DEVELOPMENT OF RIVER RIHABILITATION IN AUSTRALIA: LESSONS FOR SOUTH AFRICA

Report to the Water Research Commission

by

Mandy C Uys

Laughing Waters
Aquatic Research, Consulting and Media

WRC Report No: KV 144/03
ISBN No: 1-77005-088-4

October 2003

EXECUTIVE SUMMARY

PART 1. INTRODUCTION

1. Introduction, Background and Aims

This report is the outcome of a four month Senior Research Fellowship at the Centre for Cooperative Research for Catchment Hydrology (CRCCH) at the University of Melbourne, Victoria, Australia, during 2000. The research was led by Dr Ian Rutherfurd, then Programme Leader of the CRCCH Programme for River Restoration. Dr Rutherfurd and his colleagues had been, and are, instrumental in the development of the science and practice of river rehabilitation in Australia, and also developed the Australian Stream Rehabilitation Manuals (Volumes 1 and 2, 2000).

The purpose of the research was to learn as much as possible about the field of river rehabilitation in Australia and elsewhere, and to assess where the links lay between current South African water resource management and the international field of river rehabilitation. This discipline is in its infancy in this country.

It should be noted that this report was written in 2000/1 and that since that time institutional changes may have taken place in both Australia and South Africa, and methodologies may have been modified or further developed. The report should be read in that context.

The aim of this WRC report is to convey, at a reasonably non-technical level, what South Africa can learn from the decade of development of river rehabilitation in Australia, and from their recently-published national-level guidelines and methodologies. This report is addressed to South African and Australian readers from diverse backgrounds, and has thus been aimed at a non-technical level. In addition, geographic, environmental and socio-political 'context' has been included for Australia, as this provides the background to what drove the initiation and development of river rehabilitation. Where this is not of interest to the more scientific reader, it is advised that these individuals skip to chapters of a more technical nature. The introductory and concluding chapters are of relevance to all.

The introductory chapter provides a background to the field of rehabilitation, and a discussion of the many related terms in use to describe this discipline. While both the terms 'restoration' and 'rehabilitation' are commonly used, the more academic interpretation is that the term 'restoration' implies a return to natural pre-impact state and is thus aspirational and seldom achievable, while rehabilitation focusses on achievable objectives and also aims for improvement and protection, with the aim of the system eventually resembling its pre-impact state. The aim of 'remediation' is to improve the ecological condition of the river, while not aiming for an endpoint that resembles its original condition (Breen and Walsh in Rutherfurd and Fryirs, 1999). **On the basis that, at least in contemporary literature, equal meaning is generally attached to the use of the terms 'restoration' and 'rehabilitation', these are used interchangeably in this report.**

The issue of system 'recovery' is fundamental to rehabilitation. Recovery relates to the ways in which systems respond to disturbances, both in a geomorphic and biological sense. One of the difficulties in rehabilitation planning lies in assessing whether a system is in a state of recovery, and if so, where along therecovery trajectory it lies. This assessment requires the expertise of several specialists: at the least an experienced fluvial geomorphologist, a hydrologist, and ecologists. It includes what may be a lengthy process of acquiring information on pre-impact state, past disturbance events (natural and non-), flow records, catchment land-use, and causes of degradation. Where a stream is considered to be recovering, the rehabilitation planning decision can either be to assist with and accelerate the process, or to allow natural recovery to proceed unhindered.

In many parts of the world, river restoration has developed and advanced to the point where national and /or regional guidelines have been developed, largely based on principles and processes learnt from internal or external restoration exercises. In South Africa, there is as yet no structured programme for research and development in the field of river restoration.

South Africa is well placed to absorb the lessons of international experience and to become world class in the field of urban and non-urban river restoration without having to reinvent the wheel. Failure to recognise the timeliness of linking to, or learning from, external initiatives in river rehabilitation and protection is likely to prove extremely expensive both in economic and in environmental terms. It is less a matter of 'what are the costs of doing it', and more a matter of ***'what are the costs of not doing it?'***

PART 2. AUSTRALIA

2. Background, water resource management and policy reform

The second chapter provides a background to the geography and political history of Australia, and discusses the forces that have shaped the changes in water management since settlement and particularly over the past decade or more, and led to the growth of the field of river rehabilitation.

The major impacts to Australia's rivers post-settlement include cleared riparian zones and river banks; gullying and erosion; channel incision; water quality deterioration; flow reductions and alterations; channel straightening; and removal of large woody debris. Three three phases of river management are described by Finlayson and Brizga (2000): the Inception Phase following settlement, when clearing of land for agriculture led to extensive degradation of rivers; the Engineering Phase during which governments took the lead role in water management and water schemes flourished; and the Environmental Phase, during which resource issues gathered status, water services were privatised, and water markets were established.

Major political changes, water industry reforms and environmental flow issues occurred during the early to mid-1990s, creating a framework within which the degradation of Australian waterways could be addressed. The development of the field of river rehabilitation kept pace with this political, institutional and economic change. Changes in legislation provided the legal backing and some pressure on resource agencies to aim for catchment management and, as a subset of this, rehabilitation (Gippel and Collier 1998). This also created an environment in which the river rehabilitation received the government and public attention and funding that allowed for the rapid progress in the field. Many programmes initiated at either National or State levels spurred further research and development. Ten of the significant events or initiatives of the 1990s considered to be amongst the 'drivers' of river rehabilitation development are discussed. Of these, perhaps the most significant in terms of the ongoing research into river rehabilitation was the formation of the Cooperative Research Centres (CRCs). These are formal alliances between government, private industries, universities and other institutions. The CRC for

Catchment Hydrology and the CRC for Freshwater Ecology are key institutions in the ongoing development of rehabilitation science, practice and guidelines.

3. The development of river rehabilitation

This chapter discusses the growth of the field of river rehabilitation in Australia from the early 'pioneering' years of the 1990s. The identification of research and development requirements for rehabilitation in the later years of the decade, and the publication of national-level guidelines for rehabilitation illustrate the extent to which cognisance had, by then, been taken of the importance of this field by funders, government agencies and research institutions alike. The issues identified as requiring research attention included the use of planning, objective-setting and evaluation in individual projects, addressing the multidisciplinary nature of the task, and building communication between practitioners, researchers and managers. An international conference held in Adelaide in 1999, '*The challenge of rehabilitating Australia's streams*', attracted further national and international attention to this field. Again this represented the growth in the field, although it was felt, in review of this conference, that the papers presented were largely qualitative by nature and lacked a sound scientific basis. This is a contemporary issue receiving research attention at present.

The present situation in Australian rehabilitation is discussed in this chapter in the light of the types of activity underway; programmes and initiatives; available tools such as framework documents, national-level guidelines, assessment and priority setting models, and legislative and institutional frameworks; and integrated catchment management, of which rehabilitation is considered a sub-set.

The rehabilitation of metropolitan rivers has somewhat different components to that of non-metropolitan rivers, and is generally the duty of metropolitan water boards. Their functions are typically to ensure: the supply of adequate clean drinking water; the provision and maintenance of related infrastructure; and flood control. A case study of Melbourne Water Corporation's approach to the development of Waterway Activity Plans for all the major rivers in their jurisdiction is an example of how ecological aspects of rivers and their flow regimes are being incorporated into metropolitan river management thinking and planning. Environmental engineering approaches are also being adopted.

Increasingly, there is recognition of the need for extensive training and capacity building in river rehabilitation. This is being addressed by government agencies, academics and private consultants. Recently, a recent model for 'knowledge exchange', which takes cognisance of the critical need for integration, exchange of information and capacity building at the levels of non-experts and experts, was developed.

4. Principles and processes in rehabilitation

Fundamental principles emerge gradually in a new field, often arising from practical project experiences; successes and failures; best-available knowledge; creative thinking; and research results. In order to provide a sound scientific basis for rehabilitation, it is important that the scientific method is applied in the rehabilitation process. However, because of the issues of scale and replication in the field, and the high costs of evaluation, the linking of scientific experiments to rehabilitation is a complex issue, presently best addressed with the principles of Adaptive or Experimental Management.

Sound rehabilitation practice is ideally based on scientifically or empirically derived principles, and sound planning, implementation and evaluation processes. This chapter addresses both. Major impacts to rivers, the causes of these, and typical approaches adopted to address them in Australia are summarised. Emerging from these approaches are a set of general, non-technical guidelines and principles for rehabilitation.

The 12-step (and multi-task) generic process for rehabilitation developed by Rutherfurd et al. (2000a) is presented:

Step 1	Develop a vision
Step 2	Share the vision
Step 3	Describe the stream condition
Step 4	Identify the assets and problems
Step 5	Set priorities
Step 6	Develop strategies
Step 7	Set measurable objectives
Step 8	Check the feasibility
Step 9	Design the details
Step 10	Plan the evaluation
Step 11	Schedule and supervise the works
Step 12	Assess, evaluate and maintain the project

Any one of these steps (or the numerous tasks within a step) could take several months or years to complete, even with specialist input. That this process may appear 'quick' is misleading. The scientific input and output required is extensive, and the community processes may be slow.

Readers familiar with the South African Department of Water Affairs and Forestry's Resource Directed Measures (RDM, Chapter 5), will observe that the majority of the principles and processes recommended in the Australian methodology are already well known and in use in the RDM, with a number of sophisticated methodologies in place. It is the extension of these to a rehabilitation effort that is required, as discussed in Chapter 7.

PART 3. SOUTH AFRICA

5. Background and water resource management

This chapter deals with current initiatives in water resource management in South Africa, and the development of methodologies to support these. The relevance of these to river rehabilitation, and the links between South African Resource Directed Measures (RDM) and the Australian river rehabilitation approaches are discussed.

The South African water law reform process of the early 1990s paved the way for progressive changes in approach to water management. The naming of the river as a 'resource' rather than a 'user' of water, and the concept of 'reserving' a quantity of water to ensure the ecological functioning of the river and to supply basic human needs prior to the allocation of water to other users (the ecological and human 'Reserves'), placed South Africa amongst world leaders in terms of water law.

Associated with the implementation of the National Water Act (Act No. 36 of 1998) were, *inter alia*, the continuation of the development and implementation of water resource protection measures, and the development of a catchment management strategy. Amongst the regulatory activities that would facilitate these aims was ‘Resource Directed Measures’ (RDM). These define a desired level of protection for a water resource, and on that basis, set clear goals for the quality of the resource. The methodology for the RDM is viewed as a stepwise process with multiple components. As part of this process, the ‘Ecological Reserve’ must be determined. This process includes a multi-specialist assessment of the pre-impact, present, and ‘future desired’ states of the river; and these and other data inform the process of setting environmental flows for the system. On this basis it is clear that the RDM and the methodologies associated with them would link with the planning aspects of the 12-step river rehabilitation process described in Chapter 4. This hints at the potential for extending the RDM to allow for river rehabilitation planning.

As in Australia, river rehabilitation in South Africa will take place in a catchment-management context. The catchment management approaches followed in South Africa and the guidelines for the CM process are presented, and the broad relationship between RDM methodologies and Catchment Management illustrated.

6. Current activities linking to river rehabilitation in South Africa

A number of current initiatives in South Africa that either link, or could link, to river rehabilitation development are presented in this chapter. The intention is to illustrate a few of the activities and programmes already underway in the country which could, with some coordination, contribute to the development of the field of river rehabilitation and possibly the establishment of a national programme for this discipline. The initiatives presented are: the South African River Health Programme, a national programme which makes use of biological indicators to assess the condition of the country’s river systems; Working for Water, a successful programme launched in 1995 to tackle the twin problems of invasive alien plants and unemployment in South Africa through clearing and re-planting operations; the Mondi Wetlands Programme, which is focussed on wetland rehabilitation at a national level, and has also formed links with Working for Water; a Water Research Commission Project on the Development of Geomorphological and Ecological Principles for River Rehabilitation; a Cape Metropolitan Council project and report on the evaluation of river rehabilitation projects in the CMC area, and, importantly, the Indigenous People’s Knowledge Programme, which recognises traditional cultural and spiritual value of rivers and waters to black South Africans. These are only some of the many programmes and projects that could link to and support the development of a standardised and scientifically founded approach to river rehabilitation in South Africa.

7. Suggestions for future directions in river rehabilitation in SA

A set of recommended future directions in river rehabilitation is presented:

1. Adopt, trial and adapt. It is recommended that Australian River Rehabilitation process and related methodologies be adopted, adapted and trialled on a number of different river types in South Africa. This will allow refinement and tailoring of a rehabilitation process to fit the various regional river types in South Africa. This is also a first step towards the development of guidelines for rehabilitation.

2. Situate river rehabilitation. It is recommended that within the next two to five years, a multi-disciplinary and consultative effort is directed towards identifying and establishing the logical ‘home’ for river rehabilitation in South Africa, first at a national level and later at regional and local (catchment) levels. This may take the form of a National Department, an alliance of Departments (as with the 'Working for Water' Programme), a partnership with a current, appropriate national programme (e.g. the South African River Health Programme), a new and separate programme, or a privately funded venture with credible, accountable ownership.

3. Build on available methods and initiatives. The links between the generic processes of Resource Directed Measures (RDM) and River Rehabilitation are emphasised. Means of developing and building on these linkages should be investigated.

4. Develop partnerships and exchange information. The structured creation of links, partnerships and alliances at a number of levels is recommended.

5. Access available information. A wealth of information is available to inform rehabilitation practitioners about present and historic river conditions. An effort should be made to ensure that pertinent information is easily or centrally accessible for this purpose.

6. Identify research and information needs. It is recommended that a interdisciplinary effort be directed towards the identification of knowledge gaps and scientific research and information needs for the development of river rehabilitation.

7. Prioritise rivers for rehabilitation. At a national level, rivers should be prioritised for protection and rehabilitation, on the basis of ecological, economic and social criteria.

8. Develop expertise, tools and guidelines. It should not be assumed that river rehabilitation is common sense. It is a unique and complex discipline. Even at the specialist level, expertise must be developed to meet its needs. Scientific tools and guidelines appropriate to South African rivers will increasingly be needed.

9. Review legislative frameworks and identify policy needs. A review of national-level legislation pertaining in any way to river rehabilitation is required and should be commissioned. Conflicts between different National Acts, and between Acts and regional/local-level laws, which are implemented by different authorities, should be investigated. The interface between national level and local-authority level jurisdictions need to be clarified.

Acknowledgements

The Water Research Commission (WRC) is gratefully acknowledged for funding this report. Thanks to Dr Steve Mitchell of the WRC for his ongoing support, for coordination of the funding between Australia and South Africa, and for arranging reviews of the report. Thanks also to Professor Jay O'Keeffe for his encouragement in the application for funding for this work, and to the Institute for Water Research in Grahamstown for their administration of the funds.

Many individuals made my stay and research in Australia a worthwhile and memorable experience. My thanks to Dr Chris Gippel who initiated the discussions regarding a Research Fellowship at the University of Melbourne, and provided support during my stay. Professor Brian Finlayson provided me with a "home'' in the School of Anthropology, Geography and Environmental Sciences, and together with Dr Ian Rutherfurd of the Centre for Cooperative Research in Catchment Hydrology (CRCCH), formalised the Research Fellowship at the School. I owe both a huge debt of gratitude for their kindness, willingness to enter into discussions, and great humour. Thanks to Ian for his enthusiasm and interest in my work, and for involving me in CRCCH projects pertaining to river rehabilitation. Dr Mike Stewardson (presently CRCCH) is thanked for his patience and kindness in assisting with many of the scientific and social issues and questions regarding rehabilitation, and for input in this report. Ms Inge van der Poel was working with Mike and undertaking research similar to mine, and became a stalwart colleague, ever ready to discuss matters aquatic. Brett Anderson, Dom Blackham and Ben Miller, with whom I shared an office, provided great inspiration. Thanks to them for their encouragement, and for providing an energetic, stimulating environment to work in. Thanks also to Dr Tony Ladson for discussions and input into this report. Many others in the School, too numerous to mention individually, contributed to making my stay trouble-free and enjoyable. Thanks to all.

I would also like to express my gratitude to a number of people for making time available to meet and to discuss aspects of river rehabilitation, and for the resources they made available to me: Dr Jane Doolan and Dr Patricia Gerharty (Department of Natural Resources and the Environment, Victoria), Professor Barry Hart (Monash University, Melbourne), Dr Bruce Gray (Environment Australia, Canberra), Mr Scott Seymour (Melbourne Water Corporation), Dr Richard Norris and Dr John Whittington (Cooperative Research Centre for Freshwater Ecology, Canberra), Dr Barbara Downes (School of Anthropology, Geography and Environmental Sciences, Melbourne University), Dr Nick Schofield (Land and Water Australia, Canberra), and Ms Freya Merrick (Environment Victoria).

Mr Bill Rowlston (Department of Water Affairs and Forestry, Pretoria) and Ms Delana Louw (IWRE Environmental, Pretoria) are thanked for their assistance with content in sections of Chapter 5 (during 2000 and 2001).

The review comments of Dr Jackie King (Southern Waters cc.) and Dr Cornelius Ruiters (Department of Water Affairs and Forestry) assisted in refining the structure and content of this report. Their effort is gratefully acknowledged.

TABLE OF CONTENTS

FRAMES, FIGURES AND TABLES

LIST OF FRAMES

LIST OF FIGURES

LIST OF TABLES

PREFACE

During early 1999, the South African Water Research Commission (WRC) circulated a document regarding their strategic research directions to an audience including all South African water scientists and managers, for their comment and input. Although there was a great deal of proposed research focussed on the health and sustainability of water resources, river rehabilitation was not explicitly mentioned in this document. This was clearly an area that warranted further research and attention, to ensure that South Africa kept pace with international trends and standards. An Australian colleague, Dr Chris Gippel, who had been working on rehabilitation projects in Australia, assisted in drafting a submission to WRC with a focus on river rehabilitation, and a basic set of recommendations for a phased development of a South African river rehabilitation field.

At that time, the Department of Water Affairs and Forestry's human and economic resources were fully occupied in the creation and, later, the implementation of progressive new water-related legislation, new licensing procedures and, above all, the provision of an assured supply of clean drinking water and sanitation to a population of around 37 million people. An enormous amount of additional effort was being applied to developing methodologies for Resource Directed Measures (RDM), and a strategy for Catchment Management. Environmental flows, and the development of the science behind these and methodologies to determine them, had received a great deal of attention and funding, and this was naturally the first step towards restoring ecological process and functioning to damaged riverine ecosytems. The lack of explicit attention to river rehabilitation was, in this context, justified, but left a gap in the country's ability to address river degradation.

As the RDM, and more particularly, the Ecological Reserve Determination methodologies were developed, it became apparent that these assessment and classification procedures had a great deal in common with the rehabilitation planning processes advocated in other countries. The RDM could thus contribute towards the development of a process for river rehabilitation. It seemed logical and economically intelligent to investigate and, if possible, encourage the development of the links between the RDM and process-driven river rehabilitation in South Africa.

The further drive for this was that scientific research into river rehabilitation seemed to be attracting sparse attention in South Africa from academics, government agencies or funders. The river rehabilitation efforts underway, or known of, appeared to be largely problem-solving exercises undertaken by specialist consultants, engineers or communities, and focussed on issues such as stormwater management, bank stabilisation and habitat reinstatement. A catchment-scale perspective was lacking, planning processes appeared to be all but absent, there was little evidence of a scientific basis for the work, and interventions were still, largely, dominated by concrete structures. This was unrelated to what other parts of the world regarded to be river rehabilitation. Results of these projects were seldom published in accessible media.

In 1999 and 2000, I had the opportunity to investigate river rehabilitation models in different parts of the world, and to consider their relevance to South African conditions and present water resource management. While the British, Canadian and American (particularly Hawaiian) models for river restoration provided a wealth of useful and relevant information for these purposes, Australian river rehabilitation became the primary focus of my research, and is the main subject of this report.

Part 1: INTRODUCTION

CHAPTER 1

INTRODUCTION, BACKGROUND AND AIMS

1.1 BACKGROUND TO THIS REPORT

This report is the outcome of a four month Senior Research Fellowship with the Cooperative Research Centre for Catchment Hydrology (CRCCH), School of Anthropology, Geography and Environmental Sciences, Melbourne University (Victoria, Australia) during 2000. The CRCCH Programme for Stream Restoration was then led by Dr Ian Rutherfurd[1], who also led the team that developed a two-volume 'Rehabilitation Manual for Australian Streams' in 2000.

One of the focal projects at the time was the CRCCH Programme 6.2: *Stream Restoration Planning and Execution in the Yarra River Catchment*. CRCCH's concern was that management recognise the need to plan river rehabilitation with clear goals, measurable objectives and temporally and spatially scaled processes. Outcomes needed to be evaluated against objectives, in accordance with the principles of Adaptive Management. The associated question was how best to incorporate science into river rehabilitation to ensure that the development of the river rehabilitation field was an informed process. This led to many discussions and work sessions on the subject and an understanding of the complexities of the bridging required field which represented both science and management interests. The particular case study worked on was Melbourne Water's Waterway Activity Plans, which included management activities directed towards rehabilitation.

This report was written in 2001 and completed in January 2002. Many changes will have taken place both institutionally and methodologically by the time of publication, and the report should be read in that context. Although a great deal of information and documentation was made available in Australia, much of the information included here was sourced in from South Africa, from publicly available reports and other media.

1.2 AIMS AND PURPOSES

The purpose of the time spent with the CRCCH was to learn about the development and practice of river rehabilitation in an Australian context, and to interact with researchers actively involved in the science underpinning it.

The aim of this report is to convey, at a non-technical level, what South Africa can learn from the development of the field of river rehabilitation in Australia, and which of the Australian approaches could, appropriately, be transferred to South Africa. Attention has been focussed on the Australian socio-political context and the decade of policy reforms that favoured the emergence and growth of river rehabilitation. Clearly, without these 'drivers' (discussed in Chapter 2), there would not have been the legal, financial and logistical support from government and corporate sectors that enabled the extensive scientific research and development which has occurred over the past decade.

At the end of the report, a number of ideas are discussed for the ongoing development of this young field in South Africa.

1.3 READERSHIP

[1] *Programme Leader, CRC for Catchment Hydrology, School of Anthropology, Geography and Environmental Studies, The University of Melbourne, VIC 3010, Australia. Email:* *idruth@unimelb.edu.au*

This report aims to provide an overview of an extensive field of endeavour to a broad audience.

This is envisaged as follows:

- South African readers with a scientific, political, managerial or engineering interest in river rehabilitation;
- South Africans who aspire towards the coordinated and consultative development of a centralised field of river rehabilitation in this country (this includes academics, research funders, engineers, managers, and environmental consultants);
- South Africans who are practically involved with community-driven or other rehabilitation projects and require background or simple guidelines for their projects;
- Australian and South African readers with an interest in recent developments in South African water resource management, and how the present initiatives may be extended to incorporate river rehabilitation planning.

Because of the breadth of interests represented by this audience, the report has been kept as modular as possible to enable the reader to skip to sections of interest. It is however recommended that the introductory and concluding chapters be read.

1.4 REPORT STRUCTURE

The report is divided into three parts as shown below. Part 1 is introductory. Part 2 deals with Australia, the development of rehabilitation there, and a summarised process for rehabilitation planning and implementation. Part 3 provides a South African perspective on water resource management and concludes with a series of suggestions for the development of river rehabilitation in this country. Where considered necessary for explanatory purposes, I have included a preface to the chapter. The summaries provided at the end of each chapter are largely synthesized at the beginning of the document as the Executive Summary.

The detailed structure of the document is as follows:

PART 1: INTRODUCTION

Chapter 1
Introduction, Aims and Background .

PART 2: AUSTRALIA

Chapter 2
Background, water resource management and policy reform

This chapter presents general information on Australia's geography and political history, and outlines the socio-economic, political and environmental context which has favoured the development of river rehabilitation over the past decade. An *attempt has been made to identify the ten most important contributing factors to the growth and acceptance of river rehabilitation.*

Chapter 3
The development of river rehabilitation

This chapter provides a background to the development and current status of river rehabilitation in Australia.

Chapter 4
Principles and processes in river rehabilitation

This chapter provides a largely non-technical treatment of the principles, planning and implementation processes and the means of prioritisation that form the basis of the Australian river rehabilitation field.

The large majority of planning and implementation tools relevant to rehabilitation are scientific or technical by nature, and include approaches to stable channel design, bank stabilisation, and design of appropriate intervention structures for the channel and riparian zone. While fundamental to rehabilitation projects and of interest to scientists and engineers, these are outside of the scope of this report. The interested reader is referred to Rutherfurd et al. (2000a, Volume 2) for an introduction and cursory treatment of these intervention tools.

PART 3: SOUTH AFRICA

Chapter 5
Water resource management in SA

This chapter outlines the SA Water Law reform process of the late 1990s and the current (and developing) water management approaches in South Africa. The Resource Directed Measures (RDM) and, within these, the Ecological Reserve Determination processes are given some prominence, as these seem to be of interest to overseas readers, and because elements of the RDM process link to those of river rehabilitation. Because of the ongoing refinement of the RDM processes the detailed methodologies presented may not be current by the time of going to press, however the principles remain the same.

Chapter 6
Current initiatives linking to river rehabilitation in SA

This chapter describes current initiatives in South Africa that relate (or could relate) in some way to river rehabilitation. This is not

	a complete treatment of the subject, nor are individual case studies presented here.
Chapter 7 River rehabilitation in SA: suggestion for future directions	*On the basis of the information presented, this chapter is a series of ideas and suggestions for possible future directions in river rehabilitation as a discipline in South Africa.*

1.5 INTRODUCTION TO RIVER RESTORATION OR REHABILITATION

Interest in ecosystem restoration has grown substantially in recent decades, with the focus being directed largely towards the restoration of terrestrial ecosystems, rivers and wetlands. This has provided a much-needed positive outlook for the environmental movement, classically beset with 'doom and gloom' messages (Kondolf 1995).

The early environmental movement, typically associated with the 1960s, brought about a recognition of the large-scale land alteration and catchment damage caused by agriculture, forestry, urbanisation and water resource development in successive post-settlement generations. The increasing media coverage afforded to environmental issues, and the numerous global summits and treaties through the subequent decades, have further stimulated an awareness of the extent to which human activities have obstructed and modified natural ecological and geomorphological processes. The revival of interest in traditional attitudes of indigenous cultures towards their environments has provided a spiritual dimension to the environmental movement, and an attendant need to address the relationship between people and their natural environment. The human value system adjusts slowly towards accommodating the independent worth of ecosystems, alongside that of cultural, socio-economic and political systems. The trend towards rehabilitating damaged ecosystems illustrates this mindshift.

Larsen (1996) reports that in the earlier days of river restoration in Germany, the 1960s and 1970s, attempts to restore stretches of small rivers were undertaken by 'enthusiasts who were looked upon with benevolent amusement by the authorities and hydraulic engineers'. Today, in contrast, he notes that (at least in Germany) ecological criteria are considered on an equal footing with technical criteria. Indeed, earlier rehabilitation literature suggests something of a bias towards physical structure, re-engineering of river channels, habitat augmentation, slope stabilisation and flow regulation. The field has advanced to a recognition and treatment of the river as an ecosystem within ecosystems.

Restoration of river corridors has developed following a knowledge-based, comprehensive, interdisciplinary approach, particularly in highly developed and densely populated countries where little could be left to chance in terms of outcomes (e.g. Larsen 1996). The field draws together the disciplines of ecology, aquatic biology and chemistry, hydrology and hydraulics, fluvial geomorphology, engineering, planning, law, communications and social science. In addition, because projects are usually undertaken within a catchment context (USEPA 1995), they tend to attract the interest, participation and watchful eye of local business and industry and the greater public.

The multidisciplinary and multifaceted nature of river rehabilitation has resulted in it being perceived both as a panacea to environmental degradation and the fragmented field of resource management, and as a 'wicked problem', characterised by diverse social and scientific dimensions and often laden with conflicting interests (Geist and Galastowitsch 1999). Both are essentially positive. The former recognises the need for integration across different levels of government and profession, and for linkage between government and private sector; while the latter seeks ways of developing beneficial relationships between humans and the natural environment, through restoration (Geist and Galastowitsch 1999).

Appropriate terminology

The mixed use of the terms 'restoration' and 'rehabilitation', amidst a host of others, is confusing. In general, the term gaining favour in Britain and Australia seems to be 'river rehabilitation' (RRC 2000, Rutherfurd et al. 2000a,b), while that in the US remains 'river restoration' (e.g. USEPA 2000). In most of the contemporary literature, both are essentially aiming for the same outcome: the return of the structure and function of a degraded river ecosystem to the *closest achievable approximation* of its natural (pre-impact) state.

The term 'rehabilitation' is preferred by many because that it is felt that 'restoration' implies a return to natural pre-impact state and is thus aspirational and seldom achievable, while rehabilitation focusses on achievable objectives and also aims for improvement and protection. Rutherfurd et al. (2000a) argue that to achieve true restoration (as described), the following objectives would need to be fulfilled: the restoration of the natural range of water quality functioning; the restoration of the natural sediment and flow regime; restoration of a natural channel geometry and stability; restoration of the natural riparian communities; restoration of native aquatic plants and animals. The goal of rehabilitation, on the other hand, would be the improvement of important aspects of the stream environment with the aim of the system eventually resembling its pre-impact state.

The term 'remediation' is appropriate in cases where it is not possible to rehabilitate due to a river system being irretrievably degraded, or where a system has been fundamentally altered in character but has, over time, adjusted and achieved a state of dynamic 'stability' or equilibrium. This is often the case of a river channel downstream of a dam. The aim of remediation is to improve the ecological condition of the river, while not aiming for an endpoint which resembles its original condition (Breen and Walsh 1999).

On the basis that, at least in contemporary literature, the same *meaning* is generally attached to the use of the terms 'restoration' and 'rehabilitation', these are used interchangeably in this report.

The Relevance of 'System Recovery'

This subject is raised in the introductory chapter as it is considered a cornerstone of successful rehabilitation, and is perhaps all too often overlooked in the design and planning stages of projects. It is also currently one of the more complex issues being tackled in international rehabilitation research.

The field of river science now has an understanding of how riverine ecosystems function, and how disruptions to natural state can have multiple and continuing effects (e.g. Sweeting 1996). Though the concept of 'disturbance' has been variously defined, interpreted and misinterpreted, it is generally understood to be '*any relatively discrete event in time that disrupts ecosystem, community or population structure and changes resources, substrate availability or the physical environment*' (White and Pickett 1985). Disturbance can be either natural (e.g. floods) or anthropogenic (e.g. construction of dams). The former is an important element in the maintenance of biotic diversity and geomorphological complexity in rivers.

'Recovery' relates to the ways in which systems respond to disturbances, both in a geomorphic and biological sense. Streams first lose, then gradually (over variable timescales) recover, their structural and biotic complexity following disturbance. The new 'equilibrium' state may not necessarily resemble that of the original stream (e.g. Rutherfurd et al. 2000a, DWAF 1999).

Rehabilitation is largely about these processes of recovery. One of the difficulties lies in assessing whether a system is in a state of recovery, and if so, where along the recovery trajectory it lies.

Prior to the decision to implement rehabilitation plans, it is thus vital to have established:

- whether the system is already in a state of recovery following a natural or human-induced disturbance (this is in spite of the fact that it may not appear to be so);
- if so, how this recovery will proceed and what the extent of its effects will be, over what time period;
- if not, how the system in its present state is likely to respond to and recover from interventions, over what distance and time period.

This assessment requires the expertise of several specialists: at the least an experienced fluvial geomorphologist, a hydrologist, and ecologists. It includes what may be a lengthy process of acquiring information on pre-impact state, past disturbance events (natural and non-), flow records, catchment land-use, and causes of degradation[1]. In the event that a stream is considered to be in a recovery process, the rehabilitation planning decision can be either to assist and accelerate the process, or to allow natural recovery to proceed unhindered, and to attend to other high priority problems.

Working with the natural recovery processes of a river system, i.e. following the natural recovery trajectory, is an effective and relatively low-cost way to rehabilitate (Rutherfurd et al. 2000a). Working against natural recovery processes can lead to the failure of rehabilitation projects, and to further degradation (Kondolf 1998). The interested reader is referred to Rutherfurd et al. (2000a) and Milner (1996) for reviews of system recovery in the context of river rehabilitation.

1.6 RIVER REHABILITATION FOR SOUTH AFRICA

[1] *The processes of estimating pre-impact or 'reference' state, and assessing the nature of the trajectory of change in a river section, are included in the South African Ecological Reserve Determination process, as described in Chapter 5.*

While South Africa has proved itself to be world class in the development of water-related policy, with the recognition of the river as a 'resource' rather than a 'user of water', the determination of environmental flow recommendations, and the development of Integrated Water Resource Management and Catchment Management practice, there is as yet no process in this country to incorporate the discipline of river rehabilitation into any or all of these fields. In other parts of the world, river restoration has developed and advanced to the point where national and /or regional guidelines have been developed, largely based on principles and processes learnt from their own or others' restoration exercises.

The emerging weaknesses of most river restoration movements seem to have been the over-emphasis on partial or physical aspects of rehabilitation at the cost of the bigger picture, the lack of planning and structured processes; the paucity of available ecological and historic information on which to base rehabilitation decisions; the meagre attention to scientific process and ecological principles; and the lack of evaluation of outcomes. Currently, attention is focussed on the development of sound rehabilitation processes (planning, objective setting, priorisation), the incorporation of the scientific method into projects wherever possible, and the necessity for evaluation of outcomes.

In South Africa, concerns about river rehabilitation are at a different level and include: the lack of understanding of what rehabilitation means; the paucity of research attention and funding directed towards it; the inadequate attention of individual projects to planning and the environmental outcomes of the work; the lack of a scientific basis for rehabilitation; and the dominance of traditional engineering approaches rather than bio-engineering techniques.

South Africa is perfectly placed to absorb the lessons of international experience and to become world class in the field of urban and non-urban river restoration without having to reinvent the wheel. There are many obvious and immediate linkages that could be made to present initiatives in government and elsewhere, at both organisational and methodological levels. This would ideally occur within the context of a national programme for river rehabilitation. The desirable hallmarks of such a programme would be that it be interdisciplinary; founded on sound scientific and social research; that it adopt a holistic, ecosystem- and catchment-based approach; that it be informed by system recovery processes; that it be process- and outcome- oriented; that it strive for cost-effective planning; that it incorporate traditional indigenous cultural and spiritual values into its philosophy; and that it create awareness through education, community development and capacity building.

Failure to recognise the timeliness of linking to both international and national initiatives in river rehabilitation and protection is likely to prove extremely expensive to South Africa, both in economic and in environmental terms. If the issue regarding rehabilitation is 'what are the costs of doing rehabilitation', then the appropriate question to ask is 'what are the costs of not doing it?'

1.8 SUMMARY

The purpose of this report is to convey, at a reasonably non-technical level, how South Africa could potentially learn from the way in which river rehabilitation has developed in Australia; and to assess where the links lie between current South African water resource management and the processes inherent in this practice.

This introductory chapter has provided a background to the field of rehabilitation and the somewhat confusing use of the terms 'restoration' and 'rehabilitation', amongst others. Because both of these terms are generally used to describe the same process and purpose (at least in contemporary literature), they are used interchangeably in this report. The theoretical difference between the two has however been discussed.

The importance of developing an understanding of system recovery in order to make the correct decisions in rehabilitation planning has been raised in this introductory chapter, as it is of fundamental importance to the success and sustainability of intervention measures.

River rehabilitation as a discipline and practice is barely in its infancy in this country. Major concerns at present are the lack of understanding of what rehabilitation means; the paucity of research attention and funding directed towards it; the inadequate attention to scientific method; the inattention to bio-engineering approaches; and the lack of planning processes in individual rehabilitation projects. A coordinated programme which could guide research and the development of principles and processes appropriate to South African rivers could address these issues.

Part 2: AUSTRALIA

CHAPTER 2

BACKGROUND,

WATER RESOURCE MANAGEMENT

AND POLICY REFORM

2.1 INTRODUCTION

This chapter provides a background to Australia's geography and political history, a brief description of the condition of the country's rivers both pre- and post-settlement, a discussion of historic water resource management approaches, and a commentary on a decade of water policy reforms. The aim is to provide a picture of the state of Australia's rivers and water management approaches by the early 1990s when rehabilitation was initiated; and to provide a comparison to South African conditions, and.

The section 'A Decade of Policy Reform' is interpretive. From the extensive information available on political changes and developments in the 1990s in Australia, and from discussions or interaction with Australian scientists and water managers, ten events or programmes have been selected to represent some of the more important drivers in the development of river rehabilitation. An attempt has been made to explain the relevance of each of these to the growth of rehabilitation. The reason for including this section is to highlight the far-reaching outcomes of policy change and of public and private-sector 'buy-in' to scientific research and development.

2.2 THE PHYSICAL GEOGRAPHY OF AUSTRALIA

(Information sourced from Finlayson and Brizga (2000), Gippel and Collier (1998), Finlayson and McMahon (1988) and Imhof (1999))

The Australian continent extends from the tropics to the temperate zone. It is the world's sixth largest country, with a surface area of over 7.5 million square kilometres. Following the break-up of Gondwanaland some 80 million years ago, the country achieved something approaching its present shape. Though there is some seismic activity in the western and eastern highland areas, Australia is, on the whole, a stable, ancient landscape which for several hundred million years has been free of the forces of active uplift that have given rise to large mountain ranges in other parts of the world. There is ongoing research to 'disentangle' the landscape's geological history, and the controls that this imposes. The predominant forces of landscape evolution have been fluvial erosion, valley widening and deposition. Bedrock in many areas is over 3.8 billion years old, and some of the soils over 450 million years old.

The land is generally flat with low continental elevation. It has nutrient-poor soils, and is climatically arid. From the east coast, a narrow fertile strip merges into the extensively eroded Great Dividing Range that runs north-south. West of this range, the land becomes flat and dry. The aridity is broken by few salt lakes, protruding geological structures such as Uluru (Ayers Rock), and a few mountain ranges. Much of this Outback area is barren, with harsh stone deserts and dry lakes. The north of the country is, by contrast, tropical and lies in the monsoon belt. While the rainfall in this region appears adequate in figures, the majority of rain falls in one short burst, which has kept the area from becoming agriculturally productive.

The climate of Australia is characterised by high variability in precipitation. Weather patterns tend towards the creation of intense rainfall events. The absence of major mountain chains means that an orographic source of reliable precipitation is lacking.

Figure 2.1. A map of Australia showing the State and Territory divisions.

2.3 POLITICAL HISTORY OF AUSTRALIA

Within a generation of the arrival of the first fleet of British ships in 1788, Australia had become a nation of immigrants. While original settlers were British and Irish, today one in three Australians hail from somewhere else in the world. The population of the country is multicultural, with large numbers of immigrants having arrived after in the years following World War II from Greece, Italy, Poland, Germany, Turkey and Southeast Asia (Doring Kindersley 1998).

At the time of European settlement, it is estimated that there were up to 750 000 Aborigines in the country. The Aborigines had lived on the continent for tens of thousands of years in tribal settings, with strong links to their environment, actively managing waterways for the purpose of food gathering (Gippel and Collier 1998). The newly-arrived Europeans considered the land to be *terra nullis* – a land belonging to no-one (Doring Kindersley 1998). The effects on the indigenous people and the landscape were to devastating.

Australia became a nation in 1901 with the joining of the former colonies to form a Federation. The national government is referred to as the ‘Commonwealth’ or ‘Federal’ government and is located in the purpose-built national capital Canberra, in the Australian Capital Territory (ACT). The other self-governing States and Territories are Queensland, New South Wales, Victoria, South Australia, Western Australia, Northern Territory, and Tasmania (Figure 4.1). The Federal government is led by a prime minister, while each of the States is led by a premier, and has its own government. The Commonwealth government has only very specific powers, and residual powers reside with the States. Thus, the State governments have individual responsibilities regarding environment and river management. The fact that the States and Territories have equal representation in Parliament, regardless of size or population, has had a profound effect on Australia’s politics, entrenching the State divisions and ensuring that even the smaller States have remained powerful forces in national government (Doring Kindersley 1998). This provides a background to the Council of Australian Government (COAG) reforms, discussed later in this chapter.

The approximate population of Australia is in the order of 18.4 million (Doring Kindersley 1998), sparsely distributed over a continental land surface of 7.5 million km^2. In terms of demands on water resources and density of populace, this picture is in contrast to that of South Africa, where a population of over 37 million people (1997 census figures) occupies an area of 1.2 million km^2.

2.4 AUSTRALIAN RIVERS

The diverse rivers in Australia are not unique, however they have more in common with waters in arid, semi-arid, tropical and subtropical areas than with waters in the northern temperate region (Williams 1992). Characteristic features of semi-arid zone rivers are high flow variability and unpredictability (due to capricious rainfall), flow intermittency and the possibility of an event-driven hydrology, and opportunistic, resistant and resilient biota (e.g. Uys 1998). The geomorphic character of these rivers is influenced chiefly by high magnitude, low frequency flows, in contrast to the lower magnitude, high frequency flows (‘dominant discharges’) which control channel form in temperate zone rivers (e.g. Birkhead et al.1999).

Hydrology

The Australian hydrologic record is, like the South African one, characterised by variability, with fairly long periods of above and below ‘average’ conditions (McMahon and Finlayson 1992). The natural hydrology is driven by unpredictable and variable rainfall, and is characterised by high coefficients of variability in annual flow (C_v), flooding and extreme events (McMahon and Finlayson 1992).

Runoff is concentrated in the small humid zone of the country, along the south-eastern seaboard, where the Murray and the Darling Rivers both have their headwaters. Runoff is all but absent from the large central arid zone of the country, where significant areas are traversed by intermittent river systems. Between these two extremes is the sub-humid zone, a broad, coastal-to-inland band stretching from the north-west to the south-south east in South Australia (McMahon and Finlayson 1992).

River form

The Australian landscape is largely characterised by broad, flat valleys and limited (though occasionally extreme) relief. This, combined with the antiquity of the land, the high discharge variability and the low sediment availability of the landscape, has created conditions under which rivers have adopted patterns of geomorphic behaviour and morphologies quite different from those described in northern hemisphere literature (Brierley, 1994). Though the diversity of river styles is immense, attempts have been made to classify rivers into useful groups. Williams (1983) distinguished five river regions:

1. **The Murray-Darling River system:** a depositional, high energy system characterised by marked variation in streamflow, high turbidities and extensive floodplains.
2. **Upland rivers and streams:** fast-flowing and erosional, with low turbidities.
3. **Northern flood-drought rivers:** that flow for most of their length across a wide coastal plain and are characterised by extreme seasonal variation in flow;
4. **Rivers and streams east and south of the Dividing Range** (and in parts of Western Australia): a heterogenous group which share the features of generally being perennial and relatively short in length.
5. **Temporary streams:** found throughout the drier parts of Australia, and only flowing after substantial rain.

Brierley (1994) differentiated five primary planform styles: braided, wandering gravel bed, meandering, anastomosing and straight. Brierley’s River Styles approach does not imply discrete planforms, as the styles are more commonly intermediate between one and another or more forms.

Many of the larger lowland rivers of Australia are extensive floodplain systems (e.g. the Murray-Darling). Under natural conditions, enormous amounts of water are stored in the extensive floodplains, and provide input to the channels.

Characteristically, rivers drain low-gradient catchments and have low bedload transport rates, low sediment yields, and transport fine-particle sediments such as clays, low concentrations of which give the streams a turbid appearance (Gippel and Collier 1998, Milliman and Meade 1983). It is generally thought that Australian rivers have a relatively high natural turbidity, because of the sparse vegetation cover and high levels of fine clays in the readily erodible soils (Kirk 1985), However, data are not available to verify this Gippel and Collier (1998).

Prior to settlement, numerous coastal and inland streams, from Western Australia through to south-eastern Australia and as far north-east as Queensland, had a morphology consisting of, or including, 'chains-of-ponds' (Prosser 1991, Eyles 1977), which consist of permanent, deep pools, separated by bars of sediment stabilised with vegetation. They are typically found on smaller streams with non-perennial flow regimes. The ponds are not necessarily associated with stream bends, and there will generally be a pool located where a tributary enters the main channel (Rutherfurd et al. 2000a). Typical vegetation stabilising the bars would be rushes, reeds, sedges, grasses, paperbarks and tea trees.

The related 'swampy meadows' were poorly drained, confined valley floors in which sediments and organic matter gradually built up. These were common in south-eastern Australia prior to settlement (Prosser et al. 1994).

Rutherfurd et al. (2000a) note that the assumption underlying much stream rehabilitation work in Australia has been that in their pre-impact state, small streams had a riffle/pool type morphology, rather than chains-of-ponds and swampy meadows. Some rehabilitation groups are now using chains-of-ponds morphology as a model for stream rehabilitation.

Riparian land

In Australia, the term 'riparian land' or the 'riparian zone' is defined as '*any land which adjoins, directly influences, or is influenced by a body of water*'. This includes land immediately adjacent to small creeks and rivers (including the bank), gullies and dips which run with the surface water, areas surrounding lakes, and wetlands on river floodplains which interact with the river in times of flood (Tubman and Price 1999).

Catchments in coastal south-eastern and south-western Australia and the wet tropics of the far north are characteristically higher-gradient, forested systems. Riparian vegetation is typically sclerophyllous, and these forested streams appear to function much in the same way as their northern hemisphere counterparts (Bunn 1994). Many of the rivers in the wet/dry tropics of northern Australia drain sparsely vegetated catchments and are characterised by a relatively open riparian canopy (Bunn 1994).

Prior to settlement, riparian zones were, typically, continuously vegetated with bands of native riparian species. Though the riparian vegetation provided protection to stream banks, even under these conditions, streambank erosion and major changes of channel position occurred. Following settlement, extensive land-clearing took place for agricultural purposes. Cleared river banks are subject to vastly increased streambank erosion. The bank instability that results from both vegetation clearing and bed-lowering is one of the major stream degradation issues in Australia (e.g. Rutherfurd et al. 2000 a,b).

Extensive resources are being directed towards riparian research and the re-greening of riparian zones around Australia. Programmes and projects attending to this are discussed later in this chapter (Section 3.3.3).

Large Woody Debris (Snags)

Large Woody Debris (LWD) or ‘snags’ are considered a key feature of healthy Australian streams. In streams with a mobile bed and deep water, LWD may be the single most important habitat feature for fish, algae and macroinvertebrates. Habitat uses include shelter from fast flows, shade, feeding sites, spawning sites, nursery areas for larvae and juvenile fish, territory markers and refuges from predators. Branches extending into the water column and above the water surface provide habitat at the different water levels required by various fish species. LWD also provides important habitat for terrestrial organisms (Rutherfurd et al. 2000a).

Snags provide complex surface area for microbial and algal colonists. Bacterial and fungal components of biofilm assist the decomposition of the woody substrate, thus supplying particulate organic material to the stream. LWD thus plays a major role in carbon and nutrient processing.

The removal of LWD from Australian streams following settlement (for the purposes of navigation and flood control) had a devastating effect on stream ecosystems. The return of LWD to streams is now a major focus area in rehabilitation research and practice (Rutherfurd et al. 2000a).

Biota

The majority of flora and fauna of Australian river systems are considered resilient to the uncertainty of their environment, and well adapted to the stochastic nature of flow in the rivers (McMahon and Finlayson 1992). Taxa are largely opportunistic and capable both of surviving and of making use of unpredictable flow events (Imhof 1999). It is assumed that aquatic plants and animals have adapted to naturally high turbidity, although it is uncertain how turbid rivers would naturally be (Rutherfurd et al. 2000a).

Typically, there is the expectation that environmental adversity correlates with low species richness. This may be true of the freshwater fish complement, which is in the order of 200 species. High numbers of invertebrate taxa are however reported in studies of two Australian Rivers. A study of the Murray River reported the collection of over 400 invertebrate taxa (Bennison and Suter 1990), while a study in an intermittent river system reported over 250 taxa (Boulton and Lake 1992). Species from most of the major groups occurring in freshwater are reported to occur, even in temporary river systems (Boulton and Lake 1992).

As already discussed under ‘River form’, Williams (1983) distinguished five river region types in Australia and related general features of the biota to flow patterns and topography. At present, a great deal of research is directed towards the interaction of the biota with flow. Of particular interest is the change in hydraulic habitat caused as a result of stream degradation, and the effect of these changes on biota. This research informs the setting of environmental flows.

Many of Australia’s freshwater fish are considered migratory and have some need to move between habitat areas within streams (Rutherfurd et al. 2000a). This implies migratory movements both in an upstream and a downstream direction (Ladson pers. comm.).

Regulation

While a large proportion of Australian rivers remain unregulated (Williams 1992), the larger systems have been heavily impacted and degraded by developments. The largest inter-basin transfer in Australia is part of the Snowy River Hydro-Electric Scheme (SMHS). This generates a small percentage of the total electricity requirements for south-east Australia by moving large volumes of water from the Snowy River to the Murray and Murrumbidgee Rivers (McMahon et al. 1992). These water transfers have underpinned significant irrigation industries in inland Australia.

The Murray-Darling Basin (the Basin) is the largest water resource in Australia. South-eastern Australia forms the southern part of the Basin and comprises the States of New South Wales, Victoria and South Australia (McPhail and Young 1992). The Murray and Darling Rivers are both extensively regulated. Because these rivers receive little surface water input from the downstream sections of their catchments, regulation effects are persistent over very long distances (McMahon and Finlayson 1992).

The high levels of surface water diversion in the south-east of the country drive the need for research on the impacts of river regulation on the instream and riparian environments. This part of the country is considered by many to have the most pressing needs for river restoration (McMahon and Finlayson 1992).

2.4.1 Impacts on rivers following settlement

Aboriginal people actively managed Australian waterways for fifty thousand years for the purposes of food gathering. The impact of their activities is considered to be minor and local in comparison with the changes brought about in the 200 years of European settlement (Gippel and Collier 1998).

The term commonly used in Australia in reference to a river's 'natural' condition is 'pre-settlement state'. The British settlers arrived in Australia in 1788, '*a highly technical and bureaucratic culture in which there was an early recognition of rivers in the landscape*' (Finlayson and Brizga 2000). Within a few decades, there were dramatic changes made to rivers and their catchments in the settled areas. Forests, river banks, riparian zones and floodplainds were were cleared for agriculture, and domestic and feral animals were introduced. By 1860 there were in the order of 20 million sheep in Australia (Doring Kindersley 1998). Sheep and cattle destroyed water holes and ruined a habitat that had previously sustained humans, plants and animals. Many species of animal and plant disappeared. There was large-scale desnagging of rivers. These impacts were, however, unevenly distributed. In the States of New South Wales and Victoria, population growth and agriculture resulted in far greater modification and development of water resources than in the rest of the country. These impacts led to:

- increased runoff from catchments and larger and flashier flood flows;
- many-fold increase in rates of erosion (gullying, headward erosion) and sediment delivery;
- a decrease in bank stability and resultant undercutting, channel incision and channel widening;
- floodplain scour and massive channel widening on high-energy coastal systems;
- coarse sediment delivery to streams resulting in sand slugs and 'choking', with

dramatic loss of instream habitat;
- associated with this, an increase in nutrient loading due to greater erosion, use of fertilisers, stock access, and increased levels of phosphorus and dissolved organic carbon in groundwater;
- an increase in fine-grained sediments;
- loss of chains-of-ponds and swampy meadows;
- large-scale alteration in river hydraulics;
- loss of riparian function and instream habitat;
- change in water quality parameters (including increased light, temperature and turbidity, decreased dissolved oxygen, increased salinity and nutrient loading);
- a rise in the water table and resultant dramatic increases in salinity (Prosser et al. 1999, Rutherfurd et al. 2000a,b, Gippel and Collier 1998).

The water needs of agriculture and urbanisation have resulted in developments including impoundment of major water resources, water diversions and inter-basin transfers, straightening and hard-lining of channels, and canalisation. Changes in urban areas include dramatic increases in impermeable area within catchments, deterioration in water quality, and the general alteration of the water cycle such that the term ‘urban water cycle’ has come into being.

Nevill (in prep.) maintains that the degraded condition of many of Australia's major waterways can in part be attributed to nine important assumptions that have underlain Australian water management frameworks (which may once have been valid):

- very large dams were subject to environmental assessment, small and medium-sized dams needed only cursory assessment on an individual basis, i.e. ‘the little ones don't matter’;
- small users of surface and ground waters, and the construction of levee banks, could escape catchment-based strategic assessments on the basis that ‘the little ones don't matter’;
- the harvesting of surface flows away from watercourses did not need to be controlled, as this would not significantly reduce overall catchment flows;
- landholders should, by and large, be allowed to place dams across small watercourses, i.e. it was unreasonable for State water agencies to ask landholders to pay the additional costs involved in off-stream dams;
- the plants and animals living in the streams would look after themselves, and no particular attention was needed regarding the provision of guaranteed environmental flows to keep them alive, or to support their life-cycle requirements;
- the need to protect biodiversity necessitated the development of systems of representative reserves conserving key examples of terrestrial and marine ecosystems, and it was unnecessary and impractical to apply the concept of representative reserves to freshwater ecosystems;
- the provision of fish passage facilities was either impractical, uneconomic, or unnecessary;
- groundwaters and surface waterways were somehow separate, and could be managed independently; and finally:
- there was no need for rigorous programme implementation, compliance auditing and enforcement; that illegal dams, bores, off-takes and levee banks would be minor and insignificant features in overall water management programmes.

It is questionable whether these were assumptions as much as oversights, however, Nevill’s points are true of past water resources management or development approaches in *many* parts of the world, including South Africa. Identifying and addressing these sorts of oversights is the challenge that those involved in fields such as environmental policy reform and river rehabilitation take on.

2.5 THREE PHASES OF RIVER MANAGEMENT IN AUSTRALIA

‘*The political pressure for the continued commercial exploitation and over-exploitation of Australia’s water resources is well documented ..... Water management in Australia is as much about economics, political policies and the power of political parties as it is about hydrology and ecology*’ (Alexander 1992).

The use of water has had a profound influence on Australia’s economic development. The development of water resources has principally served the needs of urbanisation and agriculture and has benefited the productivity of many sectors (Sanders et al. 1999). Until two decades ago, the focus of river management in Australia was on protection of built assets (e.g. bridges, canals) and on economic production. Recent years have seen a global recognition of the ecological linkages and balances that drive river systems, and a shift in management focus towards goals and values associated with the environment, society, culture, and recreation. Rutherfurd et al. (2000a) list four broad interacting areas in which goals and values for river management are presently situated or developed: social and cultural, recreational, environmental, and asset protection and economic production. The explicit attachment of the concept of ‘values’ to rivers has resulted in a public awareness of the need to approach these values through sound river management approaches, including rehabilitation. The relevance of this may be better understood if placed in the context of past river management in Australia. Finlayson and Brizga (2000) divide post-settlement river management into three major phases: inception, engineering, and environmental. The authors’ description of these phases forms the basis of the descriptions presented in the next section. Sources external to this are referenced.

The relevance of this information to South African readers is that it facilitates a ‘drawing of parallels’ between what has happened in Australian and South African water management historically, and how external events, circumstances and politics have contributed to changes which have led to new modes of water management.

The Inception Phase

The ‘Inception Phase’ began with settlement. Settlers were largely pastoralists and needed to obtain water from natural surface water sources, and to drain areas considered to have high agricultural potential. Their concerns were thus storage, drainage, flooding and erosion. Watering holes were dug in streams and weirs were installed to facilitate water supply and abstraction. Large areas of land and forest were cleared and drained for the planting of crops. Extensive drainage works led, in part, to channelisation that had the potential to cause incision and headward erosion in river channels. While these effects were addressed to some extent, there was also the strange perception of benefits provided by them – for example, the headward erosion in the channel was regarded as providing the benefit of further excavation. Artificial levees were constructed to reduce the frequency of flood inundation.

The Engineering Phase

The 'Engineering Phase' represents the time during which governments and statutory authorities took the lead role in river management. This led to a predominance of engineering works and schemes designed to address issues such as water supply, flood protection, drainage, and river improvement. The river improvement schemes focussed on bed and bank erosion control, removal of snags, stream clearing, and the introduction of artificial cutoffs to increase hydraulic efficiency.

Regulation and the construction of water supply schemes had began in the fairly early years of settlement. Melbourne's water supply dam, Yan Yean, was constructed in 1857. In 1915 the first River Murray Waters Agreement was formalised between the Commonwealth government and the State governments of Victoria, New South Wales and South Australia. This allowed for the regulation of the River Murray and the sharing of its water between the three States. The agreement was effected in 1917 with the establishment of the River Murray Commission to oversee the construction of the necessary storage and regulation structures and to operate these as required.

Until the 1930s, the main reason for river regulation had been to allow for navigation for the purposes of river trading. When river trading collapsed in the 1930s, the emphasis shifted to supplying water for irrigation. By the mid-1940s, urban and industrial needs were also being supplied from regulated rivers. During this time, the institutional framework for river improvement works was also being established. In Victoria, the first State-wide mechanism providing financial support for these types of works was the 'Rivers and Streams Fund', established in 1930. The River Improvement Act of 1948 was the precursor to the foundation of River Improvement Trusts.

Post-WWII construction initiatives in Australia paved the way for three decades of dam building. With every new election, new dams were promised. The legal framework in place at the time was inadequate to slow the excessive development initiatives.

The Environmental Phase

The 'Environmental Phase' began with the global growth in environmental awareness associated with the 1960s. The growing recognition of the need to protect environmental values and conserve resources was coupled with a shift in management emphasis from water quantity to water quality. The importance of maintaining ecological links between the various physical, chemical and biological processes and components of river systems became relevant in management. In the US, legal and institutional frameworks had begun to recognise the environment as a beneficial user of resources, and the federal system of law had resulted in flow-protection measures being adopted.

Natural events played a significant role in this process. For example, the prolonged drought of 1967 forced concern over water quality in the River Murray to a head, and the River Murray Waters Agreement was amended to take into account salinity issues when regulating the river at particular localities.

Cooperative use of the resource also became an appropriate approach. During the 1980s capacity-sharing arrangements were conducted at storages in Victoria. In 1985, the Murray Darling Basin Ministerial Council was established to promote and co-ordinate effective planning and management of the use of land, water and environmental resources of the Basin.

The Murray-Darling Basin Commission (MDBC), which now manages the Basin, showed increased concern for the environmental impact of water use. An audit of water use was initiated in 1993 and in 1997 resulted in a 'Cap' on water extraction, putting a ceiling on it at the 1993/94 level of development. It has been left to the States to adhere to the Cap (Bjornlund and MacKay 2000). These developments are discussed further in Section 2.6.

The 1980-90s saw rapid developments in policy internationally. Influential organisations such as the United Nations, OECD and the World Bank promoted a suite of policy-related instruments including pricing mechanisms, property rights, water markets, devolution of ownership and operation of water infrastructure, and public education programmes. Many nations adopted these policies (Bjorlund and MacKay 2000, Eckersley 1995).

By the early 1990s in Australia, these trends had caused a shift in thinking, towards privatisation and the adoption of a market-driven approach for resolving competing demands for water. Resource economics had gathered momentum. It was gradually recognised that the future role of government would have to become that of watchdog rather than entrepreneur and financier of water development. This represented a fundamental shift towards a public-private sector sharing of responsibility for water resources management.

2.6 A DECADE OF POLICY REFORM

As discussed at the beginning of this chapter, this section is interpretive and is an attempt to provide the reader with a picture of the broader context in which the field of river rehabilitation developed in Australia. It is hoped this will promote critical thinking about the nature of the forces which drive the development of resource-related science and management, and the relevance of this to an emerging discipline such as river rehabilitation. Of particular interest is the manner in which these driving forces have changed direction in recent times, favouring environmental as well as political agendas and outcomes.

The nineties was a time of dramatic reform of the water industry in Australia (Cullen et al. 2000). This was driven to a large extent by the agenda of the new National Competition Policy (NCP), which sought to promote inter-State/Territory competition, and particularly by the agreement of the Council of Australian Governments (COAG), formed in 1994 as a coalition of Commonwealth government heads of States and Territories, in an effort to encourage a 'spirit of cooperative federalism' (Bjornlund and Mackay 1999). COAG drove the NCP reforms and initiated major water-industry related changes described later in this section.

During the same period, the allocation of water and the determination of environmental flows were attracting media and public attention. The environmental flows of two of Australia's major river systems, the Murray and the Snowy, spurred massive public debate and resulted in an increased awareness of the degraded state of rivers across parts of the country, and pressure from the public to do something about this. Alongside these developments, a number of national or State/Territory programmes, partnerships and ventures were launched, and the Cooperative Research Centre (CRC) concept materialised, providing multi-sectoral funding to relevant research in water and numerous other fields.

The following 'events' are considered some of the key drivers in the development of the science and practice of river rehabilitation.

2.6.1 National Competition Policy (NCP).
2.6.2 Council of Australian Government (COAG) reforms.
2.6.3 Water markets and the corporatisation of water supply.
2.6.4 Establishment of Cooperative Research Centres (CRCs).
2.6.5 Land and Water Resources Research Development Corporation's (LWRRDC, now LWA) *Sustainable Management of Rivers and Water Resources Programme* and sub-programmes.
2.6.6 The Snowy River Enquiry.
2.6.7 The Murray Cap.
2.6.8 The National Heritage Trust (NHT).
2.6.9 State of Environment (SoE) Reporting.
2.6.10 The National Rivers Consortium (NRC).

2.6.1 National Competition Policy (NCP)

Information in this section from Fels (1996).

In 1995 a historic agreement was signed between the Prime Minister of Australia, the Premiers of the States and the Chief Ministers of the Territories defining a new National Competition Policy (NCP). This reform legislation focussed on mutual recognition between States and Territories, and was designed to eliminate trade barriers between these, and to promote interstate competition. It also included a number of agreements between the heads of governments.

The NCP initiated a process of review and structural reforms. One of the focuses was on addressing anti-competitive regulation by governments in areas including public monopolies such as water supply. Included in the overall aim to create and enhance markets across the whole scope of economic activity was the expansion of water markets and water trading, both between States and between different sectors (see Section 2.6.3). The legislative and administrative task of implementing the reforms was divided between the Commonwealth and the States, and the appropriate body to decide on the measures to be adopted to implement the NCP was the Council of Australian Governments (COAG).

2.6.2 Council of Australian Government (COAG) reforms

In 1994, COAG was set up as an informal forum where the Prime Minister of Australia, the Premiers of the States, and the Chief Ministers of the Territories could meet and give policy directions which could then be implemented at the appropriate levels (Fels 1996).

COAG drove the implementation of the NCP reforms, and initiated others including a national-level agreement on the environment, which recognised that urgent measures were required to arrest the widespread degradation of the country's natural resources.

COAG recognised that the Australian water industry was in need of reform in order to arrest natural resource degradation in all jurisdictions. It was agreed that a strategic framework was required to achieve an efficient and sustainable water industry. The Water Resource Policy drafted by COAG was intended to address, *inter alia*, the economic, environmental and social implications of water usage (Cullen et al. 2000). The reforms of the Policy covered all aspects of the water industry, including institutional arrangements for regulation, management and service provision, water allocations and entitlements, water pricing, environmental protection, and community input into decision making. The importance of addressing both efficiency and sustainability in water services and water resource management were emphasised. A summary of the Principles of the COAG Water Policy is presented in Frame 2.1.

Because of the nature of the COAG structure, the reform agenda was devolved to the level of individual States and Territories. Each jurisdiction proceeded to implement reforms at their own pace, depending on the circumstances prevailing (Cullen et al. 2000). The following were included for reform, review or development by the individual States or Territories:

- legislation guiding the management of the jurisdiction's water resources, and implementation of this;
- identification of rivers that had been over-allocated or deemed to be 'stressed'. The definition of 'stressed' was left to each jurisdiction, as was the development of methodologies required to do this (Cullen et al. 2000);
- determination of environmental flow requirements, with the stipulation that the methodologies used should be based on the best scientific information;
- determination of environmental water provisions or allocations.

Each of the States has taken different approaches to these requirements. In Victoria, the 'Stressed Rivers Programme' was linked to river rehabilitation. Those rivers deemed to be stressed were assessed for the likelihood of successful rehabilitation. This assessment was then used to develop a list of eight priority rivers for immediate planning and rehabilitation. It was recognised that in the majority of cases, modification of flow regimes was only one issue contributing to river degradation, and that rehabilitation would require an approach which included environmental flow requirements as one of a suite of rehabilitation measures (Cullen et al. 2000).

Frame 2.1 A summary of the COAG Water Policy Principles (*from Cullen et al. 2000*). (Emphases illustrate major initiatives).

- Water pricing based on the principles of **consumption-based pricing, full cost recovery** and transparency or removal of cross-subsidies.
- Future investment in new schemes or extensions to existing schemes to be undertaken **only after appraisal indicates economic viability and ecological sustainability.**
- Comprehensive systems of water allocations or entitlements, backed by **separation of water property rights from land title**, and clear specification of entitlements in terms of ownership, volume, reliability, transferability, and where appropriate, quality.
- Formal determination of water allocations or entitlements, including **allocations for the environment as a legitimate user of water.**
- **Environmental flow requirements** wherever possible, should be determined on the best scientific information available and have regard to inter-temporal and inter-spatial water needs required to maintain the health and viability of river systems and groundwater basins.
- Trading, including cross-border sales, of water allocations or entitlements, **within the social, physical and ecological constraints of catchments.**
- Administration and decision-making to provide an **integrated catchment management approach to water resource management** and establishment of arrangements to consult with the representatives of local government and the wider community in individual catchments.
- **Institutional separation of water resource management**, standard setting and regulatory roles of government **from the role of providing water services**.
- Constituents to be given a greater degree of **responsibility in the management of irrigation areas.**
- **Consultation** where change and/or new initiatives are contemplated involving water resources.
- Jurisdictions and water agencies individually and jointly should **develop public education programmes** in relation to water use, the need for and benefits from reform, the cause and effect relationship between infrastructure performance, standards of service and related costs.
- Appropriate water related **research necessary** to progress implementation of the framework, including consistent methodologies for determining environmental flow requirements.

Challenges to science:

- Clarifying the ecological outcomes to be achieved;
- Deciding what interventions managers would need to make to achieve these outcomes;
- Measuring and demonstrating that outcomes had been achieved.

Ecological outcomes were specified in three ways:

- Developments were to be ecologically sustainable;
- Actions should maintain the health and viability of river systems.
- Consideration should be given to the ecological constraints of catchments.

2.6.3 Water markets and the corporatisation of water services

Informal water markets (allowing trading of water allocations) existed in Australia for many years. They were legalised in 1983 by the federal government through the removal of legal obstacles to transferability of allocations. Although these formalised markets worked well in many respects, they were limited due to restrictions on trading between different States and sectors (Briscoe 1997).

The 1994 COAG reforms had assessed Australia's overall economic and trade policies, and had concluded that economic growth required that water markets operate more efficiently. COAG had stated that the major goal of water resources management was '*to achieve the highest and best value of the limited resource*'. Fulfilment of this aim required the broadening of the 'reach' of water markets. Inter-State and inter-sectoral water trading became a prime objective.

In the National Competition Policy (NCP) of 1995 (Section 2.6.1), issues regarding natural resource sustainability and equity had been addressed. One of the intentions regarding water was to encourage a re-allocation of water resources to higher-value, more efficient users. Under the NCP, every State was (and still is) compelled:

- to introduce full cost-recovery prices for water (*this was considered likely to force inefficient and low-value users out of irrigation practices*);
- to privatise public utilities, devolve the management of natural resources and all associated infrastructure, and to remove government subsidies and cross-subsidies to ensure that full costs for water were passed on to users, and
- to introduce market-based mechanisms for the trading of water (*water markets were expected to facilitate the processes already described, and to provide compensation to the sellers*)(Bjornlund and McKay 2000).

As an incentive for the States to comply with the NCP, the federal government undertook to maintain the 'financial assistance grants' which they typically dispensed to the individual States on merit[1], and in addition to provide three additional 'competition payments', subject to the States adhering to the aforementioned NCP requirements (Bjornlund and McKay 2000). These grants are coveted as they bolster State-level funding of, amongst other things, river rehabilitation projects.

In Victoria, the government pursued a reform agenda that involved defining the government as the owner and regulator of water, and the water authorities as the providers of services (DNRE 1999). They encouraged the injection of capital from private corporations through schemes such as BOOT (Build, Own, Operate, Transfer). Water and wastewater services are now provided by professional, commercial, market-driven organisations. The government adopts a 'hands-off' approach to allow these organisations to run their businesses within the overall State vision and plan (DNRE 1999).

Research into early market experiences in water trading in Australia indicates that, as planned, markets are moving water to more efficient and higher value users, thus increasing the national benefits from a capped resource and at the same time decreasing the negative environmental impact of water use (Briscoe 1997).

[1] *Under the Australian Constitution the Federal Government has the power to collect income tax with no rules for its distribution. Typically the States receive 'financial assistance grants' from the Federal Government.*

2.6.4 The establishment of Cooperative Research Centres (CRCs)

The early 1990s also saw the establishment of Cooperative Research Centres (CRCs) in Australia. These are formal alliances between government, private industry, and researchers from university and other institutions. Each CRC is a centre of research expertise in a particular field, and covers long-term, collaborative research and development efforts of substantial quality and size. Each of the CRC Research and Development programmes contributes to national objectives. There are currently 63 CRCs operating across Australia with more than 200 companies involved as partners in projects. A further 800 companies are linked as supporting partners. The Commonwealth Government provides about $140 million a year to the Programme. To date, industry has committed to provide more than $1 billion to CRCs since the inception of the Programme (Minchin 2000).

The CRCs of particular relevance to river rehabilitation are the CRC for Freshwater Ecology (CRCFE) and the CRC for Catchment Hydrology (CRCCH). These have played a critical role in financing and conducting river rehabilitation research and development in Australia. The rehabilitation-related programmes run by these CRCs are described in more detail in Chapter 4.

The objectives of the CRC Programme are, in summary, 'to maximise the capture of the benefits of research through the development of enhanced cooperative linkages between researchers and research users in the public and private sector' (CRC 2001). The Programme emphasizes the importance of developing industry sectors that are internationally competitive. The CRCs are tasked with doing research which has relevance to industry's needs, and with ensuring the transfer of research-derived information to industry, via technology transfer programmes (Finlayson and Brizga 2000). Industries requiring research answers, and cooperating in the research funding, are typically partner agencies in the CRCs.

The CRC concept has major strengths and advantages, in:

- Providing a powerful mechanism for achieving both the CRC objective (stated above) and the objectives of the government, through the contractual arrangements which establish each CRC, and link the CRC to the Commonwealth.

- Strengthening collaborative links between researcher, industry and other research users in order to more effectively capture and transfer the benefits of research in natural sciences and engineering. This generates a 'feedback loop', wherein industry or resource managers inform research institutions of management issues requiring further research, and in turn, research outputs inform management decisions and actions. This represents a major improvement in communication and cooperation at the notoriously complex management/science interface.

- Increasing the efficiency of research and research training through collaboration of teams of top researchers from a variety of institutions and organisations.

- Improving the use of research resources through the sharing of major facilities and equipment.

- Promoting capacity building through the involvement of people from outside the university system in education programmes, and by offering degree and non-degree courses and training focussed on industry and other user needs.

2.6.5 Sustainable Management of Rivers & Water Resources Programme

This programme was initiated in the early 1990s and is currently active. It is driven by the federal body Land and Water Resources Research Development Corporation (LWRRDC), now known as Land and Water Australia (LWA), a Federal body which acts as lead agent and funder in partnership with a number of other government departments, agencies or organisations.

The programme has the following components:

- The National River Health Programme;
- The National Wetlands R&D Programme;
- The Rivers and Riparian Lands Programme;
- The National Eutrophication Management Programme;
- The National Groundwater R & D Programme;
- The National Programme for Irrigation R&D.

Those with relevance to river rehabilitation are described briefly.

The National River Health Programme

In 1993, the Federal Government initiated the National River Health Programme (NRHP) and funded it to the tune of A$12 million over a period of five years (Gippel and Collier 1998).

The mission of the programme is to improve the management of Australia's rivers and floodplains for their long-term health and ecological sustainability. The goals of the programme are:

- to monitor and assess Australia's rivers;
- to enhance the management of river flows, water allocation and water use;
- to ensure the sustainability of river and floodplain ecosystems;
- to encourage active management to improve the health of Australia's rivers, based on a sound understanding of the ecological and hydrological processes;
- to evaluate the effectiveness of river management actions at a national scale (Anderson 1999).

The second phase of R&D investment in river health and environmental flows was managed directly by Environment Australia, through the National Heritage Trust (NHT, Section 2.6.7).

The National River Health Programme (NRHP) developed Australia's first nationally consistent and standardised method of assessing river health, the Australian River Assessment Scheme (AUSRIVAS). This is a rapid biomonitoring method that uses macroinvertebrates as sensitive indicators of instream health. It has commonalities with the South African Scoring System version 5 (SASS5) biomonitoring methodology of Chutter (1998), but uses a multivariate technique to determine present condition as a proportion of 'expected' condition. AUSRIVAS is presently in use by all States and territories in Australia's 'First National Assessment of River Health'. More than 2000 river sites have been tested to date (LWRRDC 2001).

Further areas of NRHP R&D are upgrading of catchment condition, environmental flow assessment techniques and environmental flow provision, rehabilitation of riparian zones, stream channel improvement, management of water storages, the relationship between flow and river biota, the water requirements of wetlands, the development of decision-support tools for environmental flow management, and the production of a flow-ecology handbook (Rutherfurd et al. 1998). Many of these research activities are related to river rehabilitation.

NRHP work is considered essential to the successful implementation of the COAG water reforms.

The Rivers and Riparian Lands Programme

With the Natural Heritage Trust (NHT) funding which commenced in 1996 (see Section 2.6.8), and the increasing devolution of management responsibilities to local levels and catchment groups, there was some pressure on, and from, rural communities to address their degrading and degraded rivers and catchments. Limited access to knowledge and skills, and lack of a proper framework for river restoration, were the major stumbling blocks to progress.

The Rivers and Riparian Lands Programme was initiated to tackle these issues and to support the community's desire for healthy, sustainable rivers. The lead agency for the programme is LWRRDC (now Land and Water Australia), and additional funding comes from Agriculture, Fisheries and Food Australia (AFFA). Other support comes from State Government agencies, the CRC for Catchment Hydrology (CRCCH), and the Centre for Catchment and Instream Research at Griffith University in Brisbane.

Rivers and Riparian Lands incorporates the former Riparian Lands R&D Programme, another LWRRDC initiative, which developed scientifically-based technical guidelines for riparian land management (Lovett and Price 1999). These guidelines were supported with the production of two further technical manuals and a CD-ROM that focussed on river rehabilitation for Australian streams (Rutherfurd et al. 2000a). These are described further in Chapter 3.

The Programme has a number of experimental and demonstration/evaluation sites around Australia that are used to help improve understanding of the interactions between water bodies and their riparian lands and vegetation. Physico-chemical research includes the identification and quantification of the effects of riparian lands on channel morphology, bank stability and input of nutrients and sediment to rivers and water bodies. Ecological research is focussed on identification of the processes by which riparian lands influence in-stream ecosystems and their functioning, and the quantification of major effects.

A number of projects have been undertaken to address the need to identify and protect high value rivers and reaches; develop a holistic, integrated framework for river restoration, and assess and where possible improve Australian and international river legislation.

Information for this programme is widely distributed via issues sheets, the *RipRap* newsletter, magazines entitled *Rivers for the Future* and the *Australian Landcare Magazine*, and the media.

2.6.6 The Snowy River Inquiry

The Snowy River is one of the iconic Australian rivers (Gippel 1999). In its natural state, it was a rapidly flowing river of significant length, traversing 500km of New South Wales and Victoria. By the mid-1990s the Snowy was no longer flowing. The causes of degradation were complex, the primary factors being the reduction of flows in the river downstream of Jindabyne Dam where the Snowy Mountains Hydro-electricity Scheme (SMHS) is situated, and the loss of large stretches of riparian vegetation resulting from extensive agricultural practice in parts of the catchment (Bain and Tilleard 1999).

Post-impoundment flows downstream of Jindabyne were in the order of about 0.7% of the original flow, with the balance being captured in the Jindabyne Dam and redirected through the hydropower turbines and inland, into the Murray and Murrumbidgee Rivers. It is widely recognised that this regulation of flow has resulted in the environmental degradation of the Snowy and other rivers (Gippel 1999).

In 1998, the corporatisation of SMHS was planned. As part of this exercise, a Snowy Water Inquiry was established by the New South Wales and Victorian Governments in April 1998. This Inquiry planned to examine the environmental issues arising from the operation of the SMHS, and to provide a range of fully costed options to address these issues. The final report, released in October 1998, recommended an increase in flows from Lake Jindabyne, from the then-current release of 1% of mean annual flow to 15% of mean annual flow (Snowy Water Inquiry 1998). This was considerably less than the value of 28% of mean annual flow being demanded by public lobbies (e.g. Snowy River Alliance 1998) on the basis of an expert panel recommendation that the environmental flow release from Jindabyne should mimic the natural variability in flows (SGCMC1996).

Rehabilitation concepts and proposals for the Snowy River, including the development of an environmental flow regime (Stewardson 2001), have now been produced (e.g. Gippel 2001, Stewardson et al. 1999, Bain and Tilleard 1999, Gippel 1999).

2.6.7 The Murray Cap

The Murray-Darling River Basin (‘the Basin’) is the largest water resource in Australia. South-eastern Australia forms the southern part of the Basin and comprises the States of New South Wales, Victoria and South Australia.

By the early 1990s, flows in the rivers of the Basin had been substantially reduced due to over-allocation, over-abstraction, and diversions. The concomitant signs of catchment stress included salinisation, increasing turbidity, deterioration in water quality, algal blooms, reduction in habitat diversity and quantity and the decline of many native plants and animals. The effect of the diversions was most felt in the reduction of the number of small to mid-range floods. Water releases for dry-month irrigation also resulted in a change in the patterns of natural low flows (Whittington and Hillman undated).

The Murray-Darling Basin Commission (MDBC), who manage the Basin, showed increasing concern for the environmental impact of water use, and initiated an audit of water use in 1993. By 1997, this audit resulted in the Murray Darling Ministerial Council setting an upper limit on the amount of water that could be taken from the Murray Darling Basin (Whittington and Hillman undated). This is now commonly known as the ‘Murray Cap’. The Cap limits extraction from the rivers of the Basin to that amount which could have been diverted under the management rules and level of infrastructure that prevailed during 1993/4.

The Cap is climate-adjusted, taking into account both regional climatic differences and weather conditions within a year. For example, in Victoria, where dairy farming relies on secure water supply, usage is greater in dry years than in wet years, while in the northern part of the Basin, the reverse is true and abstraction is limited to high flows. While the Cap has the flexibility to allow for this, overall usage in wet years and dry years must balance out to remain within the long-term average extraction limit set for the region (Whittington and Hillman undated).

It has been left to the individual States to adhere to the Cap. Bjornlund and McKay (2000) report that the impact of the Cap is felt differently in the various States due to the different histories of development.

2.6.8 The National Heritage Trust (NHT)

In 1997, under the Liberal government, the National Heritage Trust was created out of the privatisation of the then-national telecommunications body, Telstra. The proceeds of the sale, AUS $90 million, was committed to a five year programme with the aim of bringing together the efforts of individuals, communities and governments, and targeting environmental problems at their source. The money was to be matched by funds from both State and local governments, such that a total of AUS $1.5 billion was available as funding.

The NHT focuses on five key environmental themes - land, vegetation, rivers, coasts and marine, and biodiversity. Funding for environmental activities is provided at the levels of community, region, State/Territory, and Commonwealth. At the Commonwealth level, the NHT is administered by a Ministerial Board comprising the Minister for the Environment and Heritage and the Minister for Agriculture, Fisheries and Forestry. The Trust is jointly administered by Environment Australia and Agriculture, Fisheries and Forestry Australia. At present, twenty programmes nationally benefit from NHT funding. Those concerning freshwater resources include:

- Murray Darling 2001;
- The National Rivercare Programme;
- Waterwatch Australia;
- The National Land and Water Resources Audit (see Section 2.6.9);
- Riverworks Tasmania;
- The National Wetlands Programme (NHT 2000).

2.6.9 State of Environment Reporting (Federal and State)

The first comprehensive national assessment of the state of the Australian environment was released in late 1996. This documented, *inter alia*, the extent of environmental degradation in streams since European settlement. The *Environment Protection and Biodiversity Conservation Act* of 1999 has since provided a legislative requirement for the production of a National State of the Environment Report every five years. The next report is due by the end of 2001 and will report on seven major themes: human settlements; biodiversity; the atmosphere; the land; inland waters; coasts and oceans; and natural and cultural heritage (Ball and Hack 2000).

Running in conjunction with the 2001 Australian SoE reporting process is the National Land and Water Resources Audit (NLWRA) which is funded by LWRRDC (now Land and Water Australia) via NHT. The NLWRA was established in 1997, under the *Natural Heritage Trust of Australia Bill* of 1996. The purpose of the NLWRA is to provide a comprehensive national appraisal of Australia's natural resource base. The Audit themes include water availability, dryland salinity, vegetation management, rangeland monitoring, agricultural productivity and sustainability, capacity for change, and ecosystem health (Ball and Hack 2000).

A collaborative project structure was developed with relevant State and Territory agencies, and a framework methodology was developed which would allow these agencies to use their own management approaches and techniques, while producing comparable outputs between States and Territories. Ball and Hack (2000) report that this project has had the benefit of creating a successful partnership with the governmental body Environment Australia, key State and Territory stakeholders, and private industry.

Set up in late 1997, the Audit has established management structures to coordinate activities over its four-year life span. One of the first tasks of the Audit Management Unit has been to determine areas of concern in natural resource management. Seven themes were identified. Most, the water, salinity, vegetation cover, rangelands and catchment issues, tend to parallel the emphasis of LWRRDC-managed R&D programmes. However two further areas for investigation are productivity issues and the ability for resource managers to adapt to change. Work plans have been completed to determine resource issues under each Audit Theme, to assess their significance to the Australian economy and social fabric, and to recommend management activities and priorities for investment.

2.6.10 The National Rivers Consortium (NRC)

The NRC was initiated in 1999 as a collaborative exercise between LWRRDC and a number of Commonwealth bodies: the Murray Darling Basin Commission (MDBC), AFFA, and the Cooperative Research Centres for Catchment Hydrology (CRCCH) and Freshwater Ecology (CRCFE).

The purpose of the NRC was to create a new approach to river restoration and protection. It was intended that this would address the major concerns about the lack of integration and communication between major stakeholders in restoration efforts, from government through to community levels. The objectives of the consortium were:

- to develop practical methods of river restoration and protection through the establishment of effective links and integration between research knowledge, policy, and the needs of on-ground management;
- to encourage integration and coordination across different disciplines and skills from a range of organisations;
- to facilitate the flow of information and expertise residing in the scientific community through to end users (State agencies, community groups) and to enhance the capacity of these groups to undertake the restoration work;
- to boost collaboration across different levels of government and administrative boundaries (Integra et al. 2000).

The role of the NRC in the strategic plan for the restoration and protection of Australia's rivers is in:

- the provision of integrated, process-oriented river rehabilitation R&D and technical support;
- the facilitation of research integration across disciplines;
- their contribution to the development and refinement of policy;
- the facilitation of best practice management procedures; and
- the improvement of the capacity of resource agencies, managers and community groups to undertake river restoration.

2.7 SUMMARY

This chapter has provided a background to the geography and political history of Australia, and the forces that have shaped the changes in water management over the past decade, and facilitated the development of river rehabilitation.

The extensive post-settlement impacts on Australia's rivers included: clearing of the riparian zone and banks, gullying and erosion, channel incision, water quality deterioration, flow reductions and alterations, channel straightening, and removal of Large Woody Debris. Three phases of post settlement river management are described by Finlayson and Brizga (2000): the Inception Phase following settlement, when clearing of land for agriculture led to extensive degradation of rivers; the Engineering Phase during which governments took the lead role in water management and water schemes flourished; and the (current) Environmental Phase during which resource issues gathered status, water services were privatised and water markets established.

Ten of the major political changes, water industry reforms and environmental flow issues of 1990s have been discussed in this chapter. These are considered to have been amongst the more important 'drivers' of river rehabilitation. Their effect was to create an environment within which the degradation of Australian waterways could be addressed, and to engender a public and private will to actively set about achieving this. The vigilance of particular academics and funding agencies ensured that the field of river rehabilitation developed alongside institutional and economic change. One of the most important developments of the 1990s was the formation of the Cooperative Research Centres (CRCs), formal alliances between government, private industries, universities and other institutions. Of the 63 CRCs, two, the CRC for Catchment Hydrology and the CRC for Freshwater Ecology, have been key organisations in the development of rehabilitation science, practice and guidelines.

CHAPTER 3

THE DEVELOPMENT OF RIVER REHABILITATION

3.1 INTRODUCTION

'*River restoration in Australia is a subject that is exercising the minds and activities of those involved with natural resources management across the country. The level of awareness and interest in river restoration is steadily increasing*' (Integra et al. 2000).

The field of 'river rehabilitation and protection' has developed in Australia over the past decade. Despite what from a South African perspective is fairly remarkable progress in a field within ten years, Rutherfurd et al. (2000a) still refer to the rehabilitation field as being in its infancy. In their opinion, the present-day priority for stream management work in Australia is erosion control in highly degraded streams. While this has obvious merit from a management perspective, the authors comment that on the basis of their ecologically-based priority system this sort of work is *not* high priority for rehabilitation and that most of the erosion control work is carried out on streams which would be classified as 'basket cases' in to their prioritisation system.

With the recent apparent trend towards the blurring of the borders between States and Territories (Fels 1996), national-level thinking has become appropriate, and partnerships between industry, management agencies and science (both within and between States) have been encouraged in the field of river restoration. In addition to this, States and Territories continue to develop approaches and methodologies appropriate to their own political and environmental conditions. International exchanges are also encouraged, in keeping with a global trend towards increased interdependence, knowledge exchange and information sharing. Scientific research increasingly informs rehabilitation practice, and practitioners in turn provide research questions.

The ongoing effectiveness of rehabilitation projects in Australia will increasingly rely on reforms in policy and regulations; political support; sound planning processes and project management; thorough training of key individuals in CMAs and catchment groups; refinement of appropriate geomorphological, hydrological, hydraulic and ecological principles for rehabilitation; development and implementation of evaluation procedures; use of adaptive management approaches; and strong public support.

3.2 BACKGROUND

The early 1990s could be considered the pioneering years of the river rehabilitation movement in Australia. With a growing awareness of a developing field, and an interest in learning from the international experience, research exchanges were arranged with international institutions and practitioners in the early years of the decade (Gippel pers. comm.). The 'partnering' and 'knowledge sharing' ethics have remained important in the development of river rehabilitation development in Australia, with research collaboration or exchanges of various kinds between Australia and New Zealand (e.g. Collier and Smith 2000, Nguyen and Quinn, 2000, Gippel and Collier 1998), Canada (e.g. Babakaiff 1999, Imhof 1999), and UK (e.g. Brierley and Downs 2000).

3.2.1 R & D needs identified

In the later years of the nineties, the Cooperative Research Centre for Catchment Hydrology (CRCCH) in Melbourne produced a report on the '*Research and Development Needs for River Restoration in Australia*', funded by the LWRRDC (now Land and Water Australia), and authored by Rutherfurd et al. (1998). The report was aimed at providing the information necessary for establishing a national stream restoration programme. The role of this programme would be the provision of information to industry, the encouragement of targeted research, coordination between States, and elevation of the profile of issues around rehabilitation.

In this report, stream rehabilitation was described as 'a developing field of endeavour'. The weak points characterising the field and needing to be addressed were:

- narrow, unclear or unrepresentative goals;
- inadequate communication amongst and between practitioners, researchers and managers;
- a poor recognition of the multidisciplinary nature of the task;
- inadequate use of professional resources and knowledge; and
- poor evaluation of the effectiveness of works or activities (Rutherfurd et al. 1998).

The report proposed the development of stream rehabilitation as a 'recognisable area of expertise', taking into account the biogeographical variation across the country. Key objectives were:

- to identify sound, sustainable techniques from the international experience and make recommendations for their use in Australia;
- to describe stream rehabilitation projects underway in Australia;
- to recommend areas for future research;
- to recommend means of interfacing the LWRRDC and National Heritage Trust programmes related to river rehabilitation; and
- to identify potential partners for the programme.

The key recommendation was to facilitate R&D that would:

- clarify stream rehabilitation goals;
- use the best available scientific and technical information in stream rehabilitation practice;
- encourage monitoring that would allow a process of learning from the success and failure of stream rehabilitation projects; and
- improve communication about stream rehabilitation.

The specific tasks required to achieve this were listed in order of importance, and a number of general principles were developed to guide stream rehabilitation in Australia (Frame 3.1).

Frame 3.1 General principles to guide the development of stream rehabilitation in Australia (*from Rutherfurd et al. 1998*).

General principles to guide the development of stream rehabilitation in Australia

- Stream rehabilitation is about restoring the physical, hydrological, hydraulic and biological complexity of streams in an effort to develop sustainable ecosystems – it is not just about having stable, attractive streams. The discipline should thus be based on a sound understanding of ecosystem processes and functioning.
- It is unlikely that Australian streams can ever be restored to their original condition.
- Protecting those remaining stretches of stream still in good condition should almost always take precedence over attempts to rehabilitate damaged reaches.
- Stream rehabilitation is a subset of catchment management.
- Stream rehabilitation is likely to take decades, rather than years, to accomplish.
- Concentrate the comprehensive stream rehabilitation efforts on smaller streams in which there is a good chance of success, and in which variables can be controlled and measured.
- Where larger streams are rehabilitated, the efforts should be restricted to flow and water quality issues (except in cases where simple changes can produce great ecological benefits, or where the publicity value of the project may outweigh the technical challenges).
- Define clear project objectives, ensure correct diagnosis of the real problem, and consider the catchment context. R & D attention is often directed towards the easiest part of the stream rehabilitation project, i.e. the selection of tools to fix the problems in the stream, rather than the more difficult ecosystem-related aspects. Also,it may be social and political factors which act as an impediment to the process, rather than a poor understanding of what to do.
- Stream rehabilitation efforts should target the ‘limiting variable’ for recovery first. Check variables in the following order: water quality; hydrology; hydraulics; interaction with the floodplain; and habitat condition.
- Evaluation of project success is necessary, with selected projects being intensively evaluated in order to achieve a level of confidence in the outcomes. (*The comment is made that in the past few rehabilitation projects had been evaluated)*.
- A number of ‘flagship’ stream rehabilitation demonstration projects should be planned, in an attempt to rehabilitate long reaches of stream. Sound evaluation of these projects is necessary.

3.2.2 International conference on Rehabilitation

The Second Australian Stream Management Conference in Adelaide in 1999 was entitled '*The challenge of rehabilitating Australia's streams*' (Rutherfurd and Bartley 1999). Over 120 papers were presented and the conference was considered a great success. Papers documented experiences in national, State-level and community programmes and projects; presented new or reviewed methodologies and approaches; considered issues such as catchment response, recovery, recovery potential, objective setting, monitoring and assessment, evaluation, and classification; provided tools for various forms of assessment (e.g. hydraulic, geomorphic); and discussed best practice guidelines and protocols.

In an Australian newsletter soon afterwards, Gippel, Stewardson and Finlayson (1999) commented: '*This conference was clear evidence that stream management has undergone a paradigm shift, from an emphasis on control over nature, response following flood catastrophe and narrow decision-making by a few individuals, to working with nature, planning ahead, and community involvement, even if the unfortunate title of 'Authority' has been attached to some of the new catchment management bodies. River management is now called river rehabilitation*.'

The commentary went on to critically review overall content of the papers, and focused attention on the fact that the majority of the papers presented relied on qualitative information and anecdote, and lacked a scientific basis, quantitative data or tests. This highlights the important and recurring concern from the scientific community, that there is a necessity to base rehabilitation on sound scientific principles, and where/if possible to devise means of incorporating the scientific method into evaluation procedures (although this proves tricky in itself, as discussed in Williams (1998), as summarised in Section 4.1).

This led to the further issue of assessment and evaluation of outcomes. The authors commented that, without these two elements being accommodated in the planning stages of the rehabilitation process, the practice of stream rehabilitation could not be assumed to be providing a solution to ecological degradation, and the failings of methodologies may only become apparent in years (or decades) to come. '*Without downgrading the need to pursue new knowledge systems about rivers, we acknowledge that scientists have a responsibility to convert their research into useful products for managers. It could equally be said that the community of action-oriented practitioners need to be more open to criticism, new ideas and appreciation of the scientific method of inquiry*' (Gippel et al. 1999).

3.3 THE CURRENT SITUATION

Currently, river rehabilitation exercises reflect a bias toward the physical components of the system, particularly physical condition and riparian management. The issues receiving less attention are flow, water quality, and ecology. As flow issues are legislated at a national rather than a State/Territory level, this separates them from the physical issues at a management level. There is, naturally, a growing requirement for integration of the ecological, hydrological and physical components of rehabilitation (Integra et al. 2001, Rutherfurd et al. 1998).

3.3.1 Levels of activity

Two distinctly separate 'levels' at which current river restoration and protection activities occur across Australia have been identified by Integra et al. (2000):

- a **strategic level** at which policy, research and practical experience come together to plan and develop future directions in the field, and
- a **tactical level** at which activity is focussed on the implementation of physical works.

State-level natural resource agencies and catchment management organisations operate at the strategic level. Here, activities are generally co-ordinated and focussed on higher-level issues such as environmental flows and instream ecological values. The composition of these bodies, their concern with these sort of issues, and their access to funding and technical knowledge provides them with a co-ordinated focus to activity.

The tactical level is typically represented by local authorities, community groups and individual stakeholders. The projects undertaken at this level are typically concerned with specific local actions to the river, such as streambank stabilisation, erosion control, or vegetation planting. It is surmised that the two levels have been separated as a result of a lack of formal linkages, and because the work happening at each level has been fundamentally different, as described. However, activities of each level are considered complementary, and Integra et al. (2000) comment that there is potential to develop meaningful tactics with a more strategic-level focus.

3.3.2 Programmes and Initiatives

The major rehabilitation R&D programmes presently active at the national level include the the Land and Water Australia (LWA)-funded *Rivers and Riparian Lands Programme*, and the LWA/CRC *Programme for Stream Restoration and Protection.* Both programmes were introduced in Chapter 2 (Sections 2.6.3 and 2.6.4), and a brief summary of current initiatives in the former were presented. Similar details for the CRC programme are presented here.

CRC Programme for River Restoration

The two CRCs chiefly involved in river rehabilitation projects in Australia are the CRC for Catchment Hydrology (CRCCH), based at the University of Melbourne, Victoria; and the CRC for Freshwater Ecology (CRCFE), which has divisions at the University of Canberra, Monash University in Melbourne, and Griffith University in Brisbane.

The CRCCH, in partnership with the CRCFE and Land and Water Australia (LWA, formerly LWRRDC), coordinate the multidisciplinary *Programme for Stream Restoration and Protection* (CRCCH Programme 6). This is divided into two groups. Each group has several projects currently underway. These are described in Table 3.1.

Table 3.1 Research projects underway in the CRCCH Programme for River Restoration (2000).

Project No.	**Group A: Stream restoration procedures and evaluation**
	Title
6.1	Developing criteria and concepts for stream rehabilitation planning
6.2	Stream restoration planning and execution in the Yarra Catchment (VIC)
6.3	Restoration ecology in the Granite Creeks (VIC)
6.4	Evaluation of riparian vegetation in a south-east Queensland catchment

Project No.	**Group B: Tools for Stream Restoration**
	Title
6.5	Hydraulics and performance of fishways in Australian streams
6.6	Developing tools to predict scour of rehabilitation works
6.7	Developing an environmental flow methodology: a trial.

3.3.3 Available tools in rehabilitation

The tools on which rehabilitation increasingly relies are scientific principles, stream assessment protocols, methods of prioritising rehabilitation actions or venues, guidelines and manuals, and monitoring.

A number of tools are available to assist the river rehabilitation and/or protection processes, particularly those driven by CMAs and trained or professional individuals within community groups. Teaching of these methodologies or guidelines is considered vital to them being applied effectively, and consideration is at present being given to the possibility of certification for certain techniques and guidelines (Integra et al. 2000).

National River Restoration Framework

This framework was produced by Koehn et al. (1999) for the National Rivers Consortium (NRC). It was developed to address the disparate and ad hoc nature of the field of restoration. The framework provides a step-by-step approach to restoring rivers, intended to bring together stream managers, communities and scientists, and to create understanding and a ‘common bond’ between these different groups.

A set of guiding principles was developed for the Framework. These are divided into three categories: General, Geo-ecological, and Management-related (Frame 3.2). The framework goes on to provide a broad, catchment-scale planning process for river restoration. This is not presented in detail in this report, as the guidelines of Rutherfurd et al. (2000 a & b) are summarised in Chapter 4.

Frame 3.2 Extracts from the River Restoration Framework *(from Koehn et al. 1999).*

Principles for the proposed River Restoration Framework

General Principles

The Framework should:

- link science, communities, stakeholders and management in the process of river restoration;
- be generic and useable across Australia;
- fit into broad spatial and temporal scales, but acknowledge all scales;
- be result oriented, i.e. provide environmental and social outcomes;
- be strategic and pro-active, with a long-term visionary approach and short, medium and long-term objectives;
- have ongoing feedback loops;
- continually increase knowledge base through education, training and field experience and research;
- address causes before symptoms;
- emphasise consultation and consensus over compromise.

Geo-ecological Principles

The framework should:

- be conservation oriented, striving to support ecologically sensitive development;
- make use of baseline data and monitoring;
- enhance biological diversity and ecological integrity toward an objectively defined ‘natural’ or pre-European condition;
- have scientific rigour and sound methodologies.

Management Principles

The framework should:

- follow adaptive management principles: learn by doing; be robust and flexible;
- incorporate community involvement, enhancing community empowerment, being honest and managing expectations;
- implement restoration activities through existing agencies and structures wherever possible;
- follow the principles of best practice, such as auditing.

National-level Rehabilitation Guidelines

Stream stabilisation for rehabilitation in North-east Queensland (Kapitzke et al. 1998). These guidelines are designed to assist with stream stabilisation, and include analytical methods and design processes. They provide a set of guiding principles, and a comprehensive approach to planning, design and implementation of stabilisation methods, following a ten-step process. The guidelines include a discussion on the types of information to be collected, and at what scale this information should be presented (Imhof 1999).

A Rehabilitation Manual for Australian Streams, Volumes 1 & 2 (Rutherfurd et al. 1999). This is a well-constructed two-volume series aimed at the public, management and specialists. Volume 1 provides valuable discussion on physical, chemical and ecological processes and functions of stream systems. Following this, a 12-step planning process for stream rehabilitation is presented from a more technical perspective than that of Koehn et al.(1999). In Volume 2, specific stream problems are discussed and addressed, and technical planning and intervention tools are presented.

Riparian Land Management Technical Guidelines, Volumes 1 & 2 (Lovett and Price 1999). These guidelines are aimed specifically at restoration activities within the riparian zone. Volume 1 presents 'Principles of Sound Management' and a 'Review of legislation pertaining to riparian management'. These are aimed at professional land managers, advisors and government officials. Volume 2 contains the management strategies themselves and is aimed at the practitioners. Canadian scientist Imhof (1999), in evaluating these guidelines, commented that '*the state of science development for river science, riparian land and ecological functions of river systems* (in Australia) *is world class and ahead of much of the work being done in North America*'.

A Review of the Guidelines vs. the Framework
Integra et al. (2000) commented that it was unfortunate that the *National Framework for Stream Restoration* of Koehn et al. (1999) had been released at the same time as the *Manual for the Rehabilitation of Australian Streams* produced by Rutherfurd et al. (2000a), as these documents covered such similar ground. Imhof (1999), however, in his review of the Framework, the Manual and the Stream Stabilisation guidelines (Kapizke et al. 1998), praised all three documents, and rather considered them a 'nested' set on the basis of the scales at which they were intended to be used:

- The Framework provides a broad perspective on the major steps in the process of developing restoration plans (adopting a catchment scale perspective, according to Koehn and Cant 1999);
- The Manual provides a more detailed approach to the assessment of problems, needs and organisation in order to develop a plan for rehabilitation (this is catchment scale to river segment and river reach scale);
- The Guidelines of Kapitzke et al. (1998) are focussed at the smaller scale, addressing one type of restoration problem, that of stabilising an unstable stream and primarily concentrating on bank stability (arguably, the scale of the river reach and morphological unit).

Imhof (1999) recommended that the manuals be presented in a consistent framework, and that a recommendation be made regarding at what spatial scale of planning and assessment each was appropriate. Each methodology could then be presented appropriate to the scale of the problem or issue and the scope of the undertaking. Imhof (1999) also recommended a formalisation of definitions in all documents pertaining to river restoration or rehabilitation.

Assessment and/or Priority-setting Models

These models are used in the assessment and monitoring phases of the rehabilitation process, as described in Chapter 4.

The Index of Stream Condition (Ladson and White 1999)
This popular stream condition assessment protocol is described in Chapter 4.

Assessment of Conservation Value and Ecological Sustainability (Sanders et al., 1999)
Techniques for assessing conservation value and sustainability of systems are under investigation by the Queensland Environmental Protection Agency. Sanders et al. (1999) document their conceptual framework together with a test case. It has three major components – waterways' significance, sustainability, and protection. Within this concept, the Conservation Value Guideline provides a stepwise process to produce descriptive summaries of conservation value, and should be used only by people with professional training. It includes indicators at all spatial and temporal scales, depending on the context of the waterway being assessed, and the scale of the planned development. Nested within this conceptual framework is a classification system based on a series of river types known as biogeographical aquatic systems (BAS), each of which may represent a linear segment of a river system.

The River Styles methodology (Brierley 1997)
This is a technique for the geomorphic categorisation of the stream, for use in prioritisation for stream rehabilitation. It is described further in Chapter 4.

Various priority-setting models, e.g. ERAPSM (Heron et al. 1999)
These models focus increasingly on risk assessment or asset assessment in determining priorities. They are described further in Chapter 4.

Monitoring

There are several monitoring tools and approaches available in the different States and Territories. These overlap or interface to some extent with the assessment protocols discussed in the previous paragraphs. While evaluation of restoration is a fundamental part of the process, monitoring tools have not been designed specifically as evaluation tools for the rehabilitation process. Only three of the more popular monitoring methods are listed here.

- **National River Health Programme**. This is described in Chapter 2.
- **AUSRIVAS** This is further described in Chapter 4.
- **SIGNAL index** (Chessman 1994). This Stream Invertebrate Grade Number, Average Level index assesses a site based on the types of macroinvertebrates found there. Invertebrates are scored from 0-10 on the basis of their sensitivity to water quality conditions.

3.3.4 Legislative and institutional frameworks

Legislation is considered one of many tools required in effective implementation of river rehabilitation and management. Other mechanisms include public financing, performance measures, market-based mechanisms and precautionary strategies (Mary Maher and Associates 1999). Integra et al. (2000) reflect that a legislative structure should encourage linking of disciplines and crossover between policy makers, scientists and river managers, and should provide ways of encouraging this integration so as to prevent the situation in which knowledge and information becomes 'owned' or inaccessible.

Under the Australian Constitution, environmental management remains a State responsibility. Each State operates its own legislative and institutional framework. In most, legislative, planning and administrative frameworks for waterway management have recently undergone a period of review and reform (Gippel and Collier 1998).

As discussed in Chapter 2, the Council of Australian Governments (COAG) reforms of the early 1990s recognised that to halt or slow natural resource degradation, measures were required which would address the economic, environmental and social implications of water usage. The National Water Reform Policy (COAG 1994) emphasised the importance of addressing efficiency and sustainability in water services and resource management. The responsibility for this was left to each jurisdiction.

Previously, values placed on rivers were largely utilitarian in law and strategy. More recently a range of values have acquired status in law. These include environmental values or 'qualities'. For example, the revised Water Act of Victoria (1989) states among its purposes: '*to provide formal means for the protection and enhancement of the environmental qualities of waterways and their instream uses; [and] to provide for the protection of catchment conditions*' (Dept. of Water Resources Victoria 1992). The 'formal means of protection' relates in part to river rehabilitation measures and to ensuring that improvements made to river condition are not reversed.

Within each State, environmental flow management and river rehabilitation are separated by legislative and institutional arrangements. This can be problematic in that these two functions should obviously be managed together. To some extent, three distinct institutional groups operate:

- streamflow management (managing environmental flows);
- river rehabilitation and management (managing physical condition and vegetation)
- ecological and fisheries management (managing ecological condition and fisheries).

There are significant areas of overlap. In addition, each of these groups also manages water quality, with the Environmental Protection Agency for each State holding ultimate responsibility (Integra et al. 2000).

While various national guidelines contributing to rehabilitation practice exist, each State has a different view of and approach to restoration or rehabilitation. Numerous research organisations, government departments, institutions and groups may be involved in river rehabilitation activities, with a great deal of overlap between roles, due in part to poorly-defined roles. Typically, Catchment Management bodies, primary industries, and natural resource management departments or agencies take a partnering role in rehabilitation projects, but seldom initiate these projects themselves. Community groups may initiate their own projects but often lack the leadership, necessary funding, technical design and/or management support to get to completion.

3.3.5 Integrated Catchment Management (ICM)

'*The push for "river restoration" is one that builds upon the integrated catchment management philosophy, and highlights the importance of interconnectedness between the biophysical, social and economic, for long-lasting change to occur*' (Integra Pty Ltd et al. 2000)

The importance of **catchment-scale rehabilitation planning, implementation and evaluation** is increasingly under the R&D and institutional spotlight in Australia. As rehabilitation is essentially a subset of catchment management, an understanding of the frameworks and structures set up to facilitate ICM within States is useful in providing the context within which rehabilitation takes place.

There is at present no national legislation to cover ICM in Australia, however three States have catchment-related legislation in place:

VICTORIA	Catchment and Land Protection Act of 1994
NEW SOUTH WALES	Catchment Management Act 1989
SOUTH AUSTRALIA	Water Resources Act 1997

In these States, planning and management powers have been devolved to the catchment/regional level. In other States and Territories, policies relating to ICM exist. Institutional obstacles to ICM have been removed by promoting the concept of '*integrated resource management*' over that of '*resource development'*. This has been accompanied by a shift in appreciation of the spectrum of values represented by natural resources (Maher & Associates 1999), such that what previously had only utilitarian value now also has amenity value, recreational value and environmental value.

Where rivers cross State borders, the States or Territories concerned are responsible for the coordination of management (Integra et al. 2000). Structures are in place to ensure, and to require, greater integration of these efforts.

Victoria
Catchment Management Agencies (CMAs) have been set up for each of nine non-metropolitan catchment and land protection areas in Victoria. These are responsible for negotiating annual programmes of service delivery with the Department of Natural Resources and the Environment (DNRE). The CMAs also provide all water and floodplain-related service delivery. CMAs are responsible for reviewing and developing regional CM strategies, and for coordinating the implementation of these. They provide advice to government on Federal and State resourcing policies, at a regional level. They also act as integrators for the efforts of community-based advisory groups (stakeholders) and community-based service delivery groups (agencies).

New South Wales
NSW has a State-level Catchment Management Coordinating Committee, with representatives from State and local government. Eighteen Catchment Management Boards have the responsibilities for functions under Total Catchment Management. This includes strategy development, coordination, works, contracts, generation of revenue, and mitigation of emergencies. There are also four Catchment Management Trusts in the State.

Queensland, Western Australia & Tasmania
These States have policies for Integrated Catchment Management, and have Catchment Committees. Participation at a government or community level is voluntary. Landcare and government extension officers support the committees.

South Australia
South Australia has no direct statutory power regarding catchment management. The Environment and Natural Resources Council is their high-level forum. The emphasis is on Integrated Resource Management. Catchment management is focussed on management of water, land and soil resources.

Summarised from Integra et al. (2000).

Addressing the shortcomings of ICM

Cullen (2000) attributes the shortfalls of catchment management to a lack of integration and co-ordination between disciplines, agencies, State governments, knowledge providers and knowledge users.

Addressing these and other issues, Australia recently conducted a national enquiry into Catchment Management, the outcomes of which were released early in 2001. These call for the setting up of:

- a National Catchment Management Authority;
- reforms to enact catchment management legislation;
- sustainability targets for catchments;
- a National Environment Audit Office;
- clear national information exchange protocols;
- a national catchment education strategy;
- greater use of the Internet as an information exchange mechanism;
- performance monitoring methods for catchment management;
- taxation incentives for Landcare; and
- a national environmental levy to fund catchment management (IWRM Bulletin 2001).

3.4 REHABILITATION IN AN URBAN CONTEXT

Waterways in Australia's large cities are managed by metropolitan water boards. Historically, these boards were responsible for water supply and sewerage, and had little or no interest or concern for the maintenance of ecological values in rivers. However, since the late 1980s, public pressure has encouraged regional governments and agencies to attend to recreational and health values of urban waterways. The Victorian State Government, for example, were encouraged by public lobbying to promote the development of urban riverine parks and waterways. The objectives are conservation, recreation and flood mitigation (Gippel and Collier 1998).

In the context of urban streams, rehabilitation or restoration is considered to be largely functional and seldom attempts to focus on the return of a stream to its pre-impact or pre-settlement state. The outcome must serve multiple environmental, amenity, and utilitarian functions, while ensuring flood control and high water quality standards (e.g. Morris and Moses 1999).

Stream rehabilitation is often a tacit aim of urban water management plans, concealed within the more functional strategic goals of service provision, asset management, flood control and river protection. The goals for river improvement or restoration are certainly implicit in these plans, however. The intention to improve river 'health' may be clearer in the outcomes of stream management and protection work than in the objectives for this. One of the reasons for the lack of explicit rehabilitation goals in public domain management plans was explained by an urban water manager (anonymous by request): if rehabilitation goals are stated in these plans, then an expectation for visible and successful rehabilitation outcomes is established, and must be achieved to satisfy the public and shareholders. The outcome of rehabilitation works can often not be predicted, particularly in terms of timescales for system response and recovery. From a strategic managerial point of view, goals must be attainable and must be reached to keep public confidence. Thus the rehabilitation component of a management plan is more strategically couched in vague 'river protection' terms. This was referred to as '*cryptic positioning in an adaptive management sense*'!

Urban Research and Development Sub-Programme

This is a sub-programme of the National River Health Programme (NRHP) described in Chapter 2. It was initiated in 1996 out of the recognition that most urban streams and estuaries (defined as those affected by runoff and discharges from urban areas) are considered degraded biologically, physically and chemically, and that appropriate methods of health assessment and management need to be developed (Anderson 1999).

The sub-programme is managed by the Water Services Association of Australia (WSSA). It focuses on the development of standardised methods for assessing the ecological health of urban streams and estuaries, which can be linked with data on water and sediment quality. There are eight research projects:

- Decision Support Systems for management of urban streams (with software and users manuals, Anderson 1999)
- RIVPACS (River Invertebrate Prediction and Classification System) for urban streams (Dr Peter Breen, CRCFE, Monash University, Melbourne)
- DIPACS (Diatom Prediction and Classification Systems) (Dr Jacob John, Curtin University, Perth)
- Sediment chemistry – macroinvertebrate fauna relationships in urban streams
- A physical classification of Australian estuaries (Digby et al. 1999)
- SEEM – Simple Estuarine Eutrophication Models (with a User's manual)
- Estuarine health assessment using benthic macrofauna (Moverley and Hirst 1999a,b).
- Literature on ecological health asssessment in estuaries (Mr David Deeley, Murdoch University, Perth).

3.5 A CASE STUDY: MELBOURNE WATER CORPORATION

This corporation has been selected as a case study as they were instrumental in much of the urban river rehabilitation research being conducted by the CRC for Catchment Hydrology. MWC is a partner in the CRCCH. I had the opportunity to interact with individuals in MWC, and to learn about their scientifically-based approaches to urban river management, and new approaches being devised in partnership with researchers from CRCCH and the CRCFE. This is a short summary of rehabilitation-related aspects of the structure, function and planning activities of this progressive metropolitan water service provider.

MWC: Corporate Structure

MWC is a statutory corporation wholly owned and regulated by the government of Victoria and managed by a Board of Directors appointed by the State government. The government regulates and makes policy for waterways and drainage issues.

The vision of MWC is '*to be a leader in urban water cycle management' (MWC 1998/9).* Its stated purpose is to *'add value for its customers and the community by operating a successful commercial business which supplies safe water, treats sewage, and removes stormwater at an acceptable cost and in an environmentally sensitive manner*'(MWC 1998/9).

The Corporation is structured as four divisions, each of which has a number of service commitments: Multifunctional Services, Regional Drainage and Flood Protection, Waterway Management, and Water Quality Management. The Waterway Management (WM) division is responsible for waterway maintenance, waterway rehabilitation, and the development of 'Streamflow Management Plans', 'Waterway Management Plans' and 'Waterway Condition Reports'. Each of these commitments has annual targets attached to it.

MWC: Waterway Rehabilitation

According to the MWC Waterways and Drainage Operating Charter (1999), the Waterway Rehabilitation programme 'contributes directly to improving the condition of waterways graded as 'moderate', 'poor' or 'very poor', and '*...works include bed and bank stabilisation, willow removal, revegetation with indigenous species, provision of fish passage facilities and other related activities*'.

MWC produces two types of waterway management plans for the surface waters within their jurisdiction: geomorphological plans for the rural streams, where the major issues are bed and bank stability; and Waterway Activity Plans (WAPs) for the urban waterways, where open space and recreation are further issues.

MWC: Waterway Activity Plans (WAPs)

WAPs focus on key waterway issues for which MWC is directly responsible, namely: flooding and regional drainage management; stream form, system and stability; asset maintenance and protection; facilitation of water quality improvement; and management of the natural resource for sustainability, research, and education. They are plans which are examine individual reaches of rivers, so that site-specific actions can be identified from the analysis of specialist reports describing river processes and condition. The WAPs are strategic and have an action focus. They provide a framework within which MWC is able to prioritise works planning for the next 10-15 years. Costs for these works are estimated in the WAP document, and detailed at the implementation stage.

The stated purposes of the WAP include:

- provision of accessible information and analysis of key waterway issues such that the relevant sections of MWC are aware of those issues and the plan's prioritisation of works for the stream;

- encouraging the Councils and community groups to be aware of the plan's contents, and providing them with a framework for undertaking additional planning or works along the stream corridor;

- addressing their responsibilities in the areas of open space management, amenity and recreation provision.

WAP reports are typically developed by teams of external specialists, in consultation with local government and community groups. The specialist teams typically include ecologists, geomorphologists, and landscape architects. For any small catchment, the following aspects of the waterway management are typically addressed:

- geomorphological processes;
- waterway stability;
- water quality issues (with options for water quality enhancement e.g. wetlands);
- stream ecology issues (to ensure maintenance and protection of existing values);
- vegetation issues (including weed management, revegetation opportunities);
- flood protection and regional drainage issues;
- amenities (allowing for development of open space and recreational activities).

One of the intentions of these plans is to identify opportunities for integrated resource management between the numerous institutional bodies who have responsibilities within the area. These include bodies responsible for water, environment, roads, railways and parks. The WAP is also required to recognise and work within applicable legislation and local regulations. Where the typical urban management issues such as flood control are addressed, the approach is to base actions on ecological and geomorphological principles and methods to attain the required outcome. For example, aims of one WAP include: '*to retain the floodplain capacity, and where possible, improve its ecological diversity and function in improving water quality*' (Thomson Berril and Fluvial Systems 1999).

The final WAP document, which is collated by MWC on the basis of the specialist input, typically consists of an introduction, a written synthesis of the individual specialist studies, a sequence of large-scale plan-view maps of the catchment, a costing analysis, and the appended specialist studies. Overlain on each map are text summaries of recommendations and actions required for the attainment of the desired future condition.

MWC's annual target is to produce new Waterway Activity Plans yearly to achieve total coverage of rivers within their operational area by the year 2002 (Operational Charter 1999). By mid-2000, eleven WAPs had been produced by the MWC.

3.8 TRAINING AND CAPACITY BUILDING FOR REHABILITATION

As river rehabilitation projects gather momentum around Australia, levels of public awareness, enthusiasm and participation grow. This creates a demand for training and capacity building. Integra et al. (2000) undertook a 'snapshot' study of training and awareness raising activities in rehabilitation across Australia. The results of their survey are summarised below and in Table 3.2, as an indication of the degree to which the field of rehabilitation is becoming a part of life for the Australian public.

General findings

- Though a substantial amount of training is taking place across Australia, much of it is ad hoc and sporadic.
- Courses range from general and non-accredited through to accredited, leading to some questions about quality assurance in the training and the 'roll-out' effects in rehabilitation projects.
- While some organisations are in a position to import knowledge in the form of specialists, others are unable to and/or may be unaware of the knowledge available.
- There are now manuals and guidelines designed for use by catchment groups, as already discussed. However, these should only be used by trained individuals who have gained some understanding of the processes involved in river restoration.
- The question is raised as to whether the manuals already produced are complementary, and what information they provide. The need for an inventory of available guidance is raised.
- While some State/Territory governments provide a centralised training facility, others make use of external consultants. There is a concern that in the latter case, follow-up support may not be provided due to costs incurred.

Recommendations

- Nurture the growing interest and keenness in learning 'how' to rehabilitate.
- Build on the government and non-government training networks which already exist.
- Ensure that training and follow-up support accompanies the use of manuals and guidelines.
- Use innovative means to introduce available techniques to communities.
- Harness the willingness of Commonwealth, State and Territory governments to improve the current disparate state of education and training in river rehabilitation.

Table 3.2 A description of training made available on aspects of rehabilitation and ICM, at different levels across Australia. (*Summarised from Integra et al. 2000).*

ENTITY	**TRAINING AND CAPACITY BUILDING**
Government or CM Organisations	**Details of Training**
Commonwealth	**Natural Heritage Trust (NHT)** funds training to support ICM, project evaluation etc. Recent NHT Regional Training Initiative established to educate catchment management groups across the country about planning and project management (resource management). **National Waterwatch Programme** coordinators train communities in water quality, using simple methods. At State level, Waterwatch Regional Coordinators are trained throughout the year.
ACT	**Environment ACT** is the lead group for river restoration and supports staff to attend external training courses and events.
New South Wales	**Department of Land and Water Conservation** has developed a set of training workshops for Landcare Officers dealing with river restoration. Rivercare officers attend three courses: Basic River Processes; Erosion Control; and Policy and Legislation, plus a conference. Courses are being reworked to align with available guidelines. Dr Gary Brierley has run River Styles courses for Rivercare workers and others.
Queensland	**Department of Natural Resources** have held workshops, training days, awareness-raising courses, and seminars covering restoration techniques. Courses on banks stabilisation have been held. CM groups and committees in the state have run workshops, seminars and courses, including courses on river restoration techniques.
South Australia	**Department of Environment Heritage and Aboriginal Affairs** does not provide formal training but works in consultation with community catchment groups in water management issues. Other departments also run courses on topics related to river restoration.
Tasmania	**Department of Primary Industries, Water and Environment:** have developed a programme for Landcare/Rivercare to assist rehabilitation groups with problems experienced. Dr Gary Brierley has run River Styles courses in Tasmania.
Victoria	**Department of Natural Resources and the Environment (DNRE)**: No formal training, but facilitates attendance of relevant people to workshops and information sessions. Bi-monthly meetings are held with CM fieldstaff. A week-long stream rehabilitation workshop has been held. CMAs are also producing training material appropriate to communities.
Western Australia	**Waters and Rivers Commission** runs a five day river restoration training programme (NHT supported) and are planning others; plus training on the manual for *Managing Stormwater Quality in Western Australia*

Table 3.2 Cont. A description of training made available on aspects of rehabilitation and ICM, at different levels across Australia. (*Summarised from Integra et al. 2000)*

ENTITY	**TRAINING AND CAPACITY BUILDING**
NON GOVT. ORGANISATIONS	
Greening Australia	Provision of training across Australia on topics including river restoration, riparian vegetation and erosion control, waterway management, riparian restoration and many more. Some of these are accredited courses and generally run for half to one day.
River Basin Mgmt Society	RBMS organises courses and workshops in response to demand from members; and runs several workshops a year on topics of interest, e.g. a "Back to Basics Riparian Workshop".
Melbourne Water Corporation	MWC invests in staff training in many aspects of river restoration, e.g. management of large woody debris, floodplains, Willow control, weed management. These may be run together with CRCFE or CRCCH.
Consultants	Many consultants offer advice and training in areas related to river restoration. Quality control is an issue of concern.
RESEARCH ORGANISATIONS	
CRC Catchment Hydrology	CRCCH runs industry seminars in all major capital cities to communicate research results. These have included seminars on river restoration and management. The CRCs also play a role in training students at a tertiary level. Dr Ian Rutherfurd has run workshops and seminars based on the Australian Stream Rehabilitation Manual. Training on Setting Priorities in River Restoration has also been developed and trialled.
CRC Freshwater Ecology	CRCFE works with other organisations to exchange river restoration knowledge. A catchment management course has been run with Australian Water Association. CRCFE also works with private organisations (e.g. MWC), to tie into existing training programmes. These may be field-based sessions.
Macquarie University	Dr Gary Brierley and Ms Kirstie Fryirs have set up short (5 day) workshops in the River Styles methodology, including lectures, practical work, field work and discussion. An accreditation procedure is currently being set up.
LWRRDC (now LWA)	The River Restoration programme has invested in several scoping projects concerning key issues in river rehabilitation. Their commitment to training has been in the production of a Framework for River Restoration and two practical restoration Manuals (discussed earlier in this Chapter).
Murray Darling Basin Commission	MDBC invests in the development of knowledge that can be used by partners in the Strategic Investigation and Education Programme. Their Riverine Programme is addressing education through production of an Environmental Flows Handbook, a Decision Support System for environmental flows, a Fish CD aimed at schoolchildren, a project looking at best ways to communicate the Murray Cap, and a University project to look at the needs of secondary, tertiary and adult education providers in the basin in communicating technical MDBC issues.

Addressing the need for knowledge exchange and capacity

The continued growth of the field of river rehabilitation in Australia is guaranteed, with a commitment from Governments at all levels, from Commonwealth to State; and a 'critical mass' of programmes, agencies, institutions, collectives and individuals pushing it ahead, with continual refinement. Perhaps the greatest requirement of the catchment management and river rehabilitation communities at large is increased integration and information/knowledge exchange within the field (e.g. Cullen 2000).

Addressing this need, the National Rivers Consortium (NRC) commissioned Integra et al. (20000) to conceptualise a means of facilitating the flow of information and expertise currently held within the scientific community through to end-users such as community groups and State agencies; and to enhance the capacity of these groups to undertake river rehabilitation work.

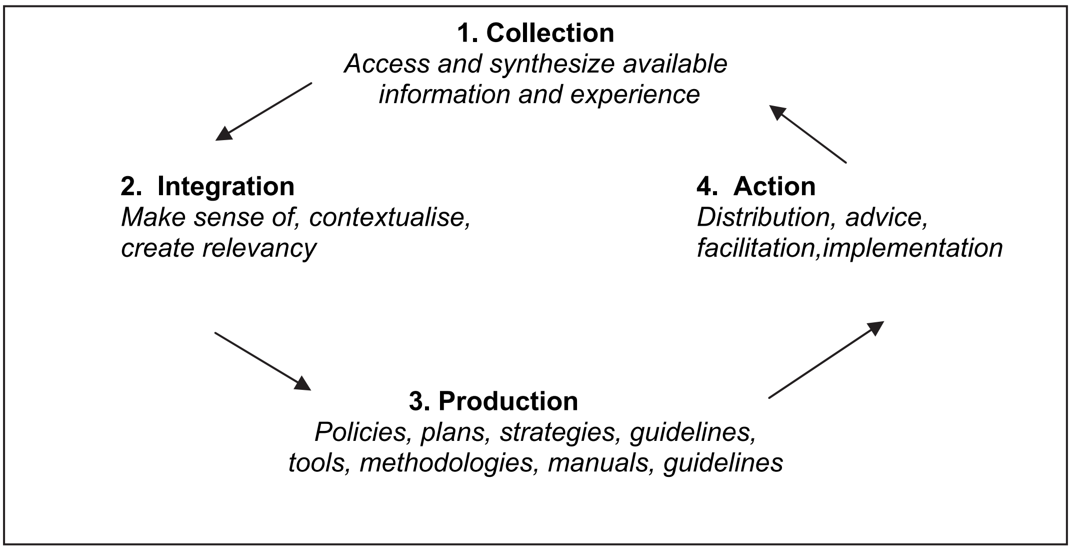
The consultants produced a model of *Knowledge Exchange and Capacity Building* which works at three levels:

- **National, State and Interstate:** at which levels policy-makers develop the policies which direct restoration research and activity, and fund it

- **Regional and Catchment level:** where the principal task for Catchment Coordinating bodies, river planners and managers is to coordinate planning and strategies for river rehabilitation; and to design and implement the works

- **Reach level and local sites:** where community river management groups engage in on-ground and in-water works which form part of the catchment management strategy or plan.

Four processes drive the exchange system at each of these levels, in a sequential manner:



Integra et al. (2000) maintain that for flow of knowledge and information to be successful, the sequence of these four activities is important. The ‘Action’ stage above is the catalyst for the ‘Collection’ stage at the next level.

Addressing the further requirements of rehabilitation groups, the capacity building component of the model aims to raise capacity within the industry; to create it outside of the trained environment (e.g. within communities); and to define and build skills unique to river restoration. The following are seen to be fundamental to the success of rehabilitation projects:

- the creation of teams of core individuals who have relevant skills and interests to take responsibility for the rehabilitation activity (it may also be necessary to develop capacity within the team during the restoration project);
- the gathering and application of relevant economic, social, technical and environmental knowledge in order to determine the limits of restoration projects and set goals at the appropriate scales;
- an understanding of key river processes, requiring capacity in the fields of hydrology, hydraulics, ecology, geomorphology, and water quality;
- the ability to understand, undertake and interpret techniques and data relevant to the assessment tools such as AUSRIVAS, River Styles and Index of Stream Condition;
- the provision of accreditation for this sort of training;
- the ability to select an appropriate priority-setting technique or asset and risk-management model and to apply it correctly;
- an understanding of techniques unique to the restoration field;
- design and construction skills and project management skills for the implementation of these techniques (specific design skills include the ability to translate concepts into documents, drawings and specifications that will enable programmes to be implemented);
- skills in materials selection and vegetation design (Integra et al. 2000).

3.9 SUMMARY

This chapter has presented a picture of how the field of rehabilitation has developed in Australia from the early ‘pioneering’ years of the 1990s. The identification of research and development needs in the later years of the decade, and the publication of national-level guidelines for rehabilitation illustrate the extent to which cognisance had been taken of the importance of this field by funders, government agencies and research institutions alike.

The weaknesses identified in the rehabilitation movement included the lack of planning, objective-setting and evaluation in individual projects, the poor recognition of the multidisciplinary nature of the task, and inadequate communication between practitioners, researchers and managers. These issues were to be recommended as key areas of research. An international conference held in Adelaide in 1999 and entitled ‘*The challenge of rehabilitating Australia’s streams*’ attracted further national and international attention to this field. It was however felt, in review of this conference, that the work presented was largely qualitative in nature and lacked a sound scientific basis. This is a contemporary issue receiving a fair amount of attention in research circles.

The present situation in Australian rehabilitation was discussed in the light of the types of activity underway, programmes and initiatives, available tools such as framework documents, national-level guidelines, assessment and priority setting models, legislative and institutional frameworks and integrated catchment management, of which rehabilitation is considered a sub-set.

The rehabilitation of metropolitan rivers has somewhat different components to that of non-metropolitan rivers, and is generally the duty of metropolitan water boards whose classical functions are to ensure the supply of adequate clean drinking water, the provision and maintenance of related infrastructure, and flood control. A case study of Melbourne Water Corporation's approach to the development of Waterway Activity Plans for all the major rivers in their jurisdiction is an example of how ecological aspects of rivers and their flow regimes are being incorporated into management approaches and planning. Environmental engineering approaches are also gaining favour.

Finally, the issue of current training and capacity building opportunities in the field of rehabilitation was dealt with. A recent model for 'knowledge exchange', which takes cognisance of the critical need for integration, exchange of information and capacity building at the levels of non-experts and experts was presented.

CHAPTER 4

PRINCIPLES AND PROCESSES IN RIVER REHABILITATION

Preface

This chapter provides an introduction to the approaches adopted in rehabilitation in Australia. General guidelines, emerging principles and the planning processes of rehabilitation are presented. As already mentioned, in this report, an attempt has been made to keep the information at a non-technical level, as rehabilitation is at an early stage of development in this country and the most urgent need is for basic principles and workable processes, which can be understood by a wide audience. At present, it seems that it is rarely ecological and geomorphological specialists who undertake the river rehabilitation work in South Africa, but more commonly water resource agencies, engineers, environmentalists and communities. The information presented here will be of interest to these groups, and it is clearly stated where specialist input is advised. 'Geomorphological and ecological principles for rehabilitation' are the subject of a separate Water Research Commission research project (see Section 6.6), and this research report will be aimed at the more technical level. As Williams (1998) comments, 'let us not pretend that we live in a world where science alone matters'. Nowhere could this be more true than in the field of river rehabilitation. This is a practical field, the science of which is still to be defined and developed in this country. Rehabilitation 'thinking' is not necessarily obvious and may even be counter-intuitive to specialists. Many of the failures of rehabilitation projects have been the result of either applying classical engineering or scientific thinking to a situation which may have required a new approach; or of assuming that rehabilitation was self-evident and that one's specialist training automatically equipped one to do it.

4.1 INTRODUCTION

While efforts to manage for human needs and safety, manage at a catchment level, set environmental flows, enhance water quality, reduce nutrient loads, and reform water management policy could all be viewed as contributing to improvement in water resource condition, none of these can in themselves be seen to be a 'rehabilitation' effort unless they are incorporated into a full rehabilitation planning, implementation and evaluation procedure. For river rehabilitation to be taking place, it must be organised, practised and viewed as a discipline in its own right, requiring specific approaches, methodology and skills.

The principles of rehabilitation presented here are sourced largely from the life-sciences, and will thus be fairly basic to water scientists, but not necessarily to others in the water management and development field. Those presented are distilled from what is known about the hydrology, fluvial geomorphology and ecological functioning of (mostly Australian) rivers, the experiences and outcomes of individuals undertaking practical rehabilitation projects, and best-available knowledge.

Further foundational elements of rehabilitation will only emerge through a greater understanding of ecological function and process. This requires a scientific basis. The linking of rehabilitation to scientific experimentation remains a topical and complex issue in Australia and elsewhere (Rutherfurd pers. comm.) The issue is probably best addressed through adaptive or experimental management type approach. While this is slightly off the subject of this chapter, it is a critical issue in rehabilitation and is worthy of mention. A brief treatment of the subject is provided in Frame 4.1.

Frame 4.1 Thoughts on Adaptive or Experimental Management (*based on Williams 1998*).

Adaptive management (AM) is, in its simplest form, 'learning by doing' – managing with a view to adapting the management approach on the basis of outcomes. It is a means of integrating scientific, social and economic concerns in management of resource problems. Computer modelling and simulation is used to demonstrate the potential effects of alternative management scenarios and scientific uncertainty. On this basis, AM provides scientists, managers, policy makers, and the public, all of whom have different political, cultural and economic concerns, with an analytical process which aims at identifying appropriate cases for scientific probing (Holling 1978). The use of computer modelling so often leads to recommendations for management experiments, that some practitioners have come to use the terms 'adaptive management' and 'experimental management' interchangeably (Holling, pers. comm. Quoted by Williams)

AM has two essential attributes: (1) it is a response to uncertainty about the system being managed, and (2) management actions are designed, at least in part, to provide new information about the system. The important point is also made that one must distinguish between managing a resource with an ecosystem approach, and managing an ecosystem. The complexity of ecosystems means that quantitative statements on their *behaviour* may never be possible. There must thus be a focus on ecological uncertainty. In order to help answer critical issues about a system, Professor Kai Lee recommended that adaptive management actions be undertaken as a series of experiments, with formal experimental designs (see also Volkman and McConnaha 1993). The components of such scientific experiments would typically be a hypothesis, experimental design, execution of the experiment, data analysis, and interpretation of results (Hurlbert 1994). The planning stages of such a management action would include an active search for key hypotheses and a commitment to test them (Volkman and McConnaha 1993). Prior to management actions being taken, hypotheses would be stated, possible biological models described mathematically, and experimental designs chosen.

In working outside of the laboratory, experimental work is complicated by the long time scales over which most ecosystems respond (years to decades), the difficulty in replicating an ecosystem and the fact that replicates are rarely if ever perfect, and the inability to control those aspects which one is testing (Hilborn and Mangel 1997). AM experiments are even more complex. As Williams puts it, "*Management experiments which only involve part of a system or a short period of time may fail to detect or recognise unanticipated factors that can render the experiment not just invalid but also misleading. For example, many biologists now believe that the survival rate of salmon in the ocean varies over a timescale of decades (Pearcy 1977). Experimental management of freshwater habitat during a period of changing ocean survival could easily give misleading results if the experiment were monitored only in terms of adults. Field experiments with small spatial scales can give similarly misleading results (Peterman 1991; Walters 1997)*".

Where management actions are treated as experiments, one needs a way to measure the response of the system being managed. Typically, monitoring programmes are used for this purpose, but g*ood* monitoring programmes are difficult to design and expensive relative to the management action itself. As there are no easy solutions to these sorts of problems, Williams considers it unreasonable to expect adaptive management experiments to produce unambiguous results within a few years. On a more positive note, he alludes to the positive development of the use of analytical statistical methods such as Bayesian statistics, considered more suitable for use in adaptive management experiments than classical statistics. He concludes: "*Adaptive managment is a bitter pill, and despite its benefits is difficult to implement. On one hand, scientists must acknowledge that in some sense they do not know what is going on, and managers must acknowledge in a similar sense that they do not know what they are doing, and on the other hand, those subject to management actions must acknowledge that uncertainty does not justify inaction. All must accept that progress will be slow, and that substantial amounts must be allocated to monitoring and evaluation, probably at the expense of additional restoration efforts. Only the alternatives are less palatable*".

General rehabilitation guidelines and principles emerging from the Australian experience are presented Section 4.4. The 'emerging principles' are preceded by a discussion of the causes of impacts and that nature of rehabilitation approaches used in Australia.

The rehabilitation process presented in Section 4.6 is a highly summarised version of that developed by Rutherfurd et al. (2000a) in their 'Australian Manual for Stream Rehabilitation, Volume 1'. It should be noted that all the available Guidelines and the Framework (presented in Chapter 3) are considered valuable in their own rights.

The 12-step process presented is generic, in the sense that it can be applied to any river and is not specific to Australian river types. It is the rehabilitation actions that are planned (within this process) that are required to be appropriate to region or river type.

4.2 ISSUES CURRENTLY RECEIVING ATTENTION

Literature on rehabilitation / restoration programmes in Australia and further afield points to a number of shortcomings in rehabilitation projects, and to areas requiring research or development. These are noteworthy in that they have been identified on the basis of actual project experiences. The issues listed are those most commonly cited, and serve to illustrate that similar problems have been experienced or identified in various parts of the world. Many of the guiding principles and processes that follow have been conceptualised to address these.

Scaling

- **Time Scale**: Public and managers may have expectations of applying 'quick fixes' – the timescale for rehabilitation is one of decades (Rutherfurd et al. 2000a). There is also a time lag between remedial action and downstream effects, which makes long-term financial investment and rehabilitation intervention necessary (Kiersch 2000, Kondolf 1995).
- **Spatial scale**: Rehabilitation is a subset of Catchment Management, but rehabilitation actions need to be considered at a local scale for manageability. This incompatibility is not always addressed. The difficulty in bringing together upstream and downstream stakeholders increases with scale (Kiersch 2000).

Planning and Processes

- The use of planning and a process for rehabilitation is not common enough (Rutherfurd et al. 1999, 2000a; Kondolf 1995).
- Clear, measurable goals, objectives and targets are often absent. These must be developed on the basis of the historic (pre-impact) and present data on the river in the area of planned actions (Gippel 1999, Kondolf and Micheli 1995). Objectives should be linked to evaluation criteria.
- The feasibility of projects is often not taken into account in planning (USEPA 2000).

Baseline Information

- There is commonly a paucity of information and knowledge about the 'natural' (pre-impact) state of the system, leading to inappropriate objectives being set, or incorrect rehabilitation measures being applied (Kondolf 1995, 1998).

- There is often insufficient understanding of, or investigation into, causes of degradation. The emphasis remains rather on treatment of symptoms (e.g. Rutherfurd et al. 2000a).

Prioritisation and emphasis

- Attention is seldom given to the prioritisation of reaches for rehabilitation (Rutherfurd et al. 2000a).
- Prioritisation is commonly based on criteria unrelated to ecosystem health (e.g. Rutherfurd et al. 2000a).
- There is a lack of effective prioritisation based on knowledge of recovery potential (see Fryirs 1999).
- There is a tendency towards overemphasis on environmental flow requirements at the cost of other degradation issues (Gippel 1999).
- There may be an overemphasis on ‘reactive’ remedial measures to badly degraded systems, rather than paying attention to protecting less degraded ones (Rutherfurd et al. 2000a, USEPA 2000).

Knowledge of Natural Processes

- There is poor knowledge of ecological and geomorphological processes, particularly those relating to system recovery (Kondolf 1998, Fryirs 1999).
- There is a tendency towards over-application of ‘cookbook’ type approaches, where classification systems are used and remedial actions are based on mimicry of a form considered to be natural (e.g. Kondolf 1998).

Integration and linkages

- There tends to be poor integration between different levels of governments, institutions and agencies (Cullen 1997, Integra et al. 2000).
- There is often an inability or resistance within multidisciplinary teams of members to communicate effectively with one another (USEPA 2000).
- Poor links exist between biophysical rehabilitation approaches and environmental flow setting practices in Australia, and these are institutionally separated (Gippel pers. comm., Integra et al. 2000).

Implementation problems

- Institutional structures may be lacking for the provision of the implementation of many of the available techniques and processes.

Evaluation and Adaptive Management

- The all-too-common lack of evaluation in rehabilitation projects can lead to repetition of mistakes and a slow learning curve for the field (Kondolf 1998, Rutherfurd et al. 1999).
- Where evaluation is not considered during the planning phases, no criteria are developed for evaluation in the objective-setting process (e.g. Kondolf 1998).

Funding

- Funding for projects may be hard to come by; poorly distributed; or restricted to the implementation phase only (so that evaluation cannot be planned for; Kondolf, 1995).

Economics

- The links between river protection and economics are not given sufficient attention (Imhof 1999).

4.3 GENERAL PRINCIPLES TO GUIDE REHABILITATION

The term 'Principles' refers here to the appropriate bases for action, and approaches to be applied in the rehabilitation process. These are broadly applicable to a range of river types. At a more technical level, principles may be specific to ecoregions or river types.

General principles of rehabilitation have been developed on the basis of knowledge of river ecosystems and river management, and practical experience of rehabilitation. As more experience and insight is gained through experimental trials or practical implementation, so more detailed geological, hydrological, hydraulic, physical and ecological principles are likely to emerge. The growing understanding of system recovery will also assist in the development of these principles.

This section is largely sourced from scientific and popular literature and various rehabilitation guidelines which emphasise design, planning, implementation and evaluation of practical rehabilitation programmes and research projects; and from discussions or correspondence with colleagues. Firstly, a set of general principles is presented as a means of addressing many of the current issues in rehabilitation listed in the previous section. Following this, the impacts to various elements of river systems are presented, together with their secondary impacts and the types of treatment applied to these problems. From the approaches to these treatments emerges a set of basic principles. The chief sources for this section are: Ladson (pers. comm. 2001), USEPA (2000), Rutherfurd et al. (2000a), Brierley (1999), Larsen (1996) and Kondolf (1998, 1995).

Scaling

Spatial: Think at a catchment scale, act at a local scale
The river or river section is only one part of the catchment. Most catchment activities will eventually be reflected in the physical and chemical condition of the river. If rehabilitation focusses only on the symptom (the degraded river) and ignores the cause (land-use and human attitudes) the results of physical rehabilitation will be short-lived, and the causes of degradation will remain and continue. Rehabilitation must consider and address the relationships in the catchment. If one has catchment-scale knowledge and information regarding present and historic land-use and sources of degradation, one can plan rehabilitative actions at the scale of the river reach or section.

Spatial: Plan first at a local scale, integrate into Catchment Management plans later
The competing uses and users of water in a catchment must be incorporated into Integrated Catchment Management (ICM) plans. Many of these uses are in conflict with one another – e.g. agricultural water requirements versus environmental water needs. Rutherfurd et al. (2000a) comment that where a stream rehabilitation plan is developed within an integrated catchment management plan, there is a risk of being left with a plan that focusses on core management activities, such as erosion control, revegetation and flood mitigation, rather than on the rehabilitation component. If the rehabilitation plan is developed as a separate exercise, there is more chance that the real ecological issues will be identified and addressed; and this plan can later be incorporated into the general management plan.

Temporal: Set realistic time scales
The recovery of a stream or river system will vary according to its natural functioning, the extent to which it has been degraded, and the remedial actions that have been applied. While interventions in a system may have apparent effects within a short time period, the likely time period for longer-term positive effects or rehabilitation measures to be manifested is in the order of **years to decades** rather than weeks to months. Expectations should be geared accordingly.

Planning and Process

Don't react: plan and set goals
Reactive management approaches are tempting and often characterise smaller, community-based rehabilitation exercises. This is categorised as a 'quick fix' by Rutherfurd et al. (2000a), and while it may provide hopeful results in the short term, is unlikely to return the natural complexity and variability to the stream hydrology, form and ecology over the longer term. Planning and the setting of attainable objectives and measurable targets are critical steps in the rehabilitation process.

Rutherfurd et al. (2000a) give the following rationale for rigorous planning:

- a transparent planning procedure ensures some public accountability;
- setting clear and measurable objectives allows the manager to evaluate the job, and provides criteria for evaluation;
- planning allows the rehabilitators to distance themselves from the obvious, visible problems, and to think about the broader context of problems;
- setting priorities avoids working on symptoms rather than causes, i.e. allows the rehabilitators to focus first on important issues instead of those which are superficially important;
- planning avoids inefficiency in the execution of the project.

Baseline Information

Know the catchment and the river
The more information available on the natural and present state/s of the catchment and river, the more effectively one can plan rehabilitation measures and attach attainable ecological targets to objectives. This coincides with the aim of attempting to return the *natural*, pre-impact functioning, processes and physical and chemical variability to the river.

Assessment of the historic, pre-settlement condition is an investigative process and involves the gathering of aerial maps and photographs; historic flow or rainfall data; development records; anecdotal information, etc., to formulate a picture of what the river may have looked like in its pre-settlement state, and at what rates and in what direction it may have changed in this natural condition.

The present condition of a river can be assessed on the basis of present physical form and processes, water quality, and the instream and riparian biota present. A number of assessment methodologies are available and in wide use, e.g. the Index of Stream Condition (Ladson and White 1999), AUSRIVAS, and the River Styles methodology (Brierley 1999).

Where possible, determine reference conditions
With sufficient information regarding the pre-impact state of a river, it is possible to formulate a picture of something approaching natural condition. In the absence of this

information, baseline data (collected over a year or more if possible) may be used to provide a statement of pre-rehabilitation condition and historic/present rates of change. Ideally, one or more physical reference sites should also be established as control/s for a project. In the case of rehabilitation, one would be a site with similar characteristics and in a similar state as the site to be rehabilitated, and possibly a second site could be found to represent the desired future condition of the site to be rehabilitated. The use of reference sites provides both replication and a control. However, as pointed out in Frame 4.1, the use of replication in a real environment is difficult because of the complexity and individuality of rivers and reaches. Thus data collection and analysis of results from the various sites must be done with caution, taking account of external factors which could influence results.

Classification and assessment

Be cautious about classification or assessment methods in untrained hands.
The classification in question is that which allows one to organise and group complex systems in a way that makes them understandable and allows us to work with them (sensu O'Keeffe et al. 1994). Classification of the stream or stream section is arguably a prerequisite to describing and understanding rivers in a regional context. There are also those who regard river classification as crucial to rehabilitation projects (e.g. Larsen 1996). However, some are understandably wary of classification techniques falling into misuse, or into the wrong hands, and discuss the pitfalls of following what may be a 'cookbook' approach, particularly if left in the hands of untrained individuals (e.g. Kondolf 1998). Assessment methodologies should ideally only be applied by trained, and preferably certified practitioners, and where feasible, interpreted by an expert.

Prioritisation

Protection and conservation precedes rehabilitation
Prioritisation is dealt with later in this chapter as one of the steps in the rehabilitation process. Prioritisation covers the questions of what gets done first, the order of importance of rehabilitation actions, how much gets done and where, and on what basis one assigns priorities (there are generally multiple criteria). For any river or section thereof, the prioritisation procedure must take into consideration locality, ecological and social importance, present state, degradation issues, representivity, recovery potential, sensitivity to disturbance, cultural and recreational value, associated risks, costs to rehabilitate etc., and balance these factors against management needs and available time and funds. There are several methods available in Australia for this sort of prioritisation. Water Service Providers may favour methods geared towards asset protection and risk assessment, while scientists and communities may follow biophysical approaches. These are discussed later in the chapter.

Preserve and protect valuable reaches first, rehabilitate second
This is a general principle which requires a good knowledge of the river system in question and in what state it is in (degrading, stable or recovering). Rutherfurd et al. (2000a) point out that one should not initiate rehabilitation in the most damaged sections of streams. In terms of stream health, it is usually more cost-effective to protect or preserve reaches of stream that are still in good condition than to spend money rehabilitating reaches which are already damaged.

Natural Processes

Understand natural processes and recovery
A knowledge and understanding of the natural physical processes in a river system, and the natural recovery trajectories is fundamental to the planning and design of restoration

actions. Developing this understanding for a river system requires specialist knowledge and may rely on long-term data-sets or simulation of pre-impact and present conditions (e.g. channel form, flow regime).

Kondolf (1998) advises that 'restoration projects should be planned and designed based on an understanding of geomorphological and ecological processes, rather than simply mimicry of form, as in 'blind application of a classification scheme'. He illustrates this with a case study of a restoration project on a creek in California, in which bank stabilisation techniques were applied to a river on the basis of scant evidence of active bank erosion, and in an attempt to restore a wet meadow. Kondolf claims that the erosion process, which was then halted by stabilisation, was subsequently shown to be an essential part of the stream's natural process of recovery and revegetation. He reasons that in this instance, it was unrealistic to restore the wet meadow in any event, due to hydrologic changes, and that the act of stopping the erosion arrested the stream's natural process of recovery and re-establishment of woody riparian vegetation.

Evaluation

Relate general objectives to specific evaluation criteria.
Develop evaluation criteria on the basis of present-day data (Kondolf and Micheli 1995)
Rehabilitation objectives should be set in such a way as to provide specific evaluation criteria. In the absence of these, the success of a treatment cannot be accurately determined. Kondolf and Micheli (1995) point out from their experience, key project objectives cannot be evaluated if pre-project data are not appropriate, or if the collection techniques for these data are not compliant with those used to evaluate outcomes. Where objectives are linked to specified time periods or other targets, a *range* of values within which the action can be considered 'successful' should be specified (e.g. if the objective is to demonstrate the required change within a year and this only occurs within two years, has the project failed or succeeded?)

Failure

Failure provides lessons
The complexity of fluvial geomorphology and aquatic and riparian ecology makes the prediction of system response to an intervention difficult (Kondolf 1995). While unsuccessful outcomes are undesirable, they have a great deal to teach, and Kondolf (1995) urges *'don't be afraid of failure!'* Results of less successful projects should be published, if only to provide precautionary input and guidance to other projects.

4.4 REHABILITATION APPROACHES & EMERGING PRINCIPLES

As mentioned, the development of geomorphological and ecological principles for river restoration in South Africa is the subject of a separate Water Research Commission research project (see Chapter 6), this subject is not be covered in great depth or detail, and the principles presented here are the more obvious ones rather than the technical ones. What is important is the approach applied in addressing particular river degradation problems.

Five interacting elements of stream health are considered in this section: **water quantity, water quality, physical structure, the biota**, and the **riparian zone** (after Rutherfurd et al. 2000a). For each, major impacts, causes and remedial approaches are presented, followed by a brief discussion. The 'emerging' principles are then listed, and are also separately at the end of the section.

The majority of the material in this section is sourced from the texts of Rutherfurd et al. (2000a,b), Lovett and Price (1999), Koehn et al. (1999) and Gippel and Collier (1998). Stream condition information generally draws on information from Ladson and White (1999) and White and Ladson (1999).

Water Quantity

IMPACT	CONTRIBUTORY CAUSES	ASSOCIATED IMPACTS	REHABILITATION APPROACHES
Alteration of flow patterns and natural hydrological regime.	Impoundments, weirs, abstraction, extension of drainage networks.	Long periods of low- to no-flow. Reduction in stream depth. Removal or alteration of seasonal breeding and development cues for biota. Altered water chemistry and temperature. Altered sediment regimes. Reduced frequency of inundation of wetlands. Channel contraction. Alteration of riparian vegetation.	Setting and implementation of environmental flows providing a % of the natural hydrology and emulating as far as possibly natural variability. Provision of dam operating rules based on these environmental flow recommendations.
Increased within-year high flow frequencies and peaks	Urbanisation and reduction of permeable surface (increase in runoff, particularly at high flows). Land clearing and changes in soil structure associated with clearing.	Increased threat of flooding in urban areas. Alteration to natural hydrological regime. Removal or change of breeding/ development cues to biota.	Expansion of permeable area, (e.g. with vegetation). Revegetation of catchments and banks. Installation of flow/flood detention structures along river courses.

Discussion

The natural variability in Australian stream hydrology means that it is difficult to discern the nature and severity of anthropogenic impacts on riverine ecosystems (Gippel and Collier 1998), and to know how far a system and its hydrology has been shifted from the pre-impact state.

The water quantity component of river rehabilitation is focussed on the provision of environmental flows, and includes attending to the frequency and magnitude of high flow and flood events. The concerns are the loss of natural flow variability and hydraulic diversity, and the alteration of flooding regimes.

Environmental flow issues are presently receiving attention at both State and Federal levels in Australia, and elicit great public interest, particularly in regard to the larger river systems such as the Snowy and Murray-Darling systems, as discussed in Chapter 2. The Council of Australian Governments (COAG) is committed to providing increased environmental flows for stressed rivers in Australia, as part of facilitating sustainable management of the country's rivers.

According to Gippel (2000), techniques currently in use for environmental flow determination in Australia include rule of thumb (Green 1993); transect-based approaches (e.g. Hall 1989); the Instream Flow Incremental Methodology (IFIM, e.g. Stewardson et al. 1996); expert panel approaches (Burgess and Vanderbyl 1996), the holistic approach (e.g. Arthington et al. 1992) and, more recently, the Building Block Methodology (King and Tharme 2000).

More recently, Stewardson (2001) has developed a 'Flow Events' methodology for environmental flow studies. This approach characterises flow variations using knowledge of the processes by which flow events influence ecological processes. In this method, flow event characteristics are often based on hydraulic analyses rather than hydrological statistics. Stewardson (2001) suggests that environmental flow targets be specified as the maximum allowable change in recurrence interval, a concept which, he maintains, would have meaning for a wide range of stakeholders and ecologists.

The desired output of the water quantity element of rehabilitation is the return and maintenance of flows that more closely resemble the river's pre-impact hydrograph, with inherent variability and disturbance elements (e.g. floods, zero flows and drying where the hydrograph indicates this naturally). However, it cannot be assumed (as it commonly appears to be) that the assessment, recommendation and implementation of environmental flows is the equivalent of a rehabilitation effort (Gippel 1999). Reduced or regulated flows may or may not be the cause of degradation. Either way, the provision of environmental flows is likely to only partially address the environmental problems of the river, and should be viewed as one component of a larger process (Gippel 1999).

Gippel (2000) also points out the flaws in the 'more water is better' approach, reminding readers that the issue of environmental flows is not only about how to allocate more water. He points out that the benefits of marginal flow increase may be localised and of little value in the presence of other degradation factors such as aquatic habitat degradation or flow discontinuities (caused by weirs, culverts, fords and hard-lining). Secondly, as historic water rights have primacy (i.e. are assured) in Australia, in many instances most of the available water has already been allocated for purposes other than the environment.

Emerging Principles: Water Quantity

- Flow regimes need to be integrated to maintain four groups of biotic and physical resources:
  - overbank flows that inundate riparian and floodplain areas
  - flood-flows that form floodplain and valley features
  - in-channel flows that sustain the functioning of the instream system
  - in-channel flows that meet critical requirements of biota (e.g. Hill et al., 1991).
- In rehabilitation planning, the consideration of hydraulics is as important as the consideration of hydrology.
- In areas where increased runoff has become a problem, it is best to treat the landscape, i.e. increase permeable area where possible and where appropriate revegetate with indigenous plant species.
- Weirs should be operated to provide the environmental flow requirements of the river.

- Where there is an increase in the frequency of high flow events, consider environmentally beneficial methods of flow or flood detention or attenuation, such as flood detention ponds, which have the added benefit of providing wildlife habitat.

Water Quality

IMPACT	CONTRIBUTORY CAUSES	ASSOCIATED IMPACTS	REHABILITATION APPROACHES
Salinity *(both land and* rivers)	Post-settlement, extensive clearing of forests, planting of crops and pastures on cleared land, and development of irrigation. These have caused an increase in water infiltrating to the naturally saline groundwater, and a resultant rise in the water table. Near the surface, this saline water affects both land and streams.	Decline in agricultural productivity. Difficult for plants and animals to regulate their salt and water contents. The cytotoxicity of high salt concentrations can be fatal. Extensive degradation or loss of native woody floodplain vegetation (e.g. River Murray floodplain)	It is seldom possible to treat salinity in drainage lines alone. Initiatives include new methods of irrigation, implementation of environmental flows, and planting of salt-tolerant plant and tree species in floodplains and riparian areas to lower the water table.
Nutrient enrichment, *particularly Nitrogen and Phosporus*.	Runoff from fertilised farm lands, erosion of nutrient-rich sediments, discharges from sewerage works, urban drains and industrial sources of organic-rich effluent.	Increases in instream algae and macrophytes to possibly damaging levels. Prolific growth can also lead to reduction or restriction of flows, sediment trapping and possibly channel blockage. This also results in loss of habitat diversity. Loss of sensitive invertebrate species, increase in pollution-tolerant species.	Prevention of the nutrients entering the system via point-source, diffuse-source and instream source routes.
Decreases in Dissolved Oxygen	High nutrient levels. Organic pollution. Reduction in flows (dowstream of impoundments). Increased salinity. Effects of toxic substances in the water. Reduced shading resultant increase in temperature due to clearing of riparian zone.	Respiratory stress and eventual death of biota. Denser salty water tends to 'sink' in pools, causing stratification and eventual hypersalinisation of the pool base. Lack of mixing leads to low dissolved oxygen and high nutrient concentrations. These are 'saline pools' and are effectively removed from available habitat.	Addressing the source of the low oxygen concentration.

IMPACT	CONTRIBUTORY CAUSES	ASSOCIATED IMPACTS	REHABILITATION APPROACHES
Increased turbidity & sedimentation	Runoff from agricultural and urban areas. Instream erosion, in-channel impoundments, bridges, sand and gravel mining.	Reduced oxygen penetration which leads to deoxygenation. Reduced light penetration & thus either reduced plant productivity or, due to nutrients binding to sediments, growth of nuisance algae. Adverse effects on aquatic and terrestrial biota.	Three approaches: - reduction of sediment at source; - trapping of sediment before it reaches the river; - trapping of sediment in the river.

Discussion

While water quality issues related to the health of the water for human use are vital to water resource management, the water quality issues dealt with in rehabilitation are rather those relating to the ecological health of the system: turbidity, sedimentation, nutrients, dissolved oxygen concentration, temperature and toxicants (Rutherfurd et al. 2000a).

The issues receiving management attention in Australia at present are those of increased salinity, turbidity, and nutrient-enrichment, particularly phosphorus-loading (Gippel and Collier 1998). Salinity is not considered as crucial an issue to the ecosystem and its inhabitants as it is to the human land- and water-users. So, while it is salinity which is seen by the public to be a major river issue and which receives a lion's share of 'river improvement' funding, this is directed towards human use rather than ecological functioning of the system (Gippel and Collier 1998).

The quality of natural waters is covered by the Australian Water Quality Guidelines for Fresh and Marine Waters (ARMCANZ & ANZECC), originally published in 1992 and due for revision in 2001. These guidelines account for the geographical variation in Australian rivers and provide documentation on natural stream water quality characteristics in different regions. They also provide a range of biological and ecological indicators of water quality (Chessman 1994). Rutherfurd et al. (2000a) present 'thresholds of concern' for the six aforementioned water quality fields. These are levels at which the variable in question is likely to be a serious threat or degrading factor.

Emerging Principles: Water Quality

- Water quality can be a limiting variable in stream rehabilitation.
- Water quality deterioration may be directly linked to altered flow.
- In order to reinstate natural water quality parameters, it is necessary to know what these would have been in the river's pre-impact state. On the basis of what is known of rivers in different regions, it is possible to deduce measurable ranges of concentration which are acceptable for the different quality variables, and to strive to achieve water quality within these ranges (Rutherfurd et al. 2000).
- Water quality objectives and targets should be set within the range of concentrations acceptable to the biota to be reinstated in the system.
- 'Thresholds of concern', and the percentage probability of these being exceeded post-rehabilitation, should be taken into account in rehabilitation planning.

- Investigate and address water quality problems at the source (point source, diffuse source and instream source).
- Focus on education of farmers to promote environmentally-sound farming practice regarding irrigation, application of fertilisers, limiting access of cattle to riparian zone.
- Revegetate catchment areas with indigenous trees and flora to reduce erosion, sources of nutrients, sediments and turbidity.
- Revegetate cleared riparian zones with indigenous trees and flora to stabilise unnaturally eroding banks and to provide natural shading to the stream.
- Where water quality is unlikely to be treated at source, consider the use of artificial wetlands as a means of water purification (this should only be considered where appropriate to the system in question).
- Sediment inputs can be addressed at source with revegetation or land-use change. Sediment entering rivers can be trapped before it reaches the river, or in the river itself.

Physical form

A problem commonly raised in Australian literature on river rehabilitation is that in the context of the great hydrological variability and uncertainty of river-flow, it is difficult to assess which of the physical characteristics of a stream are natural and have developed over time, and which are the result of imposed modifications. There are however a number of methods which assist with this. A number of the sub-indices in the Index of Stream Condition (ISC) relate to the river's physical form. The River Styles methodology also assists with the determination of geomorphological process in the system. Both of these methods are discussed in Section 4.6.1 (Step 2).

Specific degradation issues related to the aforementioned elements of physical form in Australian rivers are tabulated below. The geomorphological information presented below is summarised from Australian texts and should not be assumed to be transferable to South African and other rivers. The information rather serves as an indication of the complexity of interpreting present physical form and designing for reinstatement of 'natural' form. This is, at least initially, a task for the experienced fluvial geomorphologist.

IMPACT	CONTRIBUTORY CAUSES	ASSOCIATED IMPACTS	REHABILITATION APPROACHES
Gullying Non-natural gullies are the result of post-settlement deepening and extension of the natural stream network, often in areas that were previously swampy and highly sensitive to disturbance.	Usually a result of a combination of clearing of vegetation from catchments, extension of drainage networks by digging, concentration of flow in vehicle and animal tracks, plough lines or drainage ditches, and intense rainfall periods.	Headward erosion (the gulley heads up the drainage network as a series of erosion heads or knickpoints. Once it is incised, ground and surface water drain into it. Seepage drives erosion.) Sedimentation.	Stabilisation of gulleys, thus accelerating the natural process of recovery. The bed of the gulley should be stabilised before the bank. Methods include encouraging invasion of the channel bed by vegetation to expedite stabilisation; diversion of high flows out of the channel, and allowing low flows to assist revegetation.

IMPACT	CONTRIBUTORY CAUSES	ASSOCIATED IMPACTS	REHABILITATION APPROACHES
Channel incision Incised streams tend to move through predictable cycles of erosion and stabilisation.	The construction of small drains caused incision and widening. In-channel works (Gippel et al. 1992)	Incisions can be a major source of sediment and land loss (through erosion). Barriers to animal migration to higher reaches.	The general approach is channel stabilisation, concentrating first on the bed. The establishment of vegetation in the channel bed is one means of stabilisation. High flows should be diverted from the channel and low flows maintained to encourage vegetation growth. If coarse sediment loads are delivered, these can armour the bed, thus stabilising the channel.
Trampling of stream channels and banks.	This is generally associated with livestock grazing and watering.	Bank erosion. Damage to riparian zone plants and emergent vegetation. Cattle faeces contributes to nutrient loading.	Exclusion of cattle from riparian zones and river banks by fencing the riparian corridor and using alternative off-channel watering facilities.
Threats to "Chains-of- Ponds".	Digging of drains through the bars which separate ponds. This causes incision and headward erosion, cutting through bars to upstream ponds, and thus draining them. Damage to vegetation in the flow-line between ponds. Increased flow resulting from land-clearing or gullying upstream.	Incision. Sedimentation.	Three types of action: Prevention of the gulley from moving upstream through the chain-of- ponds; by stabilizing the gully head with a rock chute, disallowing stock, and revegetating. Protection of the chain from a sediment slug by management of sediment movement to prevent ponds filling with sand. Recreation of a chain- of-ponds by creation of stable pools and bars. Vegetated earthen and rock weirs may be installed, stream verges vegetated, and artificial sediment traps installed, with controlled sediment extraction.
Loss of Large Woody Debris (LWD) or 'snags'.	Intentional removal of LWD for past 150 years. LWD was considered a cause of stream erosion, channel blockage and increased flood stages. Clearing was also for the purpose of allowing navigation (in river trading times).	Loss of critical habitat for algae, invertebrates and fish, particularly in mobile-bed, deep streams. Loss of complex surface area for carbon and nutrient processing. Loss of in-channel roughness factors, and thus of flow turbulence and related oxygenation.	Revegetation of the riparian zone to encourage natural recruitment of snags to the stream (this is a long-term solution). Artificial, manual return of LWD to streams (this may involve attaching the LWD to the bank or bed). Suggestion that the removal of LWD should be prohibited, except under exceptional circumstances.

River Channel

Geomorphological characteristics constitute the physical template for riparian and aquatic ecosystems. The interacting elements of physical (geomorphic) form discussed by Rutherfurd et al. (2000a) in the context of river rehabilitation are: the river channel (bed and banks), instream physical habitat, lateral connectivity (channel-floodplain), and longitudinal connectivity (upstream-downstream). Each of these is briefly dealt with here.

River Bed

The extent of bed stability provides a measure of stream change from pre-impact (natural) conditions. Variations to a river bed level are often so gradual that they are unnoticeable (Wem 1998). The bed of a river is considered stable if there is no evidence of down-cutting (incision), in-filling of sediments, or unnatural channel deepening. Signs of partial bed instability with deepening are erosion of the river banks and steepening of the bed, and the presence of mobile sands or silts in the bed. Partial bed instability with sediment infilling is indicated when the bed material is more-or-less uniform in character, channel capacity is somewhat reduced, and a uniform size fraction of sediment is present on the bed and the bars. Signs of dramatic instability with incision are extensive erosion of both banks, a steep bed, or no fine sediments in the bed. Dramatic instability with infilling is indicated by the channel being blocked by fine sediments, siltation occurring on the banks, a high width:depth ratio, waterlogging of adjacent land, and a flat bed.

River Banks

The degree of bank stability is generally indicated by the extent of undercutting, the extent and rootedness of vegetation cover, the degree to which root zones are exposed, and the erosivity of the soil. Caution should be exercised in interpreting bank stability. Kondolf (1998), discussing rehabilitation of Californian streams, refers to an instance in which rehabilitation actions were focussed on the stabilisation of eroding banks, however this intervention actually halted the natural process of recovery from previous interventions. Kondolf points out that to avoid incorrect prognoses regarding physical form, a real understanding of geomorphological and ecological processes is required. Prescriptive approaches based on mimicry of known river forms may fail to recognise and maintain present processes.

The Index of Stream Condition (ISC) indicator for bed and bank stability is based on a comparison with an ‘ideal’ erosion-free river condition. This process is assisted by the use of reference photographs in the ISC manual (White and Ladson 1999) which show a range of levels of disturbance.

Emerging Principles: Channel (Bed and Banks)

(These principles are not necessarily transferable to SA rivers)

- Successful channel restoration relies on sustainable channel alignment and the stability of the channel bed and toe. Without these, the symptom is treated rather than the cause (Rutherfurd et al. 2000a, Wem 1998).
- A straightened river should, where possible, be returned to its original course.
- In stabilising the channel, the bed should be attended to first. The establishment of indigenous submerged aquatic vegetation in the channel bed is one means of stabilisation. Divert high flows from the channel and maintain low flows to

encourage vegetation growth. If coarse sediment loads are delivered, these can armour the bed, thus stabilising the channel.

- Revegetation of unstable streambanks can provide relatively cheap long-term stability, plus many other benefits for native riparian plants and animals (Lovett 1998).
- Prior to revegetation, it is important to understand the causes of bank instability.
- Where erosional processes are threatening a high value capital asset (e.g. a bridge or building) or where erosion is occurring in high-energy situations (e.g. gullies) with steep banks, revegetation may not provide sufficient resistance to protect the asset. In these cases it may be necessary to combine revegation with bio-engineering approaches (Lovett 1998).
- Engineering structures which can be used in rehabilitation to stabilise streambanks include: **rockpiles or groynes**, which are structures (usually impermeable) that project from the streambank into the channel. They are designed to increase flow resistance and direct streamflow away from the bank through a preferred channel alignment; and **rock revetment**, a structure which provides 'armouring' for the streambank against fluvial erosion, and provides stabilisation against slumping (Kapitzke et al.1998)

Instream Physical Habitat

Damage to instream habitat is usually in the form of loss of both the diversity of habitat types and the extent of available habitat area in the river. The overall effect is an increase in uniformity of the channel; straightening; loss of hydraulic diversity and complex flow velocity conditions and depth variation over short distances; and reduction in channel roughness factors. These effects may also be the result of channel widening, incision or straightening, sediment deposition, and other factors. The pre-impact instream habitat will not necessarily be easy to infer from the present state of the river, and a classification type approach may be helpful in indicating the range and extent of habitats that would, under natural conditions, have occurred in the stream type and section under investigation.

The aim of reinstating habitat is to return the surface area, cover, and associated hydraulic conditions which would, under natural conditions, have provided the food, shelter, growth and respiratory requirements of the biota which originally inhabited the stream. The return of these elements also restores the flow configuration that maintains channel form. As Rutherfurd et al. (2000a) point out, '*Much stream rehabilitation effort is directed at making streams messy again by reintroducing structures, vegetation or woody debris, which creates habitat complexity and velocity variation in the stream*'. This should not be confused with poor rehabilitation actions in which habitats assumed to be 'necessary' to improved stream functioning are placed in streams. For instance, much of the northern hemisphere work on rehabilitation has focussed on reinstatement of riffle-pool areas and spawning gravels, but it would be erroneous to assume that these sorts of actions would be transferable to rivers in semi-arid zone countries.

Emerging Principles: Instream Habitat

- Base initial attempts at providing instream habitat firstly on the provision of a stable channel, and secondly on the provision of increased hydraulic diversity (Rutherfurd et al. 2000a).
- Hydraulic habitat is as important to consider as physical habitat.

- Effective habitat structures can create a diversity of velocities, depths, substrates and lighting conditions that emulate the natural stream to whatever depth appropriate.

Lateral Connectivity (Channel - Floodplain)

Excessive flow regulation and over-abstraction have resulted in the severe degradation of many Australian floodplains (Australia Conservation Foundation ACF 2001). For example, the frequency of medium-sized floods at the South Australian border has been reduced to 57% of original, and the frequency of large floods has been reduced to 33% of original. These alterations effectively deprive an internationally protected floodplain (the Chowilla) of essential flooding. Throughout the Murray Darling Basin, ‘floodless floodplains’ and dry wetlands are common. Here, rivers and wetlands receive too little water to remain ecologically viable, or are being flooded at the wrong time of year. Average flows to the sea have been reduced by 80% due to the excessive number of dams and the volumes of water required by irrigators. Drought-like conditions now occur at the mouth of the Murray River on average more than six years out of ten, compared to the natural state of once in every 20 years (ACF 2001).

The floodplain-river ecosystem responds to disturbance over a range of levels, from organism-level response through to population and community changes and eventually, ecosystem change. In the floodplain zone of a river, lateral exchange of water between the floodplain and the channel is crucial for exchange of nutrients and the movement of biota. Factors which cause the floodplain to be ‘disconnected’ from the river channel are: clearing of natural vegetation followed by development or agricultural practice; reductions in flow and flow variability, and loss of regular high-flow events and floods of various sizes, frequencies and return intervals.

The alteration in frequency of small-to-medium floods is of particular concern with regard to the floodplain function. Downstream of a regulatory structure, these floods may be reduced in frequency, while in a context where runoff is high, they may be increased both in frequency and magnitude. In addition, alteration of normal flood regimes (changes in timing, duration and magnitude) has serious consequences to the river-floodplain ecosystem. There may be a lengthy lag period between the development or alteration to the floodplain and the visible effects on ecological function.

The reconnection of the floodplain and river ecosystems begins with the recommendation *and* implementation of environmental flows. The wetting and drying regime of floodplains must also be recognised and allowed for. This is important in determining structure and distribution of plants and animals, and in controlling the exchange of nutrients and carbon between river channels and the floodplain. These flows would include artificial high flow events and small, medium and large floods timed to coincide with the natural flow patterns during important development or migration phases for the biota and growth periods for the vegetation of the river. The magnitude, duration and frequency of these events are likely to be significantly different to those of the natural hydrograph due to competing demands on the resource. The stochastic, variable nature of the river’s flow regime cannot be entirely catered for in an environmental flow recommendation.

Emerging Principles: Lateral Connectivity

- Reconnection of the floodplain and river requires the provision of environmental flows. The wetting and drying regime of floodplains must be recognised and allowed for in the determination of these.

Longitudinal Connectivity

The longitudinal 'connectivity' of a stream or river is generally assessed by the extent of barriers to the upstream or downstream movement of aquatic and terrestrial (riparian) biota, and to the passage of organic material and nutrients from upstream to downstream river reaches. Examples of natural barriers are waterfalls, sand slugs and altered water quality zones. Non-natural barriers exist in the form of both physical obstructions (e.g. weirs, dam walls) and reduced water depth (resulting from diminished flow) or quality. In fish populations, these issues interfere particularly with the process of growth and recruitment - which includes spawning, nursery phase and juvenile dispersal into adult growth habitats.

In Victoria, 70% of indigenous fish species in the coastal basins migrate at some point in their life cycle (Koehn and O'Connor 1990), and barriers often impede this movement. For inland and coastal species, obstruction to fish passage has often led to decline in fish populations or extinctions of species from affected catchments. Many Australian fish species migrate in an upstream direction when they are juveniles (with poor swimming abilities) and in a downstream direction in order to breed. This is in contrast to North American species, which migrate upstream to breed when they are mature adults (with stronger swimming capabilities). This is a crucial factor in the design of structures that allow for fish passage in one or both directions, and cater for 'strength' factors in the fish.

Emerging Principles: Longitudinal Connectivity

- Where re-establishing longitudinal connectivity for fish passage, e.g. by provision of a fish ladder, upstream and downstream movement is important. Migration is a two-way street for Australian fish species. If a fish ladder will only allow fish to move up to spawning grounds and do not allow successful passage of juvenile species back down the system, population declines are likely (Ladson, pers. comm.).

Biota

IMPACT	CONTRIBUTORY CAUSES	ASSOCIATED IMPACTS	REHABILITATION APPROACHES
Loss or alteration of physical habitat	Extensive clearing of indigenous floodplain vegetation, canalisation or channelisation of rivers, desnagging.	Changes to riverine flora and fauna, including waterfowl.	Stabilisation of the bed and bank, followed by provision of appropriate physical and hydraulic habitat.

IMPACT	CONTRIBUTORY CAUSES	ASSOCIATED IMPACTS	REHABILITATION APPROACHES
Barriers to fish passage Contrary to N. Hemisphere salmonid species, many Australian fish migrate downstream to spawn in estuaries. It is the weaker juvenile fish in this case which swim back upstream to upper reaches. Compared with salmonids, these species are not strong swimmers or jumpers.	Construction of in-channel dams and weirs. Construction of culverts (some fish only migrate in light and will not enter these tunnels). Reduction in stream depth due to flow reduction. High flow velocities and a lack of roughness features (e.g. in culverts, fords).	Interference with recruitment (spawning, nursery phase, juvenile dispersal) and growth processes in fish life-cycles. Interruption of home-range movements of fish. Extensive declines in both coastal and inland fish populations. Extinctions of particular species in affected catchments.	Where no natural barriers to fish migration exist upstream of the artificial barriers: - Construction of fish ladders on existing weirs. Consideration of migration in both directions is vital (Ladson pers.comm.). - Use of appropriate engineering approaches in the design of new dam and weir structures. - Rock ramps (simple piles of rock placed below the offending barrier) can be used to create gentle enough water slope to provide fish passage. Replace culverts with fords.

Fauna considered important in the conservation of Australian streams are fish, macroinvertebrates, frogs, and platypus. The last of these is of particular significance to the Australian public, and is often the major motivation for a community to rehabilitate a stretch of river. Platypus are burrowing animals which require stable, well-vegetated banks with plenty of vegetation cover and a good supply of invertebrates for food. Rehabilitation with the aim of reinstating habitat and feeding conditions purely for the platypus is not uncommon. While this may be considered somewhat emotive by ecologists, Rutherfurd et al. (2000a) point out that such measures could simultaneously achieve a number of sound rehabilitation-related outcomes.

Reinstatement of the habitat diversity and hydrological and hydraulic conditions similar to those which existed pe-settlement (if these are known) will assist the return of natural biotic community structure. Increase in flow variability is generally associated with an increase in habitat and foodweb complexity. A large number of Australian river systems are naturally intermittent, and the maintenance of dry periods in these systems may be as important to the biota of these systems as flow is to the biota of perennial systems. The biota of inland (arid) river systems naturally exhibit ‘boom and bust’ cycles in biodiversity, coinciding with flood and drought events. As the biota are adapted to the flow variability and the aridity, they respond rapidly to the presence of water, and biodiversity is generally high in natural rivers and inundated floodplains (Edgar 2001).

Emerging Principles: Biota (*Riparian Vegetation dealt with separately*)

- Treat aquatic biota as dependent variables in the sense that they are affected by change or degradation in water quantity (flow modification or regulation, affecting depth, cover, hydrologic variability, hydraulic diversity etc), water quality (particularly turbidity and nutrient enrichment), temperature, physical form (e.g. fine sediments, habitat availability and extent, barriers to movement), and riparian vegetation (inputs to the stream, bank stability and shading).

- Reinstate hydrological and hydraulic diversity to provide habitat heterogeneity (and where possible something resembling natural bedform).
- Ensure that nearby colonising sources are available if particular fauna are required to colonise a reach (Ladson pers.comm.).
- Ensure that appropriate habitat is available for all the life stages of an organism if it is to successfully colonise or recolonise a reach (Rutherfurd et al. 2000a, Ladson pers.comm.).
- Attend to water quality such that it is within an acceptable range for colonising biota to succeed (Rutherfurd et al. 2000a).
- Carefully consider the longer term, 'ripple effect' of interventions such as fishways, as many organisms will adapt to human-induced changes in an ecosystem (Ladson, pers. comm.).
- More 'natural' stream conditions will not necessarily restore the biota. Exotic invasive species can still thrive and dominate in an improved environment.
- Maintain disturbance events in the flow regime, resembling those of the natural hydrograph (e.g. floods, high flows, flow intermittency, drying). These are likely to play a role in structuring biotic communities (Ladson, pers. comm.).

Riparian Lands

Clearing of riparian lands and catchment vegetation is considered the single largest cause of river degradation in Australia (Askey-Doran et al. 1999). The impacts associated with this are listed in Chapter 2 and repeated here for simplicity:

- Increased runoff from catchments and larger and flashier flood flows;
- Many-fold increase in rates of erosion (gullying, headward erosion) and sediment delivery;
- Decrease in bank stability and resultant undercutting, channel incision and channel widening;
- Floodplain scour and massive channel widening on high-energy coastal systems;
- Coarse sediment delivery to streams resulting in sand slugs and 'choking', with dramatic loss of instream habitat;
- Associated with this, increase in nutrient loading due to greater erosion, use of fertilisers, stock access, and increased levels of phosphorus and dissolved organic carbon in groundwater;
- Increase in fine-grained sediments, loss of chains-of-ponds and swampy meadows;
- Large-scale alteration in river hydraulics;
- Loss of riparian function and instream habitat;
- Change in water quality parameters (including increased light, temperature and turbidity, decreased dissolved oxygen, increased salinity and nutrient loading).
- Rise in the water table and resultant dramatic increases in salinity (Prosser et al. 1999, Rutherfurd et al. 2000a, Gippel and Collier 1998).

The net effect of changes to the riparian lands is deterioration in water quality and river health (Bunn et al. 1999a). Removal of riparian vegetation can also dramatically alter the quality and quantity of carbon energy in foodwebs. The majority of organic inputs to a stream: leaf litter; logs and branches (snags or LWD); fine particulate organic matter; and dissolved organic matter originates in the riparian zone and represent key energy sources and habitat in aquatic ecosystems (Bunn et al. 1999b). Following vegetation clearing, riparian shading is removed with the result that there are fewer inputs of terrestrial organic matter to the system, greater incoming light, and increased temperatures. Instream production shifts to larger, less palatable plants such as filamentous algae and macrophytes (Bunn et al. 1999).

Without intervention in the riparian zone, some degraded sites are unlikely to recover (Askey-Doran et al. 1999). Three recovery 'thresholds' described by McDonald (1999) are used to determine what approach to follow (Askey-Doran et al. 1999):

- **unassisted regeneration** threshold, where the system is unlikely to recover as a result of natural processes operating within the plant community, and relatively low key interventions may be able to correct processes to enable self-recovery processes to be reinstated;
- **assisted regeneration** threshold, where assisted regeneration has failed to reinstate processes, and beyond which point recovery is only possible after further reconstruction of substrates or organisms;
- **reconstruction** threshold, where conditions are so altered that recovery of the pre-existing community is impossible or impractical. In such cases a community conversion (to different taxa, such as may occur under similar local environmental conditions) may be considered.

Emerging Principles: Riparian Zone

- The recovery of populations from catastrophic events is more likely in riparian zones which are biodiverse (Askey-Doran et al. 1999).
- Fencing and revegetation of the riparian zone with appropriate indigenous flora is an accepted and widespread form of riparian zone and channel rehabilitation (in Australia, Rutherfurd et al. 2000a)
- The provision of approximately 50% of shading (by riparian vegetation) is recommended for small, forested, upland streams, for the significant improvement in ecological functions (Davies and Bunn, 1999; *not necessarily transferable to SA rivers*).
- Before planning to restore vegetation it is important to check that the stream flow and its channel are broadly in equilibrium. If the channel is in the process of widening and incision or deposition, revegetation is unlikely to be of value (Askey-Doran et al. 1999).
- Three restoration approaches are recommended, dependent on the state of degradation of the riparian vegetation: allow natural regeneration of form, process and biodiversity, assist regeneration with planting, or reconstruct the riparian environment through planting of appropriate species, and other appropriate techniques. Beyond this, conversion to a new community-style can be considered.

4.4.1 SUMMARY OF EMERGING PRINCIPLES

Water Quantity

- Provision of environmental flows is only one aspect in the rehabilitation process.
- Consideration of hydraulics is as important as the consideration of hydrology. Reinstate hydrological and hydraulic diversity.
- Flow regimes should maintain four groups of biotic and physical resources: overbank flows (floodplain), flood flows (floodplain and channel), and in-channel flows (channel and riparian vegetation).
- Natural disturbance regimes (high flows, flooding, intermittency, dryness) should be maintained in the environmental flow regime if they are relevant to the natural hydrograph.
- The 'm*ore water is better*' approach is flawed. Provision of flow may not address crucial degradation issues.
- Increase permeable area (revegetation, etc) where possible and where appropriate.
- Operate weirs to match natural flow patterns.
- Where there is an increase in the frequency of high flow events, consider environmentally beneficial methods of flow or flood detention, such as flood detention ponds.

Water Quality

- Water quality can be a limiting variable in stream rehabilitation.
- Water quality deterioration may be directly linked to altered (reduced) flow.
- In order to reinstate natural water quality parameters, it is necessary to know what these would have been in the river's pre-impact state;
- Attending to the inputs to a stream (e.g. flow, nutrients, sediment) can alter stream processes (e.g. erosion, sedimentation). The stream may then stabilise without the assistance of any interventions affecting stream structure.
- On the basis of what is known of rivers in different regions, it is possible to deduce measurable ranges of concentration acceptable for the different quality variables.
- Water quality objectives and targets should be set within the appropriate range of concentrations for the biota to be reinstated in the system.
- Investigate and address water quality problems at the source.
- Promote environmentally sound land-use practices.
- Revegetate catchment areas with indigenous species.
- Revegetate cleared riparian zones with indigenous species to stabilise river banks (reduce sediment inputs) and beds, and to provide natural shading to the stream (this addresses temperature, dissolved oxygen, etc.).
- Consider the use of artificial wetlands as a means of water purification (where appropriate to the system in question).
- Address sediment inputs at source, or trap sediment prior to reaching the river or in the river itself.

Channel (Bed and Banks)
These principles are not necessarily transferable to SA rivers.

- An understanding of geomorphological and ecological processes and system recovery is necessary to assess the current state of a channel. Historical channel analysis should be undertaken to construct a picture of a pre-impact condition.
- Successful channel restoration relies on sustainable channel alignment and the stability of the channel bed and toe.
- Channel design requires specialist expertise.
- A straightened river should be returned to its original course where possible.
- In addressing channel straightening, meanders can be returned to the system or new bends constructed. This involves an understanding of system geomorphology and technical design procedures, and should not be attempted without specialist expertise.
- In stabilising the channel, concentrate first on stabilising the bed. Divert high flows from the channel and maintain low flows to encourage vegetation growth. If coarse sediment loads are delivered, these can armour the bed, thus stabilising the channel.
- Revegetation of unstable streambanks can provide relatively cheap long-term stability, plus many other benefits for native riparian plants and animals.
- Prior to revegetation, it is important to understand the causes of bank instability.
- Where erosional processes are threatening a high-value capital asset, revegetation may not provide sufficient resistance to protect the asset. In these cases it may be necessary to combine revegation with bio-engineering approaches.
- Environmentally acceptable engineering structures that can be used in rehabilitation to stabilise streambanks include: rockpiles or groynes, and rock revetment. The combination of manmade structures with vegetation (bio-engineering) is a growing field associated with river rehabilitation in Australia.
- Fencing of the riparian zone prior to revegetation is common practice in Australia in agricultural areas

Lateral Connectivity

- Where the alteration in frequency of small-to-medium floods is in the direction of an increase, this is of particular concern with regard to the floodplain function.
- Reconnection of the floodplain and river requires the provision of environmental flows.
- The natural wetting and drying regime of floodplains must be recognised and allowed for in the planning of environmental flows.

Longitudinal Connectivity

- Where re-establishing longitudinal connectivity for fish passage, e.g. by provision of a fish ladder, consideration of upstream and downstream movement is important.

Biota

- Consider aquatic biota to be dependent variables in the sense that they are affected by change or degradation in water quantity, quality, temperature, physical form, and riparian vegetation.

- Reinstate biological diversity and focus at the level of communities rather than single species. Sensitive and rare species and communities are however afforded priority.
- Hydrological and hydraulic diversity is required to increase hydraulic habitat heterogeneity.
- Ensure that nearby colonising sources are present where particular fauna are required to colonise a reach.
- Ensure that appropriate habitat is available for all the life stages of an organism for it to successfully colonise a reach.
- Water quality must be within an acceptable range for colonising biota to succeed.
- More ‘natural’ stream conditions will not necessarily restore the biota. Exotic invasive species are likely to continue to thrive in an improved environment.
- Disturbance events resembling those of the natural system (e.g. high flows, flow intermittency, drying) are important to maintain complex and close-to-natural biotic communities.

Riparian Zone

- The recovery of populations from catastrophic events is more likely in riparian zones which are biodiverse.
- Fencing and revegetation of the riparian zone with appropriate indigenous flora is an accepted and widespread form of riparian zone and channel rehabilitation.
- Prior to planning vegetation restoration, it is important to check that the stream flow and its channel are broadly in equilibrium.
- Three restoration approaches are recommended: natural regeneration of form, assisted regeneration, or reconstruction of the riparian environment through planting and other appropriate techniques. Beyond this, conversion to a new community-style can be considered.

4.5 PRIORITISATION IN REHABILITATION

Widespread ecosystem degradation is the rule rather than the exception in most developed countries. Resource management is increasingly focussed on developing criteria for conservation priorities. These include which aspects of degradation to address, and in what sequence. This is required at national and local scales. The issue of prioritisation ties directly to the question of conservation priorities, sustainable resource management, and the economics and financing of resource management. It is a complex area because of the multiple criteria on which priorities must be based.

In its simplest state, prioritisation is a series of questions: what to protect, what issues to address first, on what basis, how to rank problems and relevant actions relative to the prevailing conditions, constraints, and resources (environmental, labour, finance, time).

Rutherfurd et al. (2000a) present a useful background to prioritisation philosophy and concepts. These authors describe the currency of stream rehabilitation, that basic measure for deciding priorities, as '***the amount of sustainable natural biodiversity that can be gained per dollar, or per unit effort, usually in the shortest time, and optimally for the greatest length of stream***'. This represents a simplification of a complex thought process. Priorities are thus based on achieving optimal and appropriate levels of biodiversity.

It would thus be considered more effective to save whole reaches of a river than to rescue individual species or communities and leave the reaches to be destroyed. While the currency of biodiversity does not ostensibly take the *composition* of the biodiversity into account, the notion of giving priority to more sensitive and/or less common communities is still upheld in the Manual, as it is in other rehabilitation work (e.g. Goals Project 1999). Ideally, one would optimise by maintaining and conserving source areas of fauna and flora with both high diversity and high conservation value.

The procedure for setting priorities is intended to be a dynamic, adaptive one. Once the general framework of priorities has been set, the details may change according to needs and outcomes.

The practical guidelines to achievable, ongoing prioritisation in stream rehabilitation presented by Rutherfurd et al. (2000a) are briefly described here, and the sequential tasks in prioritisation are included under 'Rehabilitation Process' (Section 4.6).

The principles for prioritisation are:

1. Save reaches that support valuable organisms or communities (rare or endangered) before less valuable reaches which support common organisms and communities.

2. Protect streams that are in the best general condition before attempting to improve those in poor condition.

3. Where possible, arrest degradation rather than waiting for the system to stabilise and then attempting to accelerate recovery.

4. Improve the condition of damaged reaches, beginning with those that are easy to attend to.

5. Where there are still reaches needing protection or improvement, attend to these before fixing badly degraded reaches.

6. Identify the critical or 'fatal' problems and limiting factors. The obvious problems, such as bank erosion, may be less serious than the 'hidden' problems such as polluted stormwater runoff.

Ideally, prioritisation for stream rehabilitation should proceed from the local to regional to the national scale. In practice, this means eventually comparing the condition of whole catchments rather than just reaches, a complex undertaking. However, the six principles presented above work equally for catchments.

The argument for prioritising 'best condition' reaches for protection is that it is difficult to artificially recreate a functioning physical and biological system, and attempts at doing so are also usually prohibitively expensive. One has to take the longer-term view of getting maximum return for investment over a period of decades.

The monetary costs of not protecting reaches already in good condition, which are often the upper reaches, are:

- the cost of later possibly having to recreate these reaches;
- the additional cost of rehabilitating lower reaches due to the absence of a productive seed source;
- the opportunity cost of later having to spend money on rehabilitating the upper reach, that could have been spent elsewhere.

Rutherfurd et al. (2000a) provide a hypothetical example of all three of these costs being incurred in a project as a result of favouring rehabilitation actions in degraded downstream reaches of a river and neglecting to protect or conserve the intact, ecologically sound upper reaches. The argument is that for a small extra short-term cost this upper section could be protected, thus eliminating the longer-term threats and costs associated with potential degradation of this reach.

The four criteria guiding the prioritisation and ranking of reaches in this methodology are distilled from the six principles described:

- **Rarity** (rare reaches have higher priority than common ones);
- **Condition** (reaches in good condition are easier to fix than those in bad condition);
- **Trajectory** of change (Deteriorating reaches should be stabilised before action is taken on reaches which are improving without any intervention);
- **Ease** (attend to those reaches which are easy to fix, before those that are difficult).

Reaches are assigned into one or more of nine categories in order to determine priorities for rehabilitation. These are presented in Table 4.5, and it is obvious that criteria for each of these categories would have to be developed to assist the process. Clearly, also, some reaches may fall into more than one category. This eventuality is dealt with in Step 5 of the rehabilitation process presented later in this chapter.

Once one has prioritised reaches, then the problems within the reach must be prioritised. Rutherfurd et al. (2000a) recommend that the hierarchy of problems must be identified, from fatal problems that exclude particular species from the reach, to limiting problems which stress the species in question, to nuisance problems which have minor effects on the population. Eventually all these problems should be addressed, but to speed up the process of improvement, the problems should be tackled in that order. The eventual aim of rehabilitation is to move all reaches into Category 0.

Further 'tasks' associated with prioritisation are discussed in Step 5 of the rehabilitation process described in the following section.

Table 4.1 The nine prioritisation categories into which river reaches may be assigned following specialist assessment (*after Rutherfurd et al. 2000a*)

NO.	DESCRIPTION	ACTIONS REQUIRED	
0	Reaches in good condition throughout, that are already protected.	Nothing needs to be done to these reaches, but to monitor for development of any threats.	PROTECTION OF ASSETS
1	Reaches with important regional conservation assets and/or value.	Protect these for their rarity value. This includes identifying and fixing threatening problems that come from other reaches.	
2	Reaches with local conservation value.	These include surviving remnant sections of original streams. They may be common in the area, but rare in the catchment . Prevent these from deteriorating. This involves treating all threats to the reach, including those from outside the reach.	
3	Actively deteriorating reaches.	Arrest present deterioration and prevent further deterioration.	
Important assets should by this stage have been listed for protection. The focus now turns to the improvement of the stream's structure and ecological function.			
4	Reaches in good condition.	Expand these areas. The value of quality assets is greatest when combined with other assets to form a complete stream community. Work should be prioritised. Work on (i) reaches with some high quality assets and some degraded assets, (ii) poor quality reaches that link two asset-rich reaches; (ii) poor quality reaches with asset-rich reaches at one end.	IMPROVEMENT OF ASSETS
5	Reaches with impeded recovery, degraded but in stable condition.	Where natural recovery should be occurring but is prevented by a partidular stream problem. Identification and rectifying that problem facilitates natural recovery.	
6	Moderately damaged reaches.	These are reaches with good potential to improve at reasonable cost. These need several interventions rather than just one (as in Category 5).	
7	Basket-case reaches (in very poor condition; not threatening to other reaches, and with little chance of self-recovery over time).	These are considered to have serious problems and need intervention to recover.	
8	Basket case reaches with hope (in very poor condition; not threatening to other reaches; and with some chance of self-recovery over time).	If the instability of this stream threatens downstream reaches these should be pushed up the priority list.	

4.6 THE REHABILITATION PROCESS

There are a number of procedural guidelines in Australia covering aspects of stream management, protection and rehabilitation, as described in Chapter 3. The process presented here and the notes that follow provide a framework for the planning and implementation of a rehabilitation process. The process presented is a practical rather than a specialist technical one, and is generic to river sytems in general, and thus transferable.

These 12 steps for the river rehabilitation process could potentially feed into processes and methodologies already in place within the South African Resource Directed Measures (RDM) and Catchment Management methodologies (Chapter 6), or use the information generated by these. This is dealt with further in Chapter 7.

4.6.1 A 12-step stream rehabilitation process

This process is summarised from Rutherfurd et al. (2000a, Vol.1), with some additional input from other sources (individually referenced). The decision was taken to present one methodology rather than the several available, for the sake of simplicity, and to present the process with which I had become most familiar. This is in no way an indication that other processes are considered less sound or comprehensive. The process of Rutherfurd et al. (2000a) achieves a good balance between technical considerations and practical issues. As mentioned previously, the more technical of the tools and design measures are not included here. The interested reader is referred to the Manuals.

The authors point out that this process should not be seen as linear, but rather as an iterative one. The planners are likely to constantly return to early steps and reassess them in the light of what is now known. A 'reality check' is built into each step, encouraging the planners to revisit previous steps. Each step is briefly described in the following section. This process is highly summarised here and should not be considered to represent complete guidelines.

Frame 4.2 A generic 12-step rehabilitation process (*after Rutherfurd et al. 2000a)*

	WHAT NEEDS DOING?
Step 1	Develop a vision and goal
Step 2	Share the vision and goal
Step 3	Describe the stream condition
Step 4	Identify the assets and problems
	NARROWING IT DOWN
Step 5	Set priorities
Step 6	Develop strategies
Step 7	Set measurable objectives
Step 8	Check the feasibility
	DOING IT
Step 9	Design the details
Step 10	Plan the evaluation
Step 11	Schedule and supervise the works
Step 12	Assess, evaluate and maintain the project

Step 1. Develop a Vision and a Goal

This step can be confusing purely because of the breadth of interpretation of the terms 'vision' and 'goal'. It should be noted that the approach recommended in this step is a slight modification of that proposed by Rutherfurd et al. (2000a). It is rather that of Larsen (1996) and Gippel (1999), who follow Kern's (1992) '*Leitbilt*' concept. This involves firstly developing the 'vision' for a river. This is formulated on the basis of:

(i) a description of the pre-impact, natural state of the river (as described in Step 5 of the 12-step process);
(ii) an assessment of irreversible changes to abiotic and biotic factors; and
(iii) a consideration of certain aspects of cultural ecology.

The synthesis of these efforts serves as the vision, 'guiding image' or 'model image' for the rehabilitation. **This vision, in the sense Kern (1992) describes it, is not the desired outcome, but the *optimal* solution, and serves only as a reference point from which to set realistic goals, objectives and targets.** Thus, the vision is developed as the ideal but, most likely, unattainable condition for the stream.

The 'goal' is set relative to this vision or guiding image, and is the foundation of the project. It is an overall, broad statement of what is to be achieved once the rehabilitation work is finished. It describes the underlying motivation that will sustain the period of effort required to rehabilitate the river. A goal should have clear end-points, and should be inspiring. The latter is what draws involvement from communities and others. Rutherfurd et al. (2000a) present an amusing comparison of two goals from individual projects. The goal for the restoration of the Don River in Toronto, Canada was: '*The Don that we envision for the future is a revitalised river, flowing with life-sustaining water, through regenerated natural habitats and human communities. In its upper reaches the sparkling brooks and deep forest pools will flash with fish. Downstream in the older urbanised area of the city, the Don will ripple gently under shade trees, meander across its grassy plain, and merge into wetlands alive with waterfowl*". The authors comment that this inspired, if romantic goal, is to some extent measurable and achievable, even if only from an aesthetic perspective. It is compared with one such as this: '*After the project, the creek will be environmentally improved and attractive'*. This sort of goal is both uninspiring and impossible to measure.

The goal must clarify what the stakeholders want to achieve in the overall project. One may have also goals for different sections of the river, or for features of the river (e.g. the estuary). In a later step, the goal will have achievable objectives and measurable targets attached to it.

Step 2. Share the vision and goal

This step is a reminder that rehabilitation is one of many competing demands on a stream. The idea is to identify all of the interests in the stream catchment at this early stage, to avoid the situation that at an advanced stage of the project, efforts could be disrupted by the actions of a powerful group or developer. This step not only gets people involved but also gives the rehabilitation process some measure of protection.

The four sequential tasks are:

Sharing the goal: Task 1

Identification of individuals with interests in the stream (this will include land-owners, water users, authorities, water supply agencies, etc.)

Sharing the goal: Task 2

Identification of individuals who support and oppose the rehabilitation goals. Identification of relevant legislation and local regulations.

Sharing the goal: Task 3

Identification of individuals with the power to help or hinder the attainment of the goal.

Sharing the goal: Task 4

Decision as to how to increase support for the goal.

A database of these individuals should be kept.

Step 3. Describe the stream condition

This is the generic equivalent of Steps 3 and 4 '*Set Reference Conditions'* and '*Assess Resource Status*' in the SA Resource Directed Measures process (Section 5.3.5), and Step 8 '*Assessment*', in the SA Catchment Management Process (Section 5.6). This is discussed in Chapter 7.

This step is the equivalent of a preliminary assessment. The output of this is a statement of the present state of the river, how it has changed since settlement in the area, and how much it differs from the desired 'goal' state.

The level of detail required for this stage depends on the information available, the size of the project, and the cost of getting the information wrong. The work involved is time-consuming and requires input from both the community and specialists.

The information gathered is best compiled in report form, together with a series of annotated maps. This synthesis of information will form the basis for future decision making and planning. It serves as the baseline for the project.

The sequential tasks in this step are:

Assessment: Task 1

Divide the stream into segments and reaches.

This is the process of dividing the river length into manageable units on the basis of physical and biological criteria. This allows one to consider the catchment-scale effects on each unit – e.g. considering the inputs to or impacts on a stream longitudinally (from the upstream or downstream directions) and laterally (from riparian zone and beyond).

River segments are logical divisions of the river based on broad-scale parameters such as slope or catchment characteristics; sections along which there is no significant change in the imposed flow or sediment load (Wadeson and Rowntree 1994). In rehabilitation work, these are typically measured at the scale of kilometres.

River reaches are the basic stream rehabilitation units. These are typically measured at the scale of hundreds of metres, but can be up to several kilometres for the purposes of this work (Rutherfurd et al. 2000a). A reach is typically a length of stream (channel and riparian zone) within which the constraints on channel form are uniform, resulting in a characteristic geomorphic assemblage (Brierley 1999, Wadeson and Rowntree 1994). The reach can also be defined on the basis of definable flow and sediment regimes, bed material, characteristic instream biota, riparian vegetation, etc. Reaches may also be defined on the basis of point changes e.g. tributary junctions, point source outfalls, dams, etc., if these are important to the management objectives.

The catchment context of this reach-based approach can be accommodated by considering effects on the reach from: upstream sources, lateral sources (the riparian zone), and downstream (headward erosion, barriers to fish passage).

The rationale for the reach divisions should be recorded on a map, as indicated in Figure 4.1. Sources of inputs to and outputs from a stream reach should be identified on the map to provide a catchment context for the reach.

Figure 4.1. An example of a map indicating divisions of the stream section to be rehabilitated into segments and reaches (*from Rutherfurd et al. 2000 a*)

Assessment: Task 2

Construct a template of what the stream should look like (ideally in its pre-impact state).

Rutherfurd et al. (2000a) describe the construction of a template as a formalisation of the idea a stream manager, for example, has developed of what the stream *should* look like. The formalisation procedure is empirical and relies on the gathering of information and the checking of assumptions. Where, for example, one may have assumed that riffle-pool sequences would be the appropriate hydraulic habitat to reinstate in a river reach, investigations may reveal that naturally, only pools were present. The template is the equivalent of the reference state.

This step is the equivalent to the construction of a picture of 'natural' condition described by Larsen (1996) and Gippel (1999) and presented in Step 1. The template is referred to by Larsen and Gippel as the 'model image' or 'guiding image', and is not regarded as an endpoint, but rather, as the vision towards which to work, as it is unlikely in the majority of cases that this natural state will be achievable.

The template will be based on historical information (including aerial and topographical maps); investigation of remnant features remaining (with caution in scaling-up to stream size); reaches still in good condition; empirical approaches (e.g. comparison with data on other streams); and generic models on streams in good condition. Anecdote is another source of this information, although caution must be applied and 'stories' verified.

It may be possible to devise a sequence of images of the river associated with different periods on the basis of historical information (e.g. aerial photographs, remnant features remaining in the field, similar reaches still in good condition). Wherever possible, for these images, information on the following attributes should be collected:

- diversity and populations of animals and plants present;
- riparian vegetation structure, diversity, natural regeneration;
- flow regime: flow duration and magnitude, any regulation or water diversion;
- longitudinal connection along the river: artificial barriers to movement;
- lateral connections along the floodplain, and alterations to this (including levees, changes to flow regime, blocked flood channels);
- water quality;
- channel structural complexity and stability.

Kondolf and Larson (1995) recommend that historical changes in channel form (and the independent geomorphological variables of runoff and sediment load from the catchment) should be documented from a variety of sources, including historical maps, boundary lines, aerial photography, bridge and pipeline surveys, gauging records, field evidence and archival sources. Historical riparian vegetation can also be documented from early survey records and aerial photographs. These authors recommend that historical analysis should cover an area large enough to capture all events potentially influencing the project reach.

Collection of historic information will allow some estimation of the historic *rate and direction* of change in the system, and will clarify the extent to which change has occurred. Gippel (pers. comm.) reports instances in which the perception of 'extensive change to the system', for example the claim of excessive channel widening downstream of regulatory structures, has been proved erroneous or an exaggeration, as a result of thorough historical channel analysis. Much of the information search involves identifying and contacting the numerous, often 'hidden' or forgotten sources of information. Distributional records of fauna, previous studies on the river system, engineering drawings for infrastructure etc. may be decades old, and persistence is required in the process of seeking this information and constructing the model image.

Assessment: Task 3

Describe the present condition of the stream

This task is the generic equivalent of Step 4a of the South African Resource Directed Measures methodology (*Determine the 'Present Ecological Status' (PES) of the resource unit*, see Section 5.3.5). It requires the help of a team of river specialists. There are a number of methods available to assist with preliminary assessment of current river condition in Australia (Frame 4.2), however none of these should be assumed (in themselves) to provide sufficient information to develop a report on present state. Where possible, further expert surveys should be undertaken.

Frame 4.3 Some of the assessment techniques currently available in Australia.

The use of biological or ecological assessment techniques for broad-level evaluation of river condition is now common worldwide. A number of programmes have been launched and applied in various parts of Australia: some focus on a single river attribute (e.g. water quality), while others assess a number of elements relating to overall stream health. These techniques can be useful in the rehabilitation process if applied at the correct stages (assessment, prioritisation and evaluation). As the techniques can be generally be taught to capable individuals (though interpretation should be left in the hands of specialists), they are generally considered appropriate to incorporate into river rehabilitation projects. Formal accreditation for the various methodologies is presently under consideration (Integra et al 2000).

ISC

In Victoria, the holistic 'Index of Stream Condition' (ISC) (Ladson and White 1999) has been applied state-wide to assess the condition of rural streams. This index is a cumulative one and provides an idea of the extent to which there has been change from natural or ideal conditions. Five sub-indices and 17 indicators make up one cumulative index. The sub-indices are: hydrology (flow volume and seasonality); physical form (stream bank and bed condition, presence of physical habitat and access to it by organisms), streamside zone (quantity and quality of streamside vegetation, condition of billabongs), water quality (nutrient concentration, turbidity, salinity and acidity), and aquatic life (macroinvertebrate diversity) based on the AUSRIVAS methodology to acquire invertebrate information.

RIVER STYLES

Changes to the geomorphic template of a river has direct implications for the range and extent of available habitat in a river. The River Styles methodology of Brierley (1999) was developed out of the recognition that insufficient may be known of Australian river morphology and processes to manage them adequately. River Styles provides a biophysical template through which comparisons of river character, behaviour and condition can be made both within and between catchments. This provides a biophysical basis from which to evaluate and determine the most appropriate strategies for rehabilitation of river courses. The framework has three stages: a baseline survey of river character and behaviour; an assessment of river condition framed in terms of river evolution and recovery potential following disturbance; and prioritisation of management strategies for river rehabilitation and conservation. The last of these is a catchment-based assessment, based on the 'natural' character and behaviour of river styles, the condition of each river reach, and within-catchment linkage of biophysical processes.

RIVERCARE

The Rivercare method (Raine and Gardiner 1995) is based on the premise that the starting condition for stream rehabilitation is a stable, vegetated stream. Stream reaches are ranked using a traffic-light (red, yellow, green) on the basis of the state of their bankside vegetation and stability.

STATE OF THE RIVERS

The State of the Rivers approach (Anderson 1993), which has been applied mainly in Queensland, NSW and Western Australia, assesses the state of a river in terms of the physical and environmental condition of the river, on the basis of a characterisation of the whole stream network. Each site is assessed for channel and aquatic habitat, bank condition, bed and bar condition, and riparian and aquatic vegetation. Each variable is scored in relation to how closely it resembles original condition. The highest category (100%) represents pristine and the lowest (0%) highly degraded.

AUSRIVAS

This programme, set up within the National River Health Programme is geared to provide information on the water quality condition of Australian waterways using an index of aquatic macroinvertebrate sensitivity to coarse-level water quality deterioration (e.g. organic pollution).

During this step, information on the current state of the seven river attributes mentioned in Task 2 should be collected during specialist surveys. Information on species with high conservation importance or rarity status is required.

Assessment: Task 4

Produce a variety of annotated maps

The large quantity of data collected to this point in the various surveys is now synthesised and edited to produce a clear account of the important facts.

The explanatory text should be accompanied by a variety of annotated maps, for example:

- a planform map of the entire section of river to be rehabilitated, showing divisions into segments and reaches, with notes justifying these divisions;
- a similar planform map, annotated with information on 'natural state' and 'present state', relevant cross sections etc. (Figure 4.2);
- larger scale maps on key features within the individual reaches to be rehabilitated (see Figure 4.3).

Figure 4.2 Sketch map of a hypothetical stream for a restoration project. Showing placement of channel cross-sections and permanent end points, recording the location of benchmarks in distances and compass bearings from nearby landmarks, and showing location of fixed photo-stations (*from Kondolf and Micheli 1995*).

Figure 4.3 Cutout of a map of scour and vegetation along a stream (*from Larsen 1996*).

Step 4. Identify the assets and problems

The stream in its present condition is now compared to the 'template' (of the original condition) produced in Step 3, and an assessment is made to enable further planning.

Assets and Problems: Task 1

Identify environmental assets.

Wherever there is accordance between the present state and the template, that ecological or physical component of the river is termed an 'asset' (this referring to an environmental asset). Processes or planned developments that threaten assets must be identified. The trajectory of the asset should also be evaluated to establish whether the stream is moving away from or in the direction of its natural state (degrading or recovering) or stable. The rarity of the assets must also be identified to allocate relative value. This is necessary for the setting of priorities.

Assets and problems: Task 2

Identify present problems.

'Problems' are those processes or activities which are threatening or impacting on present assets. This is the equivalent to identifying the causes of current degradation of assets. An investigation into land-use in the catchment can assist in this process. The practitioner's or specialist's knowledge and experience should be drawn upon in finding clues to causes.

Present distribution of organisms may also be of assistance. Four errors are possible in identification of cause: mistaking a natural attribute for a problem, failing to recognise that a 'problem' may be part of a natural recovery process, identifying issues which may be typically be considered problems but are not actually threatening to the fauna and flora of the stream, and identifying the wrong problem. The literature on rehabilitation abounds with examples of these sorts of errors.

Assets and problems: Task 3

Determine the trajectory of the assets and problems.

This is a complex step, and an understanding of natural recovery processes in streams is necessary to accurately determine whether a stream is in a state of recovery (moving towards a dynamic equilibrium), maintaining state, or deteriorating. The decision as to where the system lies along the recovery trajectory is important as it will inform decisions regarding what interventions are required to arrest deterioriation, protect assets, or speed recovery of assets, and will assist in identification of areas in which no action is necessary at all. Questions which need investigation include: How the asset has changed or been anthropogenically altered over time, whether the problem is likely to change in the future (i.e. what the typical ecosystem response to this problem is over time), and how assets would respond to problems which are stable.

Assets and Problems: Task 4

Map the assets and problems.

Summaries of assets and problems may be superimposed on the maps already produced.

Step 5: Setting Priorities

This section is a follow-on to the principles on which prioritisation is based (Section 4.5).

Setting Priorities: Task 1

Assign reaches to one of the nine categories presented in Table 4.1, Section 4.5.

Reaches are assigned to one of the nine categories on the basis of rarity, general condition, trajectory, and ease. With the information already acquired this should be possible.

Setting Priorities: Task 2

Rank reaches that are in the same category.

Where more than one reach falls into a single category, they are ranked on the same basis as above (rarity, condition, trajectory, and ease).

Setting Priorities: Task 3

Query and check the reach priority rankings.

Here, reasons other than ecological value are brought into consideration in the prioritisation process. Rankings may be changed on the basis of the importance of a particular reach in terms of its place in the life of a community, its proximity to other urban features, or the fact that it supports an animal with great public appeal (e.g. the Platypus, in Australia). This is where the 'science' of rehabilitation meets the 'society' of rehabilitation. It is obviously important that costs of rehabilitation are taken into account in adjusting priorities and rankings. In the case of an upstream reach being rehabilitated, it is considered best to work from upstream to downstream in rehabilitation implementation (Larsen 1996). This may be another reason for adjusting priorities. It is also necessary to consider the areas through or into which a river is flowing, as a possible further reason for raising the priority of a section of river for improvement.

Setting Priorities: Task 4

Setting problem priorities.

Prioritising which problems to address first may be complex. Causes of degradation need to be set into a hierarchy, from **fatal** problems (which are extreme and may exclude fauna or flora from a reach) to **limiting** problems (considered stressors to the expected species distribution) to **nuisance** problems (which have a minor effect on the biotic community). The interactions between different degradation factors may mean that improvement in one area causes an improvement in another.

Setting Priorities: Task 5

Check for other limiting problems.

Rutherfurd et al. (2000a) define a limiting problem as one that most severely affects an asset. If this problem persists, the aspect/s of the stream targeted by the rehabilitation is/are unlikely to recover, even if other problems are remediated.

It is necessary to identify linkages between problems. This may either be in a hierarchical fashion, such that one problem is fatal and the next limiting, or a direct relationship, such that one problem results from another. Understanding these linkages is important to ensure that problems are not solved in the wrong order.

Priorities: Task 6

Exceptions to the problem priorities: Optimising the costs.

There may be reasons to prioritise problems that are not considered fatal or limiting. In the long run this may also result in good value for money.

Where large reaches are damaged: Where the costs are equivalent, it can be more beneficial to fix a longer reach of stream than to attend to smaller scale, site-specific works.
Long-term perspective: Where rehabilitative actions are likely to take several years to take effect, such as the reinstatement of riparian vegetation (10 years in drier regions), it may be wise to initiate the recovery process sooner rather than later.
Community support: Once again a higher priority may be accorded to reaches in circumstances where the influence would be good on the community, or would improve the visibility of the stream area..

Setting Priorities: Task 7

Check if some reaches should have more than one rank.

The majority of reaches are likely to have multiple problems, and may have a number of assets to protect. In these cases, the recommended course of action is to protect the assets in this reach and then to move on to protect assets in other reaches before attending to degradation in the first reach. This first reach can be re-classified in terms of its priority, by comparing it with all other reaches, assuming that the quality reaches have been protected. The same reach may thus initially be a Category 1 (Regional Conservation Value) and, following remedial actions, be allocated to Category 4 (Expand Good Reaches).

Step 6: Strategies to protect assets and improve the stream

In this step, general strategies are identified for:

- the protection of environmental assets and/or the prevention of degradation;
- the improvement of environmental assets;
- fixing present problems.

These could involve changing stream processes by changing inputs to the stream. The strategies developed here will be transformed into objectives in the following step. It is recommended that as much effort is put into developing strategies to *protect* the stream as into attending to degradation of assets.

Strategies for changing human behaviours are also important and include providing education and motivation to prevent individuals from causing loss to biodiversity or degradation in streams; legislation and regulation (e.g. permitting certain actions), education about what to plant in the riparian zone, and how to reduce urban impacts on streams.

At the end of this step the following should have been completed: the ranking of reaches in order of priorities, with identification of major assets and potential assets in each reach; the identification of potential problems for each asset; and a list of strategies for reducing the impacts of these problems, and for enhancing or improving river protection. The continuation of this process is the setting of attainable objectives.

Step 7: Setting specific, measurable objectives

A common lesson from rehabilitation exercises around the world is that insufficient attention has been paid to the setting of objectives and the subsequent evaluation of whether or not these have been met. Without these two steps, rehabilitation projects proceed in an ad-hoc fashion towards uncertain outcomes, and, amongst other things, this approach does not justify the money spent.

Objectives are considered the specific aims of the project, and are seen as steps along the route to achieving the holistic 'goal' of stream rehabilitation as discussed in Steps 1and 2.

It may take a long time to develop these goals, and the basis for them may vary from project to project. In the Baylands Ecosystem Project in San Fransisco Bay, for example, project participants were to develop habitat goals only after assembling and analysing many kinds of data about the Baylands, and worked together for almost two years before they began making recommendations for habitat improvement goals (Goals Project 1999). When they did, they acknowledged that, although it had been required that the goals be based on best available science, *'the goals were not developed through experimental testing of scientific hypotheses – the data were too thin for this approach. Rather, the goals were developed using the best available data, reasonable inference based on these data, and the collective best professional judgement of the regional community of environmental scientists and managers'* (Goals Project 1999).

The process of setting objectives allows the practitioner/s to determine what they would consider a successful outcome of the rehabilitation. The process also forces the scope and scale to be defined for the project: what proportion of the reach will be treated, whether the present problems are to be fixed or simply reduced in severity, what are the acceptable timescales for response, etc. It becomes clear during this process which objectives are not compatible. Evaluation of project effectiveness can only be carried out if prior to the implementation being undertaken, measurable objectives attached to time periods were set (Kondolf 1995).

Setting Objectives: Task 1

Defining the extent of change desired.

It is important to state what a rehabilitation project is aiming to achieve. This will either take the form of absolute statements regarding improvement (e.g. 'sewage will no longer be discharged into the river') or may be expressed in terms of a range of acceptable outcomes, where one end of the range represents the best possible outcome, and the other end the smallest useful improvement (e.g. 'sewage discharges into the river will be reduced by a minimum of 20% and a maximum of 75% within five years'). Objectives may be also be stated in terms of maintenance. For example, when protecting an existing asset, the objective would be 'that the condition does not deteriorate'.

Setting Objectives: Task 2

Defining the spatial scope of the objective.

The spatial scope of the project is dependent on the problem being treated, the cost of the treatment, and the length of river requiring treatment in order to get a response.

Setting Objectives: Task 3

Setting the time frame.

Sufficient time must be allocated for the stream to respond to the rehabilitation actions. However, the timeframe that is set needs to be short enough to maintain the interest of those involved in the project. The manual suggests that one means of achieving this is to couch the objectives in terms of two time frames – one for the completion of the rehabilitation treatment (**output**), which is a short term objective, and another for the evaluation of the treatment (**outcomes**), which is a longer term objective, in the order of a number of years.

Setting Objectives: Task 4

Determining the type of objective.

Objectives may be framed in terms of output, as in Task 3, as long as there is some confidence that the desired outcome will follow. It is preferable to include objectives for both output and outcome.

Five general types of objective are recommended:

Output/outcome	**Type of objective**
Output	Execution of the project and treatment/s
Output	Survival of the project and treatment/s
Outcome	Aesthetics of the stream
Outcome	Physical condition of the stream
Outcome	Improvement or maintenance of ecological function and processes

It is also possible to follow an approach along the lines of the 'Objectives Hierarchy' of Rogers and Bestbier (1997) in the objectives-setting process. This protocol, described in Frame 4.4, is one of three in the '*Protocol for the definition of desired states of riverine systems in South Africa*' (Rogers and Bestbier 1997), in which three fundamental principles are recommended in the planning process: (i) forward planning, (ii) setting acceptable and achievable targets, (iii) accountability.

Frame 4.4 A brief description of the Objectives Hierarchy (*from Rogers and Bestbier 1999*).

> *''This is a protocol for the development of an Objectives Hierarchy. The hierarchy begins at the coarsest level with the organisation's "vision" for management. The protocol provides a step-by-step process for decomposing the vision into a series of "objectives" of increasing focus, rigour and achievability. The finest level of the hierarchy is defined by achievable goals* which may be either "institutional goals" or "conservation goals". Institutional goals define achievable targets for managing institutional structures and processes. Conservation goals define endpoints for ecosystem management. The higher level vision and objectives serve upper management levels with statements of strategic intent, while the low level goals provide on-the-ground managers with specific, spatially and temporally bounded, targets. These targets are termed Thresholds of Potential Concern and act as amber lights to warn managers of possible unacceptable environmental change."*

*Note that the term 'objective' is used in a similar sense by Rutherfurd et al. 2000a, however the use of the term 'goal' differs. The principle is however what is of importance. Terms relating to end points should be clearly defined at the outset of a project and should retain those definitions.

These statements of strategic intent incorporate temporal, spatial and resources limits (termed 'Thresholds of Probable Concern' or TPCs) and are, in the words of Koehn and Cant (1999), 'unequivocally achievable'.

Step 8: Checking the feasibility of objectives

Feasibility: Task 1

Is it affordable?

The costs of getting a stream rehabilitation project mobilised are often overlooked, while attention is focussed on the cost of implementation of management actions.

Planning Costs: In order to get the information and assistance required in the early phases of the project, specialists are required during the planning phase. Consultancy fees in Australia were estimated at AUS$500-$1500 per day in 1999 (Rutherfurd et al. 2000a).

Information Costs: The cost of items which are required in the early phases of the project, e.g. aerial photographs.

Establishment Costs: This includes the cost of getting the project established. If land purchases are required, or heavy machinery is to be used on site, the establishment costs could account for a large percentage of the total budget.

Compensation to other stream users: It may be possible (in Australia) to fence out and revegetate stream frontage if compensation is paid for channel watering-points for stock.

Post-project costs:
- **Maintenance:** all construction work (particularly if bio-engineering approaches have been followed) needs to be maintained.
- **Evaluation:** A detailed evaluation programme can cost more than the project itself. This includes costs of monitoring and measurement.

Other costs: These include vandalism and the unexpected consequences of the project

Feasibility: Task 2

Is it legal? What are the legislative and administrative constraints?

At the outset, it is necessary to be aware of the multiplicity of laws and regulations controlling what can and cannot be done in and around rivers. It is worth spending some time investigating and compiling a database or report of the relevant controls, particularly in the metropolitan context, where several authorities or service providers may have intersecting jurisdictions (e.g. roads, planning, stormwater control).

Feasibility: Task 3

Is it worth doing? (Do negative effects outweigh positive ones?)

This step provides assurance that the positive effects of the project will outweigh the negative ones. To maintain public support, outcomes need to be (in the balance) positive, and non-threatening. If the outcome of environmental ‘enhancement’ measures is unintentionally negative, such as flooding or erosion, public support for stream rehabilitation will dwindle. It is worth placing some assurance on the positive outcomes of the project, and calculating the chance (and extent) of possible 'negative' effects, and then checking the balance between the two. The latter may not be negative in an environmental sense, but rather in terms of public perception (e.g. the return of frequent small floods). Education focussed on the compromise between environmental needs and human needs would also assist in sustaining public support.

Key questions are listed as:
- whether the intended treatments would cause erosion or deposition;
- whether actions may influence flood height or duration;
- whether the option would affect the performance of hydraulic structures (for example, the installation of a fish ladder could compromise the performance of a weir); if so in what way, and how does one compensate for this;
- whether the option would affect the current practices of riparian landholders;
- whether and in what way/s the option affects the recreational uses of the stream;
- whether the option will affect other uses of the stream (e.g. water use, use as a drain or sewer) and how to compensate for this.

Rutherfurd et al. (2000a) provide numerous examples of stream rehabilitation plans doing more harm than good to the ecosystems in question.

Feasibility: Task 4

How much confidence do you have that it will work?

This issue relates also to balancing costs, risks and outcomes in rehabilitation. The more the project is going to cost, the greater the confidence required in the outcome (i.e. the lower the risk). Risk assessment procedures can be used here.

Feasibility: Task 5

Weigh up the feasibility.

The issues already covered in this step should have determined the cost-effectiveness, cost-benefit relationship, and any legal constraints on the project, as well as the affordability of attaining objectives. If feasibility is still a questioned on the basis of any of the aforementioned, Rutherfurd et al. (2000a) provide three options:

- **Compromise:** this will involve modification of objectives to tailor the project (where appropriate) to legal requirements, costs, and community requirements.
- **Do a trial run**: where outcomes are uncertain, it may be possible to run a low-cost pilot trial of the treatments planned, both to estimate effects and to harness further public interest and support.
- **Recognise absolute ('terminal') unfeasibility**: There may be scenarios where the potential negative effects outweigh benefits, or where legal constraints disallow the key rehabilitation actions. In certain instances it must be recognised that halting the project at this point is necessary.

Step 9: Detailed project design

This step is concerned with the detailed design of the structures to be built or actions to be taken. Basic principles related to changing the physical character of the stream are presented.

Longevity of the Strategy
Sound rehabilitation measures should still be effective in the stream decades after implementation. However, initially dramatic improvements may pale over time. A number of possible reasons, and guidelines to prevent this, follow:

- **The design should enhance natural recovery.** Case studies have shown the benefit of assisting the recovery of the stream, rather than attempting to recreate a 'natural' stream environment, which is considered the equivalent of '*cajoling the stream into a desirable, equilibrium form*' (Rutherfurd et al. 2000a).

- **Rehabilitation effects should outlast structures:** Where structural work is required in the river, the rehabilitation measures accompanying these should outlast the structures which have a finite lifespan. Bio-engineering approaches should be used for structures, where possible. Where a structure can be combined with natural measures to ensure the sustainability of the effect (e.g. planting trees on the sediment bar which forms downstream of a groyne to preserve channel alignment even once the groyne structure has gone).

- **Treat reaches and not points:** The reach should be treated as a whole, rather than a few isolated points within the reach.

- **External factors may jeopardise structures:** This concerns problems that continue after rehabilitation, such as ongoing coarse sediment loading, which can cover in-channel structures within a short space of time.

The Inclusion of Vegetation
The majority of rehabilitation works should include some form of revegetation**.** Vegetation can assist in stabilising channel beds and banks, protecting streamsides, providing shading and providing valuable habitat.

The Threats to the Project
- **Cost of failure**: The cost of designing and building a structure should be approximately proportional to the consequences of its failure. Where failure of a structure is likely to have severe costs or consequences, professional design and construction advice is advised.
- **Major nearby assets:** Note should be taken of any nearby assets which could be affected in the event of a failed rehabilitation attempt.
- **Value of biological communities being protected:** How will the project help rare, sensitive, or endangered communities, and what are the costs of failing to achieve this.
- **Potential causes of failure:** It is important in the planning stages to consider the worst possible scenarios for failure, and to assess the likelihood and acceptability of each scenario. These should be investigated upstream and downstream of planned treatments. Examples of upstream causes could be sand slugs burying the work, high debris loads which may get caught in a structure, increasing the hydraulic load and resulting in failure during flooding. Other structures in the

stream and their functioning or impeded function may provide clues as to potential causes of failure. Threats of vandalism and theft of imposed structures should be considered.

- **The threat of floods or droughts:** It is important that managers accept this risk at the outset. The flood size/s the instream works are designed and expected to survive should also be specified. Loss of the structure in a flood larger than this then does not constitute failure. Long periods of low flow or drought can also lead to failure of particular rehabilitation measures (e.g. through loss of vegetation).
- **The unexpected at high flows:** Instream structures must withstand the force of water, at least of the design flood specified. Unexpected changes may occur to the structure, for example, a permeable structure which traps flood debris may become impermeable.

The Right Tools

- **Repeated use of the same design:** The example is cited of a single type of structure being installed repeatedly through a stream system, and all failing for similar reasons. The recommended approach is to tailor the structures to the streams, and where possible to use a variety of structures.
- **The right tool for the stream in question:** Structural approaches that have worked in one stream may not work in another. Before adopting a technique which has been successful elsewhere, one should query whether the stream differs, in terms of: fauna, vegetation, sediment load, bed and bank material type, erosive potential of streambanks, stream power and size, history of disturbance and river management, or hydrology.
- **Check the approach:** Small pilot trials may allow the relative merits of different approaches to be assessed.

Step 10: Evaluation of the project

It is often assumed that restoration and rehabilitation projects will, by definition, have beneficial effects. Kondolf (1995) commented that of the aquatic habitat enhancement projects evaluated to that date, the large proportion were found to have failed outright or to have been ineffective (Frissell and Nawa 1992, O'Neil and Fitch 1992 are referenced). If evaluation had been included in projects as a standard measure, causes of failure or ineffectiveness could be investigated, practitioners would have learnt from mistakes (and passed this learning on), and similar mistakes could be prevented in other projects.

Rehabilitation is a young discipline, and, as Rutherfurd et al. (2000a) point out, '*an uncertain business*'. Post-project evaluation is essential if river rehabilitation is to advance as a field. It is the best means of increasing confidence in current processes, and researching and developing better techniques. Evaluation ensures that both practitioners and the public are informed whether or not objectives of a project have been met.

Kondolf and Micheli (1995) suggest that with the limited present level of knowledge, every stream rehabilitation project should be considered an experiment. This would reduce the pressure for 'success at all costs', and increase the pressure for evaluation. As Rutherfurd et al. (2000) comment, we can learn more from failure than from success.

Evaluation is uncommon for simple reasons: complex natural systems can be slow to respond to rehabilitative actions and the evaluation procedure is costly and time-consuming. Funders may not want to wait several years to receive news of the success of a project; and in some cases funding has been restricted to the implementation phases only (Kondolf 1995).

Evaluation: Task 1

Define the type of measurable objective

Measurable objectives should have been set for the rehabilitation programme during Step 7. These are reiterated at this stage. An evaluation can measure **outputs** (what was done) **or outcomes** (change that occurred as a result of rehabilitative actions). The types of stream rehabilitation objectives are presented in Table 4.2.

Table 4.2 Types of stream rehabilitation objectives, together with information on the evaluation of each (*from Rutherfurd et al. 2000*a)

OBJECTIVE TYPE *(& associated evaluation timescale)*	**GENERIC OBJECTIVES** & description of evaluation
Type 1: Project Execution (outputs) *(Evaluate within a year of completion)*	**To successfully complete the plan of works.** This is an evaluation of whether the project has achieved its stated objectives, whether planned actions and constructions are complete, etc.
Type 2: Project Survival (outputs) (*Evaluate up to five years after completion)*	**To install works that will withstand expected natural events**. This evaluation checks (over a period of time) whether structures installed in the river as part of a treatment have survived events such as floods, and are still present and functioning optimally.
Type 3: Aesthetic outcomes *(Evaluate up to six to seven years after completion)*	**To produce a more attractive environment.** **To promote recreational use.** This evaluation checks, on the basis of a visual (photographic or video) record, the aesthetic changes to the stream and is considered a minimum requirement for this level evaluation. Fixed photo points in the treatment areas are essential.
Type 4: Physical/chemical outcomes *(Evaluate up to eight years after completion)*	**To improve habitat by increasing physical and hydraulic diversity.** The physical attributes of the stream are easier to measure than the biota. There is the common assumption that if the physical change is successful, ecological change will follow. Parameters to be measured or assessed include channel morphology, bed sediments, flow types and patterns of depth, velocity and shear stress, and water quality variables such as turbidity, temperature and salinity.
Type 5: Ecological outcomes *(Evaluate up to ten years after completion)*	**To improve the population size, diversity and sustainability of plant and animal communities.** The core of this level of evaluation is the collection and identification of aquatic plants and biota to an appropriate taxonomic level; measurement of changes in diversity and abundance of various groups; recording the presence of different life cycle stages; and looking for differences in the behaviour of animals.

Evaluation: Task 2

Select one of five levels of evaluation (Table 4.3).

There are a number of different levels of evaluation, and the appropriate one should be selected at the start of the project. The type of evaluation selected will depend on the level of confidence in the outcome of the project; how big an effect would be considered a success; who is to be convinced with the evaluation (e.g. public, authorities, public); and how much time and money is available for the task.

Table 4.3 Levels of evaluation (*from Rutherfurd et al. 2000a*)

Level of Evaluation	Description
Level 1	Unreplicated, uncontrolled, anecdotal observation after rehabilitation
Level 2	Unreplicated, uncontrolled, sampling after rehabilitation
Level 3	Unreplicated, uncontrolled sampling before and after rehabilitation, OR Unreplicated, controlled sampling after rehabilitation
Level 4	Unreplicated, controlled, sampling before and after rehabilitation
Level 5	Replicated sampling, replicated controls, sampling before and after rehabilitation

In this approach, Level 5 represents a full, detailed scientific study, which may cost as much, if not more, than the project itself. Rutherfurd et al. (2000a) comment that most stream rehabilitation work in Australia is currently evaluated to Level 1 or 2, if at all.

Evaluation: Task 3

Design the evaluation plan.

The spatial and temporal variation intrinsic in natural systems makes experimental design critical to successful evaluation of a project. Sampling is then a matter of following predetermined procedures.

The evaluation plan will incorporate a number of features. The plan must be designed well before the rehabilitation actions are implemented, such that pre-rehabilitation (baseline) monitoring can be undertaken to provide a 'reference' state to evaluate against. The issues to consider in the design of the evaluation are those one would typically consider in a monitoring-type exercise:

- what should be measured and why;
- when it should be measured;
- with what frequency and over what period it should be measured;
- how long the evaluation is required to last;
- who will take the measurements;
- how results will be recorded;
- how data will be analysed (what statistics will be used, if any);
- how data will be interpreted and assessed, and by whom;
- how this interpretation will be translated into useful information.

Step 11: Planning and implementation

This step involves the scheduling and implementation of the solutions and strategies involved in the rehabilitation approach. This is, essentially, the 'project management' step for the implementation phase. Scheduling must allow for a logical 'flow' of work in each area, with some tasks being carried out simultaneously. Costing and budgeting of the implementation phase must account for all of the costs, including specialist input, travel, planning, and implementation of actions.

Implementation: Task 1

Divide the project into Tasks or Actions.

Each of the strategies identified in Step 9 is broken down into a series of tasks, each of which is considered a 'deliverable' of the project. Large projects may need to first be divided into sub-projects and then into individual tasks and actions. The aim is to ensure that each task is simple enough for its duration and cost to be estimated.

Implementation: Task 2

Consider the order in which Actions should be completed.

Before planning the sequence of jobs, check that there are no other actions to be completed before beginning with the jobs. For instance, it is best to finish with the earth-moving machinery before trying to begin planting vegetation.

Identify which jobs have to be done and ensure that permission has been granted to do so. If there are a number of tasks that can be done simultaneously, plan for this.

The production of time management charts with datelines for each task is considered good practice. Software such as Microsoft Office can be used to generate Gantt Charts. Identify where there may be milestones to tick off – e.g. completion of sub-projects.

Implementation: Task 3

Decision as to who will undertake the Actions.

The names of key individuals involved in the project need to be recorded. It is preferable to assign tasks to one or several individuals who will take responsibility for the implementation of that task. Contractors who have any relevant and adequate experience will be valuable to the project. Where this sort of contractor is not available, it is essential that time is spent explaining how this job differs from a normal construction-type job; that explicit instructions are given; and that expert supervision is present on site. Community participants should be assigned tasks that are within their capacity. This may include their taking responsibility for the long-term survival of works.

Step 12: Project evaluation

This is the step at which an assessment is made of whether or not a project was a success, and if not, why. It is the final stage of the evaluation procedure for the project. This is a critical step and includes reporting experiences and transferring learning both to other projects and to the field of rehabilitation as a whole.

To assess the project, a definite endpoint, attached to a time limit for the project, is required. The final analysis of the project is again based on the question of whether or not the objectives set for the project were achieved.

Success and failure should only be small parts of the final assessment. The important questions are what caused the success or failure. In the case of the former, is this repeatable or transferable? In the case of the latter, is this catchment-specific failure or does the technique and approach require further consideration? Was the failure caused by unrealistic objectives?

Where project outputs have not been successful, design, construction and appropriateness may be causes to investigate. Human interference in the form of vandalism may be another causative agent. Weather conditions and extreme events play a huge role in determining the success or failure of rehabilitation works.

If the outputs of the project have failed, successful outcomes are not likely to materialise. Where outputs have been successful, outcomes are still contingent on weather, design issues, and possibly even the evaluation.

Results of stream rehabilitation projects need to be published in an accessible, open forum, to pass on experience and learning. The wider the audience targeted the better.

4.7 SUMMARY

The foundations of sound rehabilitation practice are the principles upon which it is based, and the processes followed to plan, implement and evaluate the project. The principles and processes presented in this chapter have been largely non-technical by nature, as this is considered the primary and most urgent need in South African rehabilitation projects, and makes the material accessible to a wider audience. At this level it becomes obvious to anyone familiar with the SA Department of Water Affairs and Forestry's Resource Directed Measures (Chapter 5), that the majority of the principles and processes recommended are already well known and applied in the RDM process. It is the extension of the RDM into a full rehabilitation effort which is lacking, as discussed in Chapter 7.

The introduction of this chapter provided an explanation of the manner in which fundamental principles generally emerge in a new field: often from practical project experiences, successes and failures; best-available knowledge, creative thinking and research results. This gave rise to a short discussion of an important contemporary matter in Australia: the linking of scientific experiments to rehabilitation, following the principles of Adaptive or Experimental Management.

The current issues receiving attention in river rehabilitation were presented briefly. These are the problems commonly discussed in both Australian and other international literature, and include such issues as the scale at which projects are undertaken, and the common lack of planning and evaluation in projects. Measures have been taken to address the majority of these shortcomings, and some of the approaches adopted provide us with first-level principles. A general set of principles for rehabilitation was presented, followed by a set of emergent biophysical principles. For each element of the physical stream system (channel, banks, riparian zone, water quality, geomorphology), typical post-settlement impacts were tabulated, together with associated impacts and rehabilitation or remediation approaches. The need for prioritisation in rehabilitation was discussed, and a set of principles for priorisation criteria presented.

The 12-step rehabilitation planning process summarised in the following section was developed by Rutherfurd et al. (2000a) for the rehabilitation of Australian Streams. A description of each step, and the further tasks within each step were presented. It is noteworthy that one of these steps may take several months or years to complete, even with specialist input. That this process may have appeared ‘rapid’ is misleading. The scientific input and output required is extensive, and the community participation processes may be slow.

The descriptions of principles and processes provided in this chapter should have provided a guideline to what is currently considered best practice in rehabilitation in Australia. Although not all the **principles** may be appropriate to South African river systems, because as these **processes** are generic, they are transferable.

The following chapter provides summaries of current initiatives and water resource management methodologies in South Africa. Chapter 7 encourages a further investigation of the links between the rehabilitation processes presented in this chapter, and the generic Resource Directed Measures’ process in use in South Africa.

PART 3: SOUTH AFRICA

CHAPTER 5

WATER RESOURCE MANAGEMENT

5.1 THE BIOPHYSICAL CONTEXT

Water is a limiting resource in South Africa. With an annual average rainfall of 460mm, well below the world average of 800mm, large parts of the country are classified as semi-arid or arid. The MAR:MAP ratio is in the order of 8.6% which is similar to Australia's 9.7% but a fraction of Canada's 97% (Davies and Day 1998).

The hydrology of South African rivers is, similar to that of Australian rivers, characterised by extreme variability and unpredictability, and a high coefficient of variability (Davies and Day 1998). Perennial rivers occur over only approximately a quarter of South Africa's land surface, mainly in the southern and south-western Cape and on the eastern plateau slopes (van der Merwe 1994). Of the approximately 65 000 km of river length in South Africa, Davies and Day (1998) estimate that perhaps 40% (26 000 km) are subject to natural interruptions of flow. Temporary rivers range from rivers with intermittent flow to ephemeral or episodic, event-driven systems (e.g. Uys and O'Keeffe 1996).

The pressure on the resource in a water-scarce county is extreme from a population perspective, relative to Australia. Recent census figures estimated a population of approximately 37.9 million (Central Statistical Services 1997), unevenly distributed over a land surface of approximately 27 000 km^2. This in contrast to Australia's estimated population of 18.4 million, unevenly distributed over a land mass of 1.2 million km^2.

Addressing water needs has required the development of numerous impoundments and inter-basin transfers, with the result that the majority of the country's rivers have been altered extensively: in many cases previously perennial flow regimes have been modified to a temporary, or vice versa.

In the drier areas of South Africa, desertification is considered an ongoing threat (Jordan 1997), and this together with water scarcity has led to predictions of serious water supply problems by 2020, and predictions that severe regional conflicts will arise over the use of water. The major management issues relate to water supply, water quality, water delivery, and the provision of sanitation to a widely distributed population.

Schumm (1960) recognised two distinct types of river channel: bedrock controlled channels, and alluvial channels free to adjust their dimensions, shape, pattern and gradient in response to changes in discharge and type of sediment load. South African rivers exhibit a composite structure that is largely bedrock influenced. Within the composite channel structure, the macro-channel is large enough to hold extreme floods. Within the macro channel is a complex of channels, some alluvial and some bedrock-dominated, which carry the lower magnitude flows. As with typical semi-arid river systems, hydrology is often dominated by more extreme flow regimes, influenced by high magnitude, low frequency flow events, which are considered to be the most important discharges in terms of influencing channel morphology (Birkhead et al. 2000).

5.2 THE WATER REFORM PROCESS

The democratisation of South Africa in 1994 established the primacy of issues relating to fair and equitable access to resources, chiefly land and water. There was a growing recognition that new approaches to water management were required to meet water demands and to recognise the intensifying impacts on the resource.

At the time of the appointment of the new Minister of Water Affairs and Forestry in 1994, more than 16 million South Africans did not have reasonable access to safe drinking water, and some 20 million lacked access to safe sanitation. The Minister appointed a team of experts in the fields of policy, law, strategic resource management and aquatic ecology to guide a water reform process under the banner of 'Water for all, for ever'. The team embarked on an intensive process of consultative law reform, pioneering major changes which were anchored in human rights, social justice and environmental sustainability.

By 1998, three new policies and four new laws provided the new mandate for the Department of Water Affairs and Forestry's key functions and activities:

Water Supply and Sanitation Policy (White Paper, November 1994)
Policy on Sustainable Forest Development in South Africa (White Paper, March 1996)
National Water Policy for South Africa (White Paper, April 1997)
Water Services Act (No 108 of 1997)
National Water Act (No 36 of 1998) (NWA)
National Forests Act (No 84 of 1998)
National Veld and Forest Fire Act (No 101 of 1998).

The new Minister had also instituted far-reaching initiatives such as the Working for Water Programme (described in Chapter 6), Community Water Supply and Sanitation Programme and National Water Conservation Campaign.

5.2.1 The National Water Act, Classification & the Reserve

With input from D. Louw (pers. comm. 2001)

The National Water Act (NWA) is based on the key principles of sustainability and equity. In terms of the Act, the National Government, acting through the Minister of the Department of Water Affairs and Forestry (DWAF), became the public trustee of the country's water resources. To ensure sustainability, DWAF was mandated to '*ensure that South Africa's water resources are protected, used, developed, conserved, managed and controlled in a sustainable and equitable manner, for the benefit of all persons*'. The Minister was assigned the power to regulate the use, flow and control of all water.

One of the key provisions of the Water Law Principles and the National Water Act (NWA) is the recognition of the water resource base and the necessity to afford it protection. This is formalised in the 'Reserve' concept, embedded in both the founding Principles of the Act and the Act itself. The definition of the Reserve is*: 'that quantity and quality of water required: i) to satisfy basic human needs for all people who are, or who may be, supplied from the relevant water resource, and ii) to protect aquatic ecosystems in order to secure ecologically sustainable development and use of the relevant water resource'* (DWAF 1999). The Reserve is thus defined in terms of the quality, quantity and assurance of water. The water for human needs is known as the **Human Reserve** (quality and quantity), and that for environmental needs is known as the **Ecological Reserve** (quality and quantity).

The introduction of the Reserve concept implies that the economic use of water (i.e. those funds received for water use) subsidises the non-economic uses. With respect to the latter, the NWA also takes cognisance of South Africa's duty to ensure that neighbouring states have an equitable portion of water from shared rivers.

Resource protection is to be achieved through the implementation of the Ecological Reserve (the determination of which is described in Section 5.3.4). However, since different levels of resource use, resource protection and ecosystem health are possible, it is necessary to classify each water resource for which the Reserve is to be determined (Louw, pers. comm. 2001). The NWA describes, in Chapter 3 (Protection of Water Resources), how resource protection must be achieved by the establishment of a system for classification of water resources (*resource classification*); as well as the determination of: the class of significant water resources; resource quality objectives (water quality, quantity, habitat and biotic integrity); and the Reserve.

The classification system should not be confused with a system that attempts to group similar physical river types. This system rather describes different levels of ecosystem health. From these levels, tolerable degrees of risk to ecosystem health, and levels of acceptable use of the resource, can be determined. The volume and quality of water allocated to the Ecological Reserve therefore depends on the level of classification (Louw, pers. comm. 2001).

Classification is explained as follows:

From the White Paper on a National Water Policy for SA (Department of Water Affairs and Forestry, April 1997).

6.3.3. Resource Protection

A national resource protection classification system will be introduced. Through a process of consensus-seeking among water users and other stakeholders, the level of protection for a resource will be decided by setting objectives for each aspect of the Reserve (water quality, water quantity and assurance, habitat structure, and living organisms). The objectives for each aspect of the Reserve will show what degree of change or impact is considered acceptable and unlikely to damage a water resource beyond repair. Resources will be grouped into a number of protection classes, with each class representing a certain level of protection. Where a high level of protection is required, the objectives will be strict, demanding a low risk of damage and the use of great caution. In other cases , the need for short to medium term use may be more pressing and the need for protection lower. Some resources may already need action to restore them to a healthy state, and, in future, no resources should be allowed to become irreversibly degraded.

The classification will derive clear rules (on the basis of quality classes) for:
- the protection of basic human needs;
- the protection of aquatic ecosystems; and,
- water user requirements.

Classification and the Reserve-determination are separate processes, strongly linked in the RDM. The classification system, which will be used to assign the river resources into Management Classes, is still in the process of development. The Management Class will consist of various components, each in a category of its own, e.g. ecology, domestic use, recreation, agriculture. The ecological component (Ecological Reserve Category or ERC, term potentially still to be changed) is a technical recommendation to DWAF and represents an integration of a number of specialist assessments (Present Ecological State, Ecological Importance and Sensitivity, Trajectory of Change, etc).

5.3 THE IMPLEMENTATION OF NEW LEGISLATION

The process of implementing the NWA was divided into three phases:

1. An initial phase of preparation to ensure that the key procedures were in place by the time the Act came into effect;
2. A transitional phase of three to five years during which transitional tools and procedures would be subject to trial and refinement, leading to the development of a final suite of methods for the implementation of the Act;
3. The implementation phase of five to ten years following the legislation of the Act, when full-scale implementation would be undertaken in selected areas or catchments around South Africa (DWAF 1999).

The implementation involved the use of four types of regulatory activities (DWAF 1999):

1. **Resource Directed Measures (RDM):** RDM refers to the definition of a desired level of protection for a water resource, and on that basis, the setting of clear numerical or descriptive goals for the quality of the resource (Resource Quality Objectives or RQOs);
2. **Source Directed Controls:** Controlling impacts on the water resource through the use of regulatory measures such as registration, permits, directives and prosecution, and economic incentives such as levies and fees, in order to ensure that the Resource Quality Objectives are met;
3. **Demand Management:** Managing demands on water resources in order to keep utilisation within the limits required for protection;
4. **Monitoring:** Monitoring the status of the country's water resources on a continual basis, in order to ensure the Resource Quality Objectives are being met and to enable DWAF to modify programmes for resource management and impact control as and when necessary.

The implementation process was listed as a key objective in DWAF's Strategic Plans for 2000/2001 (DWAF 2000), involving, *inter alia*:

- the development and establishment of a National Water Resource Strategy and Catchment Management Strategy;
- the establishment, empowerment and capacitating of water management institutions;
- the continuing development and implementation of water resource protection measures;
- the development and implementation of water conservation and demand management strategies;
- the continuing development, establishment, and maintenance of national water resource monitoring and information systems;
- the implementation of a national programme for the clearing of invasive alien plants.

Scientific Services, one of five directorates dealing with water resource management in DWAF, was tasked with the implementation of Resource Directed Measures (DWAF 2000). The expected output of this activity included a final draft of a National System for the Resource Classification, and the determination of the Ecological Reserve for all 'significant'[1] water resources, including rivers, wetlands, and groundwater. The directorate

[1] *The term 'significant refers to the ecological and geographical extent of the system rather than its managerial importance.*

was also tasked with the development of information systems and tools for the implementation of the Act.

5.3.1 The concept of the Resource Base

The new legal and policy frameworks recognise the fragility of the resource, but also its capacity to both tolerate and to recover from certain levels of natural and anthropomorphic disturbance. System tolerance is defined as 'resistance' while its ability to recover from disturbance is termed 'resilience' (Fisher and Grimm 1988). The term 'Resource Base' refers to that level of ecosystem 'integrity' or 'health' which must be protected and maintained to ensure that the functionality of the system is maintained well within the limits of its resistance and resilience.

Part of DWAF's goal is twofold: to protect water users' rights, and to protect the water resources from over-utilisation or from impacts that could result in system degradation (DWAF 1999). Resource Directed Measures are thus in a large part an attempt to *quantify* the Resource Base for individual aquatic ecosystems, and on that basis, to determine appropriate levels of use and management for the system in case.

5.3.2 Resource Quality Objectives (RQOs)

The resource quality objectives (RQOs) are a set of quantitative or qualitative standards or goals to be met by the RDM process, for the water entering or resident in a receiving water body. They are a statement of the *water resource* quality rather than the *water* quality. The function of the RQOs is to ensure resource protection.

There are four components to RQOs:

Water quantity: referred to as 'Instream Flow Requirements' (IFRs) for river reaches or estuaries and 'water level requirements' for standing water or groundwater. The current methodology used to assess IFR is the 'Building Block Methodology' (BBM) of King et al. (2000).
Water quality: based on current South African Water Quality Guidelines.
Habitat Integrity: encompassing the physical structure of instream and riparian habitats.
Biotic Integrity: objectives reflecting the health, community structure and distribution of aquatic biota.

5.3.3 Development of RDM Methodology

DWAF initiated the process of developing RDM procedures in July 1997. The RDM methodology described here (Version 1.0, DWAF 1999) was constructed on the basis of a number of pre-existing methods and procedures which had been developed over previous decades by South African water specialists. These include:

Instream Flow Requirement (IFR) Methodology:
The accepted methodology for the determination of the IFR of aquatic ecosystems was the Building Block Methodology of King et al. (2000).

Water Quality Guidelines for aquatic ecosystems:
These guidelines, first published in 1997 and recently revised, provide standards which allow for the setting of water quality objectives for the protection of aquatic ecosystems.

Biomonitoring and the National River Health Programme:
The tools which have been developed for the ecological or biological assessment of aquatic ecosystem condition include the South African Scoring System (SASS5) based on the aquatic invertebrate families (Chutter 1998), the Fish Integrity Index (after Karr 1981), and a number of Habitat Integrity Assessment methods (e.g. Kleynhans 1996). The National River Health Programme makes use of these methods and their indices in a multi-scenario format that allows for the tailoring of the monitoring programme according to the river in question and the region in which it occurs, the constraints on management and the available budget. The NHRP was devolved to the level of 'river regions' or 'water management areas', of which there are 19 in the country. Further information on this programme is provided in Chapter 6.

Human Health Requirements:
The new South African Water Services Act, promulgated in 1997, provides guidelines on the determination of the basic human needs for water. The second edition of the SA Water Quality Guidelines for Domestic Use (DWAF 1996), together with a report entitled 'Quality of Domestic Water Supplies – Volume 1' (DWAF, Department of Health and Water Research Commission, 1996) provided the basis for the methodology used for setting the Human Reserve (Quality component), which is currently being reviewed and modified.

The RDM methodology was compiled by September 1999, and is currently undergoing review, refinement and trial. Recent, but not necessarily current, methodologies are posted on the DWAF website (www-dwaf.pwv.gov.za). **The version presented here is likely to have been refined by the time this document goes to press, however the principles remain the same.**

The methodology documents procedures for the preliminary determinations of the Category, Reserve and RQOs for water resources, as specified in Sections 14 and 17 of the National Water Act. Once the final RDM procedures are published in the SA Government Gazette and prescribed according to Section 12 of the NWA, all determinations of RDM, whether at the rapid, the intermediate or the comprehensive level, will be considered to be preliminary determinations (DWAF 1999).

5.3.4 RDM determinations

There are four major levels at which RDM can be determined:

Desktop estimate
This is a low confidence model that takes about two hours to complete per water resource.
Rapid determination
This is also a low confidence model. It is a combination of desktop and a quick field assessment of present ecological status. The method can be completed in about two days. It is used in the case of individual licensing for small impacts in unstressed catchments of low ecological importance and sensitivity; or for compulsory licensing 'holding action'.
Intermediate determination.
This methodology is a medium confidence model. It requires specialist field studies and takes about two months to complete. It is used where individual licensing is required in relatively unstressed catchments.

Comprehensive determination
This method gives a result with relatively high confidence. It involves extensive field data collection by specialists, and takes between 8 and 12 months. It is used in the case of all compulsory licensing; for individual licensing where there are large impacts in any catchment; and for small or large impacts in very important and/or sensitive catchments.

Finally, a **'Flow Management Plan'** acknowledges present operating constraints (mostly structural) on a river. Modified operating rules are drawn up between the management agency and the RDM study team, with the aim of implementing a more ecologically acceptable flow regime. This plan is for use in highly regulated systems where present flow control structures do not have outlets from which releases can be made to provide for the water quantity component of the Reserve (DWAF 1999).

5.3.5 A generic methodology for RDM

At all four levels described, the methodology for RDM can be viewed as a stepwise process with multiple components. The generic methodology summarised here is relevant for each level of RDM determination. The methodology is summarised from: *DWAF. 1999. Water Resources Protection Policy Implementation: Resource Directed Measures for Protection of Water Resources. Version 1.0.* This documentation draws together the work of many specialists that have been and continue to be involved in the process of the development of methodologies for the RDM. The methodology is also illustrated in Figure 5.1.

These methodologies have been developed and refined in the absence of the final Resource Classification system described in Section 5.2., as this is still in development. Assumptions have thus had to be made about how the final classification system will look. These assumptions will continue to change through this process, such that the final Reserve Determination process may differ somewhat from that presented here (Louw, pers. comm.)

Step 1: Initiate the RDM study

Identify significant water resources
The National Water Act states that the Minister must determine RDM 'for all or part of every significant water resource', where 'significant' refers to the geographic extent of the water resource for which a Class, Reserve and Resource Quality Objectives (RQOs) must be determined. Water resources or sections thereof are delineated in a manner practical for water use planning, allocation and licensing purposes, but also at a scale which allows effective management of the resource itself.

Establish study team composition
The size and composition of the study team depends on the level of the RDM study required, and the types of water resources included within the study boundaries. A comprehensive determination, in contrast to a rapid determination, may require the inclusion of several specialist sub-disciplines on the team.

Delineate the geographical boundaries of smaller resource units within a RDM study area.
The boundaries of the resource units are determined on a need-related basis and in response to the reasons for initiating the RDM. For example, if the RDM determination is triggered

by the need to evaluate a single water use license application, then the study boundaries will depend on the scale and extent of impact of the proposed water use. Upstream-downstream dependencies may require that the study boundaries take account of additional water resources upstream or downstream of the study area.

Select appropriate level of RDM determination
There are a number of rules for selecting the appropriate level of RDM determination (these are referred to in Section 5.3.4).

Step 2a: Determine the ecoregional type of each resource unit

Ecoregions or geohydrological response units represent relatively homogenous units within a catchment. Each unit would belong to a specific 'ecoregional type' or 'geohydrological response' type. Ecoregional type is determined by:

- physiographic factors (e.g. altitude, latitude, aspect, slope, climatic zone);
- geological factors (determining geochemical signature and aspects of geomorphology and habitat);
- regional natural hydrological characteristics (e.g. annual precipitation, seasonality and variability of flow);
- natural vegetation type (such as bushveld, lowveld etc);
- biotic factors (e.g. naturally occurring fish, invertebrates, macrophytes and algae).

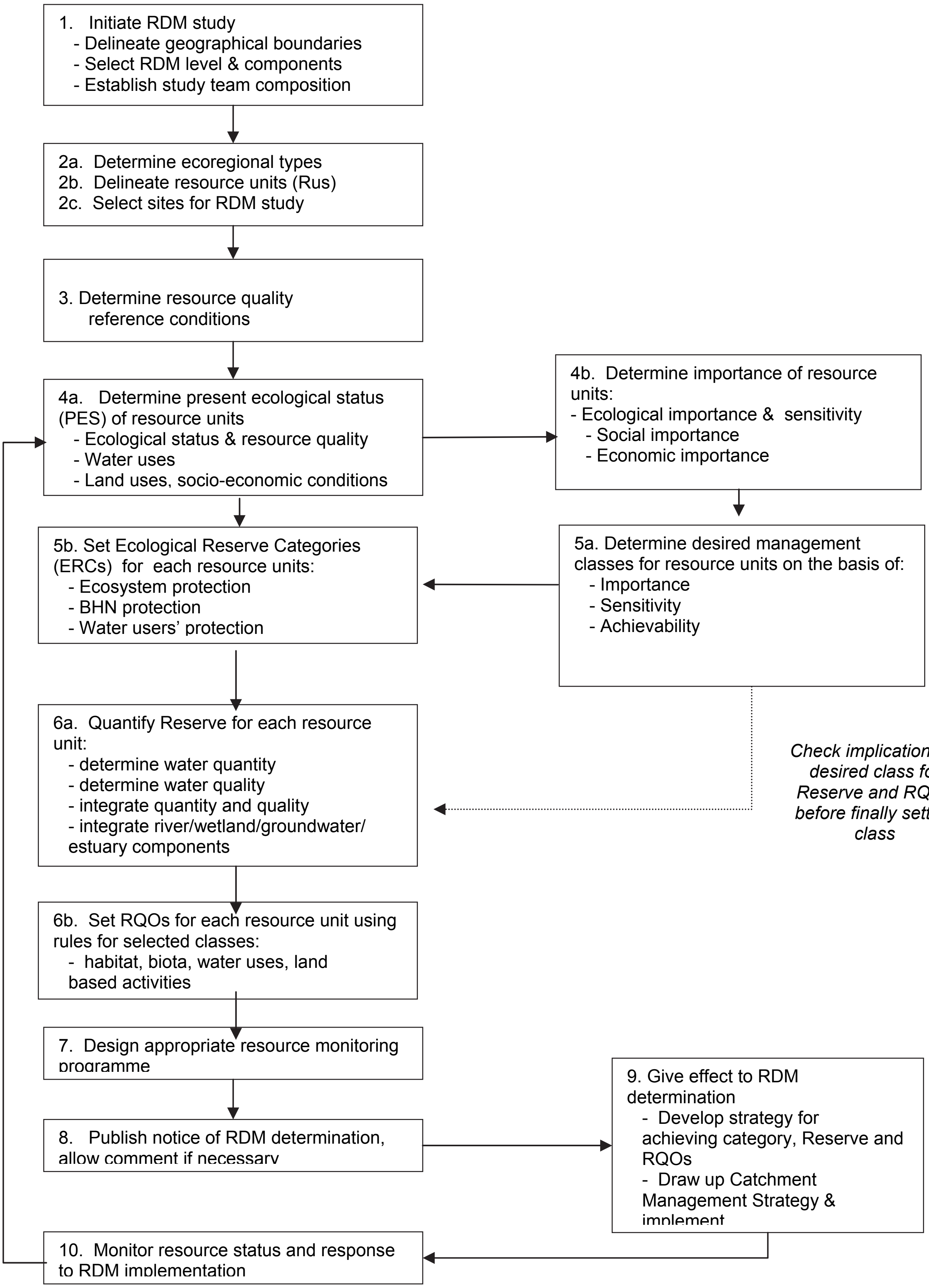
Knowledge of the ecoregional type of a resource enables predictions to be made about what kind of ecosystem could be expected to occur in that unit under natural or unimpacted conditions. This information assists to guide expert judgement in steps 3,4,5, and 6 in the quantification of water quantity and quality requirements for achieving different levels of protection of that particular water resource. Ecoregional typing is also a way of transferring understanding from well-studied water resources to data-poor resources of the same type, for which little data may be available.

During 1999, a project was initiated by the DWAF to delineate and map ecoregions for the whole of South Africa. In the interim, a procedure for ecoregional mapping is available and can be used to map ecoregions for a particular catchment as one of the first activities in a RDM study for that catchment.

Step 2b: Delineate resource units within the study area

If a Reserve determination is required for an extensive area (e.g. a catchment), the area is divided into 'resource units', each of which is sufficiently distinct in terms of physical or biotic characteristics to warrant its own Reserve determination. The geographic boundaries of each can then be clearly defined. The division is primarily on a biophysical basis, guided by the occurrence of different ecoregions and/or geohydrological response units within the catchment. Further subdivision of these units may be necessary to suit management requirements.

Figure 5.1: Generic procedure for determination of Resource Directed Measures for aquatic ecosystems (*from DWAF 1999 with relevant modifications*).



Step 2c: Select survey sites within the study area

The selection of appropriate study sites largely determines the level of confidence in the Reserve determination. Site selection is based on the various ecoregional types represented in the study area, and also depends on factors such as representivity, suitability for hydraulic calibration, and accessibility. For water quantity and water quality Reserve determination, it may be adequate to select sites that cover more than one ecoregion. The RQOs for habitat and biota may however need to be determined separately for each ecoregion.

Step 3: Determine the reference conditions for each resource unit

Reference conditions describe the pre-impact characteristics of a water resource, and quantitatively describe the ecoregional type specific to a particular water resource. Expert judgement is required in the determination of reference conditions and in the assessment of present status, to judge whether the resetting of reference conditions is appropriate.

For surface water ecosystems, reference conditions cover:

- water quantity: the amount, timing, pattern and level of flow, including seasonal and inter-annual variability, flood and drought cycles;
- water quality: concentrations of key constituents and their seasonal and inter-annual variability, diurnal patterns of variability for parameters such as temperature, dissolved oxygen and pH where relevant;
- the geomorphic and vegetational characteristics of instream and riparian habitat;
- the character, composition and distribution of aquatic biota.

For groundwater, reference conditions are assumed to include:

- water level and its seasonal and inter-annual variability;
- water quality: concentrations of key constituents and their seasonal and inter-annual variability;
- aquifer structure and composition.

The assessment of Present Ecological Status (Step 4), the selection of the future Ecological Reserve Category (Step 5) and the quantification of the Reserve (Step 6) and Resource Quality Objectives, are all carried out relative to the reference conditions for the resource in question. Reference conditions represent a baseline condition.

It is often not possible to find a site that is suitable for the accurate determination of reference conditions. Expert judgement, local knowledge, historical data and analysis of measured historical trends may be necessary to build up a picture of the expected reference conditions (within broad confidence limits).

If there is no practical way of restoring the original ecological characteristics of a particular water resource, then there may be justification for resetting the reference conditions to more accurately reflect the current ecological characteristics.

Step 4a: Assess the Present Ecological Status of the resource units

This step entails an assessment of the Present Ecological Status (PES) of the resource in terms of its water quantity, quality, habitat and biota. Further concerns are the extent of modification from reference conditions; current and projected water uses, land uses and socio-economic conditions.

The Present Ecological Status assessment is required:

- to assess the extent to which the system has been modified, and hence the current degree of risk of irreversible damage;
- to identify, if possible, whether resource quality is stable within a particular assessment category, or whether the resource is currently degrading due to past or present impacts;
- to identify what may be achievable in terms of the future management, in order to rule out unrealistic options when setting the Ecological Reserve Category in Step 5. Sometimes structural modifications to the resource (such as dams or urban development), or short-term needs for economic development may be such that a higher class than the present one cannot be practically achieved in the short to medium term.

There are six assessment categories for the determination of the PES of rivers, wetlands and estuaries. Each of these represents a broad band of 'degree of modification' from reference conditions. The categories range from negligible to critical modification. The degree of modification from reference conditions is assumed to be related to the risk of irreversible degradation of resource quality.

The six Present Ecological Status Categories (PESC) for rivers and wetlands are identified simply as categories A through F. Table 5.1 guidelines for the estimation of the PESC for a number of attributes (water quality, water quantity, geomorphology, riparian vegetation and instream biota). Various techniques are used to arrive at the PESC for the individual attributes.

Biological integrity is not directly estimated through this approach and it is acknowledged that in some systems or parts of systems, information on biological integrity is already available. In such cases, the information on biological integrity can be used as a check of the PES assessment. The mean (or default low rating due to individual scores of serious or critical modification) is used to relate the river to a particular PESC (Table 5.1).

The full PES assessment is likely to match the full management classification system (Table 5.3), in that it will address:

- ecological status of the resource;
- status of the resource for basic human needs; and
- status of the resource for water users.

Table 5.1: Guidelines for present ecological status (PES) estimation (*after Louw 2000*). This is a generic table for all the attributes of the river. For each attribute, individual methods will be used to arrive at a Present Ecological Status Categories defined on the basis of these.

<table>
<tr><th>Category</th><th>DEFINITION OF GENERIC PES CATEGORIES</th><th></th></tr>
<tr><td>A</td><td>CATEGORY A
Natural:
The resource base has not been decreased;
The resource capability has not been exploited</td><td rowspan="4">WITHIN GENERALLY ACCEPTABLE RANGE</td></tr>
<tr><td>B</td><td>CATEGORY B
Largely natural with few modifications:
The resource base has been decreased to a small extent;
A small change in natural habitats and biota may have occurred, but the ecosystem functions are essentially unchanged.</td></tr>
<tr><td>C</td><td>CATEGORY C
Moderately modified:
The resource base has been decreased to a moderate extent;
A change of natural habitat has occurred, but the basic ecosystem functions are still predominantly unchanged.</td></tr>
<tr><td>D</td><td>CATEGORY D
Largely modified.
The resource base has been decreased to a large extent;
Extensive changes in natural habitat, biota and basic ecosystem functions have occurred.</td></tr>
<tr><td>E</td><td>CATEGORY E
Seriously modified.
The resource base has been seriously decreased and regularly exceeds the resource base;
The loss of natural habitat, biota and basic ecosystem functions is extensive.</td><td rowspan="2">OUTSIDE GENERALLY ACCEPTABLE RANGE</td></tr>
<tr><td>F</td><td>CATEGORY F
Critically modified.
The resource base has been critically decreased and permanently exceeds the resource base;
Modifications have reached a critical level and the resource system has been modified completely with an almost total loss of natural habitat and biota. In the worst instances, the ecosystem functions have been destroyed and the changes are irreversible.</td></tr>
</table>

Tools for addressing basic human needs and water uses already exist, in the form of the South African Water Quality Guidelines (DWAF, 1996) and the Domestic Water Quality Assessment Guide (DWAF, DOH & WRC, 1998).

Step 4b: Assess the Ecological Importance and Sensitivity (EIS) of the resource units

The Ecological Importance of a river expresses how important it is to the maintenance of ecological diversity and functioning on both local and wider spatial scales. Ecological sensitivity (or fragility) is equated with the system's capacity to recover from disturbance (i.e. its *resilience*).

The estimation of ecological importance and sensitivity of a resource unit is based on:

- the presence of rare and endangered species;
- the presence of unique (endemic or isolated) species, populations or communities;
- species sensitivity to water quality, flow, etc.;
- species diversity;
- habitat diversity and specific habitat types (e.g. reaches with a mix of pools, riffles, runs, rapids, waterfalls, etc.);
- the importance of the resource unit (e.g. river or reach) in providing connectivity along the water resource, e.g. migration routes or riparian corridors;
- the presence of conservation areas or relatively natural areas;
- the sensitivity (or fragility) of the system and its biotic and abiotic resistance (ability to tolerate disturbance) and resilience (ability to recover following disturbance.

The assessment of economic and socio/cultural importance is based on:

- the extent to which people are dependent on the natural ecological functions of the water resource for water for basic human needs (sole source of supply);
- dependence on the natural ecological functions of water resource for subsistence agriculture or aquaculture;
- use of the water resource for recreation;
- the historical and archaeological value of the water resource;
- its importance in rituals and rites of passage;
- sacred or special places in the river (e.g. where ancestral spirits occur);
- the use of riparian plants (for building or traditional medicine), and
- the intrinsic and aesthetic value of the water resource for those who live in the catchment, or who visit it.

Social importance can be assessed within a similar framework as that for ecological importance, but in a much more qualitative manner. The results of this assessment are not intended to be subject to complex statistical analysis, nor to measure social values with precision, but to capture a general feeling of the importance of different aspects of a river.

Water resources are usually important from an economic point of view. The economic value of a water resource is traditionally assessed in terms of the amount of water that can be abstracted for offstream use. Typical economic indicators include the number and value of jobs generated by the use of the water, or the amount of revenue generated. Water resources also provide other services which are often not included in economic valuation, and in particular this applies to the services and benefits provided by aquatic ecosystems. These include transport and/or purification of biodegradable wastes; recreation and aesthetic opportunities and flood attenuation and regulation; and water-based transport.

While the development of tools for quantitative valuation of ecosystem services and benefits is still in an early stage, it is necessary that all the potential economic values of a water resource at least be identified when assessing economic importance.

The importance and sensitivity of a water resource is used to guide or influence the decision on the level of protection required, which in turn determines the Ecological Reserve Category to be assigned. The importance of a water resource, in ecological, social and/or economic terms, acts as a modifying or motivating determinant in the selection of the ERC. For example, if the present status of a water resource indicates it is very degraded, but the importance and sensitivity are high, then a higher ERC than the present status should be set as a management goal. This will lead to improvement in resource quality.

Step 5 (revised). Set the Ecological Reserve Category (ERC) for each resource unit
(formerly: Set the Management Class for the resource unit)

With input from D. Louw (pers. comm. 2001)

Recent changes have been made to this step. Where formerly the Reserve Determination team would have recommended an Ecological Management Class per resource unit, their brief is now to provide technical input to this process by determining the Ecological Reserve Category (ERC), which is just one of several components of the final Management Class for the river. Other components could be domestic use, recreation and agriculture. The default ERCs for river are shown in Table 5.2

The selection of an ERC for a resource unit is based on a number of former assessments. The Reference Condition, Present Ecological State (PES), and the Trajectory of Change of all of the river attributes are assessed for the Resource Unit. These are summarised into an 'Ecostatus', on the basis of the same categories as used for the PES. Then the Ecological Importance and Sensitivity (EIS) is assessed, and questions are asked regarding causes of change to the resource, ecological aims for the unit, and achievability of these aims (given that some prior impacts or modifications may not be practically reversible due to technical, social or economic constraints). These inform whether or not the Ecostatus should be maintained, in which case the ERC will be the same as the Ecostatus; or whether the Ecostatus should be improved, in which case the ERC would be set as a higher class than the Ecostatus, to allow for improvement in resource quality.

The ERC is selected as the target for long- term protection and management of the resource unit. Each ERC has rules concerning the derivation of numerical objectives for the Reserve and resource quality, and for which source-directed controls may be applicable within the catchment of that resource. The implications of selecting a particular ERC can be evaluated and various scenarios tested before the final class is set. The sequence of actions required for providing technical information on the ERC is shown in Table 5.3.

It is likely that there will be some iteration around selection of a possible ERC and what this implies for the Reserve and for source directed measures. The ERC finally selected will represent the optimal balance between protection and utilisation.

Of the six Present Ecological State Categories (PESC) A to F, presented in Table 5.1, only the first four (A through D) are acceptable as Ecological Reserve Categories. Categories E and F represent degrees of modification with an unacceptably high risk of irreversible degradation of resource quality, a condition which does not allow sustainable utilisation of a water resource.

For intermediate and comprehensive RDM determinations, the actual process of assigning an ERC to a specific water resource is expected to be a consultative one, aimed at involving relevant stakeholders in deciding on the level of protection that is acceptable for the resource. The process should address long-term protection requirements and account for economic and social issues, in reaching a balance between protection for long-term sustainability on one hand, and short to medium-term development needs on the other. The role of DWAF as public trustee and custodian of water resources is an important factor in this process.

The approach described in this step is used for the Comprehensive, Intermediate and the Rapid-level Reserve Determinations. However, for the latter evaluations, the specialist input into the method is scaled down significantly, and expert judgement plays a more important role. Also, the expertise involved and the components addressed at the latter levels is often limited to instream aquatic specialists (Louw pers. comm.).

Table 5.2: Default ERCs for rivers (modified from Kleynhans 1996).

DEFAULT ECOLOGICAL RESERVE CATEGORIES	**DESCRIPTION OF PERCEIVED CONDITIONS AND ALLOWABLE RISK**
A Highly sensitive systems No human induced hazards allowed	Highly sensitive systems. The natural abiotic template should not be modified. The characteristics of the resource should be determined by unmodified natural disturbance regimes. There should be no human induced hazards to the abiotic and biotic maintenance of the resource.
B Sensitive systems Small risk allowed	Sensitive systems. Only a small risk of modifying the natural abiotic template and exceeding the resource base should be allowed. Although the risk to the well-being and survival of especially intolerant biota (depending on the nature of the disturbance) at a very limited number of localities may be slightly higher than expected under natural conditions, the resilience and adaptability of biota must not be compromised. The impact of acute disturbances must be totally mitigated by the presence of sufficient refuge areas.
C Moderately sensitive systems Moderate risk allowed	Moderately sensitive systems. A moderate risk of modifying the abiotic template and exceeding the resource base may be allowed. Risks to the well being and survival of intolerant biota (depending on the nature of the disturbance) may generally be increased with some reduction of resilience and adaptability at a small number of localities. However, the impact of local and acute disturbances must at least partly be mitigated by the presence of sufficient refuge areas.
D Resilient systems Large risk allowed	Resilient systems. A large risk of modifying the abiotic template and exceeding the resource base may be allowed. Risks to the well-being and survival of intolerant biota (depending on the nature of the disturbance) may be allowed to generally increase substantially with resulting low abundances and frequency of occurrence, and a reduction of resilience and adaptability at a large number of localities. However, the associated increase in the abundance of tolerant species must not be allowed to assume pest proportions. The impact of local and acute disturbances must at least to some extent be mitigated by refuge areas.

Table 5.3 The sequence of actions required for providing technical information on any one component, for the ERC (*from Louw 2001*).

How did the river used to look?	1. DETERMINE REFERENCE CONDITIONS
Compared to how the river used to look, what does it look like now?	2. DETERMINE PRESENT ECOLOGICAL STATUS (CATEGORY A-F)
Is the river changing, and if so, how? **How severely?** **How fast?**	3. DETERMINE TRAJECTORY OF CHANGE (FOR EACH COMPONENT WITHIN REASON) ASSUMING THAT THE STATUS QUO IS MAINTAINED. TRAJECTORY OF CHANGE (0, +, -) SHORT TERM AND/OR LONG/TERM
What is the main cause of change? **What are the sources of the causes of change?**	4. DETERMINE CRITICAL CAUSE OF CHANGE OF THE PES AND/OR THE TRAJECTORY OF CHANGE, AND GIVE THE SOURCE OF THE CAUSE OF CHANGE
How ecologically and socially important is the river?	5. DETERMINE IMPORTANCE AND SENSITIVITY CATEGORIES (LOW, MODERATE, HIGH, VERY HIGH) AND STATE CONFIDENCE IN EVALUATIONS.
What would the ecological aims be for the river?	6. CONSIDERING IMPORTANCE AND SENSITIVITY, AND THE PES, SHOULD THE PES BE IMPROVED (IF SO, BY HOW MUCH) OR MAINTAINED? (CATEGORY A – D)
Can the main cause of change realistically be addressed to achieve the ecological aims?	7. DETERMINE WHAT WOULD BE REQUIRED TO ADDRESS THE CAUSES. 8. DETERMINE HOW DIFFICULT IT WOULD BE TO ADDRESS THE SOURCE OF THE CAUSES (RESTORATION/REVERSIBILITY POTENTIAL) AS EASY, REASONABLE, DIFFICULT OR VERY DIFFICULT. PROVIDE REASONS.
What should the Ecological Reserve Category be for the river?	9. CONSIDERING THE ECOLOGICAL AIMS AND THE DIFFICULTY OF ACHIEVING THE AIMS, DETERMINE THE ATTAINABLE ECOLOGICAL RESERVE CATEGORY FOR EACH COMPONENT.

Step 6a: Quantify the Reserve for each resource unit

This involves the quantification of the Reserve (water quantity and water quality) for a particular water resource, according to the rules associated with the Ecological Reserve Category which has been assigned to the resource unit in Step 5.

Explicit rules have been proposed for setting of the ecological Reserve (quality), linked to the ecological reserve categories. For the ecological Reserve (quantity), equivalent rules are in development, but the determination of the water quantity component of the Reserve still relies heavily on expert judgement and the application of site-specific knowledge. For the basic human needs Reserve, regulations under the Water Services Act of 1997 provide the preliminary rules.

Integration of the water quantity and water quality components of the Reserve
Determination of the water quantity and water quality components of the Reserve must be carried out in an integrated manner. Details of proposed procedures for integration are presented as an appendix to the document 'Resource Directed Measures (Rivers)' (DWAF 1999). In the determination of RDM, cross-checks are essential to ensure that modification of water quantity patterns in the water resource does not lead to non-achievement of water quality requirements for the Reserve.

Matching the RDM requirements for connected ecosystems
The RDM requirements of each resource unit must be matched with those for the adjacent resource units. For example, the Reserve determination for an estuary must be matched to the Reserve determination for the river reach immediately upstream, not only in terms of the amount and quality of the river flow, but also in terms of the time-step and units in which the Reserve requirements are presented. This matching should be carried out within the RDM determination process, with all relevant study team members present.

Step 6b: Set Resource Quality Objectives for each resource unit

Numerical or narrative RQOs for instream habitat are also set according to the rules associated with each Ecological Reserve Category. The extent, distribution, type and integrity of instream habitat is strongly dependent on the water quantity and water quality conditions which are set for the Reserve. However, RQOs must also be derived for other factors which influence instream habitat. For example, where excessive soil erosion in the catchment increases instream sedimentation rates to an unacceptable level, requirements relating to the sedimentation impacts of land-based activities use may also be included in the RQOs.

Riparian habitat is at risk from activities such as construction, river diversion, ploughing on river banks and urban development. Numerical or narrative objectives should be set which would ensure the appropriate extent, distribution, type and integrity of riparian habitat, in order to maintain an acceptable level of protection for the aquatic biota which rely on the habitat.

RQOs for aquatic biota can include measures of biotic integrity such as the SASS (invertebrate) and fish integrity index scores. RQOs (in terms of scores) can be set for biotic integrity but the achievement of these objectives can only be assured through maintenance of an appropriate abiotic template (water quantity, water quality and habitat integrity).

The National Water Act (NWA) also provides for the option of setting RQOs, which can be narrative or numerical, to ensure 'the regulation or prohibition of instream or land-based activities which may affect the quantity of water in or quality of the water resource' (NWA Section 13(1)g).

Step 7: Design an appropriate resource monitoring programme

Objectives of post-RDM monitoring:

- To collect data to improve the confidence of a future RDM determination at the next level (e.g. to prepare for a future comprehensive Reserve determination if the present Reserve determination was at intermediate level);
- To monitor the response of the aquatic ecosystem to the Reserve and RQO that were set, to check that the Reserve and RQO do actually provide the level of protection required by the selected Management Class;
- To monitor resource quality status in order to ascertain whether management actions are adequate to achieve compliance with the requirements of the Reserve and RQO.

Step 8. Notice of RDM

The final step is the publication of notice of the RDM as a DWAF policy statement if preliminary, otherwise in the Government Gazette.

5.4 INTEGRATED WATER RESOURCES MANAGEMENT (IWRM)

IWRM may be defined as '*an evolving, iterative process for the co-ordinated planning and management of water, land and environmental resources for their equitable and sustainable use*'. This approach is increasingly being adopted as international practice. IWRM focuses on the underlying causes of problems rather than their symptoms, using a combination of technological and social approaches. It involves a holistic understanding of water:

- and as an ecological system in which surface water, ground water, water quantity and water quality interact and are interdependent, within the hydrological cycle of rainfall, runoff, infiltration, and evaporation;
- as a system which interacts with, and is affected by, other ecological systems, e.g. land and air (and the use of and impacts to these);
- as a social economic good (e.g. Briscoe 2000).

The achievement of IWRM in South Africa relies on linkages being established and activated between the various government departments responsible for legislation governing the various aspects of water resources. The term 'co-operative governance' is applied to this interactive process. However, this in itself is not considered adequate to ensure that, for example, the National Water Act's intentions are realised. The support and cooperation of society at large will assist this goal.

Cooperative governance in IWRM

The Constitution of South Africa requires that (natural) environment is protected for the benefit of present and future generations, and also requires inter-departmental cooperation. If these requirements are to be met, the environment must be regarded as an integrated system, and managed as such. However, at present, many of the laws related to resource management are in conflict with one another.

DWAF is obliged to ensure that activities related to the management of water resources are carried out in accordance with the requirements of the National Water Act, They are also required to comply with the National Environmental Management Act, 1998 (Act No. 107 of 1998) (NEMA) and those parts of the Environment Conservation Act, 1989 (Act No. 73 of 1989) (ECA) which have not yet been repealed by the NEMA.

In terms of NEMA, DWAF has prepared a Consolidated Environmental Implementation and Management Plan (CEIMP) that describes, among other things, the Department's functions, policies, plans and programmes, and how they comply with environmental legislation. This plan also describes existing and proposed cooperative arrangements with other departments in all spheres of government to ensure their compliance with water-related policy and legislation.

A 'Committee for Environmental Coordination' has been established at a national level to coordinate the process of promoting cooperative governance in environmental issues between relevant government departments. Departments are obliged to prepare Environmental Implementation and/or Environmental Management Plans, and all plans prepared by departments must be consistent with one another. It is one of the functions of the Committee to assist this process. The Plans are seen as important tools for the promotion of a consistent approach to, and co-operative governance in, environmental management.

There is a further requirement to strengthen the interface between the management of water resources (a national government function) and the provision of water services (increasingly, and ultimately to be a local government function). Alignment of the relevant strategies and planning is particularly necessary to facilitate the implementation of the catchment strategies required by the Act.

5.5 CATCHMENT MANAGEMENT (CM)

The Water Law Review process has been a springboard for the development of a number of inter-related processes, including Integrated Water Resources Management (IWRM) and, within that, Catchment Management (CM).

Catchment Management (CM) is considered the cornerstone of Integrated Water Resources Management. CM recognises a need to integrate economic, environmental and social issues within a catchment into an overall management policy, process and plan, and to achieve consensus of the majority of stakeholders in the process. The catchment management process is, by its nature, complex, continuous, recursive and perpetual (DWAF 2000).

Although the Water Research Commission (WRC) had initiated research into 'Integrated Catchment Management' (ICM) several years earlier, the law reform of the late 1990s renewed the interest and debate on this subject, and provided an opportunity and some urgency for the clarification of the principles of ICM (WRC 2000). By March 1997 the Water Law Review process had come up with a number of discussion documents which would form the basis of the White Paper on National Water Policy. Two of these focussed on IWRM and specifically ICM. In March 1997, the WRC commissioned a team of specialist consultants to consolidate what was known of catchment management in South Africa into a set of guidelines for the development of Catchment Management Plans as essential building blocks for IWRM (DWAF 2000).

The final report produced by this team is entitled 'Guidelines for Catchment Management to Achieve Integrated Water Resources Management in South Africa' (DWAF 2000)
It is a three part report:

1. The Conceptual and Institutional Context
2. Guidelines for the Catchment Management Process
3. Outline of a Catchment Management Process and a Catchment Management Strategy/Plan

The remainder of this Section is based on material contained in these documents.

5.5.1 Terminology

Clarification is provided on the meanings adopted for the following terms:

Integrated Water Resource Management (IWRM) is simultaneously a philosophy, a process and an implementation strategy to achieve equitable access to and sustainable use of water resources by all stakeholders at catchment, regional, national and international levels, while maintaining the characteristics and integrity of water resources at the catchment scale within agreed limits.

Integrated Catchment Management (ICM), in its widest sense, is simultaneously a philosophy, a process and an implementation strategy to achieve a sustainable balance between utilisation and protection of all environmental resources in a catchment and to grow sustainable society through stakeholder, community and government partnerships in the management process.

Catchment Management (CM), as foreseen by the National Water Policy, is simultaneously a philosophy, a process and an implementation strategy to achieve a sustainable balance between utilisation and protection of **water resources** in a catchment. Catchment Management recognises the need for mutual dependence of water, land-use and aquatic ecology management, and for consensual participation by relevant stakeholders, communities and organs of state.

The **Catchment Management Strategy/ Plan,** as foreseen by the National Water Policy**,** records a water-focused vision for the catchment and a water-focused mission for Catchment Management. It relates how real or perceived or potential water-related issues, and their associated land-use, social and aquatic ecology aspects, will be addressed through agreed management strategies within a specified time period in that specific catchment. It outlines an associated legislative, procedural and technical framework and programme of actions for implementation. It reflects stakeholder and government (national, provincial, local) commitments, responsibilities and accountabilities, and it requires legal status.

5.5.2 Integrating management at different catchment scales

While the reasons for Catchment Management are generally understood, particularly in the context of a 'new', democratic society, there are issues that detract from the notion that the catchment and river basin are ideal water management units:

- Catchment boundaries seldom coincide with administrative boundaries, so that more than one local authority can be operational inside even a small tributary catchment, while many river basins are shared by different provinces or even different countries. This leads to institutional problems with the responsible administrative bodies concerned.

- Difficulties may arise in cases where inter-basin transfers cause water to cross catchment boundaries.

- Ecological systems often traverse the boundaries of different catchments and even large river basins, requiring unconnected sub-basins to be linked for ecological management, in which water management may play a role.

The authors conclude that it is clear that, for many reasons, water management needs to occur at, and be integrated across, many different scales ranging from local tributary sub-catchment scale through catchment and basin scales up to regional, provincial, national and international scales (DWAF 2000).

5.5.3 Levels of integrated management

In the CM report, four levels of integrated management are recognised:

1. management of the water 'system', i.e. surface and groundwater quality and quantity;
2. integrated water resources management (IWRM);
3. integrated environmental resources management (land, air, water, ecology);
4. integrated development management.

This is additional rationale for the current use of the term 'Catchment Management' rather than 'Integrated Catchment Management'. 'Ideal' ICM would integrate environmental resource issues within a catchment, while the Catchment Management adopted here is limited to water. In integrated development management (which adopts a regional perspective) the focus of an industrialised society would be urban-industrial, so that the catchment may not be a logical geographical unit for regional planning and socio-economic development (DWAF 2000).

The reality being that wherever ICM features prominent on the agenda, it is conceptually situated somewhere between the first and third levels mentioned above. That is, it ranges from little more than management of water quantity and quality in a particular river; through to IWRM in which there is some recognition of the need for integration between water, environmental and land management at a local scale; all the way to the level at which there is recognition of the need for integrated management of all environmental resource use in a catchment (WRC 2000).

5.5.4 Institutional structures for Catchment Management

The report summarises the proposed institutional structure in terms of Water Policy as follows:

- All water resources management functions vest in the Department in terms of its role as custodian of water;
- The Department may, in its discretion, establish Catchment Management Agencies (where conditions permit, and where the unit of management is not necessarily a catchment) and delegate to them certain functions, but subject to policy, which dictates that overall management of catchments may not be delegated;
- There are no prescriptions on the structure and establishment of CMAs, and the Department may decide on the manner of appointment;
- The Department may refrain from establishing CMAs and retain all functions, but establish Catchment Advisory Committees to assist it by way of advice.

5.5.5 The Catchment Management Process

In whatever form CM takes (state-driven or community-driven), the process can be expected to develop iteratively, and through similar stages:

1. **Initiation** - the start of the management process would be triggered by one or more issues related to the water-environment, or to urban or economic development and may be informally championed by a few individuals, or more formally driven in a structured committee format. An interim vision is required at this stage for the desired future status of the catchment.
2. **Assessment** - studies are undertaken to understand the physical and socio-economic cause-and-effect relationships governing the key water-related problems in the catchment, and to evaluate the administrative environment in terms of water, land and aquatic ecology management requirements.
3. **Planning** - armed with understanding through the assessment tasks, stakeholder consensus is sought about institutional needs, water and land management strategies, social and ecological concerns, funding and stakeholder responsibilities, which would lead to a more permanent vision for the catchment and, more importantly, a permanent Catchment Management 'Institution Structure'. This then needs to be promulgated as a Catchment Management Strategy/Plan.
4. **Implementation** - responsible parties identify and implement Programmes of Actions to address the management strategies specified in the Catchment Management Strategy/Plan.
5. **Administration -** the Catchment Management Institution Structure monitors the implementation of management strategies, fine tunes these, applies agreed procedures to screen new development proposals and maintains stakeholder support and funding for the Strategy/Plan.
6 **Monitor** - information is continuously gathered, processed, stored and interpreted on water use and catchment water health in terms of quantity and quality indicators.
7. **Review and Audit** - periodically reassess, replan and revise responsibilities, objectives and strategies, based on internal and external audits to assess the success of the catchment management process.

There is overlap between these stages, and a great deal of feedback between tasks and stages.

5.5.6 Guidelines for the CM process

The guidelines developed for the possible components of the Catchment Management Process are presented here, as summarised from DWAF (2000). These provide a general outline of the nature, structure and ingredients of the process of Integrated Water Resource Management on a catchment basis, and require interpretation and adaptation to suit local catchment conditions.

1. Vision and focus

The values underlying catchment management relate to the spiritual, ethical, social, economic and environmental value systems of the catchment community. The unique character of each catchment and resource is recognised. There is a requirement for the development of appropriate vision of the catchment's future, and an appropriate process.

As there can be no universal template for catchment management, each CM process will be to some extent unique. CM should focus on a few perceived water issues in the catchment, and gradually deal with other issues as experience and success is achieved. All components of the water resources and the hydrological cycle should be addressed. The need for building a vision and developing a focus for the CM process is recognised, together with the requirement for systematic planning, and the allocation, application and budgeting for the financial resources required. It is warned that because the search for appropriate vision and focus may be considered 'soft' in comparison with more pressing issues (e.g. water quality), this phase of the process may disintegrate into 'cosmetic or ad-hoc processes'.

2. The Scale

It is argued that administration of CM should be dealt with on a catchment or river system scale on the basis of the economies of scale which could be achieved by coordination of arrangements at this level. The actual area defined by the term 'catchment' is however broad and does not necessarily imply the primary catchment area. The recommended units for CM within the administrative catchment areas are sub-catchments of small enough area to be relatively homogenous. Policy and strategic water resource development is then coordinated at national, regional and/or river system levels.

3. The Integrated Management Process

The process of ICM would involve a number of stages, within a flexible timeframe: initiation, assessment, planning, implementation, administration, monitoring and review. Overlap and linkages would be necessary between all stages, and the process should reflect a growing integration of relevant issues and elements affecting the water resources in the catchment. The management process should improve the linkage of all the available resources in the catchment. The role and responsibility of provincial governments and local authorities in CM ensures a process that is both horizontally and vertically integrated.

4. Stakeholder and Public Participation

The principles of representivity and inclusivity should be enshrined in all consultative and participatory processes. Allowance must be made for the differentiation between the processes of stakeholder participation and public consultation. Effective communication is vital for public participation which is considered the cornerstone of CM. Mobilisation and capacity building of the catchment community is the aim, and continuity of participation should be fostered. The process may or may not be paced according to community consensus. The pace may need to be accelerated through careful capacity building and wide exposure of small successes.

5. Initiation

Either representative and inclusive interim catchment management structures should be formed to guide the process from the outset. Key catchment issues must be scoped through public and stakeholder consultation, to provide a focus for the catchment management process and the basis for an associated interim vision and goals, which reflect the stakeholders' priorities and needs. Adequate resources and energy need to be allocated for the continuing process. A 'champion' or mentor for the process is advocated, however where capacity is lacking, DWAF, local authorities or non-government organisations (NGOs) may act as mentors or facilitators for the process, and assist with the scoping, problem identification and issue prioritisation.

6. The Catchment Management Structure

Equitable representation of stakeholders, regulatory authorities, statutory agencies and non-government sectors is required. The CM structure would have to balance the need for representivity with the need for effective management. This means acknowledging the lack of capacity and expertise in the community, and focussing on building expertise through skills transfer and the provision of technical advice. The CM structure should evolve from an interim arrangement to a full Catchment Management Agency (CMA) over time.

It is recommended that the CMA is established at catchment or river system level, and that sub-committees be made responsible for the management of the individual units within the catchment.

Devolution or delegation of relevant powers to a Catchment Management Agency under the National Water Act should be based on criteria related to capacity, representativeness, inclusivity and the development of an appropriate catchment management plan. The delegated powers of a Catchment Management Agency should correlate with the scope of the catchment management strategy/ plan. The catchment management structure should be consulted by the national water authority or its delegate in all decisions concerning policy and strategic water developments that may affect a particular catchment.

Where neither a Catchment Management Agency nor an interim management structure exists, the national water authority or its delegate should continue water resource management in the catchment, and continue to build capacity until such time as such a structure can be established. To ensure that the gap between catchment water governance and national government does not grow too large, an effective role for local authorities and provincial governments should be assured. In catchments where managerial and/or technical advice is not readily available, it may be necessary to hire this expertise on a cost recovery basis.

7. Financing

Three levels of funding are required: seed funding to initiate the process; ongoing or continuous assured income to fund the activities of the catchment management structure and the process of developing a management plan; and finance for individual projects within the CM strategy.

Ensuring sustainable availability of water from a catchment induces three separate costs, those of the infrastructure, catchment management, and resource conservation. In principle, charges for all three should be levied, but only the latter two should be directly used for catchment management. The infrastructure charge should be payable only by the beneficiaries of a particular water supply scheme and should be used to recover the full financial cost of supplying water from that scheme. The catchment management charge should be imposed on all water used in or exported from the catchment and should (as far as equity allows) be charged to all water users (including cultivators, afforestation, etc). These funds should be used to recover the costs of catchment management. The resource conservation charge should be payable, under a competitive system, by holders of time-limited water use allocations in water-scarce catchments (where demand approximates the total utilisable resource). Part of this income should be spent in the catchment of origin, and the rest kept in a central fund to support catchment management nationally.

A system would be needed whereby provision could be made to waive part of, or all of these three water charges, specifically to: allow equitable access to basic water supplies, address the inequalities of the past, promote sustainability, or meet international river basin-sharing obligations. Direct grants should be made available from the central treasury to catchment management structures in catchments where there is a scarcity of economic users of water. A pollution charge should be imposed on all discharges of effluent or return-flows to rivers. The income derived from this should be used by the catchment management structure for the catchment management process.

8. Assessment

This refers to preliminary assessment and understanding of the catchment issues (social, economic, land use, infrastructure, natural resource conditions, pressures, processes) as a component of the planning, decision making, implementation and operational processes. There are two stages to the Assessment process: (i) information gathering, collation and storage; and (ii) quantification, interpretation and assessment.

It is advised that assessment only be performed at the level of detail required to address information needs about the relevant CM issues. The emphasis is on a needs-driven process and an understanding of the key problems in the catchment at an appropriate scale and resolution. The assessment should be based on interpretation of existing data rather than the collection of new information. Causal factors and their effect on key management issues should be the focus, to allow for prioritisation for management planning. It is advised that key issues are addressed and lower priority issues are included at a later stage.

The information attained in this process should be modelled to support future decision-making. Recommended tools include geographical information systems (GIS), procedures for ongoing monitoring of monitoring data, various numerical quantification tools, and hydrological models configured to allow water balance calculations and water quality and quantity assessments for all major natural components of the catchment, as well as all major human impacts on the hydrological cycle.

This process should be fully understood and communicated to representatives on the CM structures in order to facilitate sound decision-making. The issue of trust between individuals is strongly emphasised as a central feature of achieving understanding and consensus. This should be nurtured during the assessment phase particularly.

During the assessment period, a water use, conservation and protection policy needs to be drawn up by water users in the catchment, for both current and future conditions. This should be embedded in the management plan. The particular focus is on water use efficiency. Following this, the water allocation required for the Reserve (basic human needs, basic ecological needs) must be quantified, and all legal obligations regarding shared water courses must be estimated and allowed for, prior to any allocation of water to new users. The next requirement is the quantification of available water. Social and economic benefits of use need to be taken into account. Finally, the CM structure should provide adequate funding for catchment assessments at suitable levels of detail.

9. Planning

The key catchment management issues and their associated primary causal factors should be prioritised for both immediate and longer-term management. Integrated decision-making should be based on an holistic view of the various elements of an issue gained during the assessment stage. The development of consensus and agreement should be encouraged during decision-making, in order to assist the implementation and administration of decisions through voluntary compliance. The appropriate management units in the catchment should be agreed upon at this stage, and a final vision and goals drawn up for each unit in order to provide the basic unit for planning. Following this, measurable objectives should be agreed upon for the priority catchment management issues.

Management strategies reflecting the approach and expected reduction in contribution by the relevant causes of the priority catchment issues must be agreed.

CM strategies outline the measures which need to be taken to alter people's behaviour, activities and actions to address the causes of the priority issues in the catchment. CM strategies should also take into account: criteria for selection of management actions; who is responsible for strategy implementation; the timeframe for selecting and implementing the associated actions; responsibility for administration and auditing; anticipated effect on the priority water resource issues; performance criteria against which to evaluate implementation measures; possible legislation of catchment-specific regulations to enforce the CM strategy.

The water resources in the catchment will have to be classified according to their desired protection status, striving for consensus between the water users, national priorities and other stakeholders. The objective being to arrive at a series of objectives which will be required to maintain the resource within some desired state. Evaluation of source-directed control measures should be evaluated and catchment source-directed measures formulated where necessary. RDMs will set clear objectives for the desired state of the resource. The implementation and success of national source-directed controls measures should be evaluated, and catchment or site-specific source-directed measures formulated where necessary. Provision should be made to influence or prevent land use decisions which may lead to unacceptable impacts on the water resource.

10. Catchment Management Strategy/Plan

The Catchment Management Strategy/Plan records a vision for the catchment and formalises the understanding of the water, land, social and aquatic ecology issues or concerns in terms of that vision. It states how such issues or concerns will be addressed through agreed management strategies within a specified time period in that specific catchment, and outlines an associated legislative, procedural and technical framework for implementation. It reflects stakeholder commitments and requires legal status, either as a contract or as a legal proclamation.

The CM Strategy or Plan represents the formalisation of the decisions and agreements made to address the critical management issues in the entire catchment. The CMS/P is part of the ongoing, wider catchment management process, and periodic review and update may be necessary to reflect changing priorities and pressures in the catchment. The CMS/P will either be gazetted as a statutory regulation, and administered either by an established CMA or by an existing regulatory authority until such time as a CMA is established; or can be adopted as a legal contractual agreement between the existing CM structure and relevant stakeholders with the co-operation of the appropriate authorities.

The CMS/P should include a framework reflecting its vision, goals, objectives and strategies for each 'management unit' agreed to during the CM process until that time. A programme to translate the strategies contained in the CMS/P into a programme of actions needs to be developed. A procedural framework for the ongoing implementation, administration and review of the CMS/P should be specified. A single CMS/P should be derived for each catchment, with a regulatory framework for each management unit. The CMS/P and regulatory frameworks should be effectively communicated to stakeholders and updated regularly.

11. Implementation

The CMS/P is translated into implementable actions which are absorbed into a programme of actions. A secretariat is appointed and the CM structure and sub-committees should facilitate and ensure that these actions are implemented as specified in the programme.

12. Administration

Administration of the process should be based on the procedures outlined in the CMS/P, supported by the information system and managed by the CMA. The monitoring programme and information system outlined in the CMS/P should be set up and maintained. The building of trust and credibility amongst stakeholders will be dependent on open communication and disclosure of positive and negative experiences. CM structures must comply with 'access to information' legislation.

13. Review

The effectiveness, relevance, implementation and administration of the CMS/P should undergo an auditing process. The understanding of catchment issues should be reassessed (and planning reviewed) as pressures on the catchment change. The work of the CM structure should be audited.

14. The Way Forward: Towards Integrated Catchment Management

CM structures should strive to increase the integration of spatial and environmental resource planning and management initiatives, as steps towards achieving ideal ICM. Those opportunities presented by environmental management (e.g. EIAs) should be incorporated into catchment management. Spatial planning and land-use management should be coordinated with CM initiatives, to provide appropriate catchment land-use control. There should be interaction between the CM process and the development initiatives from a national and regional level.

5.5.7 Legal requirements for CM Structures

The National Water Act makes formal provision for the establishment of water management institutions, which include CMAs and Water User Associations (WUAs). Under Chapter 7 of the Act, CMAs are statutory bodies, and manage water resources within what is known as a 'Water Management Area'. South Africa has been divided into 19 Water Management Areas. CMAs form the second tier of the water management structure provided under the Act, and are responsible for developing Catchment Management Strategies in accordance with the National Water Resource Strategy. The CMA may delegate the activities associated with local implementation of these strategies to other institutions (DWAF 2000).

5.6 LINKAGES BETWEEN CM AND RDM

The points of linkage of the RDM methodology and Catchment Management approaches and methodologies are best explained by Figures 5.3. and 5.4 (from DWAF 1999b).

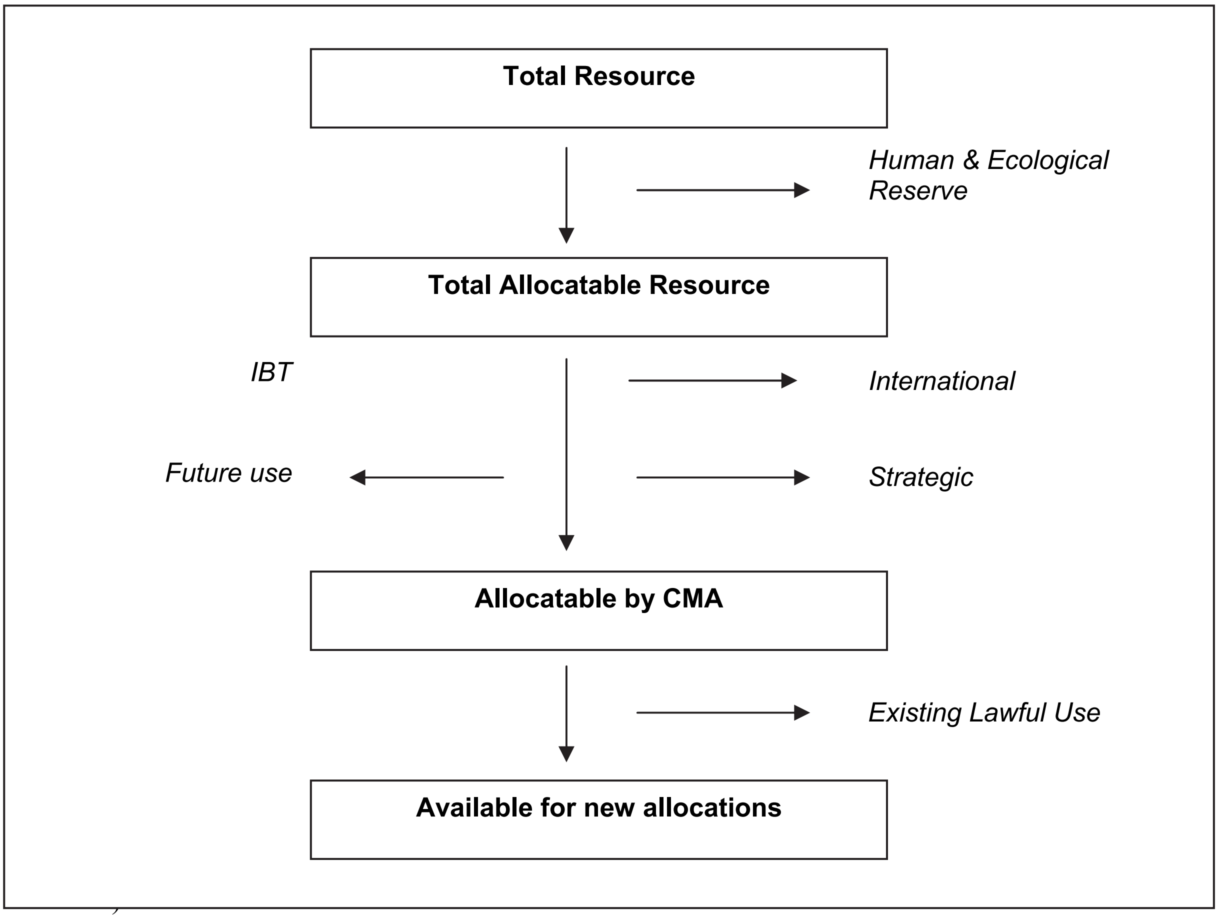


Figure 5.3. The process of determining water available for allocations, and the relative positioning of RDM methodology and CMA decision making (*after DWAF 1999*).

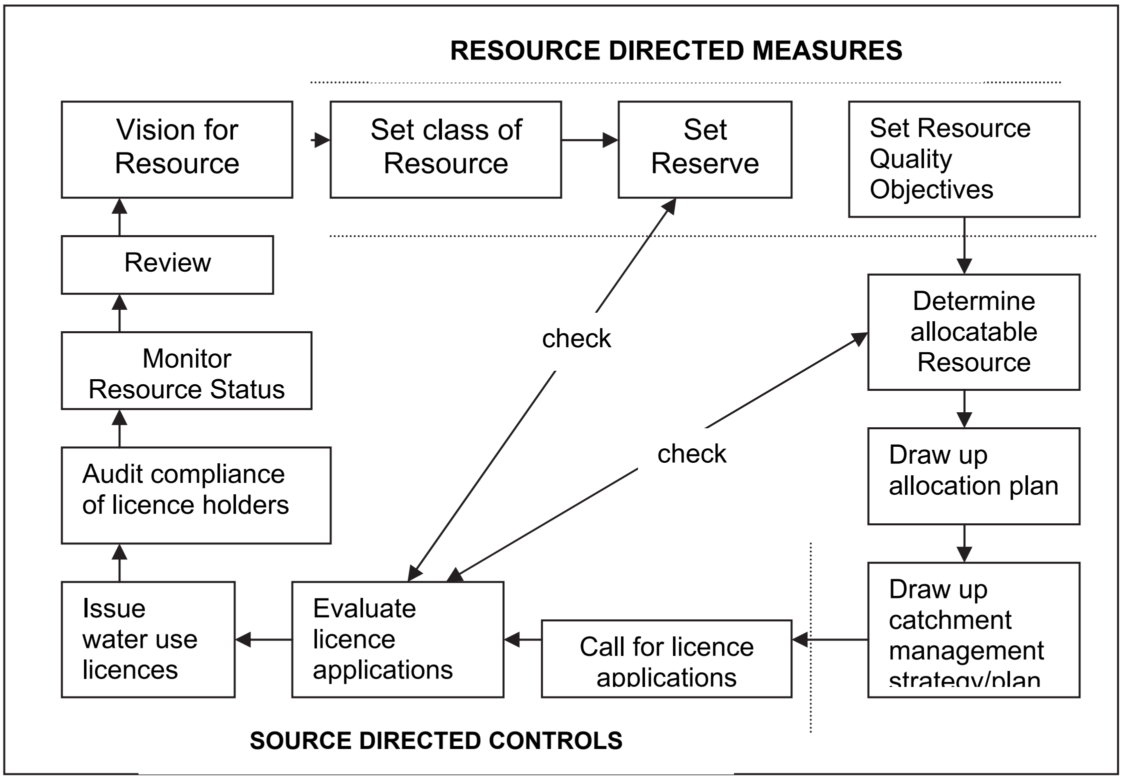


Figure 5.4 The broad relationship between RDM methodology, Catchment Management Strategy and Source Directed Controls (*after DWAF 1999*).

5.7 SUMMARY

This chapter has dealt with current initiatives in water resource management in South Africa, and the development of methodologies to support these. The relevance of these to river rehabilitation, and the links between South African Resource Directed Measures (RDM) and the Australian river rehabilitation approaches, have been discussed.

The South African Water Law Review process of the early 1990s paved the way for progressive changes in approach to water management. The naming of the river as a 'resource' rather than a 'user' of water, and the concept of 'reserving' a quantity of water to ensure the ecological functioning of the river and to supply basic human needs prior to the allocation of water to other users (the ecological and human 'Reserves'), placed South Africa amongst world leaders in terms of water law.

Associated with the implementation of the National Water Act (Act No. 36 of 1998) were, amongst other things, the ongoing development and implementation of water resource protection measures, and the development of catchment management strategies. Amongst the regulatory activities that would facilitate these were 'Resource Directed Measures' (RDM). These define a desired level of protection for a water resource, and on that basis, set clear management goals for the quality of the resource. The methodology for the RDM is viewed as a stepwise process with multiple components. As part of this process, the 'Ecological Reserve' must be determined. This process includes a multi-specialist assessment of the pre-impact, present, and 'future desired' states of the river. These and other evaluations inform the process of setting environmental flows for the system, as part of the Ecological Reserve methodology.

As in Australia, river rehabilitation in South Africa will take place in a catchment-management context. The catchment management approaches followed in South Africa and the guidelines for the CM process have been presented, and the broad relationship between RDM methodologies and Catchment Management illustrated.

While the term 'rehabilitation' may not appear anywhere explicitly in the methodologies associated with RDM or CM, a large portion of the planning process for rehabilitation is accommodated in both, and the RDM process in particular, as discussed further in Chapter 7.

CHAPTER 6

CURRENT INITIATIVES IN SOUTH AFRICA LINKING TO RIVER REHABILITATION

6.1 INTRODUCTION

Although there is no centrally coordinated programme for the rehabilitation of riverine ecosystems in South Africa, there are a number of current initiatives in the country which are either presently active in rehabilitation, or would serve as excellent partners to a river rehabilitation programme. Those that have been identified as the logical initial 'points of contact' are described here. This is not a complete treatment of the subject, nor are individual case studies presented here. Many of the practical river rehabilitation projects in this country are undertaken by private companies, consultants or community groups, and are seldom reported in accessible media. This means that they are 'lost' in terms of the learning they could contribute to the development of the field of river rehabilitation in South Africa.

The theoretical possibility of linking to these initiatives in the development of the river rehabilitation field has been discussed wherever possible with project coordinators or researchers. I acknowledge, in particular, discussions or interactions with:

Dr Dirk Roux	Programme Coordinator, SA River Health Programme
Mr David Lindley	Programme Coordinator, Mondi Wetlands Programme
Mr John Dini	Programme Leader, DEAT/WFW Wetland Rehabilitation Programme
Mrs Penny Bernard	Researcher: SA Indigenous People's Knowledge Programme
Mr Karl Reinecke	MSc Researcher on WRC Project 1161 'The development of geomorphological and ecological principles for river rehabilitation'
Dr Liz Day	Co-Leader of a Project to Develop Guidelines for Project Evaluation

I am grateful to all the above for their time, enthusiasm, ideas and input, and for permission to present summaries of the projects which they represent, here.

While an attempt has been made to source information on rehabilitation-related initiatives from as wide a network as possible, I do not presume to have identified all those initiatives or programmes which may be underway and/or relevant to this discussion. The process of identifying possible linkages is an ongoing one. Individual case studies of rehabilitation projects in South Africa are not presented, as this is considered beyond the scope of the report. The results of these projects are unfortunately difficult to access, as their results are seldom published in readily accessible literature. Some assessment of projects with a rehabilitation-type focus in the Cape Town area has however been undertaken, as discussed in Section 6.7.

6.2 THE SOUTH AFRICAN RIVER HEALTH PROGRAMME (RHP)

Information sourced from RHP (2000) and D. Roux (pers. comm.).

The South African River Health Programme (RHP) primarily makes use of biological indicators (e.g. fish communities, riparian vegetation, aquatic invertebrate fauna) to assess the condition or health of river systems. The rationale for using biological monitoring is that the integrity of biota inhabiting river ecosystems provides a direct, holistic and integrated measure of the integrity or health of the river.

Goals and Objectives

The goal of the RHP is to serve as a source of information regarding the ecological state of river ecosystems in South Africa, in order to support the rational management of these natural resources. The objectives of the RHP are to:

- measure, assess and report on the ecological state of aquatic ecosystems;
- detect and report on spatial and temporal trends in the ecological state of aquatic ecosystems;
- identify and report on emerging problems regarding aquatic ecosystems;
- ensure that all reports provide scientifically and managerially relevant information for national aquatic ecosystem management.

History

The RHP was initiated by Department of Water Affairs and Forestry (DWAF) and the Water Research Commission (WRC) in 1994 in consultation with a number of specialist consultants from research institutions. The main purpose of the programme was to provide a central source of information regarding the **overall ecological status** of river ecosystems in South Africa. The RHP makes use primarily of instream and riparian biological communities (e.g. fish, invertebrates, vegetation) to **characterise the response** of the aquatic environment to multiple disturbances. The rationale is that the integrity or health of the biota inhabiting the river ecosystems provides a direct and integrated measure of the health of the river.

A phased approach was adopted for the design of the monitoring programme, to facilitate:

- **Formulation of a design framework**: A needs analysis was done involving local resource managers and scientists as well as international benchmarking. This exercise allowed the setting of programme objectives, scope and specifications.
- **Conceptual development of the programme within the design framework**: This phase dealt with selecting and/or developing technical protocols.
- **Small-scale implementation to test and demonstrate the programme**: It was shown that information from the programme provided a substantial broadening of the conventional water quality monitoring and assessment focus. This monitoring tool is ideally geared to serve state-of-environment reporting, and has now been used on a number of rivers. The first in a series of State of the Rivers Report has been produced for the Crocodile River.
- **Anchor the RHP so that it becomes part of 'the way we do things around here'**: This phase is to ensure that the RHP becomes part of the relevant water management institutions in terms of required expertise, skills and budgets. The overall goal of the 'Anchoring Phase' described below is to help implementation agencies to go through the different steps of implementing the programme as well as to internalise the programme into their organisations.

Anchoring the RHP

The RHP is intended for national and long-term application, and has been tailored in recognition of local capacity and resource availability. The technical specifications of the programme have been kept as simple as possible to encourage adoption and implementation by water management institutions. However, the success of adoption and maintenance of the RHP will largely be determined by the operational effectiveness and efficiency with which it can be implemented. For this reason, the focus of attention has recently shifted from what to do (product development) to how to do it (process development). A key objective of the Anchoring Phase is to increase institutional capacity for implementing the RHP within provinces, water management areas and catchments. Some of the formal components supported by the anchoring phase are:

- **Implementation of procedures for quality control and assurance**
- **Implementation procedures for data management**: A 'Rivers Database' has been developed specifically for the RHP. The Rivers Database is seen as a complementary facility to the DWAF's national Water Management System (WMS).
- **Coordination of national and regional initiatives:** A National Coordination Team (NCT) will be responsible for activities such as business development through funding partnerships as well as the coordination of related R&D initiatives, provincial implementation activities and processes within the anchoring phase.

Recently, the first in a series of 'State of the Rivers' reports has been produced by the RHP. This is a report on the state of the Crocodile, Sabie Sand and Olifants River systems (Water Research Commission Report No. TT 147/01).

6.3 WORKING FOR WATER

Working for Water was launched in 1995 as a multi-departmental public works programme, in an effort to tackle the twin problems of invasive alien plants in South African river catchments and unemployment. The departments involved in the programme were the Department of Water Affairs and Forestry (DWAF), the Department of Environmental Affairs and Tourism (DEAT) and the Department of Agriculture (DoA).

The aims of the programme are: to enhance water security; to improve ecological integrity and biodiversity; to restore the productive potential of land and promote sustainable use of natural resources; and to invest in the most marginalised sectors of South African society (WFW 2001, Dini 2000, Haigh 2000).

Working for Water is a developing example of how partnerships can be crafted at the inter-departmental level in government and of how to promote the governance that helps address the inequalities of the past. Although the programme is not without its problems, it is considered to have been one of the most successfully integrated environmental and social rehabilitation projects undertaken by the new democratically elected government of this country (Haigh 2001).

WFW projects

In the 2000/1 financial year, the programme had 313 projects across South Africa, run as integrated initiatives. Projects are selected on the basis of the need for follow-up of areas previously cleared, the impact on regional water resources, the extent and distribution of alien plants, the level of poverty and unemployment, sustainability, capacity and the potential for institutional partnerships.

The major invasive species being tackled by the programme are: *Hakea*, rooikrans, pine, *Sesbania*, bugweed, syringa, silver wattle, brambles, eucalyptus, prosopis, poplar, and wild tobacco. Different provinces have different priorities with regard to these.

Alien vegetation control projects include at least the following 3 phases:
Initial control: drastic reduction of existing population
Follow-up control: control of seedlings, root suckers and coppice growth
Maintenance control: sustain low alien plant numbers with annual control.

The importance of rehabilitating land that has been infested with alien plants is noted. A handbook documenting '*Rehabilitation recommendations after alien plant control*' (Kellner et al. 2000) was produced as a jointly funded venture aimed partly at providing guidance for this important process.

According to Haigh (2001), the most immediate danger to the success of the environmental rehabilitation programme is the will among government and other funding agencies as well as landowners to sustain the follow-up programme. This is expensive and will be long-term, most likely much longer than the life span of the initiators of the project. This is because the seedbed of these alien plants are both long-lived and large, and re-growth can take on frightening dimensions if not removed regularly on an annual basis.

Social development within WFW

Social development is an integral part of Working for Water. The thrust of this is poverty relief, but the programme seeks to optimise benefits in general. During the financial year 2000/1 over 20 000 people were employed by WFW (this includes management), of which a significant proportion were funded from Poverty Relief funds (Haigh 2001).

Examples of the programme's commitments to this social development are illustrated by the targets for this component of the project, for 2001:

- the creation of 18000 jobs per annum for previously unemployed individuals;
- 60% of the jobs to be allocated to women, 20% of the jobs to be allocated to youth (under 23 years), 2% to be allocated to disabled persons;
- every worker to average of two days of training every month and at least an hour of HIV-AIDS awareness training every quarter;
- every project to have a functional steering committee, with worker representation, and must facilitate access for workers to childcare (WFW 2001).

The programme has a national training programme, supplemented by regional training. It provides an ideal platform to train people in a range of work-related and general life skills including machine operation, gabion construction, driving, first aid, sexual education and AIDS awareness, teamwork, supervision, personal financial management and business management skills.

In the 1998/99 financial year, a total of 70 500 person days were spent on the training component of the programme (Haigh 2001). The ultimate aim is to arrive at a situation where empowered workers can form viable business units that can tender for work resulting from the Working for Water Programme.

Research

Research initiatives presently underway for WFW include:

Biocontrol: A study on the risks and benefits of using either biological control agents or herbicides in the fight against water hyacinth.
Hydrology: a number of studies, including

- **KwaZulu Natal study**: Analysis of Black Wattle's use of water in catchment areas; impact of the trees' water consumption rates, etc.
- **George Case study:** Conceptualising and costing a number of water supply augmentation options.
- **Breede River riparian zone study:** A study addressing the potential impacts of alien vegetation on channel pattern and shape and on the biodiversity of riparian vegetation and recovery rates after removal.

Soil Organics: a study of the loss of soil organic matter as a result of alien plant invasions, and the link between intense fires and damage to organic matter.
Herbicides: a study investigating the ecological and other impacts of using herbicides when clearing.
Fire intensity: a study on the impact on vegetation recovery.
Catchment stability after fire: a study on the possible impact of vegetation types on sediment runoff after fire.
Resource Economics

- **Insurance risks:** a project investigating the threats posed by fires that are fuelled by invasive alien plants.
- **Benefits and costs:** A macro-level evaluation of the benefits and opportunity costs of the WFW Programme.

Social Development

- **Gender Issues:** Study on gender issues in the WFW programme. Looking at challenges facing women in the programme, and possible opportunities within WFW.
- **Personal Financial Management:** a study focussing on how workers in the project level use wages from WFW employment.

Secondary industries

- **Biomass converter technology**: a comprehensive survey of the available biomass conversion technologies.

A number of research reports have also been completed for the WFW programme.

6.4 WETLAND REHABILITATION

The Convention on Wetlands (1971) defines wetlands as: '*areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres'* (Article 1.1). The classification system based on this definition, for use by the Convention, classifies wetland habitats into marine, estuarine, riverine, lacustrine, palustrine and endorheic wetland systems (Cowan 1999, Ramsar Convention Bureau 1997).

To some extent, within this definition and classification, rivers and their habitats could be considered to be classified as 'wetlands'. Whether this is true or not, wetlands and rivers are, under natural conditions, *linked* ecosystems. However, in many instances, long histories of resource exploitation has result in the loss of this link. The re-coupling of these ecosystems is one of the functions of an ecological restoration movement. For this reason, it would be short-sighted for river rehabilitation initiatives in South Africa not to partner and collaborate with current programmes in wetland rehabilitation, which are described here.

The Mondi (formerly Rennies) Wetland Programme

The Mondi Wetlands Project is one of the few projects in South Africa working on rehabilitation at a national level, from the ground-level to the political decision-making level. The project promotes the rehabilitation, wise use and sustainable management of South African wetlands. It aims to influence political decision makers at national and provincial levels, to ensure that wetland management will be included in policy making and macro-scale planning.

The project was started in 1991 by the Worldwide Fund for Nature, the Wildlife and Environment Society, Rennies, the Natal Parks Board, the Mazda Wildlife Fund and South African Breweries. It was known as the 'Rennies Wetland Project' until 2001 when Mondi took over major sponsorship of the project.

The first phase of five years was managed by the Natal Parks Board and operated mainly in KwaZulu-Natal. The aim was to raise the awareness of wetland owners and the public about wetlands. Workshops, farmers' day-talks and practical advice were provided, to farmers and agriculture/nature conservation extension officers.

The second five year phase of the project began in April 1996, and was managed by the Wildlife and Environment Society of South Africa (WESSA). This phase operates at a national level, promoting the wise use and rehabilitation of South Africa's freshwater wetlands. It is mainly directed at wetland owners/managers, conservation/agricultural extension officers and key governmental decision makers. The project employs a full time national co-ordinator, Mr David Lindley, who is a conservation ecologist with the Wildlife and Environment Society of South Africa.

The output of the first five-year phase was a series entitled 'Wetland Fix', developed in consultation with farmers and agriculture/conservation extension officers in KwaZulu-Natal, the Eastern Free State and Mpumalanga. Wetland Fix is South Africa's first illustrated set of field guides on the assessment, management and rehabilitation of wetlands. The guides are aimed at wetland owners, agriculture and conservation extension officers, and individuals interested in wetlands, and include sections on wetland assessment, wetland burning and grazing guides, streambank stabilisation and channel plug development, indigenous plants suitable for rehabilitation, a spring protection guide, and an alien plant control guide.

Working for Water links with Wetland Rehabilitation

There are government programmes and policies in place to conserve South Africa's wetland heritage and biodiversity. These focus on halting the loss of wetlands and promoting their wise use, and also on the restoration of these fragile ecosystems. The science of wetland rehabilitation is however considered to be in its infancy, and until late

2000, there was no national programme in place for the wetland rehabilitation and the reinstatement of ecosystem function and biodiversity (Dini 2000).

During July 2000, Working for Water (WFW) held discussions with the Department of Environment Affairs and Tourism (DEAT), and the Rennies Wetland Programme (now the Mondi Wetland Programme). It became apparent that WFW could be an ideal vehicle through which to effect wetland rehabilitation on a large scale. There was a logical connection between WFW's focus of increasing water yields through eradication of invasive vegetation, and restoring the capacity of wetlands to store, purify and slowly release this water (Dini 2000). In addition, wetland rehabilitaton is labour intensive, biodiversity would be protected in the process and the costs of follow-up were not considered to be great. These benefits match well with the aims of WFW (see previous section).

The discussions culminated in a partnership being formed between WFW, DEAT and the Rennies (now Mondi) Wetland Programme. For the 2000/2001 financial year, WFW allocated R20 million to the rehabilitation programme. Within the programme, WFW's role is implementation of projects and financial control, while that of DEAT is identification of projects, review of rehabilitation plans and monitoring of aspects of implementation.

The sustainability of the rehabilitation measures is a core theme throughout the projects. The causes of degradation are sought and commitment from landowners to undertake follow-up work is to be ensured. Education and awareness-raising of the value of wetlands are considered key components of the individual projects. Research, monitoring and evaluation are funded to ensure that there is learning from the experiences on each project (Dini 2000). Recently, research requirements of the programme, which stem from the individual project experiences, have been identified and tabled by the project (Dini, pers. comm.).

The DEAT/WFW wetland rehabilitation projects for the 2000/2001 year are listed in Table 6.1.

Table 6.1 DEAT/ WFW Wetland Rehabilitation projects during 2000/2001

WETLAND	PROVINCE	TYPE OF REHABILITATION
Rietvlei wetland	Gauteng	Structural
Wolkberg wetlands	Northern Province	Alien plants
Orange River Estuary	Northern Cape	Alien plants
Edith Stephens Wetland Park	Western Cape	Structural
KwaZulu-Natal Drakensberg Park wetlands	KwaZulu-Natal	Alien plants
Upper Blyde River wetlands	Mpumalanga	Structural
Verloren Valei wetland	Mpumalanga	Structural
Lenjane Wetland	**KwaZulu-Natal**	Structural
Zoar & Driepan wetlands	**KwaZulu-Natal**	Structural
Waterberg wetlands	**Northern Province**	Structural
Upper Sand River wetlands	**Northern Province**	Structural
Krom River wetland	**Eastern Cape**	Structural
Ntsikeni wetland	**Eastern Cape**	Structural
Ugie wetlands	**Eastern Cape**	Structural

6.5 INDIGENOUS PEOPLE'S KNOWLEDGE PROGRAMME

The way in which indigenous people interact or interacted with their environment has attracted interest for many decades of the environmental movement, but has recently surged, as is evidenced by texts such as Gottlieb (1996). Mrs Penny Bernard, an anthropologist at Rhodes University, Grahamstown, SA, has been researching the significance of water spirits within the African tradition for several years. Bernard is presently conducting research on issues of protection of, and rights of healers' access to, sacred water sites in South Africa. This project is being funded by the National Research Foundation (NRF) Indigenous People's Knowledge Programme. The following is summarised from an article written by Bernard for the DEAT Wetlands Newsletter November 2000, with the kind permission of both.

The importance of indigenous knowledge systems (IKS) has been acknowledged worldwide, together with a call for the formulation of proposals for its protection and preservation from a number of sources:

World Wildlife Fund (WWF)
International Union for the Conservation of Nature (IUCN)
Convention on Biodiversity (CBD – UNCED 1992)
International Labour Organisation (ILO)
United Nations Working Group on Indigenous Populations (WGIP)
World Intellectual Property Organization (WIPO)

Aligning with this, the South African National Research Foundation has identified a new research focus, that of the Indigenous People's Knowledge Programme. The programme is geared to capitalise on the potential economic value and possible commoditisation of such knowledge and the value of such knowledge in itself. Bernard notes her concern that the former could pose a serious threat.

The belief systems of southern African indigenous people regarding water, river systems and riparian zones are complex. The spirit world is believed to be the ultimate source of these life-sustaining resources. There are various manifestations of the spirit world, including the snake and the mermaid. These spirits live in or beyond the water and associate with humans in a number of ways. These spirits are central to many African healing traditions, still practised today. The central feature of a number of different Southern African ethnic groups' myths and legends is the association between the water spirits and the 'calling' of individuals to become diviners, chosen by the ancestors to receive the gifts of healing, sacred knowledge and psychic abilities.

Water in itself is considered among many African religions to be a living force, a powerful symbol and a medium for purification and healing. Water sources are vital parts of the landscape and are used for conducting rituals to aid communication with the spirit world. Certain places are more favoured by the river spirits than others. The spirits are believed to live in deep pools of certain rivers, often below waterfalls or fast moving 'living' water, or in the sea. It is believed that the ancestors or spirits of the water live in a dry area at the bottom of these pools and have a very similar lifestyle to people living on earth. These water sources are generally believed never to dry out, and it is said that the role of the spirits is to protect the water sources and keep them alive. The spirits are thus viewed as the guardians of the water.

The presence of certain vegetation, such as *Typha capensis*, is considered a sure sign of habitation by the water spirits. These areas are afforded a profound sacred status for Southern African indigenous communities, and there exists a range of taboos surrounding access to and use of them. In the past, a great deal of care was taken to avoid disturbing or angering the water spirits, and access was restricted except for healers associated with the water.

It is believed that together with the European colonists came a 'noise' which made many of the water snakes leave their pools forever, resulting in aridity. The departure of the snakes was also prompted by the disobedience of many. Damming or channeling of water from rivers also upset the river snake: during the building of the Kariba Dam, local people greatly feared that *Nyaminyami*, the great water serpent, would be angered. The many disasters which befell the dam project were attributed to *Nyaminyami's* distress at being separated from its mate downstream of the wall. Similar fears were expressed by the local communities during the building of Katse Dam for the Lesotho Highlands Water Project.

Bernard's research into this field provides an insight into the complex perceptions of water and water resources in southern Africa, and the importance of recognising and placing value in traditional indigenous beliefs and practices when planning for river rehabilitation. Bernard recommends that cognisance be taken of local taboos and observances regarding river access and utilisation, and that respect should be shown for these. Increasingly, there is likely to be backing from international organisations to minimise the threat of loss of indigenous knowledge and practice. '*This knowledge is now under tremendous threat of being discarded and forgotten as many communities are abandoning their traditional ways in favour of western education and capitalist enterprise, where the priorities for individual accumulation override the collective needs of the group, with devastating effects on the environmen*t' (Bernard 2000).

6.6 RESEARCH ON PRINCIPLES FOR RIVER REHABILITATION

Research is currently being conducted into the development of geomorphological and ecological principles for river rehabilitation. This project was initiated by Dr Jackie King (representing the University of Cape Town's Freshwater Research Unit), and is being undertaken as two projects, one led by Dr King and the other led by Dr Jan Boelhouwers (or representative) of the University of the Western Cape Department of Earth Sciences. Three post-graduate students are doing the majority of the research, under the guidance of these senior researchers and three senior academic advisors. The projects are funded over a period of three years (2000-2002) by the SA Water Research Commission.

The overall aim of the projects is the development of muli-disciplinary expertise in river rehabilitation, with the more specific aims of:

- providing a review of the world literature on river rehabilitation, assessing initial problem conditions and remedial actions taken;
- assessing and categorising the physical and ecological degradation of rivers in the Western Cape;
- evaluating past regional case studies of river rehabilitation;
- undertaking a regional study of the application of ecological and geomorphological principles for river rehabilitation in one urban and one rural catchment;
- generating a draft set of ecological and geomorphological principles for river rehabilitation.

6.7 PROJECT TO EVALUATE THE ECOLOGICAL EFFECTS OF MANAGEMENT ACTIVITIES

The Cape Metropolitan Council Administration's Catchment Management Department and the South Peninsula Administration (City of Cape Town) has appointed the Freshwater Consulting Group to compile the pilot phase of a handbook aimed at assessing the intentional or accidental ecological effects of a range of management activities in rivers and wetlands in the CMA area. The handbook includes strategies aimed at addressing:

- flooding issues;
- water quality issues;
- erosion;
- sedimentation;
- improving amenity value;
- improving wetland or riverine habitat.

Some or all of these may fall within projects dealing with river rehabilitation or restoration. The Freshwater Consulting Group (Day, pers. comm) states that the implementation of many of these projects has had ecological impacts that have often not been anticipated during their planning stages. Common problems include: poor timing of construction activities; under-budgeting of the time required for construction/planting activities; inadequate post-construction maintenance budgets, supervision or time; and inappropriate choice of plant material - either for the social environment or the ecological nature of the area. Similarly, many projects have been highly successful - either through good design or good fortune.

The purpose of the handbook is to provide a practical, working guide to the activity categories above from an ecological perspective, describing the successes and failures associated with each project, the lessons learned, and the ecological implications of both planned and unplanned activities associated with the project implementation and subsequent maintenance/operational phases of the system.

Freshwater Consulting Group have requested the assistance of practitioners in contributing case studies which will guide the development of appropriate approaches. The handbook is not intended as a criticism of situations where projects have not been implemented as planned, or where implementing recommended measures has not resulted in the anticipated product. Rather, it provides an opportunity to consolidate successes and failures of the past, for the benefit of future projects.

6.8 SUMMARY

A number of current initiatives in South Africa that either link, or could link, to river rehabilitation development were presented in this chapter. The intention was to illustrate a few of the activities and programmes already underway in the country which could, with some coordination, contribute to the development of the field of river rehabilitation and possibly the establishment of a national programme for this discipline. Those presented are only some of the many programmes and projects which could support, and be supported by, a standardised and scientifically-founded approach to river rehabilitation in South Africa. The writing of this chapter was an enlightening exercise, simply in establishing the levels of enthusiasm for rehabilitation in this country, and the willingness of individuals and projects to link up to develop the field collectively. The road ahead for rehabilitation in South Africa is likely to be a long one, however there are many wishing to participate in the growth of the science and practice of river rehabilitation. The strengthening of links both within the country and between rehabilitation practitioners in SA and internationally will equip this young field to keep pace with (and participate in the setting of) international trends. The development of a programme for river rehabilitation in South Africa would centralise efforts and facilitate the standardisation of generic approaches, and the development of regionally-appropriate guidelines.

CHAPTER 7

RIVER REHABILITATION IN SOUTH AFRICA: SUGGESTIONS FOR FUTURE DIRECTIONS

7.1 INTRODUCTION

Although the development of a 'new' discipline in the field of water resource management can scarcely be afforded in this country, the lack of a coordinated programme for river rehabilitation is likely to prove costly in the long term. There are a number of rational, cost-effective ways to approach the development of the field at both national and regional levels, building on lessons from the international experience and the excellent work already underway in water resource management in South Africa.

A great deal of time and money could be saved by adopting and and trialling Australian river rehabilitation processes, and adapting these to South African river types. In exchange, the ongoing export of expertise in the form of methodologies and approaches developed in this country, such as the *Building Block Methodology* of King,Tharme and de Villiers (2000), the *Objectives Hierarchy* of Rogers and Bestbier (1997), and certain of the DWAF's Resource Directed Measures (RDM) methodologies, would strengthen the reciprocal relationship between the two countries. Following a similar approach of knowledge exchange and partnering within South Africa, it would be possible to promote early development of a set of research needs, and within several years, both scientific and popular rehabilitation guidelines and procedures for use by South Africans. This would add some measure of quality control. A national database of rehabilitation approaches, projects, actions and outcomes would be an asset.

The recommendations made in this chapter should be regarded as preliminary, and serve to provide possible avenues to explore and investigate further. I take full responsibility for these ideas. I make no attempt to deal with the sort of logistics, R&D and negotiations that would be necessary to implement these recommendations, via the establishment of a national programme. This would be the subject of separate consultative research, and a comprehensive treatment of the subject would ideally be undertaken by a multidisciplinary task team.

7.2 ADOPT, TRIAL AND ADAPT

'First, demonstrate small successes...' D. Roux (pers.comm.)

The Australian River Rehabilitation process presented in this report is a generic one and was, in itself, strongly informed by experiential learning and by lessons from other countries. It is recommended that the *12 Step Process* of Rutherfurd et al. (2000a) and other procedural guidelines mentioned in Chapter 5 be subjected to scrutiny by South African river specialists. Once there has been some debate on the methodology, it is recommended that it be adopted, adapted where necessary, and trialled on a number of different river types in South Africa, initially at a small scale. Ideally, this would take the form of a number of small pilot projects dedicated to reahabilitation, in identified catchments. This will allow the gradual refinement and tailoring of the rehabilitation process to fit South African conditions. It also represents the first practical step towards the consultative development of regionally-appropriate guidelines for the rehabilitation and protection of SA rivers in a catchment context. The added benefit of this exercise would be the creation of a number of demonstration sites around the country. The value of these 'showcase' sites, for their role in engendering public support and enthusiasm, has been documented in several parts of the world (e.g. USEPA 2000).

7.3 SITUATE RIVER REHABILITATION

Up to now in South Africa, rehabilitation efforts have typically been on a project-by-project basis. This approach is piecemeal and ad hoc, and contributes nothing to the development of the field. Unfortunately, because the idea of restoration and rehabilitation is contemporary and fashionable, the title ‘rehabilitation’ is attached to many projects which in actual fact have very little to do with reinstating ecosystem process or function, and would be more accurately described as ‘river improvement’, ‘stormwater control’ or ‘greening of urban areas’ – all of which have value in themselves but are not rehabilitation. This inappropriate association of concepts could lead the field of rehabilitation into disrepute, particularly in the eyes of scientists and public.To avoid this, centralised definition and coordination of river rehabilitation is recommended.

Many of the countries which have developed fields of river rehabilitation coordinate activities through a national-level Programme. In the US, the Environmental Protection Agency (EPA) coordinates restoration at Federal and State levels, and in keeping with their ‘Watershed Protection Approach’ (WPA). The EPA is progressive in partnering with natural resource agencies, programmes, and communities to achieve common goals (USEPA 2000).

In Australia, as discussed in Chapter 3, the Federal agency Land and Water Australia (LWA, formerly LWRRDC) funds and coordinates a National Research and Development Programme into the rehabilitation and management of rivers and riparian lands. This is coordinated by the Cooperative Research Centres for Catchment Hydrology (CRCCH) and Freshwater Ecology (CRCFE) and undertakes the research in areas identified as gaps in the knowledge of the field. While smaller-scale rehabilitation projects may still proceed informally and doubtless in an ad-hoc fashion, the production of national-level guidelines for river and riparian restoration and stream stabilisation in Australia will gradually encourage the acceptance and use of common (albeit generic) approaches and processes. This will accelerate the cycle of continuous improvement in the practice of rehabilitation, and is likely to encourage the coming together of practitioners to share experiences and to collectively address technical issues.

It is recommended that within the next two to five years, a multi-disciplinary effort is directed towards identifying and establishing the logical ‘home’ for river rehabilitation in South Africa, first at a national level and later at regional and local (catchment) levels. This is a measure to provide the field with a national identity. The ‘home’ may take the form of a national Department, an alliance of Departments (as with the Working for Water Programme), a partnership with a current, appropriate national programme (such as the SA River Health Programme), a new and separate programme, or a privately-funded venture with credible, accountable ownership. The process of centralising the science and practice of river rehabilitation should, ideally, be broadly consultative. The issues to consider in the process include: the prevailing socio-political and economic milieu, funding mechanisms, legislative and policy frameworks, logistical requirements and constraints, existing linkages to build on, required linkages, resource management priorities and constraints in South Africa, and appropriate models of leadership.

7.4 BUILD ON AVAILABLE METHODS AND INITIATIVES

Methods for addressing the ecological sustainability of rivers (as ‘the resource’) have been developed and are in use in South Africa, within the Integrated Water Resource

Management, Catchment Management processes and Resource Directed Measures, as discussed in Chapter 5. A significant portion of the baseline information required in the river rehabilitation procedure is generated by these processes.

Links with IWRM, RDM and CM

As in all other countries, river rehabilitation is likely to be nested within Catchment Management, which in turn is nested within Integrated Water Resources Management (IWRM). There are clear linkages between the processes of river rehabilitation (Chapter 4), Resource Directed Measures (RDM), and Catchment Management (Chapter 5). Tables 7.1(a) and 7.1(b) illustrate some of these linkages. As RDM are a legal requirement, it would be effective to transfer the information acquired in these processes to river rehabilitation planning, or at least to make this information centrally accessible to rehabilitation practitioners. Measures to achieve this would have to be developed consultatively with relevant government Departments.

It is recommended that over the longer term, the integration of river rehabilitation planning and processes into IWRM and catchment management be considered, as this would be the most cost-effective and logistically efficient manner in which to approach these.

Table 7.1a. Generic steps and tasks in the South African RDM methodology. Similar steps in the 12-step rehabilitation process of Rutherfurd et al. (2000a) (Table 7.1b) are indicated.

STEP	GENERIC RESOURCE DIRECTED MEASURES PROCESS	Similar step in 7.1b
1	Initiate the RDM study:	
	- Identify significant water resources	5
	- Establish study team composition	11
	- Delineate geographical boundaries of smaller resource units within RDM study area	Part of 5
	- Select appropriate level of RDM determination	Part of 5
2a	Determine the ecoregional type of each resource unit	3
2b	Delineate resource units within the study area	3
2c	Select survey sites within the study area	Part 5,9
3	Determine the reference conditions for each resource unit	3
4a	Assess the present ecological status of the resource units	3,4
4b	Assess the importance and sensitivity of the resource units.	4
5	Set the Ecological Reserve Category for each resource unit	3
6a	Quantify the Reserve for each resource unit	-
6b	Set Resource Quality Objectives for each resource unit	7
7	Design an appropriate resource monitoring programme	3, 10
8	Notice of RDM	-

Table 7.1b. Generic Stream Rehabilitation Methodology *(from Rutherfurd et al. 2000a)* Similar steps in the South African RDM process (Table 7.1a) are indicated.

STEP	12 STEP STREAM REHABILITATION PROCESS	Similar step in 7.1a
1	Develop a vision	
2	Share the vision: • Identify who has interests in the stream • Identify who supports and opposes the goal • identify who has power to assist or obstruct the goal • identify mechanisms to increase support for the goal	Implicit in 1
3	Describe the stream • Divide the stream into segments and reaches • Construct a template of what the stream should look like (original condition, good condition, desired condition, model and scale analysis) • Describe the present condition of the stream	2a 2b - 4a
4	Identify assets and problems in the stream • Identify assets • Identify problems • Determine the trajectory of assets and problems • Map the assets and problems	 3,4a 3,4a 4b -
5	Set priorities • Assign reaches to one of nine categories (see Ch 5) • Rank the reaches that are in the same categories • Consider reasons for altering priority rankings • Identify fatal problems within reaches • Identify other limiting problems • Assign more than one rank to certain reaches	1, 2c Part 3,4a,b
6	Develop strategies to protect assets and improve the stream • Identify the range of options to solve the problems (including doing nothing, interventions, and altering people's behaviour)	- -
7	Develop specific and measurable objectives • Evaluate desired extent of change • Decide at what spatial scale to rehabilitatre • Set timeframes for a response • Consider what type of objectives to set • Query whether the objectives are achievable (in the context of having to evaluate the project on the basis of achievement of objectives)	6b
8	Evaluate feasibility of objectives • Affordability • Legal considerations • Holistic cost-benefit (negative vs positive outcomes) • Confidence in achieving desired outcomes • Assess feasibility	-

STEP	12 STEP STREAM REHABILITATION PROCESS	Similar step in 7.1a
10	Design the Evaluation • Define the type of measurable objective and the type of evaluation • Select one of five levels of evaluation (see Ch 5) • Design the evaluation plan.	7
11	Plan and implement the project • Break projects into tasks • Consider the order in which tasks should be done • Set realistic timelines and schedules • Decide on who will undertake tasks	Implicit in 1-8
12	Evaluate the project on the basis of its objectives, using the evaluation plan.	-

As is evident from Tables 7.1a and b, many of these processes are similar or overlap. Much of the information sourced during the RDM process could be transferred for use in the rehabilitation process, most particularly if sufficient collaboration between these two initiatives could be arranged at an individual project level. Agreement on priority reaches, survey sections etc. may not be possible because of the somewhat different nature of information requirements of each. However a great deal of the work done for the RDM process would inform the rehabilitation process, and in so doing facilitate both, and substantially reduce costs.

7.5 DEVELOP PARTNERSHIPS AND EXCHANGE INFORMATION

Throughout the world, the river rehabilitation movement seems to have been characterised by the building of, or at least the desire for, successful partnerships and linkages, for example, between:

- national and State/regional level governments (and their various laws);
- regional and local level authorities;
- authorities, management agencies, scientists and policy-makers;
- the private and public sector.

Certainly one of the reasons for the extraordinary success of some of these partnerships has been the presence of enabling legislation which has forced traditionally separate sectors together around a table.

Partnerships, joint ventures and strategic alliances are known to be valuable from a number of perspectives. These include: knowledge sharing, the development of multidisciplinary expertise *('the whole is greater than the sum of the parts'*); marketability; acquisition of funding; the provision of 'critical mass' of professional or experienced individuals which provides legal and political leverage; competitive edge; acceleration of learning; and development of best practice. The types of alliances which may be valuable to pursue in the building of the river rehabilitation field in South Africa are listed in Table 7.2.

Table 7.2 Possible partnerships and linkages at a number of levels to bolster the development of the field of river rehabilitation.

Level	**Possible linkages/partnershps:**	**Examples from elsewhere:**
National Level	• to foreign expertise, such as that from governments, agencies and academic or other institutions overseas, with an involvement in river rehabilitation development.	The Australian Federal Agency Land and Water Australia (formerly LWRRDC) makes provision for regular research exchanges (into and out of Australia) as part of its national River Restoration Programme.
National Level	• between different Government Departments (e.g. Water and Forestry, Environment and Tourism, Agriculture, Health, Education, Transport).	The national US Environment Protection Agency (EPA), USA, also operates at a State level. The EPA coordinates and facilitates river restoration activities on the basis of a watershed approach in each state, with national supervision. No ownership of the field is assumed by EPA, and Programmes and Projects are run by a suite of organisations, agencies and groups in consultation with the EPA (e.g. EPA 1995).
National and Regional	between: • Para-statals (e.g. CSIR, Agricultural Research Council)\ • Government • Industry & Private Sector (e.g. mining, agriculture, Chamber of Business etc) • Non-government organisations • Resource Management Agencies • Academic institutions	The concept of Cooperative Research Centres (CRCs) has worked extremely well in Australia. As described in Chapter 2, these are partnerships between government, industry, agencies and research institutions. Funding for academic research is largely provided by agencies and corporate partners, who also channel research needs and management questions to the academic partners.
National and Regional	to (or between) relevant national-level Programmes (e.g. SA National River Health Programme; Working for Water; DEAT Wetland Rehabilitation Programme; Indigenous People's Knowledge Programme)	R & D in the field of River Rehabilitation in Australia is increasingly occurring within the LWRRDC–funded Programme for River Restoration. This is the central body coordinating guideline development and attending to research needs, in collaboration with various CRCs.
Regional or Provincial	between: • Catchment Management Agencies / Authorities • Provincial authorities • Service providers	In Victoria, Australia, rural river rehabilitation planning and implementation is devolved to the level of Catchment Management Agencies, who work in close cooperation with the State body Department of Natural Resources and the Environment. Metropolitan rivers are managed by service providers in consultation with CRCs.
Local	to and between: • Local authorities, businesses, media • Catchment forums and community groups • NGOs and Conservation organisations • Educational institutions	This is the typical form of partnership that a small, community-based rehabilitation project would adopt. While there are countless projects of this nature, they are seldom documented in a critical fashion such that they can provide insights and learning to other similar projects (e.g. Kondolf and Micheli 1995)

7.6 ACCESS AVAILABLE INFORMATION

There is a wealth of information already in existence that would contribute to rehabilitation projects on an individual basis, and would also bolster the development of a framework for river rehabilitation. A database detailing how to access and use this information would be of great value to scientists, engineers, resource managers, developers or communities with river rehabilitation interests or projects. This would also allow identification of the gaps in our present knowledge (see Section 7.7).

Information presently available from the international field includes:

- published papers on rehabilitation experiences in the international literature;
- reports on programmes and individual river rehabilitation projects;
- practical rehabilitation guideline manuals from several sources in Britain, USA, Canada, Australia and other countries;
- educational video material on teaching of restoration principles and processes, and demonstration sites;
- a wealth of web-based material on river rehabilitation and case studies;
- internet-based discussion groups on rehabilitation in a catchment context;
- published texts and conference proceedings pertaining to river rehabilitation;
- newsletters from around the world relating experiences and learning.

It would be useful to have access to certain local information relevant to the rehabilitation process, for example:

- RDM methodologies e.g. Assessment of Present Ecological State, Ecological Importance and Ecological Reserve Classes;
- records of Ecological Reserve Determinations and major IFR outcomes;
- National Water Quality Guidelines;
- the Rivers Database of the SA River Health Programme;
- archives and Databases of Floral and Faunal Distributions in South Africa;
- other relevant guidelines, methodologies, software models, DSS's and protocols.

7.7 IDENTIFY RESEARCH AND INFORMATION NEEDS

The identification of research needs for river rehabilitation in Australia was carried out as part of a nationally-funded project (Rutherfurd et al. 1998), as discussed in Chapter 3. This is a structured and directed approach to guide scientific R&D, which would be critical to the development of processes and principles to underpin rehabilitation. It is recommended that this be considered within the next two years in South Africa. If the identification of research and information requirements is neglected, there is the likelihood that research efforts in the field of river rehabilitation will lack a collective and complementary approach and direction and the costly duplication of effort will result, and SA will not keep pace with international research in this field,

7.8 PRIORITISE RIVERS FOR REHABILITATION

There are already mechanisms in place to review which of the country's rivers have the greatest ecological, social, cultural, utilitarian and recreational 'value', and on the basis of this, which should be given priority in terms of conservation (Roux, pers. comm). RDM methodologies are clearly also directed towards establishing levels of Ecological Importance and Sensitivity of river systems throughout the country, and assigning Ecological Reserve Categories and Management Classes to these, which represents the equivalent of assigning a protection status (though not an enforceable one), as described in detail in Chapter 5.

Such prioritisation procedures could be extended to accommodate the prioritisation of rivers or sections thereof for rehabilitation or for enforceable protection (e.g. assigning National Heritage type status or the equivalent). The means of achieving this are worthy of consideration, even at this junction. At a general level, the sorts of questions this raises include: How are our resources being valued? In economic, political, utilitarian, social or ecological terms, or a number of these? Why? *(Investigate cause rather than symptom)*. Which values are dominant at present? Why? Should we aim to change this? If so, how? What are our time perspectives in resource management – short-term or long-term? Which can we really afford? With current priorities, can we justify financing proactive management approaches in preference to reactive management? Are we taking account of the costs of *not doing*, as much as we are the costs of *doing*?

Two 'prioritisation' models for river rehabilitation are presented here: one at a national level (US) and one at a state level (Germany). These are presented as concepts, rather than models to follow, as it has been difficult to source published material on their successes. Both were undertaken in countries wealthier than South Africa. Were either of these types of approach to be favoured in South Africa, it would be worth considering attaining at least partial financial support for the venture from industry and private sector.

A US Model: American Heritage Rivers (AHR)

In 1997, US President Bill Clinton issued the American Heritage Rivers Order (Executive Order 13061, 1997). This initiative had three objectives: natural resource and environmental protection, economic revitalisation, and historic and cultural preservation. The policy of the Federal government, in this regard was to allow communities to nominate a river or a section thereof to become an 'American Heritage River'. Rivers were to be nominated within the first stage on the basis of natural, economic, agricultural, scenic, historic, cultural or recreational resources of the river that rendered them distinctive or unique. Ten rivers would finally be selected as Heritage Rivers. The Federal Government role would be to support community-based efforts to preserve, protect and restore these rivers and their communities. Designated Executive Agencies (such as the EPA) were tasked with coordinating Federal plans, functions, programmes, and resources, to preserve, protect, and restore rivers and their associated resources. These Agencies were encouraged to develop partnerships with State, local and tribal governments, and non-governmental organisations.

The rivers selected in the first phase of AHR were:

- the Blackstone and Woonasquatucket Rivers (Massachussets, Rhode Island);
- the Connecticut River (Connecticut, Vermont, New Hampshire, Massachussets);
- the Cuyahoga River (Ohio);
- the Detroit River (Michigan);
- the Hanalei River (Hawaii);
- the Hudson River (New York);
- the Lower Mississipi (Louisiana, Tennessee);
- the New River (North Carolina, Virginia, West Virginia);
- the Rio Grande (Texas);
- the Potomac (DC, Maryland, Pennsylvania, Virginia, West Virginia);

- the St Johns (FL)
- the Upper Mississipi (Indiana, Illinois, Minnesota, Missouri);
- the Upper Susquchenna and Lachawanna Rivers (Pennsylvania);
- the Willamette River (Oregon) (American Heritage Rivers 2001).

According to anecdotal reports, and on the basis of personal interaction with Programme work and participants on the Hanalei River, Hawaii, the AHR approach has created an ethic of partnering between EPA, other agencies, NGOs and communities, and their approaches are proving effective.

A German Model

In the mid 1980s, the Ministry of Environment in the State of Baden-Wǚrttemberg (south-western Germany) inaugurated a research project to obtain information and experience with the re-naturalisation of the watercourses within the State. Fifteen sections of streams distributed throughout the State were selected as pilot projects to be executed and monitored through a ten-year period. Sections were typically selected within damaged reaches, and were in the order of a few kilometres in length. Some of these projects were in the monitoring stage by the mid-1990s (Larsen 1996).

7.9 DEVELOP EXPERTISE, TOOLS AND GUIDELINES

It is not unrealistic to expect that society's enthusiasm for undertaking rehabilitation projects will continue to grow, and that there will be an increasing and urgent need for both scientific and more popular processes and principles to guide rehabilitation, design 'tools', intervention approaches based on sound scientific and environmental engineering principles, and rehabilitation 'specialists'.

River rehabilitation is a unique discipline and requires the development of dedicated skills and expertise. Ideally, it should eventually become a recognised discipline. It is dangerous to assume that river rehabilitation is 'common sense' to the experienced specialist in a relevant discipline (as many such specialists seem to think). Expertise specific to the field must be developed in this country. In particular, the further development of the field of fluvial geomorphology should be promoted, and student training in this discipline encouraged. Provision of training and research opportunities directed towards creating an understanding of ecological and geomorphological processes, ecological uncertainty, disturbance, ecosystem recovery, and eco-hydraulics should be considered urgent requirements in this field.

At a 'ground-roots' level, in projects directed by community groups, the absence of educational tools and guidelines will undoubtedly lead to incorrect diagnoses of the causes of river degradation, and the subsequent implementation of incorrect measures to halt or rectify these. Once rehabilitation trials have been initiated on South African rivers, the phase of refining methodologies and developing guidelines specific to South African rivers (and river regions) should commence.

7.10 REVIEW LEGISLATIVE FRAMEWORKS, IDENTIFY NEEDS

A comprehensive review of existing legislation, policy, regulations and by-laws is required alongside the development of a rehabilitation programme. This should take the form of an electronic report that can be upgraded when and where necessary. Information requirements include:

- The jurisdictions of different authorities, and where overlap may occur;
- Areas of conflict in legislation or policy enacted by different government departments, or different levels of government;
- How National legislation interfaces with local regulations and by-laws. This must take cognisance of issues which could arise at his level, for example building by-laws in a city may be in conflict with National regulations on floodplain developments. Ways of addressing these conflicts should be considered.
- The features of international legislation and policy which has had positive outcomes for river restoration (e.g. in the US, the Endangered Species Protection Act and the Clean Water Act; and in Australia, National Competition Policy and COAG reforms).
- Legitimate ways of dealing with local and higher-level problems that are likely to occur in the planning and practice of rehabilitation.

This review would also provide for the recognition of 'gaps' in present legislation and policy, regarding river rehabilitation, which could be addressed at a higher level.

7.11 SUMMARY OF RECOMMENDATIONS

1. Adopt, Trial and Adapt. It is recommended that the generic Australian river rehabilitation processes be adopted, adapted and trialled on a range of river types in South Africa. This would allow refinement and tailoring of a rehabilitation process to fit South African regional river conditions. It also represents a practical step towards the development of national guidelines for rehabilitation.

2. Situate River Rehabilitation. It is recommended that within the next two to five years, a multi-disciplinary effort be directed towards identifying and establishing the logical 'home' and identity for river rehabilitation in South Africa, first at a national level and later at regional and local (catchment) levels. This 'home' may take the form of a national Department, an alliance of Departments (as with the Working for Water Programme), a partnership with a current, appropriate national programme (e.g. the SA River Health Programme), a new and separate programme, or a privately-funded venture with credible, accountable ownership.

3. Build on available methods and initiatives. The links between the generic processes of Resource Directed Measures (RDM) and River Rehabilitation are emphasised. Means of strengthening and building on these linkages should be investigated.

4. Develop Partnerships and Exchange Information. The structured creation of links, partnerships and alliances at a number of levels is recommended.

5. Access available information. A wealth of information is available to inform rehabilitation practitioners about present and historic river conditions. An effort should be made to ensure that relevant information is accessible for this purpose, through the use of, for example, a centralised database.

6. Identify research and information needs. It is recommended that an interdisciplinary effort be directed towards the identification of knowledge gaps and research and information needs for the development of river rehabilitation.

7. Prioritise rivers for rehabilitation. At a national level, a number of rivers should be prioritised for protection and rehabilitation, on the basis of a diverse set of criteria.

8. Develop expertise, tools and guidelines. It should not be assumed that river rehabilitation is common sense. It is a discipline in its own right. Even at the specialist level, expertise must be specific to the needs of the field. Tools and guidelines appropriate to the different South African river types will increasingly be needed. Development of these should proceed consultatively, informed initially by international experience (where appropriate) and by the outcomes of rehabilitation projects.

9. Review legislative frameworks and identify policy needs. It is recommended that a review of national legislation pertaining in any way to river rehabilitation be commissioned. Conflict in Acts implemented by different authorities should be investigated. The interface between national level and local-authority level jurisdiction should be clarified.

7.12 CONCLUDING REMARKS

Kondolf (1995), in his discussion of Californian river restoration projects, sounded a warning: '*Of the aquatic habitat enhancement projects evaluated to date, however, a large portion were found to have failed outright or to be ineffective. ... The project designers undoubtedly had the best intentions, but rivers are complex systems whose geomorphic behaviour is not easily predicted. The attitude behind the building of these projects is not unlike that prevailing when many rivers were modified in the first place: absolute faith that we can predict river behaviour, that we can modify the river so that its behaviour is more in accord with our notions of what is desirable, and that significant negative consequences will not result.* ***Today the over-arching programmatic goal may be "environmental restoration" instead of flood control or navigation, but the simplification of the riverine system and the faith in human modifications is strikingly similar***' *(emphasis mine)*.

Scientifically-based river rehabilitation is planned and undertaken in the good faith that it is possible to restore river systems both ecologically and structurally, such that they eventually bear a resemblance to their pre-impact states. Whether or not one has accurately determined the desired future state on the basis of *the river system* rather than *the human system and preference* is a cause for concern, and critical thinking around this issue should be central to the planning of rehabilitation projects. However, there is no reason to believe that rehabilitation is not an advance on previous modes of river management. Simply the fact that this 'new' science and practice has emerged at a time in history when the spiritual relationship between humans and their environment is openly discussed at scientific conferences (indicating the extent to which it has become accepted), engenders it with a value quite different to that prevailing in historic water management approaches. That the engineering and environmental worlds have begun to engage and to engage work collaboratively is further encouragement that the natural environment will increasingly be a worked with, rather than dominated by, developers. Increasingly, mitigation against the negative environmental consequences of developments is required by legislation.

It should not be hoped or expected that a recently rehabilitated river environment will show dramatically different ecological function in the short term, or for that matter, that the human mindset or political agendas will change rapidly to incorporate river rehabilitation purely for the benefit of river systems. Like catchment management, rehabilitation is not intended to be a quick solution or an academic exercise, but rather a new approach to our place within the natural world and our management of it. Every step in that direction is a success, however small it may be.

REFERENCES

Note that personal communications are listed separately at the end of references.

Alexander, J. 1992. Political, social, economic and environmental issues in Australian water management. *In:* J.J. Pigram and B.P. Hooper (eds). *Water Allocation for the environment – Proceedings of an international seminar and workshop.* Armidale, Australia.

Alexandersson, O. 1982. *Living Water*. Viktor Schauberger and the Secrets of Natural Energy. Turnstone Press Ltd, Stockholm.

American Heritage Rivers. 1997. *American Heritage Rivers*. Executive Order 13061. Dated 09-11-1997, Office of the Press Secretary, The White House, USA.

American Heritage Rivers. 2001. Website: www.americanheritagerivers.com.CHECK

Anderson, J.R. 1999. *Basic Decision Support System for Management of Urban Streams*. Reports A-D (incorporating Software and Users Manuals). National River Health Programme, Urban sub-programme, Reports No. 1, 2,3,4. LWRRDC Occasional Papers 8,9,10,11/99.

Anonymous, 1994. Australian River Research Newsletter 1. *National River Health Programme*. Published by CRC for Freshwater Ecology, Monash University, Victoria, Australia. Pp 1-4.

Arthington, A.H., King, J.M., O'Keeffe, J.H., Bunn, S.E., Day, J.A., Bludhorn, D.R and Tharme, R. 1992. Development of a n holistic appraoch for assessing environmental flow requirements of riverine ecosystems. *In*: Pigram J.J. and Hooper, B.P. (eds). *Water allocation for the environment*. Proceedings of an international seminar and workshop, Centre for Water Policy Research, University of New England, Armidale, NSW. pp 69-76.

Askey-Doran, M., Pettit, N, Robins, L. and McDonald, T. 1999. The role of vegetation in riparian management. Chapter 8 *In:* S. Lovett and P. Price (eds). 1999. *Riparian Land Management Technical Guidelines*, Volume One: Principles of Sound Management. LWRRDC, Canberra.

Australia Conservation Foundation. 2001. *River Flows*. A fact sheet. Published on the website: http:www.acfonline.org.au.

Bain, M. and Tilleard, J. 2000. A proposed plan for the rehabilitation of the Snowy River in Victoria. In: *In:* I. Rutherfurd and R. Bartley (eds). Second Australian Stream Management Conference. The challenge of rehabilitating Australia's Streams. Adelaide, South Australia, 8-11 February 1999. Cooperative Research Centre for Catchment Hydrology.

Ball, J and Hack, B. 2000. An Australia-wide water quality assessment: a model of cooperation. In: Water 2000.

Bennison, G. and Suter, P. 1990. Macroinvertebrates. *In:*N.MacKay and D. Eastburn (eds). *The Murray.* Murray Darling Basin Commission, Canberra, Australia.

Bernard, P. 2000. *Water Spirits*. Indigenous People's Knowledge Programme. The relevance of indigenous beliefs for river health and wetland conservation in southern Africa. In: South African Wetlands Newsletter (Published by DEAT). No 11.

Birkhead, A.L., James, C.S., Rogers, K.H. and van Niekerk, A. 2000. *Geomorphological change models for the Sabie River in the Kruger National Park*. Water Research Commission Report No 782/1/00.

Bjornlund, H and McKay, J. 2000. Are water markets achieving a more sustainable water use? In: *Water 2000.* Tenth World Water Congress, Melbourne.

Boulton, A.J. and Lake, P.S. 1992. The ecology of two intermittent streams in Victoria, Australia. II. Comparisons of faunal composition between habitats, rivers and years. *Freshwater Biology* 27: 99-121.

Breen, P. and Walsh, C. 1999. Remediation. *In*: Rutherfurd, I.D., Jerie, K.and Marsh, N. 2000. *A Rehabilitation Manual for Australian Streams*. Volumes 1 & 2. A joint publication by the Cooperative Research Centre for Catchment Hydrology, and Land and Water Resources Research and Development Corporation (now Land and Water, Australia). Accessible at: www.rivers.gov.au

Brierley, G. 1995. River styles: An integrative template for river management. Rutherfurd, I. and Bartley, R. (eds) 1999. *The challenge of rehabilitating Australia's streams.* Second Australian Stream Management Conference. Adelaide, South Australia, 8-11 February 1999. Cooperative Research Centre for Catchment Hydrology.

Brierely, G.J. 1994. River reach analysis as a geomorphic tool for river classification. *In:* M.Uys (Ed). Classification of rivers and environmental health indicators. Proceedings of a joint South African/Australian workshop, February 1994, Cape Town, SA. Water Research Commission Report No. TT 63/94.

Brierley, G. and Downs, P. 1999. Learning from international experience: River rehabilitation in Australia and UK: Convergence or divergence? *RipRap Edition* 13, 1999.

Brink, P., Nilsson, L.M. and Svedin, U. 1988. Ecosystem redevelopment. *Ambio* 17, 84-89.

Briscoe, J. 1997. Managing Water as an Economic Good: Rules for Reformers. Keynote Paper to: The International Committee on Irrigation and Drainage Conference on Water as an Economic Good. Oxford, September 1997.

Brizga,S. and Finlayson, B. 2000. Conclusions: Future Directions. In: In: B.I. Finlayson and S.O. Brizga (eds). *River management: the Australasian experience*. John Wiley and Sons, Chichester.

Bunn, S. 1994. Riparian stream linkages. In: M.Uys (Ed). *Classification of rivers and environmental health indicators*. Proceedings of a joint South African/Australian workshop, February 1994, Cape Town, SA. Water Research Commission Report No. TT 63/94.

Bunn, S., Mosisch, T. and Davies, P.M. 1999. Temperature and Light. In: Lovett, S. and Price, P (eds). *Riparian Land Management Technical Guidelines*, Volume One: Principles of Sound Management. LWRRDC, Canberra.

Bunn, S., Davies, P.M., Negus, P and Treadwell, S. 1999. Aquatic Food Webs. Chapter 4 in: Lovett, S. and Price, P (eds). *Riparian Land Management Technical Guidelines*, Volume One: Principles of Sound Management. LWRRDC, Canberra.

Burgess, G.K. and Vanderbyl, T.L. 1996. Habitat analysis method for determining environmental flow requirements. In: *Water and the Environment*, Proceedings, 23rd Hydrology and Water Resources Symposium, Institute of Engineers, Australia, 21-24 May 1996, Hobart, Tasmania.

Capon, S. 1999. Floodplain vegetation in Cooper Creek: A variable, arid zone catchment. *In: Riprap* Edition 14: Managing and Rehabilitating Riparian Vegetation. A LWRRDC Newsletter.

Central Statistical Services. 1997. Census 1996. Preliminary estimation of the size of the population of South Africa. Pretoria: Central Statistical Services.

Chessman, B. 1994. The use of macroinvertebrates for the rapid biological assessment of streams in the Sydney region, New South Wales, Australia. *In:* M.Uys (Ed). *Classification of rivers and environmental health indicators.* Proceedings of a joint South African/Australian workshop, February 1994, Cape Town, SA. Water Research Commission Report No. TT 63/94.

Chutter, F.M. 1998. Research on the rapid biological assessment of water quality impacts to streams and rivers. Water Research Commission, WRC Report No 422/1/98

COAG. Council of Australian Governments. 1995. Water Allocation and Entitlements: A National Framework for the Implementation of Property Rights in Water. Canberra.

Cook, A. 2000. Lessons from the past: land, water and salinity in the Goulburn Valley, Australia. In: *Water 2000.* Tenth World Water Congress, Melbourne, March 2000.

Cowan, G.I. 1999. *Biota of South African Wetlands in relation to the Ramsar Convention*. Department of Environmental Affairs and Tourism, Pretoria.

CRCCH. Cooperative Research Centre for Catchment Hydrology. 2000. Proposal for projects for 2000 under the River Restoration Programme. CRCCH Document, Melbourne University.

CRC Cooperative Research Centres. 2000. CRC website. www.isr.gov.au/crc/index

Cullen, P. 2000. Water reform. *Water 2000* . Tenth World Water Congress. Melbourne, March 2000.

Cullen, P., Whittington, J. and Fraser, G. 2000. *Likely ecological outcomes of the COAG Water Reforms*. Cooperative Research Centre for Freshwater Ecology.

Davies, B.R. and Day, J. 1998. *Vanishing Waters*. UCT Press, Cape Town.

Department of Natural Resources and the Environment (DNRE). 1999. *State Water Planning 2050*. DNRE, Victoria, Australia.

Department of Water Resources Victoria. 1989. *A Resource Handbook*. Water Victoria, Victorian Government Printing Office, North Melbourne, Victoria, Australia.

Digby, M.J. Saenger, P., Whelan, M.B., McConchie, D., Eyre, B., Holmens, N. and Bucher, D. 1999. *A physical classification of Australian estuaries.* National River Health Programme, Urban sub-programme, Report No. 9, LWRRDC Occasional Paper 16/99.

Dini, J. 2000. Major boost for wetland rehabilitation. *South African Wetlands Newsletter*, No. 11, November 2000.

Doring Kindersley. 1998. *Australia.* Doring Kindersley Publishers.

DWAF (Department of Water Affairs and Forestry) 2000. Guidelines for Catchment Management to achieve Integrated Water Resources Management in South Africa. July 2000. Published on the DWAF Website: www-dwaf.pwv.gov.za.

DWAF (Department of Water Affairs and Forestry). 1999. *Water Resources Protection Policy Implementation: Resource Directed Measures for Protection of Water Resources.* Version 1.0. Department of Water Affairs and Forestry, South Africa. Accessible at URL: www-dwaf.pwv.gov.za

DWAF (Department of Water Affairs and Forestry). 1996. SA Water Quality Guidelines for Domestic Water. DWAF, Pretoria.

DWAF (Department of Water Affairs and Forestry), DOH (Department of Health) and WRC (Water Research Commission). 1998. *Quality of domestic water supplies*. Volume 1: Assessment Guide.

DWAF (Department of Water Affairs and Forestry), DOH (Department of Health) and WRC (Water Research Commission). 1996. *Quality of domestic water supplies.* Volume 1.

Eckersley, R.(Ed.) 1995. *Markets, the State and the Environment: Toward Integration*. Macmillan Education Australia Pty Ltd., Melbourne.

Edgar, B. 2001. Inland rivers and riparian zones. In: *RipRap* Edition 8: Inland Rivers and Riparian Zones. A LWRRDC publication

Environment Protection Agency (EPA), US. 1995. *Watershed protection: a Statewide approach*. EPA report no. 841-R-95-004.

Fels, A. 1996. *Decision Making at the Centre*. Chairman, Australian Competition & Consumer Commission. European University Institute Workshop on the Implementation of Antitrust Rules in a "federal" Context. 19 April 1996.

Finlayson, B.I. and Brizga, S.O. 2000. Introduction. In: B.I. Finlayson and S.O. Brizga (eds). *River management: the Australasian experience*. John Wiley and Sons, Chichester.

Finlayson, B.I. and McMahon, T.A. 1988. Australia vs. the world: a comparative analysis of streamflow characteristics. In: Warner, R.F. (ed.). *Fluvial geomorphology of Australia*. Academic Press, Sydney. pp17-40.

Fisher, S.G. and Grimm, N.B. 1988. Disturbance as a determinant of structure in a Sonoran Desert stream ecosystem. *Verhandlungen der Internationale Vereiniging fur Theoretishche und Angewandt Limnologie* 23: 1183-1189.

FISRWG, 1998. Stream corridor restoration: Principles, processes and practises. Federal Interagency Stream Restoration Working Group, Washington.

Frissel, C.A.and Nawa, R.K. 1992. Incidence and causes of physical failure of artificial habitat structures in streams of western Oregon and Washington. *North American Journal of Fisheries Management* 12: 182-197.

Fryirs, K. 1999. Effectively prioritising river rehabilitation strategies based on recovery potential. In: *Riprap* Edition 12, March 1999. pp11-13.

Geist, C. and Galatowitsch, S.M. 1999. Reciprocal model for meeting ecological and human needs in restoration projects. Conservation Biology 13 (5), pp. 970-979.

Gippel, C.J. 2000. *The Victorian Snowy River, Review of Historical Environmental Changes and Proposed Rehabilitation Options*. Report by Fluvial Systems Pty Ltd, Melbourne in Association with ID&A Pty Ltd, Wangaratta to East Gippsland Catchment Management Authority, Bairnsdale, Victoria.

Gippel, C.J. 1999. Developing a focused vision for river rehabilitation: The Lower Snowy River, Victoria. Rutherfurd, I. and Bartley, R. (eds) 1999. *The challenge of rehabilitating Australia's streams.* Second Australian Stream Management Conference. Adelaide, South Australia, 8-11 February 1999. Cooperative Research Centre for Catchment Hydrology.

Gippel, C.J. 1995. Potential use of turbidity monitoring for measuring the transport of suspended solids in streams. *Hydrological Processes* 9, 83-97.

Gippel, C.J. and Collier, K.J. 1998. Degradation and rehabilitation of waterways in Australia and New Zealand. Pp.269-299 *in:* L.C.De Waal, A.R. Large and P.Max Wade. *Rehabilitation of rivers: Principles and implementation*. John Wiley and Sons, Chichester.

Gippel, C.J., Stewardson, M. and Finlayson, B. 1999. Commentary: The 2nd Australian Stream Management Conference: Enthusiastic dancing, but the footwork is still a little clumsy. Newsletter.

Goals Project. 1999. *Baylands Ecosystem Habitat Goals*. A report of habitat recommendations prepared by the San Fransisco Bay Area Wetlands Ecosystem Goals Project. US Environmental Protection Agency, San Fransisco, California/ S.F. Bay Regional Water Quality Control Board, Oakland, California.

Gorgens, A.H.M., Bengu, R., Grobicki,A.,Loots, L., Pegram, G.C., Tanner, A and Uys, M. 2000. Guidelines for catchment management to achieve Integrated Water Resources Management in South Africa. July 2000. Published on DWAF website: www-dwaf.pwv.gov.za.

Gottlieb, R. (Ed.) 1996. *This sacred earth*. Religion, Nature, Environment. Routledge, New York.

Green, P. 1993. *A review of the minimum target flow downstream of Balranald*. NWS Department of Water Resources Technical Report 93/01. Paramatta, NSW.

Haigh, E. 2001. Whacking Wattles for Water - the South African Working for Water Project. An innovative integrated approach to social and environmental rehabilitation. *Science in Africa.* June 2001. URL: www.scienceinafrica.co.za

Hall, D.N. 1989. Preliminary assessment of daily flows required to maintain habitat for fish assemblages in the Latrobe, Thomson, Mitchell and Snowy Rivers, Gippsland. Arthur Rylah Institute for Environmental Research. Technical Report Series 85, Department of Conservation and the Environment, Heidelberg, Victoria.

Heron, S., Chesterfield, C. and Sovitslis, A. 1999. ERAPSM: A model for setting priorities for environmental aspects of waterway management. In: I.Rutherfurd and R. Bartley (eds), *Proceedings of the Second Australian Stream Management Conference*. 8-11 February 1999. Adelaide, South Australia.

Hill, M.T, Platts, S. and Beschta, R.L. 1991. Ecological and geomorphological concepts for instream and out-of-channel flow requirements. *Rivers.* 2(4): 285-94.

Hobbs, R.J. and Norton, D.A. 1996. Towards a conceptual framework for the restoration ecology. *Restoration Ecology* 4 (2): 93 –110

Holling, C. S. (ed). 1978. *Adaptive Environmental Assessment and Management*. John Wiley and Sons.

Integra (Pty) Ltd, ID&A (Pty) Ltd & Lovett Clarke Consulting. 2000. *Knowledge Exchange and Capacity Building in River Restoration and Protection.* Design of a programme of activities to meet the needs of Australia's River Managers. Report to the National Rivers Consortium.

Integrated Water Resources Management Bulletin. April 2001.\A publication of Integrated Resource Management Research Pty Ltd, Brisbane. Australia. URL: www.catchment.com. The report on Catchment Management is available at URL: http://www.aph.gov.au/house/committee/environ/cminq/cmirpt/contents.htm

Imhof, J.G. 1999. *Holistic River Restoration in Australia: Observations, Tools and Approaches.* Travelling Fellowship Report. December 1999. Report to LWRRDC .

Kapitzke, I.R., Pearson, R.G., Smithers, S.G., Crees, M.R., Sands, L.D., Skull, S.D. and A.J. Johnson. 1998. *Stream stabilisation for rehabilitation in North-East Queensland*. LWRRDC. Occasional Paper Series 1998. 216pp.

Karr, J.R. 1981. Assessment of biotic integrity using fish communities. *Fisheries* 6(6): 21-37.

Kellner, K., Mappledoram, B., Findlay, J.B.R., Henderson, L., Kluge, R. and Campbell, P. 2000. Rehabilitation recommendations after alien plant control. A handbook jointly sponsored by the Plant Protection Research Institute, Pretoria; Water Research Commission, Pretoria; Rand Water, Gauteng; South African Wattle Growers Association, Dorpspruit; and the National Department of Agriculture, Pretoria.

Kern, K. 1992. Rehabilitation of streams in South-west Germany. *In*: P.Carling and G.E.Petts (eds). Lowland Floodplain Rivers: Geomorphological Perspectives. Wiley, Chichester.

King, J., Tharme, R.E. and de Villiers, M.S. 2001. *Environmental flow assessments for rivers: Manual for the Building Block Methodology*. Water Research Commission TT131/00.

Kleynhans, C.J. 1996. A qualitative procedure for the assessment of the habitat integrity status of the Luvhuvhu River (Limpopo system, South Africa). *Journal of Aquatic Ecosystem Health* 5:1-14

Koehn, J. and Cant, B. 1999. *National River Restoration Framework*: *A case study*. Report to LWRRDC.

Koehn, J. and Cant, B. 1999. *River restoration activities in Australia*. Report to LWRRDC.

Koehn, J.D. and O'Connor, W.G.1990. Threats to Victorian native freshwater fish. *Victorian Naturalist* Vol 107 pp 5-12.

Koehn, .D., Brierley, G.J., Cant, B.L. and Lucas, A.M. 1999. *National River Restoration Framework*. A report for the National Rivers Consortium.

Koehn, J.D., Nicol, S.J. and Lucas, A.M. 1997. River restoration through integrated management. Project No. R7001. Report to the Murray Darling Basin Commission.

Kondolf, G.M. 1998. Lessons learned from river restoration projects in California. *Aquatic Conservation: Marine and Freshwater Ecosystems*. 8: 39-52.

Kondolf, G.M. 1995. Five elements of effective evaluation of stream restoration. *Restoration Ecology* (3) 2: 133-136.

Kondolf, G.M. and Mitcheli. 1995. Evaluating stream restoration projects. *Environmental Management* 19 (1): 1-15.

Kotze, D.C., Steytler, N. and Kirkman, S. 1997. *Assessment and participatory management of riparian systems*. Draft of a report produced for the RIPARI-MAN Project and WWF. Institute of Natural Resources, Pietermaritzburg, South Africa.

Ladson, A.R. and White, L.J. 1999. *An Index of Stream Condition: Reference Manual*. Department of Natural Resources and Environment, Melbourne, Australia.

Land and Water Australia.(LWA) 2001. Formerly Land and Water Resources Research Development Corporation (LWRRDC). Website: www.lwrrdc.gov.za.

Larsen, P. 1996. Restoration of River Corridors: German Experiences. Pp124-143. *In:* G.Petts and P.Calow (eds). *River Restoration.* Selected extracts from *The Rivers Handbook.* Blackwell Science, Oxford.

Lloyd, C.J. 1988. *Either drought or plenty. Water development and Management in New South Wales*. Department of Water Resources, New South Wales, Paramatta, NSW, Australia.

Lovett, S. and Price, P (eds). 1999. *Riparian Land Management Technical Guidelines*, Volume One: Principles of Sound Management. LWRRDC, Canberra.

Louw, D. 2001. Starter Document for the Ecological Reserve Categories Meeting, Thukela Water Project. The Reserve Determination Model. Department of Water Affairs and Forestry.

LWRRDC. 2001. Land and Water Resources Research Development Corporation, now 'Land and Water Australia'. Website: www.lwrrdc.gov.za.

Lynch, R.J. and Caterall, C.P. 1999. Riparian wildlife and habitats. In: Lovett, S. and Price, P (eds). 1999. *Riparian Land Management Technical Guidelines*, Volume One: Principles of Sound Management. LWRRDC, Canberra.

Maher and Associates. (in prep). *Legislative arrangements for catchment strategies*. Mary Maher and Associates, Environmental Science and Services, Melbourne, Australia.

Maher, M., Nevill, J., and Nichols, P. (in prep.) *Improving the legislative basis for river management in Australia – Stage 2 Report,* Land and Water Australia, Canberra.

Mazza, P. 1995. *Bringing Back the Human Place in Nature: The Revolution in Ecological Restoration.* Published on: http://www.tnews.com/text/SER.html

McMahon, T.A., Gan, K.C. and Finlayson, B.L. 1992. Anthropogenic changes to the hydrological cycle in Australia. In: R.M. Gifford and M.M. Barson (eds). *Australia's Renewable Resources: Sustainability and Global Change*. Bureau of Rural Resources Proceedings No. 14, Australian Government Printing Service, Canberra, ACT, Australia. pp35-66.

McPhail, I.R. and Young, E.M. 1992. Water for the Environment in the Murray-Darling basin. IN : J.J. Pigram and B.P. Hooper (eds). *Water allocation for the environment*. Proceedings of an International Seminar and Workshop, 27-29 November 1991, The Centre for Water Policy Research. The University of New England, Armidale, NSW, Australia. pp191-210.

Melbourne Water Corporation. 1999. *Corhanwarrabul, Monbulk and Ferny Creeks Waterway Activity Plan.* Melbourne Water Corporation, Melbourne, Australia.

Melbourne Water Corporation. 1998/9. *Annual Report*. MWC Waterways and Drainage Operating Charter.

Milliman, J.D. and Meade, R.H. 1983. Worldwide delivery of river sediment to the oceans. *Journal of Geology* (91): 1-21.

Milner, A. M. 1996. System Recovery. In: G. Petts and P. Calow (eds). *River Restoration*. Selected extracts from the Rivers Handbook. Blackwell Science, Oxford.

Minchin, N. 2000. Media Release: Cooperative Research Centre successes highlighted. Senator Nick Minchin. Minister for Industry, Science and Resources. 6 December 2000. Website: www.crca.asn.au/press-releases/20001206-01.htm

Morris, S. and Moses, T. 1999. Urban stream rehabilitation: A design and construction case study. *Environmental Management* (23) 2: 165-177.

Moverley, J.and Hirst, A. 1999. Estuarine health assessment using benthic macrofauna. National River Health Programme, Urban sub-programme, Report No. 11, LWRRDC Occasional Paper 18/99.

Nevill, J. (in prep.) Freshwater Biodiversity: protecting freshwater ecosystems in the face of infrastructure development.

Nguyen, L. and Quinn, J. 1999. New Zealand Research: Riparian wetlands: Maintain, don't drain. *Riprap* Edn. 13: Benefiting from overseas knowledge and experience. LWRRDC Publication.

NHT (The National Heritage Trust). 2001. Website: www.nht.org.au

NHT (The National Heritage Trust). 1996. *National Heritage Trust Bill of Australia*. Accessible on URL: www.nht.org.au.

O'Connor, N., Lewin, K., Moore, S., & Bradshaw, E. 1999. *Sediment chemistry – macroinvertebrate fauna relationships in urban streams*. National River Health Programme, Urban sub-programme, Report No. 8, LWRRDC Occasional Paper 15/99.

O'Neil, J. and Fitch, L. 1992. *Performance audit of instream habitat structures constructed during the period 1982-1990, in south-western Alberta*. Page 4 in Abstract for meeting of the American Fisheries Society, September 1992, Rapid City, South Dakota.

Parslow, J., Hunter, J. and Davidson, A. 1999a. *Estuarine eutrophication models*. National River Health Programme, Urban sub-programme, Report No.12, LWRRDC Occasional Paper 19/99.

Parslow, J., Hunter, J. & Davidson, A. 1999b. *SEEM – Simple estuarine eutrophication models.* User's manual. National River Health Programme. Urban sub-programme, Report No.20, LWRRDC Occasional Paper 13/99.

Pettit, N. 1999. Natural regeneration of riparian vegetation in Western Australia. Case Study 1. *Riprap* Edition 14: Managing and Rehabilitating Riparian Vegetation. LWRRDC Newsletter.

Price, P. 1999. Benefiting from overseas knowledge and experience. Editorial, *Riprap* Ed. 13: Benefiting from overseas knowledge and experience. LWRRDC Newsletter.

Prosser, I. and Bunn, S.1999. Australian Riparian Research. LWRRDC Research Programme A: Sediment, nutrients and erosion. *Riprap,* Edition 13. LWRRDC Newsletter.

Prosser, I., Ogden, R., and Bunn, S. 1999. The influence of space and time. In Lovett, S. and Price, P (eds). 1999. *Riparian Land Management Technical Guide*lines, Volume One: Principles of Sound Management. LWRRDC, Canberra.

Prosser, I., Karssies, L., Ogden, R. and Hairsine, P. 1999. Using buffers to reduce sediment and nutrient delivery to streams. Section D *in* P. Price and S. Lovett (eds). *Riparian Land Management Technical Guidelines,* Volume Two: On-ground Management Tools and Techniques, LWRRDC, Canberra.

Ramsar Convention Bureau. 1997. The Ramsar Convention Manual: a guide to the Convention on Wetlands (Ramsar, Iran, 1971). 2nd Edition. Ramsar Convetion Bureau, Gland, Switzerland.

Rhodes, B.G. 2000. Water resources planning for Melbourne for a new century. *Water 2000*. Tenth World Water Conference. Melbourne, March 2000.

Rogers, K. and Bestbier, R. 1997. Development of a protocol for the definition of the desired state of riverine ecosystems in South Africa. Department of Environmental Affairs and Tourism, Pretoria.

RHP (River Health Programme). 2000. Information sourced from website at URL: http://www.csir.co.za/rhp/

Rutherfurd, I. 2000. Some human impacts on Australasian stream channel morphology. Pp11 – 49, in : B.I. Finlayson and S.O. Brizga (Eds). *River management: the Australasian experience.* John Wiley and Sons, Chichester.

Rutherfurd, I. and Bartley, R. (Eds) 1999. *The challenge of rehabilitating Australia's streams.* Second Australian Stream Management Conference. Adelaide, South Australia, 8-11 February 1999. Cooperative Research Centre for Catchment Hydrology.

Rutherfurd, I.D., Jerie, K. and Marsh, N. 2000a. *A Rehabilitation Manual for Australian Streams*. Volumes 1 & 2. A joint publication by the Cooperative Research Centre for Catchment Hydrology, and Land and Water Resources Research and Development Corporation (now Land and Water, Australia). Accessible at: www.rivers.gov.au.

Rutherfurd, I., Abernethy, B. and Prosser, I. 2000b. Stream erosion. In: Lovett, S. and Price, P (Eds). 1999. *Riparian Land Management Technical Guidelines*, Volume One: Principles of Sound Management. Land and Water Australia (LWRRDC), Canberra.

Rutherfurd, I., Ladson, A., Tilleard, J., Stewardson, M., Ewing, S., Brierley, G & Fryirs, K. 1998. 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.

Sanders, N., Watson, M., Bennett, J., Phillips, N., Moulton, D., Redfern, F. & Bain, J. 1999. New approaches to sustainability of Water Resources. In*:* I. Rutherfurd and R. Bartley (eds). Second Australian Stream Management Conference. *The challenge of rehabilitating Australia's Streams*. Adelaide, South Australia, 8-11 February 1999. Cooperative Research Centre for Catchment Hydrology.

Schumm, S.A. 1960. The shape of alluvial channels in relation to sediment type. *US Geological Survey Prof. Paper* 352B.

SGCMC. 1996. *Expert Panel Environmental Flow Assessment of the Snowy River below Jindabyne Dam*. Snowy Genoa Catchment Management Committee, Cooma, Australia.

Snowy River Alliance. 1998. Submission to Snowy Water Inquiry, May 1998, Part 2, *Oral history of the Snowy River.* Dalgety, New South Wales.

Snowy Water Inquiry. 1998. *Snowy Water Inquiry Final Report*. Snowy Water Inquiry, Sydney.

Stewardson, M.J. (In press). The flow events methodology for developing environmental flow regimes.

Stewardson, M., Gippel, C. and Tilleard, J. 1999. Hydraulic aspects of rehabilitation planning for the lower Snowy River. In: I.Rutherfurd and R. Bartley (eds). Proceedings of Second Australian Stream Management Conference, CRC Catchment Hydrology, Adelaide, pp. 601-607.

Stewardson, M.J., Gippel, C.J., & O'Neill, I.C. 1996. Evaluation of the hydraulic models used in PHABSIM for assessment of stream habitat. In: Proceedings of the Victoria Falls Conference on Aquatic Ecosystems, 15-19 July 1996, Zimbabwe, South African Society of Aquatic Scientists.

Stringer, D. 1995. Water markets and trading developments in Victoria. *Water*, March 1995, Melbourne, Australia.

Sweeting, R. 1996. River Pollution. In: G. Petts & P. Calow (eds). *River Restoration*. Selected extracts from the Rivers Handbook. Blackwell Science, Oxford.

Thomson Berril Landscape Design Pty Ltd and Fluvial Systems Pty Ltd. 1999. *Corhanwarrabul Creek. Waterway Activity Plan Report.* Report for Melbourne Water Corporation.

Treadwell, S., Koehn, J. and Bunn, S. 1999. Large woody debris and other aquatic habitat. In: S. Lovett and P. Price (eds). *Riparian Land Management Technical Guide*lines. Volume One: Principles of Sount Management. LWRRDC, Canberra.

Uys, M.C. 1998. The invertebrates of temporary rivers in the Eastern Cape, South Africa. PhD dissertation. Institute for Water Research, Rhodes University, Grahamstown, South Africa.

Uys, M.C. and O'Keeffe, J.H. 1996. Simple words and fuzzy zones: Early directions for temporary river research in South Africa. *Environmental Management* 21 (4) 517-531.

Volkman, J.M. and McConnaha, W.E. 1993. Through a glass darkly: Columbia River salmon, the Endangered species Act, and adaptive management. *Environmental Law* 23: 1249 – 1272.

Wem, P. 1998. The secret to successful riparian or channel restoration. *Riprap.* Newsletter of LWRRDC's Riparian Lands R&D Programme Issue 10.

White, L.J. and Ladson, A.R. 1999. *An index of stream condition*. (i) Field manual and (ii) Catchment manager's manual. Department of Natural Resources and Environment, Melbourne, Victoria.

White, P.S. and Pickett, S.T.A. 1985. Natural disturbance and patch dynamics: an introduction. In: White, P.S. and Pickett, S.T.A. (eds*). The ecology of natural disturbance and patch dynamics*. pp 3-13. Academic Press, New York.

Whittington, J. and Hillman T. Undated. *Sustainable rivers: the cap and environmental flows*. Information brochure distributed by the CRC for Freshwater Ecology & the Murray Darling Freshwater Research Centre, Canberra.

Williams, J.G. 1998. *Thoughts on Adaptive Management.* A discussion paper. Published on the website of the School of Landscape and Environmental Planning, Berkeley, California. Web Address: www-laep.ced.berkeley.edu/people/rrestoration/publications/williams98.doc

Williams, W.D. 1992. Water for sustainable resource management within a semi-arid continent. Keynote address. Pp11-17. In: J.J. Pigram and B.P. Hooper (eds). *Water Allocation for the environment* – Proceedings of an international seminar and workshop. Armidale, Australia.

Williams, W.D. 1983. *Life in Inland Waters*. Blackwell: Melbourne.

Working for Water. 2001. Information accessible at URL:
http:// www-dwaf.pwv.gov.za/wfw/Ref.asp.

PERSONAL COMMUNICATIONS

Bernard, Mrs Penny. 2001. Department of Anthropology, Rhodes University, Grahamstown. Email: p.bernard@ru.ac.za

Birkhead, Dr Andrew. 2001. Streamflow Solutions, 17 van der Linde Road, Bedfordview 2007, Gauteng, South Africa. Mobile: (+27)(0) 828535779. Email: streamflow@icon.co.za

Dini, Mr John. 2001. Assistant Director, Wetlands Conservation Programme, Department of Environmental Affairs and Tourism, Private Bag X447 Pretoria 0001, South Africa. Tel: +27 12 310 3789 Fax: +27 12 320 7026.

Day, Dr Liz. 2001. The Freshwater Consulting Group, 6 Flamingo Crescent, Zeekoevlei 7941, Cape Town. Email: lizday@mweb.co.za.

Gippel, Dr Christopher. 2001. Fluvial Systems (Pty) Ltd. P O Box 4117, University of Melbourne, VIC 3010, Australia. Email: C.Gippel@civag.unimelb.edu.au.

Hill, Dr Martin. 2001. Agricultural Research Council. Plant Protection Research Institute. Private Bag X 134, Pretoria, South Africa, 0001. E-Mail: Rietmh@Plant2.Agric.za. Tel: Int. + 27

12 3293276 (Local): 012-3293276 Fax: Int. + 27 12 3293278 (Local): 012-3293278

Ladson, Dr Anthony. 2001. Cooperative Research Centre for Catchment Hydrology, Department of Civil and Environmental Engineering, University of Melbourne Vic 3010 Australia. Tel +613 8344 6646 Fax +613 9923 6020 Mobile 0408 562 127 <t.ladson@unimelb.edu.au>

Lindley, Mr John. 2001. Coordinator: Mondi Wetlands Project. Wildlife and Environment Society of South Africa, Gauteng. Email:lindley@wetland.org.za.

Louw, Ms Delana. 2001. IWR Environmental, P O Box 122, Persequor Park, South Africa. Email: iwre@icon.co.za.

Roux, Dr Dirk. 2001. CSIR Environmentek, Pretoria. Mobile: (+27)(0) 824962144 Email: droux@csir.co.za.

Rutherfurd, Dr Ian. 2000. Cooperative Research Centre for Catchment Hydrology, School of Anthropology, Geography and Environmental Sciences, University of Melbourne, Victoria. Email: idruth@unimelb.edu.au

WEBSITES

Cooperative Research Centres (CRCs)	www.isr.gov.au/crc/index
DEAT/WFW Wetland Project	www.ccwr.ac.za/wetlands/
DWAF, SA	www-dwaf.pwv.gov.za
Land and Water Australia (LWA/LWRDC)	www.rivers.gov.au
River Health Programme	www.csir.co.za/rhp/
US EPA	www.epa.gov
Working for Water, SA	www-dwaf.pwv.gov.za/wfw/Ref.asp.