Demonstrate to the local community effective methods of controlling severe streambank erosion, reducing siltation and improvement catchment water quality.
40	950041	Improve the environment of the lower Nowendoc River System by preparing a River Management Plan to identify existing problems in relation to riverbank erosion, stream obstruction and general gravel build up. Rectify any identified existing problems outlined in the plan, significantly improve the water flow and stability of the riverine environment.
41	950042	Develop a river management plan leading to river works to encourage channel stability and improved water quality
42	950045	Reduce the amount of nutrient run-off into streams and rivers by systematically fencing off the waterways over several years to allow the establishment of biological filter strips.
43	950065	Encourage more landowners to participate actively in the protection, repair and maintenance of their areas of the creeks. Show comparative working models of stabilisation techniques in several different situations.

Table 8
Australian stream projects (mostly pre-NHT) that have been strongly motivated by ecological considerations.

State	Stream	Aim	Organisation	Status	Evaluation?
Western Australia	Kalgan and Blackwood catchments	Major revegetation projects—not strictly in-stream rehabilitation.	Landcare groups,	In progress	Inspection
	Dandalup River	Reinstate large woody debris	LWRRDC funded research project	Being installed	Full evaluation of biological response
	Urban Perth sand bed streams	Aesthetis, but some biodiversity	?	Planned	?
Queensland	Shelley Ck (Les Atkinson Pk)	Remeandering of 200m urban stream to create stable and pleasant stream	Brisbane City Council	Built 1997	Inspection
	Gowri Creek, Toowoomba	Stabilise, beautify and rehabilitate creek through the city	Toowoomba City Council	Planned	
	Various urban streams	Artificial riffles installed for stormwater and habitat	Gold Coast City Council	Constructed (filled with sediment)	Inspected only
NSW (sample only of projects)	Macintyre River, Macquarie Rivulet	Experimental rock fishway designs	NSW Fisheries, Dept. Land and Water Conservation and others	Built	Fish numbers being counted
	Sydney urban streams (eg. Eastern Ck Raceway)	General range of projects aimed at improving habitat, stormwater filtering, and stability	Various councils (advised by Department of Land and Water Conservation)	Constructed	Inspected for survival only
	Clear Paddock Ck, (Georges R)	Re-meander and ‘naturalise’ a 2.5 km reach of concrete lined storm-water channel.	Australian Conservation Foundation, Fairfield City Council etc.	Construction plans done	Full evaluation planned
	Nambucca River	Log sills installed to stabilise bed, maintain pools and return riffles	DLWC	Constructed (many failed)	Failure documented
Victoria	Latrobe River	Reinstate six cutoff meander bends to reduce erosion, and improve instream habitat and riparian vegetation.	Latrobe River Improvement Trust	All completed	None
	Lower Barwon River	Experimental rock fishway	Dept. Natural Resources & Env.	Structure completed	Fish counts, In progress
	Wimmera catchment	Rio Tinto Project Platypus—Aim is to reduce sediment load from the catchment	Rio Tinto Pty Ltd, Department of Natural Resources and Environment, Landcare etc.	Planning completed, early works begun	Limited evaluation
	Snowy River	Artificially reinstate alternate bars for fish habitat	E. Gippsland Catchment Man. Board, DNRE	Early planning stage	Expected full evaluation

Table 8 (continued)
Australian stream projects (mostly pre-NHT) that have been strongly motivated by ecological considerations.

State	Stream	Aim	Organisation	Status	Evaluation?
	Several urban streams	Platypus habitat creation	Australian Platypus Foundation	Gathering data on platypus distribution & habitat	Good evaluation of projects
	General Melbourne urban & rural streams	Wetlands, stabilisation, general improvement, platypus habitat (spending $11 million)	Melbourne Water	In progress	Post construction survival only
	Broken R & Ryans Ck. (NE of state)	Installed various habitat features (snags, rocks, riffles)	Landcare Funding Mid-Goulburn Broken Waterways, Department of Natural Resources and Environment, MAFRI, ID&A.	Constructed	Post construction monitoring continuing
	Tambo & Mitchell Rivers	Returning large woody debris to the stream	East Gippsland Catchment Management Auth.	Planned	Physical and biological response
Tasmania	King River	Rehabilitation of stream damaged by release of mine tailings	Dept. of the Environment and others	Tailing release stopped	Monitoring continues
	Various sites across rural Tasmania	Mostly revegetation projects, but with in-stream stabilisation works	Various Landcare groups	Completed	Inspection only
South Australia	Streams of the Mt Lofty Ranges (+ Inman River)	Many projects planned, mostly emphasising revegetation, willow control	Mt Lofty Ranges Catchment Board, SA Govt.	Planned, some in progress	Inspection only

APPENDIX 6

Some research ideas for stream rehabilitation in Australia

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To provide background for further discussion, future research priorities were canvassed by asking:

1. members of the project team
2. members of the ecological community in Australia via a set of questions sent-out on the Australian Society of Limnology email discussion list (this produced six substantial responses, and several more comments)
3. catchment managers via a questionnaire sent to most peak catchment management groups around Australia
4. interviews with ecologists Sam Lake, Tim Doeg, and John Koehn
5. members of the River Research Network in NSW (workshop on 1/12/97).

The R&D requirements are discussed in relation to the framework for stream rehabilitation projects described in Section 1 and Appendix 6:

- R&D needs—problem recognition, setting goals objectives and priorities.

  Table 9 includes a discussion of the need to develop participative procedures for setting goals and priorities for river rehabilitation. There is also a need for project evaluation protocols and procedures to quantify benefits of stream rehabilitation projects.

- R&D needs—scientific research.

  Table 10 includes areas where fundamental research is required to more clearly define threats to streams and to guide development of rehabilitation strategies.

- R&D needs—technique selection.

  Table 11 includes suggestions for R&D on methods to select appropriate rehabilitation strategies including decision support systems and development and communication of guidelines.

- R&D needs—stream restoration techniques.

  Table 12 lists specific stream restoration techniques that require further research and development. This includes guidelines for establishing vegetation, improving physical habitat and alternatives to willows for erosion control.

These tables are not meant to be a comprehensive list of Research and Development needs in river restoration, rather, they are presented to stimulate discussion amongst scientists and practitioners and form the basis of future consultation. It was clear that the project team believed that R&D was not just required on stream restoration techniques but at all of the steps that make up a stream restoration project including problem recognition, goal setting, allocating priorities, developing scientific understanding of problems, and technique selection.

Table 9
R&D needs—problem recognition, setting goals objectives, priorities and evaluation of project success.

R &D need	Comment
Facilitate goal setting for rivers.	Setting clear goals for river management is a vital part of stream rehabilitation. Such goals drive selection of appropriate rehabilitation techniques and form the basis for evaluating project success. Goals are also important to guide actions that guard rivers from further damage or protect existing rivers of high conservation value. These goals must be set through participation of management agencies, the community, researchers and river users. An R&D priority is to develop appropriate goal setting processes. Goal setting should encompass not just what to do within an individual river reach, but also what are the objectives for a river catchment or region.
Set priorities for stream restoration projects.	A R&D need is the development of an approach that can help set priorities for stream rehabilitation projects. This would assist with decisions about which aspect of a stream should be rehabilitated first and where the greatest benefits would accrue from stream rehabilitation works. The list suggested in the 'Framework' section above is a start of this process.
Set national priorities for river restoration	Where should stream rehabilitation resources be directed nationally? Why this catchment and not this one? At present the process tends to treat the worst problems rather than taking a strategic view based on relative value (perhaps based on recovery potential as well as the magnitude of damage). We need a strategic approach to prioritising rivers and reaches for attention. eg. priorities could be set in terms of prioritising endangered ecosystems, or maximising bio-diversity, or saving endangered landforms (eg. chains-of-ponds). As an example, the National Forest Agreement limits forestry to 85% of a particular forest type. Much of the basic information for this processes already exists in the states. However, the information needs to be evaluated in relation to some basic principles of 'value'. What 'values' need to be used to develop priorities is also an open question at present. This type of priority setting may already have been done in some places.
Quantify the benefits of stream rehabilitation projects.	The costs of stream restoration are easily quantifiable and accrue to well defined groups. Benefits are much more diffuse and less easy to quantify. Researching and developing methods to quantify benefits, and benefiting groups, would help address this imbalance.
Establish protocols for project evaluation.	LWRRDC is presently supporting work by Dr Barbara Downs (Univ. of Melbourne) describing protocols for experimental design for strict evaluation of ecological change. But simpler procedures are also required so that there can be routine evaluation of stream rehabilitation projects that are funded by NLP, NHT and other bodies. For example, there is a need to develop evaluation techniques for rapid assessment of change in morphology and biology. The Index of Stream Condition represents one possible approach to routine evaluation (Ladson et al. 1996).
What can we learn from existing stream rehabilitation projects?	There are hundreds of projects around the country at present that include some element of stream rehabilitation. What can we learn from these projects before launching into hundreds of new ones? Our experience is that nobody wants to talk much about less successful projects, but it is from these that we learn the most. This project may involve explicitly asking NLP project coordinators, for example, what they have learned from their projects.
Examine effectiveness of the legislative framework for stream rehabilitation	Stream rehabilitation projects usually operate over a reach of stream. Projects can easily be threatened by up or downstream activities (eg. dams, extraction of water or sediment, water quality). Are the state-based legislative frameworks adequate for protecting stream?

Table 10
R&D needs—scientific research

R&D need	Comment
Monitoring and evaluation of long-term, big studies	The effectiveness of stream rehabilitation may take decades to be seen (eg. Kissemee River—expecting results in 30 years). It is imperative that some large, rigorously monitored demonstration projects are developed as quickly as possible as flagships for the industry.
Research the impact of pest plants on streams	Pest plants in both tropical and temperate areas of Australia are invading riparian vegetation. Further research is required to better define this threat and suggest management responses. Impact of willows on Victorian waterways are discussed by Ladson et al. (1997)
Develop morphological relationships for Australia Specify stream discharges for design	Much channel design relies on empirical relationships derived from international literature that generally have not been verified for Australian conditions (eg. relationships between catchment area and stream width). These relationships are widely used as the basis for the design of rehabilitation projects. 'Channel maintenance' flows or 'Dominant discharges' are the cornerstone of many of the stream rehabilitation techniques used internationally. Research is required on their application and utility in Australian streams
Detailed design rules for habitat enhancement works	Clearer design guidelines are needed for habitat enhancement works in Australian streams (eg. there is a grain size gradation curve for stable rock chutes, but what would be an equivalent curve for macroinvertebrate habitat). In short, turning ecological research into best-practice guidelines.
Understand paths of recovery that streams take with and without rehabilitation projects.	How will the system recover (geomorphologically, biologically, and vegetatively) and at what rate? Can these paths be predicted based on consistent variables (eg. stream power, seed sources)? This information will assist in the deciding the levels of intervention required for stream rehabilitation projects. "Will it be enough to simply exclude stock here?"
Understand sensitivity to disturbance	Some stream systems are more sensitive to disturbance than others (both physical and biological disturbance). There is also likely to be variation in the response of stream systems to rehabilitation measures. Understanding these differences could assist with selecting streams that should be protected from disturbance, and those in which rehabilitation measures are more likely to succeed.
Document requirements of native vertebrate and invertebrate fauna	Further research is required on the biological requirements of aquatic species. For example, the limiting life requirements of most native species are not understood in the way the requirements of trout and salmon are known from studies in the Northern hemisphere.
Understand predict and mitigate impacts of exotic domestic and feral animals on streams.	There is currently limited information on the impacts of cattle, sheep and feral animals on streams but there could be significant effects. For example, the NSW Healthy Rivers Commission (1996) reported that 26% of the phosphorus load in the Williams River came from cattle. Thus, cattle grazing could contribute to increased phosphorus levels and algal problems.
Document natural condition of Australian streams	There is poor baseline data on the original condition of many types of Australian streams. This information would help set the benchmark for restoration and rehabilitation projects.
Relationship between floodplains and channels	Better understanding of the rehabilitation impact of de-coupling floodplains from streams (eg. floodplain as a source of energy for terrestrial systems)
Bedload transport rates in Australian streams	Bedload transport rates are fundamental to many aspects of stream ecological function. Measured information on these rates in Australian streams is poor to non-existent.

Table 11
R&D needs—technique selection.

R&D need	Comment
Communicate existing R&D results	There is already extensive information about stream rehabilitation but this is not always available to, or sought by, people undertaking stream restoration projects. There is a LWRRDC project investigating the integration of research into catchment management. Any relevant results from this project should be used to guide integration of research into stream restoration. Specific suggestions include a stream restoration newsletter, funding of state or national coordinators, preparation of case study reports and guidelines. Another option is the 'Stream restoration clearing house' described elsewhere in the report.
Develop procedures for technique selection based on stream power	Stream power is a valuable criterion for defining a large range of issues central to stream rehabilitation including the type of approaches and cost of any required structures. The international literature shows the difficulty and cost of trying to rehabilitate high-energy streams. Physical rehabilitation is more successful in lower energy streams.
Assess the 'template' approach to stream restoration	The 'template' approach involves using existing high quality stream reaches as templates for the reach to be restored. This is the favoured technique for many restoration projects. Guidelines for the use of this approach are required.
What to do when there is no template?	How do you define a 'target's stream condition if there is no undisturbed template reach? We need some guidelines for defining achievable target conditions (eg. chain-of-ponds) for differing landscape settings.
Develop Decision Support Systems	Many of the above issues could be tackled through decision support methodologies to guide selection of appropriate techniques.

Table 12
R&D needs—stream restoration techniques

R&D need	Comment
Develop guidelines for vegetation establishment	Guidelines are required for selection of revegetation technique eg. direct seeding, natural recovery, burning, planting of tube-stock etc. At present there is a jumble of confusing recommendations being used across the country.
Promote alternatives to willows and exotic species for erosion control	Bio-engineering techniques (ie. approaches in which the vegetation is directly incorporated into engineering structures instead of being an add-on) are becoming the mainstay of stream rehabilitation work in the Northern hemisphere. Internationally these rely on the capacity of willows and similar species to grow from cuttings. We need to develop techniques in which Australian vegetation is incorporated directly into structures. These approaches will tend to be very regional in their application (eg. regional species), but the principles can be more universal.
Develop guidelines for physical habitat improvement	There is a need for guidelines for improving physical habitat in stream rehabilitation projects. This includes re-introduction of large woody debris.
Improved fish passage	Research into fish passage. Develop and trial better methods of overcoming existing barriers (particularly culverts), and designs for new barriers.
Restoration techniques for saline streams	The dominant rehabilitation hurdle for long lengths of stream in Australia is salt. We need to develop region-specific approaches to rehabilitating these streams, including identification of native revegetation species
Establish techniques for control of pest fish	There has been discussion of biological control of noxious fish including genetic control of carp. There is now a need to move from research to development and application of specific techniques.

APPENDIX 7

Notes on R&D issues relating to the effective targeting of onground restoration

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In order to identify the R&D required to “ensure that onground restoration works carried out under the NHT program will be successful and effectively targeted”, we need first to understand the way in which resource allocation under the NHT is presently managed.

Under the NHT, funding is allocated according to priorities identified in catchment or regional plans. In general, preference is given to projects which are part of a strategic land, water or vegetation management plan.

Whether or not NHT funding is allocated to river restoration projects, therefore, depends largely on whether a need for river restoration has been identified at a regional level and, if so, what order of priority has been allocated to the issue *vis-à-vis* other resource management issues in the region.

This then begs the question of how regional priorities are identified. For example, do current planning and priority-setting processes have access to adequate information to inform the planning process at a regional level ? How can R&D inform this assessment and priority setting process ?

It is said that the NHT will inject $260 million into projects improving water quality and the ecological health of Australia’s river systems (EA & DPIE 1997). The (new) National Rivercare Initiative, established under the NHT, is the component of immediate relevance to river restoration. It is delivered through three programs:

1. National Rivercare Program (NRP)

   The $97m NRP will assist “the sustainable management, rehabilitation and conservation of rivers outside the Murray–Darling Basin. Rivercare projects are expected to comply with the Council of Australian Governments” (COAG) water reform framework and National Water Quality Strategy requirements. Rivercare builds upon existing programs including the National River Health Program, Waterwatch Australia and elements of the Fisheries Action Program (EA & DPIE 1997)

2. Murray–Darling 2001 (MD-2001)

   The NHT will allocate $163m for the MD-2001 project with the objective of improving the health of key river systems, encouraging ecologically and economically sustainable land use, restoring riverbank land systems, wetlands and floodplains and improving water quality.

3. National Wetlands Program (NWP)

   The NWP promotes the conservation and wise use of wetlands and supports activities aimed at monitoring the health of wetlands, improving the management of nationally significant wetlands (eg. RAMSAR sites) and demonstrating the wise-use principle of managing wetlands.

Needs assessment

As noted in a recent report by the Australian National Audit Office (ANAO 1997) a key factor in value-for-money program delivery, is a rigorous assessment of needs to ensure that those projects which maximise the likelihood of achieving program objectives receive funding. However, the ANAO has noted that a comprehensive assessment of needs was not undertaken as part of the design of the National Landcare Program (NLP) and, more importantly, has not yet been done for the NHT. It *is* likely that such an assessment will be one of the key outputs from the National Land and Water Audit, which is being developed as part of the NHT. However, as noted by ANAO, current progress suggests that the Audit will not be complete until a substantial amount of the existing NHT funds have already been spent (that is, mid-1999). In the meantime, NHT funds will continue to be allocated in the absence of reliable, comprehensive, information. ANAO notes that *local knowledge* is often the basis of project applications and the regional assessment process.

The partnership between community and government which underpins the NHT, requires that the assessment of NHT bids be done by panels “comprising a balance of natural resource management and nature conservation expertise”, with a majority of community members and chaired by a community representative (EA & DPIE, 1997a: 4). Projects are usually assessed in a two-stage process. In most states, panels are formed in regions or catchments (Regional Assessment Panels, RAPs) to allocate a priority to project bids, having first determined whether it aligns with a relevant catchment or regional strategy. Each State and Territory has formed a State Assessment Panel (SAP). The SAP reviews the RAPs’ recommendations and reviews the priority of each project according to State/Territory and national priorities.

The ANAO has found that recommendations of priorities through the RAP/SAP process are “often based on intuitive judgements, rather than any robust needs assessments” (ANAO, 1997: 39). Of particular concern is the absence of hard data on environmental needs and priorities, which clearly has implications for resource allocation to river restoration projects. ANAO also notes a concern of conservation groups, that there is a potential for systematic bias against biodiversity-oriented projects at the RAP and SAP levels, since the information and expertise on the panels is often skewed in favour of agricultural interests.

The ANAO found clear indication that greater scientific rigour is required in assessing needs under the NHT. It has recommended that DPIE and Environment Australia:

consider options for further developing and applying strategic research from bodies such as the Land and Water Resources Research and Development Corporation to the needs assessment process of the NHT (ANAO 1997).

In the absence of a comprehensive assessment of needs for programs under the NLP/NHT umbrella, other approaches being developed to assist RAPs and SAPs in setting priorities. One approach, being developed in Victoria, is Multi-Criteria Analysis, the application of which is outlined briefly in the following section.

Priority setting: the use of Multi-Criteria Analysis in Victoria

In Victoria, the Victorian Catchment and Land Protection Council (VCLPC) and the Department of Natural Resources and Environment (DNRE) are promoting more objective and rigorous processes of setting priorities for natural resource management in Victoria. The NLP funded a 3-year project addressing this aim, titled *‘Economic, Social and Environmental Priorities for Land and Water Management’*. Broadly, the project aimed to:

1. provide an assessment of the economic, social and environmental value of impacts caused by land and water degradation issues;

2. and develop and apply a decision-making framework to determine priorities for government investment in programs to address the impacts of land and water degradation issues in Victoria.

The VCLPC has a statutory responsibility to advise the Government on statewide priorities for catchment and land protection programs. The same advice is used by the SAP in its assessment of statewide bids for NHT funding. Presently, SAP membership is drawn from the VCLPC.

A number of approaches were considered in this project, of which the Multi-Criteria Analysis (MCA) technique was selected as the most promising. In 1996–97, the MCA technique was used by each of the State's ten Catchment and Land Protection Boards and, statewide, by the VCLPC.

Briefly, the procedure required a series of steps to be undertaken, namely:

1. definition of land and water degradation issues to be assessed
2. definition of the economic, social and environmental criteria;
3. definition of resource management units;
4. collation of information describing the *impacts* of the issues, as defined in (ii);
5. scoring of the impacts;
6. weighting of scores; and
7. final ranking of issues based on scores.

In all, 23 land and water degradation issues were considered (Table 13):

Table 13
Land and water degradation issues

Changed fire regimes	Groundwater depletion	Salinity—waterways
Changed flow regimes	Habitat loss	Soil acidity
Changed land use	Habitat modification	Soil nutrient decline
Chemical contamination	Pathogens	Soil structure decline
Erosion—water	Pest animals	Turbidity & sedimentation
Erosion—wind	Pest plants	Water repellence
Eutrophication/ nutrients	Salinity—dryland	Waterlogging
Flooding	Salinity—irrigation	

Table 14 gives an overview of the criteria used to score various issues. The environmental impacts of each of the 24 'issues' were measured in part, according to their impact upon rivers, streams and the riparian zone. In combination, the three environmental sub-criteria (terrestrial, wetlands and rivers/streams/riparian) were designed to assess the impact of issues/threatening processes on the conservation of Victoria's biodiversity.[1]

1 Biodiversity refers here to the variety of all life forms: the different plants, animals and microorganisms, the genes they contain and the ecosystems of which they form a part (DNRE, 1997).

Table 14
Overview of criteria and sub-criteria

Criteria	Sub criteria				
Economic	Primary production	Public infrastructure	Household & downstream consumers	Other industry	Tourism & recreation
Social	Resources for future generations	Employment	Regional viability	Health & social harmony	Aesthetics & cultural heritage
Environmental	Terrestrial	Rivers, streams & riparian	Wetlands & estuarine		

To measure the impacts of threatening processes on biodiversity at a level of resolution appropriate for a statewide perspective, Victoria was divided into 29 ecological units called Broad Vegetation Types (BVTs). For each BVT, the impact of the issues/threatening processes on biodiversity values was considered in relation to their effect on the three ecosystem types. .

Of particular interest to this project is the scoring system used to measure biodiversity in rivers, streams and riparian zones, namely: extent of river or stream length with good to excellent environmental rating; representation in conservation reserves; and numbers of endangered, vulnerable and rare species systems (Tables 3 and 4). Scoring was based on information contained in the DNRE's *State of the Rivers* database and DNRE's *Flora Information System* and *Wildlife Database* (1993 listings). The MCA Manual notes, however, that 'estimates are approximate and while adequate for this exercise, should not be quoted'.

The results of the statewide assessment done by the VCLPC are given in Table 5. The issues are listed in descending order of total impact, as given for the weighting suggested by Council. That is, a weighting of 40% to economic, 20% to social and 40% to environment. Two alternative scores are provided to indicate the sensitivity of the result to different weightings of the scores from each of the three criteria. The weightings are as indicated.

Clearly, the effectiveness of a priority-setting process such as the MCA approach is largely dependent upon the quality of the information used to inform the scoring decisions. In this instance, participants were reliant upon 'unquotable' estimates derived from DNRE databases. Substantial research and administrative capacity is required to service this process, to establish needs and set priorities.

In future, it is likely that regional scale projects will attract increasing support from the NHT. This approach is supported by the ANAO which recommends that discretionary block grants be allocated to regional catchment committees "where appropriate accountability and performance measurement mechanisms have been put in place" (ANAO 1997).

Project performance

One of the other key issues relating to resource allocation and the NHT, is need for information relating to project (and program) performance. In order to make informed decisions, decision-makers need access to information about project performance; that is, the extent to which a project has been successful in achieving its objectives.

One of the failings of the Decade of Landcare Plan, is the absence of clearly defined outcomes and performance indicators. The ANAO reports that DPIE and Environment Australia have each acknowledged the difficulties in establishing performance indicators for environment and natural resource management *programs*. Key performance information is now being developed for the NHT; this includes the development of economic, physical and biological indicators for strategies, plans and projects (ANAO, 1997: 34).

It is essential that project bids for the NHT are not only well-targeted but are also well-designed with clearly stated measurable objectives, targets and milestones.

Ideally, project bids should also be well-informed. River restoration projects should, for example, build upon best-practice advice which, in turn, has been informed by current R&D. The extent to which this communication flow is effective, from the research community to those designing projects, is critical.

One way in which best practice can be communicated is through the project guidelines developed each year for the NHT. For example, if a stream restoration project on a particular reach were to include a component of riparian revegetation, assessment panels and project bidders should have ready access to technical advice which sets out minimum standards for that activity. In this example, standards might be established for the minimum acceptable width of the proposed planting, according to best practice and to the broader project objective. Personal experience suggests that technical advice of this nature is not readily available.

Under the NHT (and formerly, the NLP), successful project applicants are required to complete a project management agreement which sets out conditions for funding, including reporting requirements on the progress and results of the project. ANAO notes that roughly 62% of final reports of projects funded over the past three to five years, under the Commonwealth-State and Community components of the NLP, are overdue. This poor clean-up rate may be partly explained by inadequacies in DPIE's Program Management Database (PMDB).

In recent years, DPIE has published a Compendium of Projects listing all NLP Community Group projects funded in the financial year (eg. Department of Primary Industries and Energy 1996). It describes each project, its objectives and proposed project activities. However, the Compendium lists *new* projects only. So, as noted by ANAO (1997: 73):

project progress noted on *continuing* project application forms and project completion reports are not included as part of the Compendium. As a result, the Compendium only records what projects *intend* to do and aim to achieve rather than *actual* project achievements.

From an R&D point of view, this paucity of information is disappointing, most particularly because there may be missed opportunities: to observe, assess, augment and support current (perhaps innovative) onground practice; and/or to work alongside potential users of R&D outcomes, jointly implementing, for example, stream restoration projects.

ANAO has recommended that DPIE and Environment Australia consider applying sanctions or incentives to encourage greater compliance with the conditions of project management agreements. It has recommended specifically (4.40) that further NHT funding be withheld until current or previous grant acquittal and/or project performance reporting requirements are met. If this recommendation is to be implemented, it clearly underlines the imperative for good project design.

The role of an R&I strategy

As identified in 4.4 above, effective communication of R&D to decision-makers is fundamental. This, in part, requires that decision-makers have access to integrated R&D information, in various forms, which identifies research activity and outcomes relevant to their interest (Woods, Moll, Coutts, Clark and Ivin 1993; Ewing, Grayson and Argent 1997).

In recognition of the need for a strategic approach to catchment planning, DNRE and the VCLPC in Victoria have recently developed a Research and Investigation (R&I) strategy for catchment management and planning (Gutteridge 1997). To inform this process, a literature review was undertaken, in order to identify and document the current range of research and investigation activities that relate to catchment management in Victoria. The review was based on the search results from CD ROM databases and was limited to R&I that has occurred, or is occurring in Victoria and which has been reported since 1990.

Research data sheets were generated for a range of 'aquatic habitat' topics, including:

1. Riparian environments
2. Wetland decline
3. Flow modification
4. In-stream processes
5. Environmental flow regimes
6. Decline of ecological values
7. Eutrophication
8. Turbidity and sedimentation
9. Salinity of waterways
10. Water pollution
11. River point waste pollution

On the basis of the database search and consultations with research groups, the strategy identified eight key R&I investigation needs and gaps relating to 'aquatic habitat': [2]

1. the impact on fish movements of fish barriers and fish-ways
2. wetland water requirements—River Red Gum forests
3. improved index of stream conditions
4. aquatic fauna population distribution and numbers—especially threatened species
5. more detailed understanding of fauna habitat management requirements
6. wetland management and water volume and quality requirements; tolerance of species to variations in flow
7. role of water birds as easily-visible indicators of wetland habitat health
8. identification of key habitats in rural Victoria which act as reservoirs for threatened species and biodiversity.

Clearly, one of the limitations of a one-off search and consultation (as described above) is that it is just that—a 'snapshot' of research activity at one point in time. The R&I strategy developed for DNRE ensures that the identification of research needs is an ongoing process, in which research needs and priorities are constantly updated as new information comes to hand. A sound R&I strategy should help facilitate effective communication of research outcomes to the decision-makers.

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2 This is the closest reference to issues related directly to river restoration.

Industry Commission (IC) Inquiry into Ecologically Sustainable Land Management (ESLM)

During 1997, the IC has been conducting an inquiry into ecologically sustainable land management. This inquiry has focused upon the management of land and its associated natural resources, used or useable for agricultural production and the ecological sustainability of such practices. Specific issues set down for review in the terms of reference include:

1. the roles and contributions of governments, landowners, land managers and community groups to ESLM; and
2. the effectiveness of existing mechanisms, policies and programs relating specifically to ESLM (Industry Commission 1997).

The Commission has just released its draft report on which submissions will be received until mid-November, 1997.

At the time of writing, the report is not to hand but it is understood that three key reforms recommended by the IC are:

i. that regulation be re-cast—towards a more self-regulating system based upon the principle of 'duty of care';
ii. that markets for resources (such as water, forestry, flora and fauna) be improved and extended; and
iii. that greater provision be made for nature conservation, particularly on private land.[3]

Prima facie, for this 'duty of care' principle to be effective, there will need to be adequate definition of what might be considered 'reasonable and practicable' action by land owners. It underlines, once more, the need for R&I outcomes to be continually, and effectively, incorporated into the policy-making process—for example, in the construction of agreed 'codes of practice'.

Concluding comment

If onground river restoration works carried out under the NHT program are to be both successful and effectively targeted, attention needs to be given to mechanisms by which R&D outcomes can actively inform the various priority-setting and resource allocation processes, such as those described in this paper.

The extent to which this occurs depends largely upon the capacity of the R&D community to share its findings with stakeholders, including government, industry and land owners.

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3 Presentation to the Australian Agricultural and Resource Economics Society by Jeffrey Rae, IC Commissioner: 'Ecologically Sustainable Land Management—Review of the Industry Commission's Draft Report' at the University of Melbourne, September 17, 1997.

APPENDIX 8

Provisional list of contacts with interests in stream rehabilitation

Australian Landcare Council

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Coverage: National

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Inland Rivers Network

Inland Rivers Network is a coalition of groups to promote and facilitate a flow of information with the objective of achieving ecological sustainability for Australia's inland rivers.

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Save the Rivers

Coverage: National

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Water and Rivers Commission, WA

Coverage: Western Australia

Water and Rivers Commission
Western Australia
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Healthy Rivers Commission

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