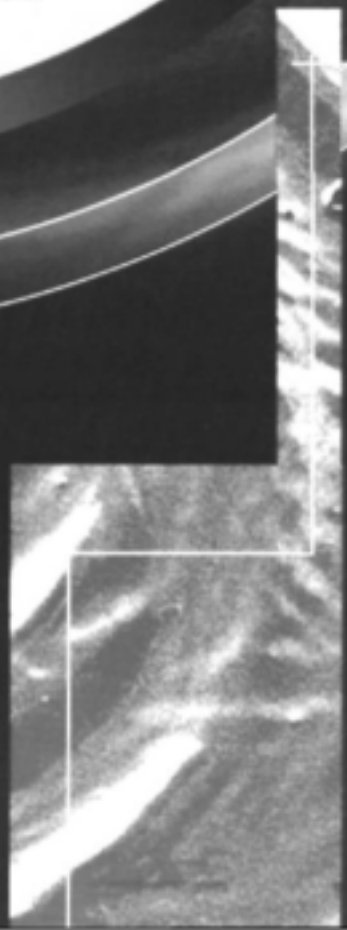
INVESTMENT STRATEGY FOR THE CROSS-CUTTING DOMAIN: WATER AND THE ENVIRONMENT

H Mackay · P Ashton · M Neal · A Weaver

WRC Report No. KV 148/04



Water Research Commission

INVESTMENT STRATEGY FOR THE CROSS-CUTTING DOMAIN: WATER AND THE ENVIRONMENT

Prepared for the Water Research Commission by:

Heather MacKay, WRC
Pete Ashton, Marian Neal and Alex Weaver, CSIR

Report No KV 148/04

June 2004

Obtainable from:

Water Research Commission
Private Bag X03
Gezina
0031

The publication of this report emanates from two projects entitled:
Development of an investment strategy for the environmental governance and biodiversity thrusts of the crosscutting domain: Water and the Environment (WRC Project No K8/498);
Development of the strategy for the Environment domain to project level (WRC Project No K8/546

ISBN 1-77005-193-7

Printed in the Republic of South Africa

TABLE OF CONTENTS

1 INTRODUCTION 1

2. HOW THIS CROSSCUTTING DOMAIN FUNCTIONS WITHIN THE WRC 5

3. INVESTMENT FRAMEWORK 7

4. FURTHER DEVELOPMENT OF THE STRATEGY 11

APPENDIX 1: APPROACH TO THE DEVELOPMENT OF A RESEARCH STRATEGY FOR THE "WATER AND THE ENVIRONMENT" CROSSCUTTING DOMAIN

APPENDIX 2: BACKGROUND INFORMATION PAPER FOR FOCAL GROUP MEETINGS

APPENDIX 3: PRELIMINARY LIST OF PRIORITY ISSUES FOR FUTURE RESEARCH (THRUST 1)

Any comments or queries on this document should be referred to:

Dr Heather MacKay
Head of the Crosscutting Domain: Water and the Environment
Water Research Commission
P Bag X03, Gezina
0031 South Africa
Email heatherm@wrc.org.za

1 INTRODUCTION

1.1 Background

The Water Research Commission (WRC) is a dynamic hub for water-centred knowledge, innovation and intellectual capital, providing leadership for research and development through the support of knowledge creation, transfer and application. The WRC engages stakeholders and partners in solving water-related problems that are critical to South Africa's sustainable development and economic growth, and are committed to promoting a better quality of life for all.

The WRC vision is to be a globally recognised leader in providing innovative solutions for sustainable water management that meet the changing needs of society and of the environment.

As stated in its core strategy the WRC will continue to focus on building a sustainable water-related knowledge base in South Africa by:

- Investing in water research and development;
- Building sustainable and appropriate capacity;
- Developing competences/skills for the water sector; and
- Forming strategic partnerships in order to achieve objectives more effectively while making optimal use of the latest global information/knowledge and other available technologies.

The core strategy of the WRC calls for specific mechanisms to address key strategic issues of national importance; these are dealt with in four crosscutting domains that have been established specifically for this purpose. During 2002/2003 the importance of these issues was highlighted when they emerged as major issues in the WSSD agenda and the newly developed agenda for NEPAD. These domains form integrating frameworks that cut across the Key Strategic Areas (KSAs) and draw together ongoing programmes and projects within the portfolios of each of the KSAs, and address issues relevant to the domains. The crosscutting domains may also drive specific programmes and/or projects that are overarching and relate to all KSAs in a more general manner.

The crosscutting domains address the following key issues:

- Water and Society;
- Water and the Economy;
- Water and the Environment; and
- Water and Health.

This document provides the strategic context for the Water and Environment domain and describes the proposed investment framework for this domain. The document comprises four sections plus two appendices: **Section 1** places the Water and Environment domain within the overall strategy of the WRC and outlines the rationale and scope of the research needs to be addressed. **Section 2** lists the principles, objectives and proposed success criteria that form the operating model for the domain. **Section 3** presents the investment framework down to research programme level, whilst **Section 4** charts the way forward. **Appendix 1** consists of a description of the process followed in drafting this strategy, whilst **Appendix 2** contains a copy of the background paper that was circulated to the individuals who were invited to

participate in the strategy development process. **Appendix 3** contains the preliminary list of issues identified as priorities for future research in Thrust 1 (Environmental functioning), and presented as research questions.

1.2 Integrating governance systems with ecological systems for effective, sustainable management

The hydrological cycle as an ecological system

Segmentation of the environment into different components (atmospheric, marine, aquatic, terrestrial and subterranean) demonstrates that the hydrological cycle links every component of the broader environment (**Figure 1**). This means that water resources are linked, via the water itself, to all the other components of the broader environment. For example, a disturbance or change to the atmospheric water component of the environment, whether natural or as a result of a direct human-induced impact, can be propagated via indirect impacts to terrestrial, aquatic and marine ecosystems. The additional complexity conferred by feedback loops and second and third order effects is omitted from **Figure 1**; these relationships are described more fully in the background paper contained in **Appendix 1**. The connections between components of the environment are bi-directional, in that direct impacts on non-water aspects of the environment can affect water, while direct impacts on water (such as abstraction or waste discharge) can affect the broader environment as well.

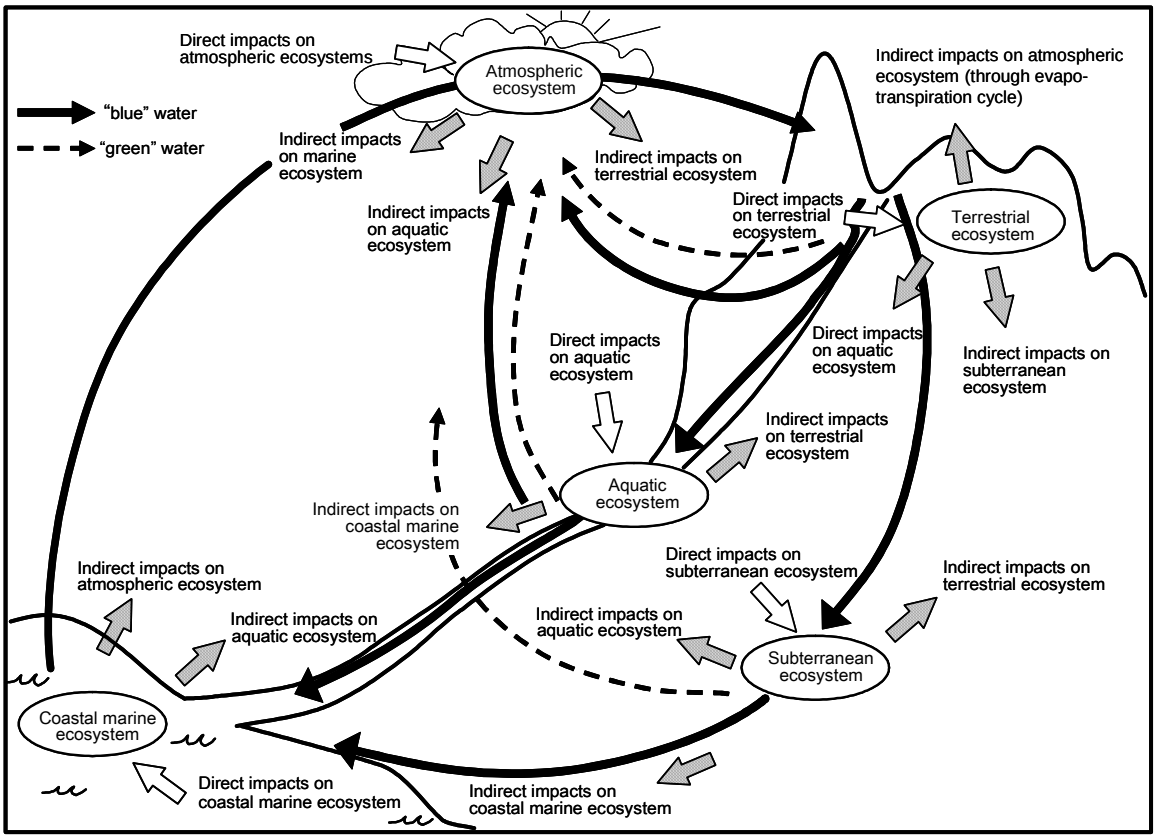


Figure 1: Phases of the Hydrological Cycle, showing the inter-relationships between environmental components and the so-called "blue" and "green" water components of the hydrological cycle, where "blue water" refers to all water that is controlled by physical processes and "green water" is the water that is influenced by biological processes such as evapo-transpiration by vegetation. Note that aquatic ecosystems include all surface water aquatic systems, i.e. riverine, wetland and estuarine ecosystems.

There are biophysical, biochemical and ecological links within and between each of the components comprising the hydrological cycle. Ecological processes play a critical role in regulating the hydrological cycle, and are themselves affected by biophysical and biochemical processes occurring within the hydrological cycle. Here, the structural, functional and compositional aspects of biodiversity play a variety of roles, at several different scales, in governing linkages within and between the components of the hydrological cycle. In addition, ecological functions and processes occurring within the hydrological cycle both affect the humans who are part of the governance/social system, and are affected by their activities.

Water in the hydrological cycle is affected by processes of landscape change. These can be due to changes in the topography and morphology of the landscape, which primarily affect the "blue water" component of the hydrological cycle, or due to changes in vegetation and land cover, which primarily affect "green water" through affecting infiltration and evapotranspiration. In South Africa, the principal piece of legislation in the water sector, the National Water Act (Act No. 36 of 1998; DWAF, 1998), recognises that water occurs in all phases of the hydrological cycle, and that interventions in one phase of the hydrological cycle can have knock-on effects in other phases. However, the National Water Act contains regulatory provisions to govern mainly "blue water" in aquatic ecosystems, which includes surface water and groundwater (as per the definition of a water resource in the Act). Atmospheric water is dealt with in other legislation, mostly environmental regulation at provincial level. "Green water" may be indirectly addressed, and even then only in part, in water legislation through the control of Stream Flow Reduction Activities (SFRAs), and by legislation and regulation in the environment, agricultural and land use planning sectors.

The National Water Act, in principle, does not allow the Department of Water Affairs and Forestry (DWAF), the primary water management agency in the country, to undertake integrated catchment management, because that would entail management, control and regulation of activities on the land as well as those directly affecting water. DWAF is mandated only to undertake "integrated water resources management", which is not as encompassing as "integrated catchment management". In terms of the Constitution, control of land-based activities is within the mandates of several other government departments. The only influence which DWAF as the water agency has, is the ability to set conditions on the nature, extent and significance of the impacts of land-based activities, at the point where these impacts directly affect water resources, not necessarily at their origin.

Aligning the governance system with the ecological system

For the purpose of this document, the governance system is defined as including typical governance elements, such as institutional forms and procedures, but also the social and economic structures of human society. The governance system related to the environment is shaped and determined partly by social values and imperatives, and partly by the constraints and opportunities afforded by the ecological system around which the governance system has evolved.

In recent years, a philosophy has been gaining ground which recognises that the separation between the ecological system and the governance system is artificial, and that humans should be considered as an integral part of the global ecological system, interdependent with that

ecological system. While this may be a philosophy that better reflects the realities of human dependence on and interdependence with ecological processes, most conventional government and legal institutions, at national as well as international level, still adhere to the view that "man is separate from nature".

Conceptually, the governance system can be superimposed onto the ecological system: this highlights the linkages between these systems (**Figure 2**), although still reflecting the perceived separation of humans and ecosystems. The role of biodiversity[1] in these linkages is not well understood, though it is believed to occur through the effects of changes in biodiversity on the flow of those goods and services that are valuable to society. There is an underlying assumption here that the ecological system sets constraints and limits on society's activities, and these determine whether or not society can survive, develop and prosper. For example, when the so-called "carrying capacity" of a particular ecosystem is exceeded, the consequences for society are often undesirable, though the precise consequences are seldom fully predictable or appreciated.

Ideally, therefore, a particular governance system should be matched to and aligned with the biophysical and ecological processes occurring within the ecological system that supports a society or community. Decisions about management, use and allocation of natural resources such as water should reflect the realities of the supporting ecological system. While the ideal might be a governance system that is fully integrated with the supporting ecological system, a governance system that is relatively better aligned with the ecological system is at least a significant step forward from the current situation.

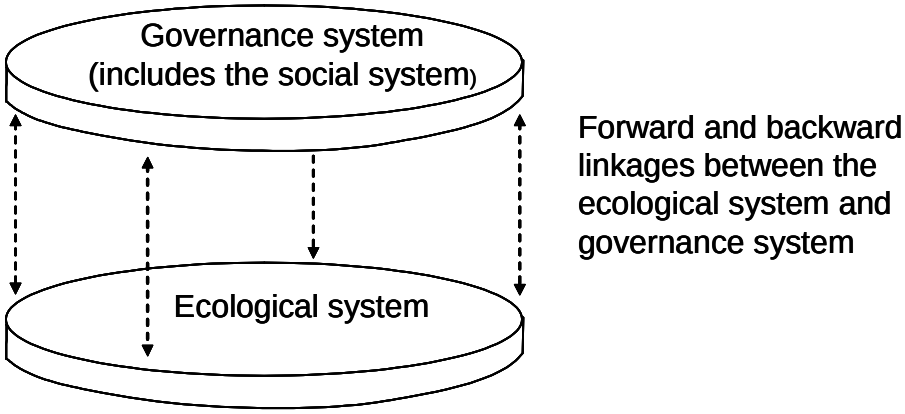


Figure 2: Conceptual diagram, showing the forward and backward linkages between a governance system and the ecological system, where the ecological system is represented by the hydrological cycle (as described in **Figure 1**).

1.3 The primary focus of this domain

In accordance with the principles of sustainable development, we need to ensure that: "*Our governance systems are aligned with our understanding of environmental processes and*

[1] The term biological diversity, or 'biodiversity' as it is more commonly known, is a multidimensional and multifaceted concept that refers to the diversity (in terms of both the variety and variability) of all organisms and their habitats, as well as the inter-relationships between organisms and their habitats. Basically, biodiversity is an expression of many different spatial levels or scales of organization, from genes to landscapes, with each level or scale having three different sets of attributes or components, namely: composition, structure and function.

functioning, in order to support sustainable water resource management that meets the needs of society".

Therefore, the primary challenge for South Africa will be to design and implement a governance system for water in the environment that:

- Is more closely tailored to the structure, function and processes occurring in the ecological system (i.e. the hydrological cycle), both within and between compartments of that ecological system;
- Can efficiently, effectively and promptly respond to change in the ecological system, either through adapting the governance system itself, or through feeding back into changed behaviour at the individual and/or institutional levels of the governance system; and
- Encourages management interventions that sustain healthy ecological systems, so that these can provide the necessary water-related goods and services to society.

To support this process, research in this crosscutting domain will address three key aspects:

1. Understanding the ecological system, and the role of biodiversity in that system, to enable prediction of the impacts of society's actions or the likely endpoints of observed trajectories of change;
2. Understanding the forward and backward linkages between the ecological and governance / social systems; and
3. Understanding the environmental governance structures and processes within society, and how to design a system for good governance, that better reflects and can respond to changes in the ecological system.

2. HOW THIS CROSSCUTTING DOMAIN FUNCTIONS WITHIN THE WRC

Currently the technical knowledge base on individual environmental components (for example, groundwater or riverine systems) is considered to be relatively well developed. However, our understanding of the complex processes and interactions between these components is still incomplete. The skills and experience of very high-level systems integrators could be deployed with relatively small investment to generate important new insights, understanding and knowledge about the linkages between causes and effects within and across the hydrological cycle. In addition, this domain will encourage and facilitate closer collaboration between specialists, beyond their traditional discipline-based, research and educational frameworks. Barriers to such trans-disciplinary collaboration and integration, both in terms of organisational structure and in terms of reward systems, still exist: these barriers need to be identified and ways of overcoming them must be explored and implemented.

Within the WRC, this crosscutting domain will:

- Work with the KSAs to guide and influence their programmes, whilst helping to integrate knowledge emerging from them;
- Promote the idea of "fellows", whereby researchers with specific experience in high-level integration are commissioned to do 'meta-research' on linkages within the hydrological cycle and between these components and the governance system. This could take the form of sabbatical secondments;
- High-level integration across WRC and other relevant national or international research programmes. As an example, evaluation of "the nitrogen issue" (the

implications of global climate change for the nitrogen cycle, and consequences for water management).

Enhanced integration is the primary mechanism that will be used to achieve the objectives of this domain. Different types / forms of integration will be encouraged, for example:

- Across disciplines involved in various components of the hydrological cycle and environmental governance;
- Across the KSAs, in the form of a cross-cutting framework;
- Across environmental components (air, land, marine, terrestrial, freshwater);
- Across relevant governance units/sectors;
- Across funding agencies working in the field of water in the environment; and
- Across the boundaries between researchers and water resource managers.

In order to measure the contribution of this domain to attainment of the high-level goal of aligning governance systems for water with ecological systems, the following set of "criteria for success" have been proposed (**Table 1**). These could form the basis for the development of key performance criteria for this domain.

Table 1: Proposed set of "criteria for success" in the crosscutting domain.

Time Scale	**Criteria for Success**
Short-term (< 3 years)	• Strategy developed and refined to project level. • Priority projects have been commissioned. • Key concepts have been communicated to the WRC, as well as members of the Research community and Governance community, via popular articles, publications, conference papers • Syndicated projects involving multiple funders have been initiated
Medium-term (3-8 years)	• At local, national and regional levels there should be: • Raised levels of debate in society, as evidenced by questions in Parliament, press clippings, etc., reflecting improved understanding of whole-ecosystem approaches to water management • Active participation by domain researchers in relevant policy debates. • Incorporation of domain concepts into relevant policy and legislation. • Incorporation of domain concepts into relevant institutional structures.
Long-term (> 8 years)	• We have sufficient understanding of the structure, processes and functioning of ecosystems throughout the hydrological cycle. • Our governance systems reflect our best understanding of the roles of ecosystem functioning. • Our governance systems are well aligned with our understanding of ecosystem functioning.

3. INVESTMENT FRAMEWORK

The Scope of the Crosscutting Domain: Water and the Environment

The close linkages between air, water and land, through the hydrological cycle, ensure that surface and ground water resources are strongly influenced by changes and processes that originate within the broader natural environment. Effective and sustainable management of water resources requires that we recognize and account for natural processes as well as human induced impacts occurring in the natural environment, which influence all phases of the hydrological cycle. This is one of the key principles of Integrated Water Resource Management (IWRM), which underpins South Africa's water policy and legislation.

Incomplete knowledge and understanding of the linkages between environmental components (atmospheric, marine, terrestrial, aquatic, subterranean) within the hydrological cycle, and between the hydrological cycle and governance systems, hinder sustainable water resources management. This crosscutting domain promotes enhanced understanding of whole-ecosystem functioning in the context of the broader environment and its effects on water resources, and supports the development and application of good environmental governance systems. Activities within this domain contribute to sustainable water resources management that meets the changing needs of society, by combining:

- Our understanding of good governance principles; with
- Our knowledge of environmental components (atmospheric, marine, terrestrial, aquatic, subterranean) and processes within the hydrological cycle.

The primary focus of the domain will be to integrate existing and new insights generated by research within and between the KSAs and by other institutions working in related fields. In addition, this domain will stimulate the generation of specific new knowledge and understanding that will equip the water sector to anticipate and respond appropriately to changes within the biophysical environment. Although this domain is characterized by integrating research at a high / meta-data analysis level, it is recognized that such research is only possible on the assumption that we have a sound foundation of appropriate basic research (and data) in place.

The objective of the domain is to contribute to achieving a situation where our governance systems and our understanding of environmental processes and functioning are aligned to support sustainable water management that meets the needs of society.

Thrust 1: Environmental functioning within the hydrological cycle	
Scope: All environmental components and processes within the hydrological cycle depend on and are regulated by the structural, functional and compositional aspects of biodiversity. Environmental components and processes also respond to and impact on society's decisions and actions. Historically, research has been narrowly focused on separate environmental components within the hydrological cycle rather than the processes and relationships between them. This thrust focuses on understanding these relationships within the hydrological cycle, their role in maintaining flows of water-related goods and services to society, and their vulnerability to change in the broader environment.	
Programme 1: Regional and global-scale changes in the (biophysical) environment	Changes in the broader environment at regional and global level may lead to significant long-term impacts on some or all of the components of the hydrological cycle. This includes the impacts of climate change on hydrology, water quality, biodiversity and ecosystem function, as well as the impacts of regional processes such as desertification; urbanization; migration of populations due to political, social, economic or environmental pressures (including HIV/Aids). This programme focuses on understanding the scope and significance of potential impacts of regional and global scale processes on environmental components and processes within the hydrological cycle, and hence on the availability, quality and reliability of surface and groundwater resources, and developing appropriate policy responses to these impacts.
Programme 2: Biodiversity	The structural, functional and compositional aspects of biodiversity underpin the resource base from which ecosystem goods and services are derived, yet our understanding of all these three aspects of biodiversity, their response to natural or human-induced change, and their role in sustaining the flow of ecosystem goods and services remains limited. This programme focuses on understanding the role of biodiversity in sustainable water resources management, the key drivers of changes in biodiversity, the implications for society and the economy of changes in biodiversity in the aquatic, marine, terrestrial, subterranean and atmospheric components of the hydrological cycle, and options for protection of biodiversity. The development of water resource management indicators that better reflect structural, functional and compositional aspects of biodiversity, and which are based on our best scientific understanding of the links between environmental stressors and ecosystem response, is an important activity within this programme.
Programme 3: Impacts and management of introduced species	Deliberate or accidental release of non-endemic species can have significant impacts on ecosystem structure and function across the hydrological cycle. This includes the introduction of commercial agricultural and forestry species, alien species (particularly those that are invasive), and introduction of genetically modified organisms (GMOs). This programme focuses on understanding the current and potential impacts of introduced species on environmental components and processes within the hydrological cycle, as well as the development of appropriate policy responses and integrated approaches to managing these impacts.
Programme 4: Interfaces	This programme focuses on developing both conceptual and quantitative understanding of biophysical and ecological processes occurring at the interfaces between components of the hydrological cycle, e.g. marine-freshwater, atmospheric-aquatic, groundwater-surface water, in order to identify critical points for management intervention, and to provide information and tools to support integrated management across the hydrological cycle.
Programme 5: Resource Directed Measures (RDM)	This programme focuses on integrating work done within the KSAs on the basic human needs and ecosystem aspects of resources directed measures for protection of water resources (those contained in Chapter 3 of the National Water Act: the classification system, the Reserve and resource quality objectives), and ensuring that the outputs of WRC-funded research are taken up within a co-ordinated national strategy for policy development related to protection of water resources.

Thrust 2: Environmental governance systems

Scope: Internationally, good governance is based on principles such as inclusivity, representivity, accountability, efficiency and effectiveness, as well as social equity and justice. In turn, good environmental governance should reflect our best understanding of the structure, functions, processes and variability that typify natural systems. Although there has been considerable development within the field of public, corporate and natural resource governance, little attention has been paid to the development of good environmental governance systems. This thrust focuses on water-related governance within society and the design of systems that better anticipate, reflect and respond to changes in environmental components and processes within the hydrological cycle.

Programme 1: Integrated planning processes	As water is a critical limiting resource for all development, water resource issues must be incorporated into spatial planning and development processes, such as IDP and SEA. This programme focuses on supporting the development of integrated planning frameworks in which the links between the environmental components of the hydrological cycle are explicitly recognized.
Programme 2: Harmonisation of national governance systems related to water in the environment	This programme focuses on identification of critical gaps or conflicts in national and provincial governance systems (including policy, law, regulation and practice), and the development of processes to promote co-operative governance or harmonization of governance systems that address water in every component of the hydrological cycle.
Programme 3: Policy mapping	Other sectoral policies (e.g. agriculture, mining, etc.) can have significant impacts on the water sector and vice versa. Therefore, it is important to undertake cross-sectoral and inter-sectoral mapping of the impacts of agricultural, economic, social development, biotechnology, trade & industry policies on the water sector, and to extend our understanding of the impacts of water policy on these sectors. This will also require that we identify gaps and potential points of conflict, as well as understanding and contributing to the development of integrated policy options that support environmentally sustainable development.
Programme 4: Regional and global governance	South African water-related governance systems are influenced by, and must respond to, regional and global environmental policy and governance, including SADC treaties and protocols, commitments related to international environmental agreements, and the NEPAD and WSSD outcomes. It is therefore important to identify national implementation issues that should be supported through water-related research, as well as to contribute to the development of new (improved) regional and global environmental governance related to water.

Thrust 3: Integrative knowledge for ecosystem-based water resource management

Scope: This thrust focuses on the generation, application and communication of higher-level knowledge and understanding of ecosystem approaches to water resource management, which can recognize and account for natural processes and human-induced impacts that affect water resources. This is achieved by stimulating the generation of new insights and information, through:

- Synthesizing outputs from relevant programmes and projects within the WRC's research portfolio;
- Combining these with the findings of other relevant national and international research initiatives; and
- Influencing and initiating appropriate new research to address gaps in current knowledge and deal with emerging new issues.

In order to strengthen the capacity to develop and apply ecosystem approaches to water resource management, the thrust will need to facilitate collaboration with other funding agencies and encourage partnerships between different research initiatives and with resource managers.

The desired outcomes of this thrust are:

- The development of mechanisms and communities of practice that integrate within and between the different specialist disciplines and knowledge bases related to both the biophysical environment and environmental governance systems;
- Co-operation between relevant governance sectors, helping to develop and harmonize environmental governance systems related to water; and
- Interactions between these groups, in support of good environmental governance practices.

Programme 1: Communication	Communication of results of integration to water sector, environmental research community and other affected sectors; communication of emerging environmental issues to water research community and water sector management community for the purpose of equipping the water sector to respond to changes in the biophysical environment. Preparation of strategic issues papers and popular literature items. Participation in workshops & conferences.
Programme 2: Capacity building	Building capacity for: high-level integration; application of higher-level knowledge; understanding of whole-ecosystem approaches. Promoting mentorship and supervision of young scientists on tasks involving high-level integration in thrusts 1 and 2. Promoting understanding amongst resource managers of how to apply this knowledge.
Programme 3: Networking	Promoting communities of practice related to thrusts 1 and 2 above. Enhancing interaction and communication between disciplines, institutions and individuals in order to achieve improved understanding and integration across people/groups working on components of the hydrological cycle, and between governance/water groups.
Programme 4: Futures	Maintaining awareness of national, regional and global environmental issues and trends that could/should inform water-related research in southern Africa. Stimulation of relevant new research or new activities, through preparation of strategic issues papers, briefing documents for government and parliament, terms of reference for solicited projects within the KSAs.
Programme 5: Strategy maintenance	Regular review of the domain strategy and adjustment or revision to take account of new research, changes in the governance system, and changes in the biophysical environment.

4. FURTHER DEVELOPMENT OF THE STRATEGY

The Water and Environment Crosscutting Domain forms one layer of an integrating framework that links the WRC's five Key Strategic Areas. The goal of this domain is to promote research that develops and aligns our understanding of good governance systems with that of environmental processes and functioning in the hydrological cycle. Ultimately, the objective is to strengthen and support sustainable water management to meet the needs of society.

This strategy document outlines the investment framework needed to achieve this domain's goal. The research framework identifies three thrusts and their associated research programmes. In order to inform the ongoing strategy development, and to identify research needs at programme and project level, two reviews were initiated in the 2003/04 financial year. The details of these projects are as follows:

1. A review of the national governance system related to water in the environment. This review will appraise and evaluate all the relevant governance elements (principles, policy, legislation, regulation and practice) at international, national and provincial level that are presently in place and which directly relate to or potentially impact upon water in all phases of the hydrological cycle. The purpose is to identify key areas of conflict or gaps that require research to support a process of harmonisation, or development of new governance elements. Where necessary, the links to equivalent governance systems in neighbouring states will be highlighted; these will have a very significant influence on the management of shared river systems.

2. A review of the national research portfolio (within the WRC and within other national agencies and research institutions) in the field of "water and the environment". Particular emphasis will be paid to the large catchment-scale studies that were conducted from 1975 onwards. Other relevant research, and that currently in progress, will also be included. The purpose is two-fold:
   - To identify and evaluate our existing knowledge base, to identify opportunities for high-level integration that could yield substantial new knowledge from relatively low levels of new investment. In this analysis, particular emphasis would be placed on knowledge about system processes and linkages between components of the hydrological cycle.
   - To identify critical knowledge gaps that preclude a deeper and more complete understanding of processes within the hydrological cycle. The linkages between biophysical components and ecological processes are particularly important.

The results of these reviews, plus additional inputs on this draft strategy from stakeholders, will be used to guide the revision of this strategy and the definition of thrusts down to project level (see Appendix 3 for preliminary list of priority issues for the thrust: Environmental functioning). These projects will include those supported directly within the KSAs as well as those cutting across all the KSAs and being led by the Water and the Environment Domain. The research framework has formed the basis for solicited and unsolicited project proposals for the 2005/2006 funding cycle, and for business planning for the period to 2009.

APPENDIX 1

APPROACH TO THE DEVELOPMENT OF A RESEARCH STRATEGY FOR THE "WATER AND THE ENVIRONMENT" CROSSCUTTING DOMAIN

A background paper (**Appendix 2**) was prepared which addresses two of the most important thrust areas within the Water and Environment Domain, namely 'Environmental Governance' and 'Biodiversity Protection and Environmental Functioning'. The primary purpose of the background paper was to serve as an introductory document to support a process of identifying the central issues related to environmental governance, biodiversity protection and ecosystem functioning, particularly as they relate to *the management of water in the environment*. This is intended to help position WRC research investments in this arena so that they can make a meaningful contribution to ensuring healthy ecosystem functioning and effective water resource management on a long-term, sustainable basis.

Numerous stakeholders are engaged in research and the application of research results to management issues as these relate to different aspects of governance, biological diversity and ecosystem functioning in aquatic, terrestrial, estuarine and marine ecosystems. The experience and opinions of these individuals and organizations represent a vital source of information that should be used to shape, test and ratify the WRC's investment strategy in the water environment. To achieve this engagement effectively, an invitation was issued to a wide range of stakeholders to participate in focused discussion groups. Despite the fact that not all the individuals who were invited could attend these meetings, the project team were able to hold thirteen focus group discussions with 63 selected stakeholders representing 21 different organizations (including research institutes, government departments, universities, NGOs and the private sector) from across the country (**Table A1**). The background paper was used to elicit their opinions, concerns and recommendations and to stimulate debate.

The inputs received from stakeholders, the original WRC outline for this domain, as well as a set of opportunities and constraints derived from a formal process of strategic analysis, formed the basis for the design of the three thrusts and their associated programmes (**Section 3** of the domain strategy document). **Figure A1** summarizes the approach used to formulate this strategy. The draft strategy was then used to elicit further feedback and commentary prior to revision. The results of work initiated in 2003/04 (see **Section 4** of the domain strategy document) will be used to further inform and revise this strategy.

The original background paper on environmental governance and biodiversity will be revised on the basis of comments received during the strategy development process, and will be submitted in this revised form for publication in a relevant journal.

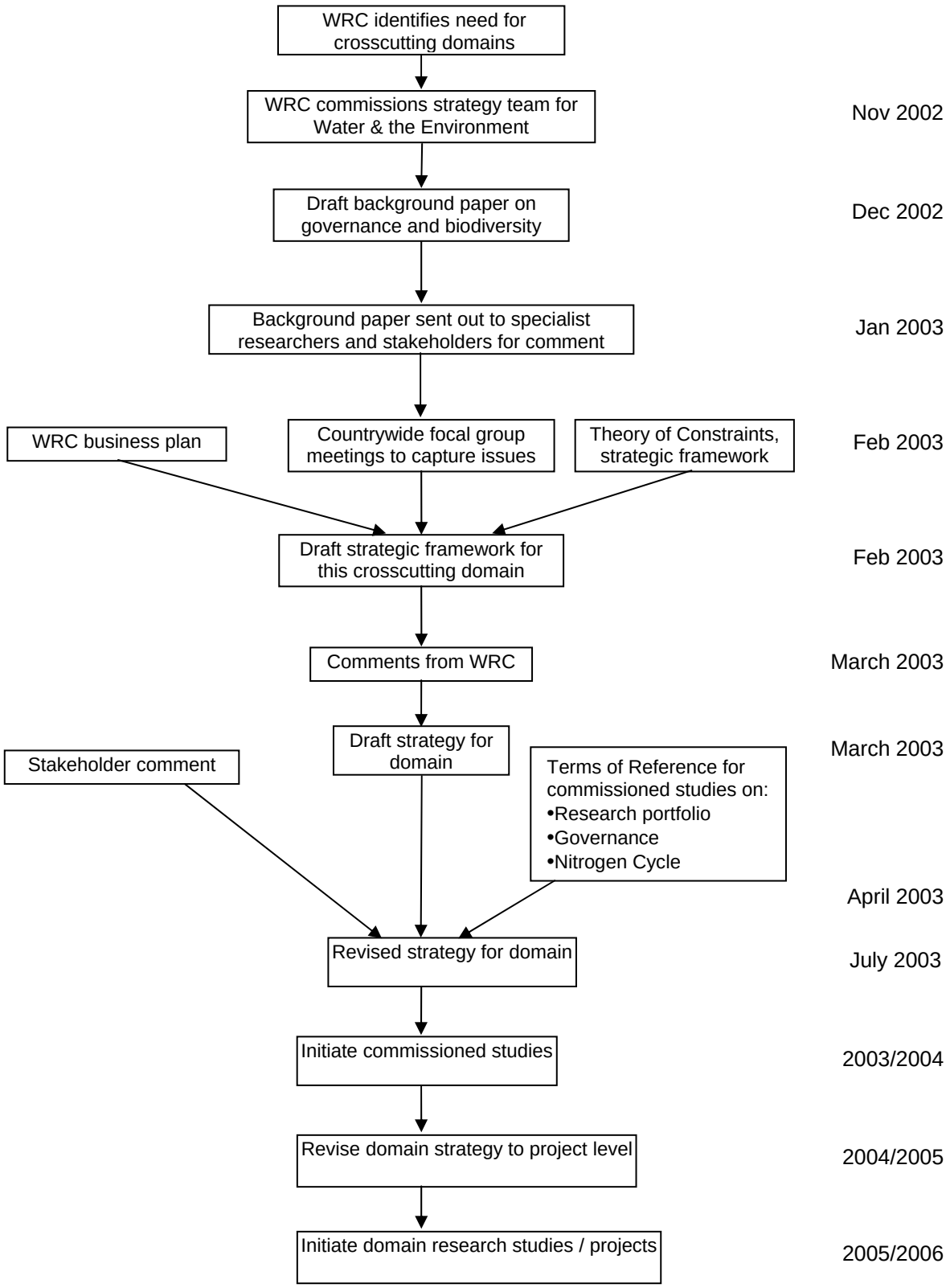


Figure A1: Flow diagram illustrating the approach to strategy development for the Water and Environment crosscutting domain, together with timescale and schedule of activities.

Table A1: List of participants who took part in the Focal Group Meetings.

Venue: WRC, Pretoria	**Date: 14 January 2003**
Participants	**Organisation**
Steve Mitchell	WRC
Kevin Pietersen	WRC
George Green	WRC
Meiring du Plessis	WRC
Rivka Kfir	WRC

Venue: DWAF, Pretoria	**Date: 14 January 2003**
Participants	**Organisation**
Neels Kleynhans	DWAF
John Dini	DEAT
Geoff Cowan	DEAT
Bill Rowlston	DWAF
Barbara Weston	DWAF
Harrison Pienaar	DWAF
Jean Msiza	DWAF
Cornelius Ruiters	DWAF

Venue: CSIR, Pretoria	**Date: 14 January 2003**
Participants	**Organisation**
Bob Scholes	CSIR
Dirk Roux	CSIR
Linda Arendse	CSIR

Venue: WITS, Johannesburg	**Date: 15 January 2003**
Participants	**Organisation**
Andrew Duthie	Oryx Environmental cc
Kevin Rogers	WITS
David Lindley	Mondi Wetland Project

Venue: INR, Pietermaritzberg	**Date: 16 January 2003**
Participants	**Organisation**
Peter Thompson	KZN Wildlife
Carol Goge	KZN Wildlife
Peter Kuyler	DAEA
Charles Breen	Institute for Natural Resources

Venue: CSIR, Durban	**Date: 17 January 2003**
Participants	**Organisation**
Bruce Kelbe	University of Zululand
Digby Cyrus	University of Zululand

Venue: UCT, Cape Town	Date: 20 January 2003
Participants	**Organisation**
Tony Barbour	UCT
Jessica Wilson	Environmental Monitoring Group
Ahmed Khan	Working for Water
Tobias van Reenen	University of the Western Cape
Jan Glazewski	UCT
Guy Preston	Working for Water
Lewis Jonker	University of the Western Cape
Christo Marais	Working for Water

Venue: CSIR, Stellenbosch	Date: 22 January 2003
Participants	**Organisation**
Albert van Jaarsveld	Stellenbosch University
Sarah Davies	CSIR
Leanne Seeliger	Stellenbosch University
Christine Colvin	CSIR
Susan Taljaard	CSIR
Brian van Wilgen	CSIR
Steve Lamberth	DEAT - MCM
Fanie Cloete	Stellenbosch University
Lara van Niekerk	CSIR
Alan Boyd	DEAT - MCM
Dave le Maitre	CSIR

Venue: Kruger National Park	Date: 30 January 2003
Participants	**Organisation**
Freek Venter	SANP
Andrew Deacon	SANP
Harry Biggs	SANP

Venue: Rhodes University, Grahamstown	Date: 4 February 2003
Participants	**Organisation**
Denis Hughes	Rhodes University
Paul Skelton	JLB Smith Institute
Lil Haigh	Rhodes University
Jay O'Keefe	Rhodes University
Kate Rowntree	Rhodes University
Lungisa Bosman	Rhodes University
Martin Hill	Rhodes University
Nikite Muller	Rhodes University

Venue: University of Port Elizabeth	Date: 5 February 2003
Participants	**Organisation**
Janine Adams	University of Port Elizabeth
Guy Bate	University of Port Elizabeth

Additional Participants	Organisation
Richard Fuggle	UCT
Martin Fey	Stellenbosch University
Andre Görgens	Stellenbosch University
Ben Cousins	University of the Western Cape
Cathy Oelofse	University of Natal-Durban
Dianne Scott	University of Natal-Durban

APPENDIX 2

WATER RESEARCH COMMISSION

Background Information Paper for Focal Group Meetings

THE DEVELOPMENT OF STRATEGIC INVESTMENT FRAMEWORKS FOR THE ENVIRONMENTAL GOVERNANCE SYSTEMS AND BIODIVERSITY PROTECTION & ENVIRONMENTAL FUNCTIONING THRUSTS

Prepared for:
Water and Environment crosscutting domain of the Water Research Commission

Prepared by:
Pete Ashton, Heather MacKay, Marian Neal and Alex Weaver

Date:
November 2002

CSIR

TABLE OF CONTENTS

1. THE WATER RESEARCH COMMISSION'S STRATEGIC PLAN 3

2. DEVELOPMENT OF AN INVESTMENT STRATEGY FOR THE WATER AND ENVIRONMENT DOMAIN 5

3. THE CONTEXT FOR THE WATER AND ENVIRONMENT DOMAIN 5

3.1 Water as a component of the environment 5
3.2 Water resources management in the context of the broader environment 7

4. IDENTIFYING PRIORITIES FOR INVESTMENT IN THE WATER AND ENVIRONMENT DOMAIN 8

5. WATER AND ENVIRONMENTAL GOVERNANCE SYSTEMS: A FRAMEWORK FOR ANALYSIS AND ASSESSMENT OF PRIORITIES 10

5.1. Governance of water in the environment 10
5.2. What is governance 11
5.3. A simplified framework for analysis and development of governance systems 12
5.4. Research priorities for development of the governance system for water in the environment 13

6. BIODIVERSITY PROTECTION AND ENVIRONMENTAL FUNCTIONING ... 17

6.1 Introduction 17
6.2 National, Regional and International Policy and Legislative Framework 21
6.3 Biodiversity Issues in Relation to Integrated Water Resource Management 27
6.4 Practical Issues and Implementation Considerations 28
6.5 The Way Forward 30
6.6 The Next Few Steps 31
6.7 References 31

Note:

This document is intended to provide background information for individuals who have been invited to participate in focus group discussions to develop an investment strategy for the Water Research Commission in the broad arenas of 'governance' and 'biodiversity'. All individuals are invited to read the introductory sections 1 to 4 of this document; these provide a general overview and describe the approach to be adopted. Thereafter, readers should choose between the 'governance' (section 5) and 'biodiversity' (section 6) sections of this document, according to their specific fields of interest.

1. THE WATER RESEARCH COMMISSION'S STRATEGIC PLAN

The Water Research Commission (WRC) has recently drawn up a strategic plan to direct their investments in future research in the South African Water Sector. The plan identifies five key strategic areas and an additional four cross-cutting domains that will serve to integrate research efforts between strategic areas. The key strategic areas (KSAs) are:

- Water Resource Management,
- Water Linked Ecosystems,
- Water Use and Waste Management,
- Water Utilization in Agriculture, and
- Knowledge Management.

Cutting across these five Key Strategic Areas are four domains, namely, Water and Environment, Water and Economy, Water and Society, and Water and Health (**Figure 1**).

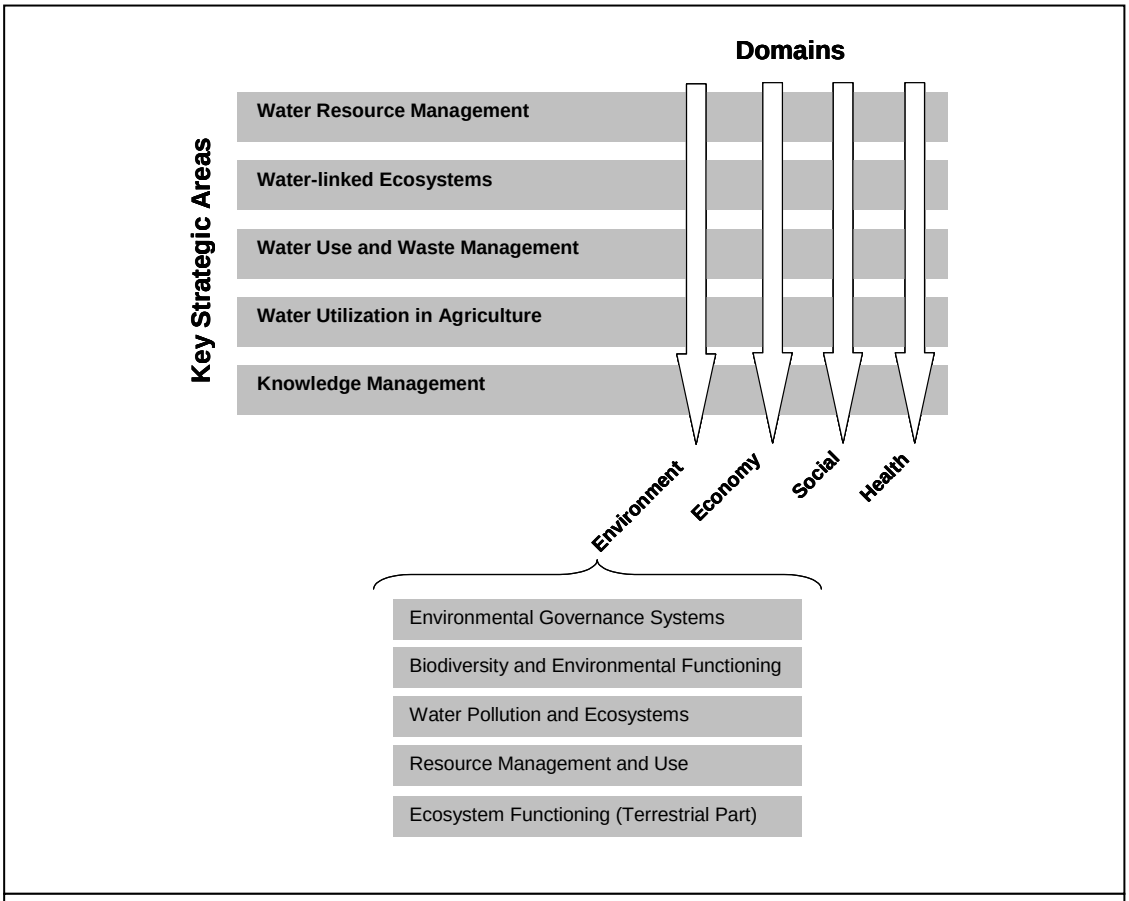


Figure 2: Key Strategic Areas and Cross-cutting Domains within the Water Research Commission

The Water and Environment crosscutting domain will contribute to a holistic understanding of the environmental (air, land, marine, aquifer, aquatic) linkages through the hydrological cycle, how environmental degradation impacts on water resources, how water-related activities impact on the environment and which methodologies need to be developed or can be used to minimise detrimental impacts. The approach will be based on the philosophy that "*prevention is better than cure*" through the development of appropriate source-directed controls and an

understanding of the natural assimilative capacity of the environmental system. Maintenance and improvement of the atmospheric, land and marine ecological environment will also be championed in this crosscutting domain. This will be done through understanding water-use practices and resultant disturbances that may occur as a result of improper use. Responsible use of natural resources associated with the water environment will be advocated through equitable allocation and appropriate conservation practices which take into account the consequences of depletion and degradation of the resource.

The 'Water and Environment' domain is related closely to the 'Water-linked Ecosystems' key strategic area. The domain focuses on "*the provision of knowledge to enable the utilisation and sustainable management of the aquatic ecosystem in a water-scarce country in a time of demographic and climate change*", but differs from 'Water-Linked Ecosystems' by having a wider environmental perspective. This perspective includes air, land, marine and terrestrial ecosystems, with the overall objective of supporting a broader understanding of the interlinkages of the hydrological cycle in relationship to the environment, so as to enhance and facilitate sustainable development practices.

To support a broader understanding of the interlinkages between the hydrological cycle and components of the environment, so as to facilitate sustainable development practices, the Water and Environment domain therefore aims to:

- Support development of technologies and processes (including best practice) that minimise release of waste in the water environment (source-directed controls);
- Better understand the impact of various land uses on the different components of the hydrological cycle and associated risks to the environment (e.g. biodiversity loss);
- Contribute to prevention of environmental degradation (atmosphere, land and terrestrial ecosystems) by water-related activities;
- Support use of the goods and services associated with the water environment in a responsible and equitable manner that takes into account the consequences of the depletion of the resources;
- Assist in developing environmental governance systems (including communication systems) that are appropriate to SADC circumstances. This needs to include understanding those issues that hamper environmental governance (e.g. HIV aids; poverty and the depreciation of the Rand); and
- Understand impacts of policy on the water environment, by establishing integration and co-operative mechanisms between the various legislative frameworks and policy directives.

The 'Water and Environment' domain comprises five strategic thrusts that address specific environmental issues. Each of these thrusts must provide clear guidance to the WRC and the research community as to the specific research needs and information requirements that must be met (**Figure 1**). These thrusts are:

- Environmental Governance Systems,
- Biodiversity Protection and Environmental Functioning,
- Water Pollution and Ecosystems,
- Resource Management and Use, and
- Ecosystem Functioning (Terrestrial Part).

2. DEVELOPMENT OF AN INVESTMENT STRATEGY FOR THE WATER AND ENVIRONMENT DOMAIN

The following sections address two of the most important thrust areas within the Water and Environment Domain, namely 'Environmental Governance" and 'Biodiversity Protection and Environmental Functioning'. The primary purpose of these sections is to serve as an introductory document to support a process of identifying the central issues related to environmental governance, biodiversity protection and ecosystem functioning, particularly as they relate to the 'water environment'. This is intended to help position WRC research investments in this arena so that they can make a meaningful contribution to ensuring healthy ecosystem functioning and effective water resource management on a long-term, sustainable basis.

Numerous stakeholders are engaged in research and the application of research results to management issues as they relate to different aspects of governance, biological diversity and ecosystem functioning in aquatic, terrestrial, estuarine and marine ecosystems. The experience and opinions of these individuals and organizations represent a vital source of information that should be used to shape, test and ratify the WRC's investment strategy in the water environment. To achieve this engagement effectively, several focus group discussions will be held with identified key stakeholders, where the relevant sections of this document will be used to elicit their opinions, concerns and recommendations. The document will be revised to reflect the inputs of all stakeholders that have been consulted, and will then be submitted to the WRC for incorporation into their strategic investment framework. If appropriate, the final version will also be submitted for publication in an appropriate scientific journal so as to promote shared understanding of the key issues amongst the wider southern African water resource research and management community.

3. THE CONTEXT FOR THE WATER AND ENVIRONMENT DOMAIN

3.1 Water as a component of the environment

We can consider the broader environment as being composed of the marine environment, the terrestrial environment (which includes the unsaturated zone of the soil horizon), the aquatic environment, the subterranean environment (which includes aquifers, cave systems and the saturated zone of the soil horizon) and the atmospheric environment. In this context, the term "environment" is a broad term that includes:

- The biophysical and biochemical template which is formed through the natural interactions of geology, topography, sediment and climate, and which provides varied forms of habitat;
- The plant, animal and microbial species which inhabit that template and, in turn, exert their own modifications to their habitats;
- The ecological processes which link these species to the template; and
- The humans who cohabit the biophysical and biochemical template along with the other species, as well as the processes which link humans to the template and to other species, generally through the impacts of human activities such as waste discharge or resource utilisation.

The first three aspects listed above (i.e. the habitat template, the biota and the linking processes) are, for the purposes of this document, collectively termed the ecosystem. Hence

the concept of 'the environment' includes ecosystems as well as humans and their activities. This means that economic and social factors need to be considered along with ecological factors in studying the broader environment.

Water itself appears in various forms as a component of all aspects of the environment, reflecting the different phases of the hydrological cycle (**Figure 2**):

- In atmospheric ecosystems in or related to South Africa, water is generally in the vapour or liquid form, and occasionally in the solid form as hail or snow.
- In terrestrial ecosystems, water may be held in vegetation and/or the unsaturated zone of the soil horizon and be part of the evapo-transpiration cycle – the term "green water" has been recently coined to describe water in this aspect (Falkenmark, 1999).
- Water in aquatic, marine and subterranean ecosystems appears in its liquid form, where it is usually termed "blue water" – this includes water held in aquifers, or in the saturated zone of the soil horizon. In the context of this background paper, aquatic ecosystems are those in which water is generally fresh or brackish (but may include hypersaline inland systems). Marine ecosystems include the estuarine and marine aspects of water, and for the purposes of this background paper, marine ecosystems are limited to the coastal marine environment.
- Water as ice tends to be common to terrestrial and aquatic ecosystems, and when held in glaciers forms a kind of bridge between terrestrial and aquatic ecosystems. Since there are no glaciers and no permanent snow cover in southern Africa, this form of water is limited to hail and snow when it is found in the atmosphere.

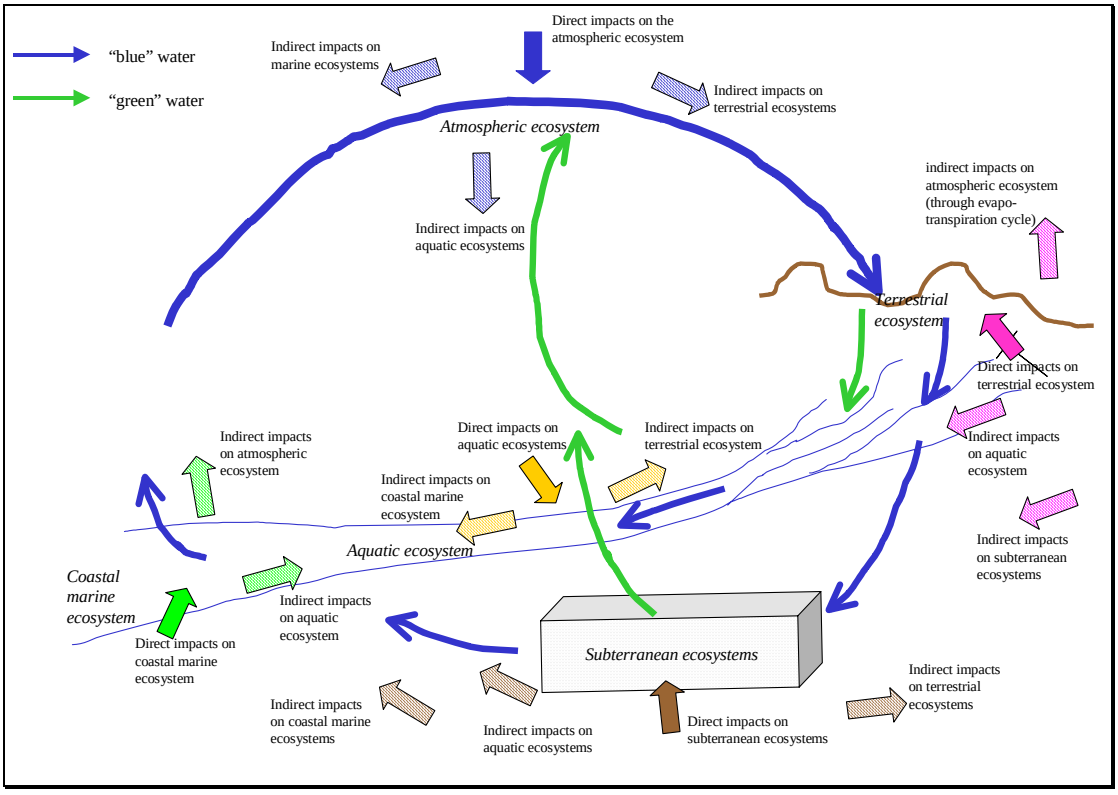


Figure 2: Phases of the hydrological cycle.

The point of the rather simplistic breakdown in **Figure 2** of the environment into different components (atmospheric, marine, aquatic, terrestrial and subterranean) is that the hydrological cycle links all these components of the broader environment, and this means that water resources are linked, via the water itself, to all the other components of the broader environment. A disturbance or perturbation in the atmospheric component of the environment, for example, whether natural or as a result of a direct human-induced impact, can be propagated via indirect impacts to terrestrial, aquatic and marine ecosystems. **Figure 2** indicates this, without showing the real-life complexity of feedback loops and second and third order effects. The connection between components of the environment is bi-directional, in that direct impacts on the non-water aspect of the environment can affect water, while direct impacts on water (such as abstraction or waste discharge) can affect the broader environment as well.

3.2 Water resources management in the context of the broader environment

The conventional water sector, in most countries, deals with water primarily as a commodity which, while it may be provided by and come packaged within an ecosystem, is usually delivered to people through some kind of infrastructure such as dams, pumps and pipes and is usually utilised outside the ecosystem from which it was derived, for agricultural production, industrial production or human consumption. The problem with the conventional approach to management of water as a commodity, separate from ecosystems, is that many of the values which humans place on water, aside from just having an adequate supply when they turn on a tap, are dependent on that water being a component of a healthy, functional ecosystem.

Humans have many uses for water, when it appears within ecosystems, such as for maintenance of a supply of food, fibre and timber products, transport, recreation, support of cultural and spiritual practices, purification and removal of some kinds of wastes. Ecosystems, particularly those in which water is a critical component or the main component, are resilient and can withstand a certain degree of impact, including abstraction of water, abstraction of food and fibre resources, discharge of waste or modification of the biophysical and biochemical template. However, if too much water is taken out, too much waste put in, or the template is modified too greatly, the structure and function of an ecosystem is often irreversibly changed, leading to irreparable changes in the availability and quality of the services which the ecosystem formerly provided, such as a predictable supply of water of good quality, or a certain stock of fish resources. Human activities impact the ecosystem, and thus the water itself. Hence there is a need, in the water sector, for water resources to be managed as ecosystems, in order to sustain the values, benefits and services of water for both instream and offstream uses (DWAF, 1997). From both government and governance points of view, this requires either removal of the artificial boundary between the environment sector and the water sector (and a few other sectors besides), or very close co-operation between environment, water and related sectors (MacKay & Ashton, in prep.).

In terms of management of any one component of the environment, there is a need to manage both direct and indirect impacts on that component (see **Figure 2**). For example, removal of terrestrial vegetation has direct impacts on a terrestrial ecosystem. The cause of the impact might be overstocking, leading to overgrazing, which leaves the soil surface exposed to rain and wind erosion. Erosion can lead to indirect impacts on associated aquatic ecosystems through sedimentation and subsequent loss of aquatic habitats. Removal of vegetation might

also have indirect impacts on the atmospheric ecosystem due to changes in the evapo-transpiration cycle.

In general, it is possible to identify the major direct and indirect impacts on a component of the environment which are of most concern and which require management interventions. In order to design the most appropriate and effective management intervention(s) in each case, it is necessary to understand and be able to quantify the chain of cause and effect linkages between the impact of concern and the origin of that impact, whether the origin is within that component of the environment, or whether it is located in some other component. The most effective intervention may need to be made at the origin of the impact, or somewhere along the cause-effect chain, in order to meet certain desired outcomes in the component of the environment that is of interest. For example, the major issues of concern with respect to water resources might be listed as follows (this is not an exhaustive list):

- Salinisation;
- Acidification;
- Eutrophication;
- Toxic pollution;
- Microbiological pollution;
- Sedimentation;
- Change in flow patterns;
- Change in temperature patterns; and
- Degradation of aquatic ecosystem health.

Typically, an impact such as salinisation may have its root causes both within the water sector, through the discharge by industry of saline effluents (a direct impact on the aquatic ecosystem), and within the agricultural sector, through saline irrigation return flows (an indirect impact on the aquatic ecosystem, originating within the terrestrial ecosystem). Addressing the problem of salinisation of surface waters will require understanding of how both the direct and indirect impacts that lead to salinisation are generated, and how they should best be controlled. Clearly, interventions will be required both in the water sector and within other sectors, predominantly the agricultural sector. While the interventions may be implemented and administered by different agencies, the ultimate objective should be the same. This is where the issue of co-operative governance becomes so important: the responsible agencies must share common objectives for the management of salinisation of surface water resources, and must act accordingly; otherwise, their interventions will, at best, be less effective than they could, and at worst, may even be in conflict. The best way to ensure common objectives is through taking an ecosystem approach, understanding the interactions between different components of the environment, and viewing water resources as only one component of the broader environment, to be managed as such.

4. IDENTIFYING PRIORITIES FOR INVESTMENT IN THE WATER AND ENVIRONMENT DOMAIN

The sustainable management of surface and groundwater resources in the context of the broader environment requires the development a very wide “net” of governance, consisting of governance elements within several different administrative sectors, that extends over the broader environment, including the terrestrial, atmospheric and coastal marine components. To design that governance net, we must first understand the linkages between the different components of the environment, and how impacts are propagated and transformed along the

hydrological cycle from one environmental component to another. Only then can we design the most appropriate policy and regulatory interventions that will effectively address key water resources management priorities.

The WRC's biodiversity thrust addresses the understanding of the role of biodiversity in supporting sustainable water resources management. Research in this field must be directed towards promoting our understanding of cause-effect relationships within the broader environment that significantly affect water resources, and vice versa. The governance thrust addresses the design of an appropriate governance net that is built on our understanding of environmental cause-effect relationships, and which will help us to achieve the national objectives of sustainable, equitable water resources management.

The purpose of the focus group discussions upon which we are embarking is to draw upon the insight and experience of a diverse group of stakeholders, in order to identify priorities for strategic research investment, to form the basis of an investment strategy for the Water and Environment domain. The simplified concept of the broader environment, as set out in **Figure 2** provides a useful framework for identifying the major issues of concern, direct and indirect impacts on water resources and the origins of these. The focus groups may wish to utilise a set of fairly broad questions to guide their discussions:

- What are the most significant impacts, direct and indirect, on aquatic ecosystems that affect water resources management, including issues that are current and those that are emerging as significant?
- What are the root causes of these impacts?
- In each case, do we sufficiently understand the cause-effect linkages between the origin(s) and the impact in order to be able to quantitatively predict the effects of different management interventions?
- If not, what research is needed to generate this level of understanding?
- What governance elements, management or regulatory interventions are currently available to address these impacts?
- In each case, are these governance elements or interventions effective?
- If not, what research is needed to fill the gaps in the governance net with effective, efficient and cost-effective interventions?

5. WATER AND ENVIRONMENTAL GOVERNANCE SYSTEMS: A FRAMEWORK FOR ANALYSIS AND ASSESSMENT OF PRIORITIES

5.1. Governance of water in the environment

The water and environment sectors are often viewed as separate, and are managed and governed separately. As a general rule, the environment sector is considered to include ecosystems, whether aquatic, terrestrial, atmospheric or marine, and government within the sector is aimed at managing and controlling the impacts of human activities on ecosystems.

In terms of government of water (governance and government being two different things), specifically legislation and regulation governing the utilisation of water and the impacts on water of human activities, different provisions are generally required to address each different form that water takes, reflecting the different management approaches that are needed for the different forms, as well as the boundaries between sectors. The fact that a number of government agencies have regulatory responsibilities for different components of the environment, and hence for different aspects of the hydrological cycle, can lead to problems if gaps are left or inconsistencies occur in the overall management and regulatory framework.

In South Africa, the principal piece of legislation in the water sector, the National Water Act (Act No. 36 of 1998; DWAF, 1998), recognises that water occurs in all phases of the hydrological cycle, and that interventions in one phase of the hydrological cycle can have knock-on effects in other phases. However, the National Water Act only contains regulatory provisions to govern "blue water" in aquatic ecosystems, which includes surface water and groundwater (as per the definition of a water resource in the Act). Atmospheric water is dealt with in other legislation, mostly environmental regulation at provincial level, while "green water" may be indirectly addressed, and then probably not adequately, by legislation and regulation in the environment, agricultural and land use planning sectors.

There are some critical gaps in the governance "net" as far as the whole hydrological cycle is concerned. It is interesting to note that the National Water Act, in principle, does not allow the Department of Water Affairs and Forestry (DWAF), the primary water management agency in the country, to undertake integrated catchment management, because that would entail management, control and regulation of activities on the land as well as those directly affecting water. DWAF is mandated only to undertake "integrated water resources management", which is not as encompassing as "integrated catchment management". In terms of the Constitution, control of land-based activities is within the mandates of several other government departments. The only influence which DWAF as the water agency has, is the ability to set conditions on the nature, extent and significance of the impacts of land-based activities, at the point where these impacts directly affect water resources, not necessarily at their origin.

For administrative efficiency, there must be some drawing of boundaries, however artificial these may seem. But, in practical terms, this separation of responsibilities for different components of the environment can lead to ineffective protection and management of water resources, unless the overall national regulatory and management framework (the government component of the governance "net") is comprehensive and co-operative governance is made a reality.

Impacts on water resources may originate from within the water environment itself, for example through discharges of wastewater or abstraction of water, or they may originate in other components of the environment which are under the jurisdiction and management of other administrative sectors, for example the acidification of surface water as a result of emissions of SOx compounds into the atmosphere. In most cases, where the impact on a water resource originates in another component of the environment, the most efficient place to make a management or regulatory intervention is at the origin of the impact. This may require that an agency other than DWAF make the regulatory intervention, through their own sectoral legislation. However, an intervention in another component of the environment than water will only be effective in terms of the water resources outcome if there is common understanding of the cause-effect relationships between the activity and its impact on water resources, if there is agreement on what kind of intervention to make, and if the policy, legislation and regulations of both agencies are harmonised to ensure that both agencies share common objectives in terms of the final outcome. There are also cases when an activity that is regulated from within the water sector has impacts on other components of the environment; in this case, DWAF may have to make the regulatory intervention on behalf of another administrative sector.

Some countries, notably South Africa, have addressed the need for removal of sectoral boundaries by reforming water sector legislation to promote or allow for an explicit ecosystem approach to management of water resources. Others are promoting co-operative governance between sectors, with greater or lesser degrees of success. However, even South Africa's progressive new Water Act does not address water in all its forms in all phases of the hydrological cycle. Unless this is done, either by co-operation or by sectoral reform, then the full protection of water resources, as well as full protection of the environment (since the connection between water and environment is bi-directional), might not be achievable.

We can assume that in South Africa, the governance of water in the hydrological cycle as a whole will remain distributed amongst several government agencies at different levels of government, as well as new institutions such as Catchment Management Agencies. Integrated management of water across the hydrological cycle will need to be effected through co-operative governance, including the government, non-government and civil society sectors. There is a need to review the current governance "net", and where necessary, to fill critical gaps with appropriate interventions, at the appropriate levels. The purpose of this section of the document is to provide a suggested framework for review and identification of research priorities related to governance.

5.2. What is governance

Governance, in the context of governance of water or governance of the environment, includes the full suite of mechanisms for managing water or other natural resources according to objectives that reflect the goals of society. A system of governance within a particular sector ideally should include all three sectors of society:

- Government organisations,
- Non-government organisations,
- The corporate sector, and
- Community or civil society.

These sectors are then stratified into different levels, from international through regional, national, provincial, local and neighbourhood.

There are several levels of governance:

- At the highest level, principles are a statement of society's values in relation to a specific issue such as water or environment. Principles may be universal, such as those which form the basis of multilateral international agreements; national, as in the South African Constitution, or sectoral, such as the Water Law Principles.
- Policy at the national level is a statement of intent by government of what will be done in order to ensure compliance with the principles (Cloete & Wissink, 2000). Policy can also be set at lower levels, for example at Water Management Area level, where it would be expressed through a Catchment Management Strategy.
- Legislation is the primary tool of government for implementing policy, and sets out how policy objectives will be implemented and enforced.
- Regulation usually provides the quantitative or rigorous detail relating to the relevant legislation, and governs everyday activities of all sectors of society. For example, minimum standards for discharges are set in regulation, as are the general authorisations for water use, since the quantitative limits on these could change as new technology becomes available, or as more stringent standards are needed on a site-specific basis. Regulations can be changed more easily than legislation, and can be tailored to specific situations.
- Practice is a general term that covers a wide range of activities, which may not be regulatory, but which nevertheless reflect the principles and support implementation of policy. Practice may include "best practice" tools such as guidelines, which are not necessarily statutory, but which are documented, peer-reviewed and may be adopted by professional practitioners. Practice can include customary or traditional practices, and may be overseen by or from within civil society, whereas policy, legislation and regulation are usually administered by government or an agency to whom authority has been delegated by government. Practice may be influenced by education or advocacy programmes, through the imposition of non-regulatory instruments including economic tools, peer pressure and through voluntary binding agreements between and within sectors of society.

A complete "net" of governance for water, then, would be a three-dimensional system of tools, including principles, policies, legislation, regulation and practice. Each of these would have elements at global, regional, transboundary river basin, national, Water Management Area, provincial, local and neighbourhood levels; each element of which might have components for which government, non-government organisations, the corporate sector or civil society would be responsible.

5.3. A simplified framework for analysis and development of governance systems

Given the multi-dimensional nature of governance systems, it is not surprising that achieving co-operative governance between sectors, let alone within a single sector, is proving so difficult in South Africa, with our highly stratified and diverse human society only adding to the complexity. Super-impose the different environmental components (atmospheric, marine, aquatic, terrestrial and subterranean), as well as the high biogeographical diversity of southern African ecosystems, and the problem of developing governance systems that ensure coverage of all the issues, at all the appropriate levels, for all components of the environment, can quickly become intractable.

In **Table 1**, a simplified framework is presented for organisation of the relevant components of a governance system within one sector. For the water-environment nexus, following this framework as indicated in **Table 1** should lead to identification of all the necessary elements of a governance system. In theory, once one reaches provincial level and lower, the multitude of regulations, by-laws and practices will quickly become overwhelming. In practice, however, a single piece of national legislation such as the National Water Act may address many elements at once. In practice, also, the analysis should probably only be conducted at provincial, local and neighbourhood levels on a site-specific basis, since each different local or neighbourhood level situation can be addressed by a unique selection and arrangement of only a few of the plethora of potential governance mechanisms. So for example in a rural area where most people might still live according to traditional customs, and where customary law and practices can provide adequate protection for natural resources, there may be no need for formal legislation or regulation, or for government sector agencies to play more than an advisory or auditing role.

A point to note about **Table 1** is that the "root causes" of the indirect impacts which are identified as priority issues are only traced back to as far as is practical to intervene in terms of environmental or water governance. For example, the deepest root causes of deforestation may be related to poverty and land tenure issues. In fact, the root causes of many environmental problems can be traced back to poverty issues: these need to be addressed at the broad societal level through macro-economic and social policies, but management of the impacts will require governance elements to be developed and administered from within the environmental, water or land sectors.

5.4. Research priorities for development of the governance system for water in the environment

For the purposes of developing an investment strategy for governance research, the framework can be used to prioritise particular issues. For example, it might be agreed by relevant stakeholders that in South Africa, the priority issues related to water at the atmospheric-aquatic interface are acidification of surface waters due to SOx emissions, and potential reduction in rainfall due to climate change (global climate, local climate or micro-climate). Both of these issues tend to be more important in some geographic areas than in others, and so research into appropriate governance should be focused on interventions at only the appropriate level(s), whether regional, national, provincial, local or neighbourhood.

The framework in **Table 1** could be used in a process of analysis, prioritisation and identification of strategic research areas, which might go along the following lines:

- For each environmental component, what are the priority issues?
- For each priority issue, identify (if available) the relevant principles, policy, legislation, regulation and practices, doing this for global, regional, national, provincial, local and neighbourhood levels (giving generic examples only for local and neighbourhood levels).
- In each case, answer the questions:
    - Does the appropriate element of the governance system exist for this issue at this level?
    - Is it effective? In other words, does it fully address the issue; is it efficient; will sustainable development objectives be achieved?

- If the appropriate element does not exist or is not effective, is it a priority (low, medium or high) that an element of governance (say, a new national policy directive) be developed?

In the focus group discussions, we would like to collate the insights, experience and opinions of key stakeholders to particularly identify the priority issues for which governance is currently inadequate, outdated or non-existent.

Table 1: Framework for analysis, prioritisation and development of governance systems for water-environment sectors (atmospheric-aquatic linkages and one terrestrial-aquatic linkage shown as examples)

Environmental component	Root cause	Priority issues	Governance element					
			Level	**Principles**	**Policy**	**Legislation**	**Regulation**	**Practice**
1. Direct impacts of humans on atmospheric ecosystems								
▪ Direct impacts on water in the atmospheric ecosystem								
o Indirect impacts on aquatic ecosystems	Release of SOx emissions into the atmosphere	Acidification of soil and surface waters due to acid rain	Global					
			Regional					
			Transboundary river basin					
			National					
			WMA					
			Provincial					
			Local					
			Neighbourhood					
	Release of excess CO_2 into the atmosphere	Reduced rainfall due to climate change	Global	Climate Change Convention	Climate Change Convention	None	Kyoto Protocol	
			Regional					
			Transboundary river basin					
			National			None		
			WMA					
			Provincial					
			Local					
			Neighbourhood					
o Indirect impacts on terrestrial ecosystems								
o Indirect impacts on marine ecosystems								
2. Direct impacts of humans on terrestrial ecosystems	Removal of vegetation cover	Erosion of land surface						
▪ Direct impacts on water in terrestrial ecosystems		Water flowing over the land surface has higher suspended sediment loads						
o Indirect impacts on aquatic ecosystems		Sedimentation in surface water resources (loss of water volume; change in benthic	Global	Convention to Combat Desertification (CCD)	CCD			
			Regional		SARCCUS			

Environmental component	Root cause	Priority issues	Governance element					
			Level	**Principles**	**Policy**	**Legislation**	**Regulation**	**Practice**
		habitats; increased turbidity)	Transboundary river basin					
			National			Conservation of Agricultural Resources Act; National Water Act (protection of riparian vegetation only)		Guidelines for soil erosion prevention; SA Water Quality Guidelines for Aquatic Ecosystems
			WMA					
			Provincial					
			Local					
			Neighbourhood					
o Indirect impacts on atmospheric ecosystem (through evapo-transpiration cycle)								
3. Direct impacts of humans on aquatic ecosystems								
▪ Includes impacts on all aspects of aquatic ecosystems (water, biota, habitat, processes)								
o Indirect impacts on terrestrial ecosystems								
o Indirect impacts on coastal marine ecosystems								
o Indirect impacts on atmospheric ecosystems								
4. Direct impacts of humans on marine ecosystems								
▪ Includes impacts on all aspects of coastal marine ecosystems (water, biota, habitat, processes)								
o Indirect impacts on terrestrial ecosystems								
o Indirect impacts on aquatic ecosystems								
o Indirect impacts on atmospheric ecosystems								

6. BIODIVERSITY PROTECTION AND ENVIRONMENTAL FUNCTIONING

6.1 Introduction

The word 'biodiversity' is an abbreviation of the term 'biological diversity' and its use in this form was first popularised by the ecologist Edward O. Wilson in 1988 (Wilson, 1988). In essence, biological diversity or 'biodiversity' is a multidimensional and multifaceted concept that refers to the diversity (in terms of both the variety and variability) of all organisms and their habitats, as well as the inter-relationships between organisms and their habitats. As such, great care should be taken when attempts are made to reduce biodiversity to a single number or surrogate index, since this usually results in an inappropriate loss of information and understanding (Purvis & Hector, 2000). Rather, the different facets of biodiversity can be quantified and expressed individually to suit specific needs (see **Table 2**). Basically, biodiversity is an expression of many different spatial levels or scales of organization, from genes to landscapes, with each level or scale having three different sets of attributes or components, namely: composition, structure and function (Franklin, 1988, Noss, 1990; Chapin *et al*., 2000; McCann, 2000; Purvis & Hector, 2000).

Table 2: A conceptual framework showing the major components of biodiversity and their relationships in a nested hierarchy of organizational levels, with examples of measurable variables at each level. Table modified from Noss (1990) and Le Maitre *et al*. (1997).

Organizational level	Component		
	Composition	**Structure**	**Function**
Genes	Allelic diversity	Heterozygosity	Rate of genetic drift
Species / Populations	Variety of species, Species abundance, Density, Phylogeny	Age / sex structure, Spatial distribution, Habitat type, Environmental correlates (e.g. seasonal variation)	Competitive ability, Relative growth rates, Food chain dynamics, Keystone or indicator species
Community / Ecosystem	Species richness, Evenness or patchiness, Guilds, Description of communities using particular species	Population density and layering, Habitat types and distribution	Influence on nutrient fluxes, Disturbance processes and succession
Landscape / Region	Habitat richness, Importance or uniqueness of community in region	Patchiness, Grain, Connectivity, Relative importance of habitat distribution and size	Disturbance dynamics, Fluxes, Migration routes, Barriers

To place these components in their proper perspective, we need to appreciate the precise meaning and implications of each form or expression. In its most basic sense, *genetic biodiversity* refers to the diversity of genes and their expression within individuals and within populations of species. At the other end of the scale, *landscape biodiversity* encompasses the variety of ecosystems or habitats, as well as the relationships and interdependencies between them, within a particular landscape unit (for example, a catchment). Between these two ends of the continuum lies a diverse and variable array of niches, habitats and ecosystems comprised of populations, communities and aggregations of different species, each occupying

different positions and fulfilling different functions or roles within the system. The term *compositional biodiversity* refers to the variety or diversity of 'units' that are present, whether these are particular genotypes, species or habitats. Similarly, *structural biodiversity* reflects the ways in which these units are arranged relative to each other in space and time, and also indicates the relative abundance and importance of each form or unit. Finally, *functional biodiversity* expresses both the different roles that each unit plays in the ecosystem, and their importance in sustaining ecological processes and delivering ecosystem goods, services and benefits (Franklin, 1988; Noss, 1990; Le Maitre *et al*., 1997; Tilman, 1999, 2000; Chapin *et al*., 2000; Purvis & Hector, 2000).

This background explanation of the scope, meaning and implications of the term 'biodiversity' provides an appropriate framework to examine the ways in which this understanding can be applied to aquatic ecosystems, including those terrestrial and subterranean ecosystems that depend on ground water. Here, it is important to remember that several different scales are involved and, in particular, the inter-linkages between components and processes within the hydrological cycle (see **Figure 2**). In the context of aquatic ecosystems and ground water-dependent terrestrial ecosystems, the various components, processes and linkages whereby the multiple roles of biodiversity are influenced and expressed, are shown schematically in **Figures 3 to 5**. These diagrams demonstrate the importance of biodiversity as a determinant or regulator of biotic and abiotic process controls, as well as energy and materials fluxes, through the expression of species traits and species interactions, as well as their vulnerability to human activities (Chapin *et al*., 2000; Purvis & Hector, 2000; Tilman, 2000).

From these diagrams it is clear that biodiversity plays a central role in regulating ecosystem processes in ways that ensure the provision of a wide variety of ecosystem goods and services. Whilst these goods and services represent many of the human benefits that are the basis for social and economic development, they are also highly vulnerable to disturbance and disruption by human activities. The urgent need to maintain the flows of these ecosystem goods and services on a sustainable basis underpins water resource management decisions and actions that aim to achieve a balance between resource protection and use. However, the wide array of intricate linkages and inter-relationships between water and terrestrial ecosystem components are seldom fully understood, further complicating the task of water resource management. Ultimately, all components of the hydrological cycle will have to be addressed from an ecosystem perspective if water resources are to be managed on a long-term, sustainable basis. This will require a dramatic shift in approach to both biodiversity and governance issues in the water sector.

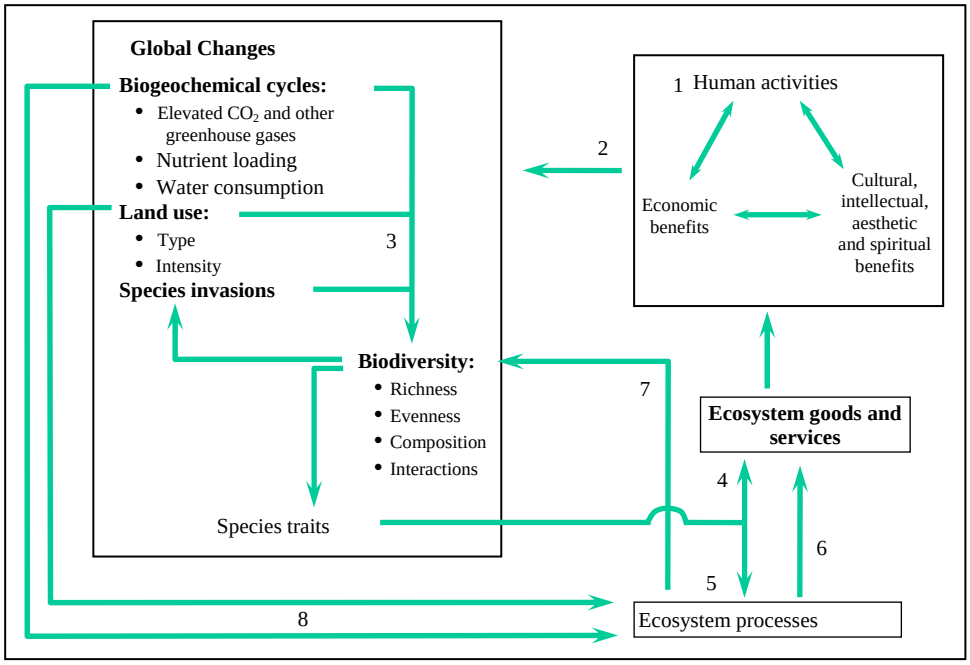


Figure 3. The role of biodiversity in global change. Redrawn from Figure 1 in Chapin *et al.*, (2000). Human activities that are motivated by a diverse array of goals (1) cause ecological and environmental changes of global significance (2). These global changes contribute to changes in biodiversity and this, in turn, feeds back on susceptibility to species invasions. Changes in biodiversity (3), expressed as changed species traits, have direct consequences for ecosystem services (4) and human activities. In addition, changes in biodiversity influence ecosystem processes (5). Altered ecosystem processes, in turn, influence ecosystem goods and services (6) that benefit humanity and feedback to further alter biodiversity (7). Global changes in land use patterns and biogeochemical cycles may also directly affect ecosystem processes (8).

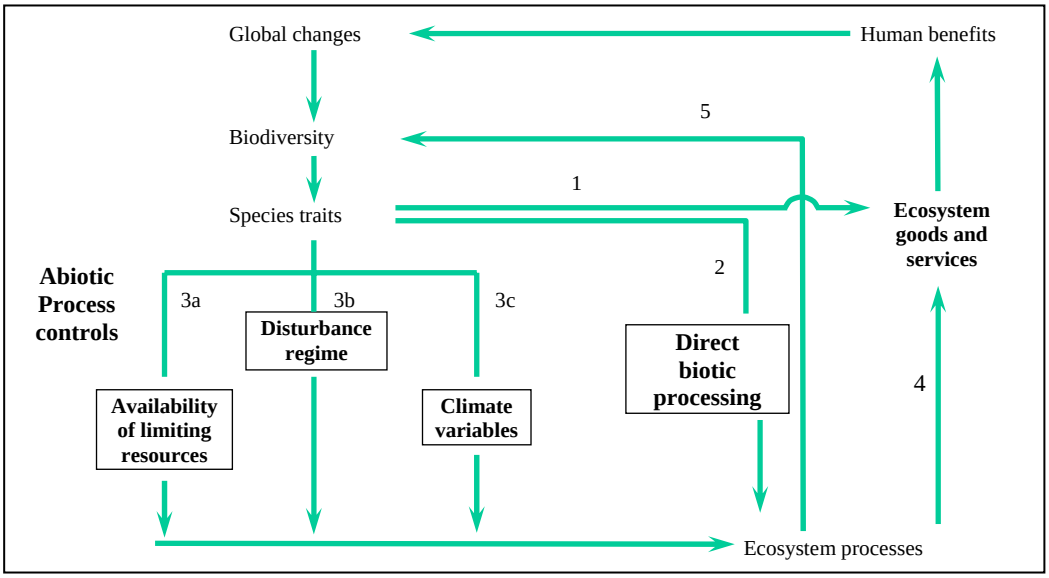


Figure 4: Mechanisms by which species traits affect ecosystem processes. Redrawn from Figure 4 in Chapin *et al*. (2000). Changes in biodiversity alter the functional traits of species in an ecosystem in ways that directly affect ecosystem goods and services (1). Changes in species traits affect ecosystem processes directly through changes in biotic controls (2) and indirectly through changes in abiotic controls such as availability of limiting resources (3a), disturbance regime (3b) or micro- and macroclimate variables (3c). Altered processes can influence the availability of ecosystem goods and services directly (4) or indirectly by further altering biodiversity (5).

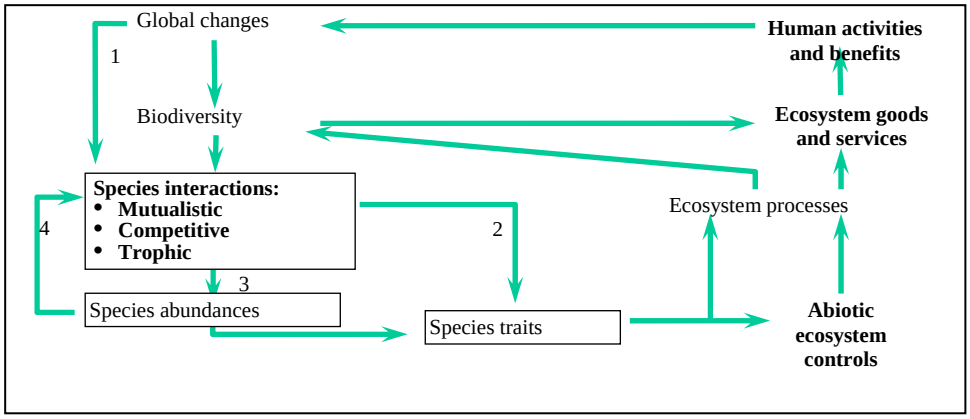


Figure 5: Mechanisms by which species interactions affect ecosystem processes. Redrawn from Figure 5 in Chapin *et al.* (2000). Global environmental change affects species interactions both directly (1), and through its effects on altered biodiversity. Species interactions may directly affect key traits in ecosystem processes (2) or may alter the abundance of species with key traits (3). Changes in species interactions and abundance, and the resulting changes in community composition (3) may feedback to cause a cascade of further effects on species interactions (4).

In the context of water resource management, the term 'aquatic ecosystems' covers a large and diverse group of systems that encompass several types of waterbodies, their associated habitats, and an enormous diversity of living forms. There are many types of waters covered in this definition, both above and below ground, moving and still, large and small, fresh, brackish or saline. These include rivers, lakes, streams, ponds, marshes, swamps, bogs, floodplains, estuaries, coastal zones, aquifers, and underground rivers and lakes, to name a few of the commoner forms. Different ecological zones, as well as mosaics of habitats and niches, are associated with all of these systems, making the term 'aquatic ecosystem' a very broad and far-reaching ecological concept. Importantly, aquatic ecosystems also comprise an equally varied array of different plant, animal and microbial species, arranged or distributed in an enormous variety of ways, together with the associated roles, functions and processes that they fulfil in these ecosystems (Tilman, 1999, 2000; Chapin *et al*., 2000; Hirji *et al*., 2002; UNEP, 2002a, b).

Processes of population growth coupled with social and economic development have relied heavily on the goods, services and benefits derived from aquatic ecosystems; these include water supply, waste disposal, fuel, food and recreation. However, the patterns of human utilization of aquatic ecosystems have resulted in an enormous array of changes and alterations to the structure and functioning of these systems and this has been accompanied, in some cases, by dramatic changes to the diversity and abundance of organisms that occupy and characterize these systems (Gleick, 2002; Hirji *et al*., 2002). Many aquatic systems are undergoing continual degradation and cannot deliver the suite of ecosystem goods and services that were originally provided (WRI, 2000; UNEP, 2002b). This has led to a growing recognition of the need to improve the ways in which aquatic ecosystems are managed on a sustainable basis so that they can continue to meet the demands that are made of them (Falkenmark, 1999; FAO, 2000). In turn, this awareness has stimulated the development and application of a suite of local, national and international policy and management tools that aim to minimize the damage or loss of aquatic ecosystem biodiversity and improve the prospects for long-term, sustainable use of these systems (Ashton & Seetal, 2002; Hirji *et al*., 2002; Revenga & Cassar, 2002). Efforts to meet the escalating demands for water and other

ecosystem goods and services that are made on aquatic ecosystems, whilst simultaneously striving to protect these ecosystems from undue exploitation, represent an enormous challenge to southern Africa's water resource managers (Pallett, 1997; Falkenmark, 1999; Ashton & Seetal, 2002; Hirji et al., 2002; UNEP, 2002b).

6.2 National, regional and international policy and legislative framework

Water is a scarce and unevenly distributed resource that is vulnerable to global factors such as climate change, regional factors such as the management of transboundary waters, and national and local factors such as population growth, pollution and environmental degradation. As a response to these pressures, an array of international, regional and national conventions, policies, agreements, accords and legislation have been adopted or promulgated to ensure environmental sustainability and the effective protection, planning and management of water resources and their associated aquatic biodiversity.

National

In South Africa, the Department of Water Affairs and Forestry (DWAF) is responsible for water resource management within South Africa. This management is regulated by the National Water Act (Act No. 36 of 1998; DWAF, 1998). The guiding principles of sustainability and equity are the central tenets of the Act that direct the protection, use, development, conservation, management and control of water resources. Specific initiatives for biodiversity protection are contained explicitly in the National Water Act. Part 3 of the Act "deals with the Reserve, which consists of two parts - the basic human needs reserve and the ecological reserve. The basic human needs reserve provides for the essential needs of individuals served by the water resource in question and includes water for drinking, for food preparation and for personal hygiene. The ecological reserve relates to the water required to protect the aquatic ecosystems of the water resource. The Reserve refers to both the quantity and quality of the water in the resource....". Thus, the National Water Act considers the entire aquatic ecosystem to be the resource, and not a competing user of water as was the case in the past. This principle provides for the allocation of water of appropriate quality and quantity to protect aquatic ecosystems as part of the obligation of the state (DWAF, 1997, 2002).

The control and regulation of activities on the land that directly affect aquatic ecosystems falls within the ambit of the government Department of Environmental Affairs and Tourism (DEAT). The White Paper on the Conservation and Sustainable Use of South Africa's Biological Diversity (Notice 1095 of 1997) is the central policy pertaining to the conservation and management of South Africa's biodiversity in its broadest sense (DEAT, 1997). Currently two bills are being drafted from the White Paper, namely: the National Environmental Management: Biodiversity Bill and the National Environmental Management: Protected Areas Bill. The objectives of these proposed Acts will fall within the framework of the National Environmental Management Act (Act No.107 of 1998; DEAT, 1998a). However, it will be important to ensure that these Bills are passed into legislation as soon as possible if their provisions are to have any impact on resource management efforts. A brief summary of additional relevant policy and legislation is outlined in **Table 3** below.

Table 3: National legislation and policy pertaining to aquatic biodiversity protection.

National Water Act
Sustainability and equity are the central tenets of the Act that guide the protection, use, development, conservation, management and control of water resources. Part 3 of the Act deals with the Reserve, which consists of two parts: the basic human needs reserve and the ecological reserve. Reference: DWAF (1998).
National Water Resource Strategy
This strategy provides the implementation framework for the National Water Act. The four main objectives of this the NWRS are establishing a framework for managing water resources, establishing a framework for the preparation of catchment management strategies, provide information and identify development opportunities and constraints. Reference: DWAF (2002).
White Paper on a National Water Policy
The objective of this White Paper is to set out the policy of the Government for the management of both quality and quantity of our scarce water resources. Reference: DWAF (1997).
White Paper on the Conservation and Sustainable Use of South Africa's Biological Diversity
Conserve the diversity of landscapes, ecosystems, habitats, communities, populations, species and genes in South Africa Reference: DEAT (1997).
National Environmental Management: Biodiversity Bill
The objectives of this Bill are to provide for *inter alia* the management and conservation of biological diversity, the use of biological resources in a sustainable manner, the fair and equitable sharing of benefits arising from the use and application of genetic resources and material and for co-operative governance in biodiversity management and conservation. Reference: DEAT (2002a).
National Environmental Management: Protected Areas Bill
The objectives of this Bill are to *inter alia* provide for the declaration and management of protected areas, to give effect to international agreements on protected areas, to provide for co-operative governance in the declaration and management of protected areas and to provide for the continued existence of South African National Parks. Reference: DEAT (2002b).
National Environmental Management Act
To provide for co-operative, environmental governance by establishing principles for decision-making on matters affecting the environment, institutions that will promote co-operative governance and procedures for co-ordinating environmental functions exercised by organs of state; and to provide for matters connected therewith. Reference: DEAT (1998a).
Wetlands Conservation Bill
To provide fro the application in the Republic of the Convention on Wetlands of International Importance especially as Waterfowl Habitat; the prohibition of prospecting or mining in listed wetlands; the prohibition of detrimental activities in wetlands and listed wetlands; and the prohibition of activities detrimental; to catchment areas, and to provide for matters connected therewith. Reference: DEAT (1995).
Marine Living Resources Act
To provide for the conservation of the marine ecosystem, the long-term sustainable utilization of marine living resources and the orderly access to exploitation, utilization and protection of certain marine living resources; and

for these purposes to provide for the exercise of control over marine living resources in a fair and equitable manner to the benefit of all the citizens of South Africa; and to provide for matters connected therewith.
Reference: DEAT (1998b).

World Heritage Convention Act

To provide for *inter alia* the incorporation of the World Heritage Convention into South African law; the enforcement and implementation of the World Heritage Convention in South Africa and the recognition and establishment of World Heritage Sites.
Reference: DEAT (1999)

Bioregional Approach to South Africa's Protected Areas

To ensure the effective conservation of biodiversity, DEAT is proposing a new policy framework, which advocates a system of formally protected areas. In addition to the conservation of biodiversity, this policy aims to provide a stable base for the tourism and fishing industries and their associated jobs and income. The government is increasingly adopting a bioregional approach to conservation where conservation efforts are focused on local centres of diversity and endemism.
Reference: DEAT (2001).

The critical area for biodiversity conservation in South Africa that could result in fragmented and thus ineffective management of our biodiversity lies in the fact that much of the policy and legislation focuses on individual levels of biodiversity organisation (see **Table 2**), where specific legislative frameworks are built around a particular ecosystem type and seldom explicitly recognise the links between ecosystem types. These artificial boundaries, prescribed by the line function separation of government departments, compound this problem, so that the responsibility for a part of the landscape or part of the hydrological cycle is divided between different organs of state. There is a pressing need to develop management frameworks that are comprehensive and stimulate increased co-operative governance especially between the key government departments of Water Affairs and Forestry and Environmental Affairs and Tourism.

Regional

The New Partnership for Africa's Development (NePAD) is a pledge by African leaders, based on a common vision and shared conviction, that they have a pressing duty to eradicate poverty and to place their countries, individually and collectively, on a path of sustainable growth and development (NePAD, 2001). NePAD thus provides an overarching strategy that will influence all future development, decision-making and management of Africa's natural resource base. It has been recognized that a healthy and productive environment is a prerequisite for the success of NePAD. In order to address this need an Environment Initiative has been developed within NePAD that targets a range of themes for intervention. These include Combating Desertification, Wetland Conservation, Invasive Alien Species, Coastal Management, Global Warming, Cross-border Conservation Areas, and Environmental Governance (NePAD, 2001). All of these initiatives have a direct bearing on the protection, planning and management of water resources and associated aquatic biodiversity in South Africa.

Of the Regional Economic Communities that are to be consolidated under NePAD, the one directly relevant to South Africa is the Southern African Development Community (SADC). This community was established in 1992 through the signing of a Declaration and Treaty in Windhoek, Namibia. Article 5(g) of the SADC Treaty (SADC, 1992) aims to achieve the sustainable utilisation of natural resources and to effectively protect the environment. Over the years, South Africa has entered into several regional protocols and agreements with its neighbouring SADC countries, these are briefly summarised in **Table 4**.

Table 4: Regional protocols and agreements pertaining to aquatic biodiversity protection.

SADC Treaty
The objectives of SADC shall be to achieve development and economic growth, alleviate poverty, enhance the standard and quality of life of the people of Southern Africa and support the socially disadvantaged through regional integration. Reference: SADC (1992).
SADC Policy and Strategy for Environment and Sustainable Development
This Policy provides the basis for implementing Agenda 21 - the global action plan for environment and development adopted at the 1992 Earth Summit - in the southern African context. Recognising poverty as the main cause and consequence of environmental degradation, and poverty alleviation as the SADC Community's overriding goal and priority, it identifies equity as a crucial element to be added to environment and development in order to make Agenda 21 more applicable and operational southern Africa. Reference: SADC (1996).
Protocol and Revised Protocol on Shared Watercourse Systems in the Southern African Development Community (SADC) Region;
Some of the key provisions of these Protocols state that member States lying within the basin of a shared watercourse system shall maintain a proper balance between resource development for a higher standard of living for their people, and conservation and enhancement of the environment to promote sustainable development and that member States within a shared watercourse system undertake to establish close co-operation with their neighbours regarding the study and execution of all projects likely to have an effect on the regime of the watercourse system. Reference: SADC (1995) and SADC (2001a).
Protocol on Fisheries
Article 14: Protection of the Aquatic Environment of this Protocol advocates that state parties shall *inter alia* conserve aquatic ecosystems, including their biodiversity and unique habitats, which contribute to the livelihood and aesthetic values of the people and the Region and apply the precautionary principle to ensure that activities within their jurisdiction and control do not cause excessive transboundary adverse impacts. Reference: SADC (2001b).
Protocol on Wildlife Conservation and Law Enforcement
This protocol aims to promote *inter alia* the sustainable use of wildlife (where wildlife is defined as animal and plant species occurring within natural ecosystems and habitats); Promote the conservation of shared wildlife resources through the establishment of transfrontier conservation areas; and facilitate community-based natural resources management practices for management of wildlife resources. Reference: SADC (1999).

Although these SADC protocols and treaties may not be accorded the same status as global-scale conventions, nor comprise the compulsory jurisdiction and enforcement that characterise national legal systems, they still represent important strategic agreements that formalise co-operation on the management of resources especially those that are transboundary in nature.

International

In addition to the national and regional legislation, policies and protocols, a number of international conventions are also relevant to water resource management and the protection of associated aquatic biodiversity. International conventions provide statutory guidance or cornerstones when striving for effective and efficient protection, planning and management (UNCED, 1992). South Africa is a signatory state to many of these agreements and it is therefore appropriate to briefly review the provisions of the most important conventions (**Table 5**).

Table 5: Some international conventions pertaining to aquatic biodiversity protection.

Convention on the Law of the Non-Navigational Uses of International Watercourses.
Is designed to apply to the uses of international watercourses and their waters for purposes other than navigation, and to ensure that suitable measures are taken for the protection, preservation and management of these watercourses and their waters. South Africa ratification 26 October 1998 Reference: UNCSW 1997.
Convention on Biological Diversity
To conserve biological diversity, promote the sustainable use of its components, and encourage equitable sharing of the benefits arising out of the utilization of genetic resources. Such equitable sharing includes appropriate access to genetic resources, as well as appropriate transfer of technology, taking into account existing rights over such resources and such technology. South Africa signatory 4 June 1993 Reference: UNCBD 1992.
Cartagena Protocol on Biosafety
The Conference of the Parties to the Convention on Biological Diversity adopted a supplementary agreement to the Convention known as the Cartagena Protocol on Biosafety on 29 January 2000. The Protocol seeks to protect biological diversity from the potential risks posed by living modified organisms resulting from modern biotechnology. South Africa not signatory Reference: UNEP 2000.
International Treaty on Plant Genetic Resources for Food and Agriculture
Aims to ensure better use of plant genetic diversity to meet the challenge of eradicating world hunger. The treaty takes into consideration the particular needs of farmers and plant breeders, and aims to guarantee the future availability of the diversity of plant genetic resources for food and agriculture on which they depend, as well as the fair and equitable sharing of the benefits. South Africa not signatory Reference: FAO 2001.
Convention relative to the Preservation of Fauna and Flora in their Natural State
To preserve the natural fauna and flora of certain parts of the world, particularly of Africa, by means of national parks and reserves, and by regulation of hunting and collection of species. South Africa entry into force 14 January 1936 Reference: UNEP 1933.
International Plant Protection Convention
To maintain and increase international cooperation in controlling pests and diseases of plants and plant products, and in preventing their introduction and spread across national boundaries. South Africa ratification 21 September 1956 Reference: FAO 1951.
International Convention for the Protection of New Varieties of Plants
To recognize and protect the rights of breeders of new varieties of plants and their successors in title. South Africa entry into force 6 November 1977 Reference: UNGA 1961.
Convention on International Trade in Endangered Species of Wild Fauna and Flora
To protect certain endangered species from over-exploitation by means of a system of import/export permits South Africa ratification 15 July 1975 Reference: CITES 1973.

United Nations Forum on Forests

To promote the management, conservation and sustainable development of all type of forests.
South Africa not member state
Reference: United Nations Forum on Forests 1992.

Convention on the Conservation of Migratory Species of Wild Animals

To protect those species of wild animals that migrate across or outside national boundaries.
South Africa entry into force 1 December 1991
Reference: UNEP 1979.

Convention on Wetlands of International Importance Especially as Waterfowl Habitat

To stem the progressive encroachment on and loss of wetlands now and in the future, recognizing the fundamental ecological functions of wetlands and their economic, cultural, scientific and recreational value.
South Africa entry into force 21 December 1975
Reference: Ramsar 1971.

International Convention for the Protection of Birds

To protect birds in the wild state, considering that in the interests of science, the protection of nature and the economy of each nation, all birds should be protected as a matter of principle.
South Africa not signatory
Reference: FMFA 1950.

Convention on Fishing and Conservation of the Living Resources of the High Seas

Through international cooperation, to solve the problems involved in the conservation of the living resources of the high seas, considering that through the development of modern techniques some of these resources are in danger of being over-exploited.
South Africa entry into force 20 March 1966
Reference: UNGA 1958.

International Convention for the regulation of Whaling

To protect all species of whales from overfishing and safeguard for future generations the great natural resources represented by whale stocks. To establish a system of international regulation for the whale fisheries to ensure proper conservation and development of whale stocks.
South Africa entry into force 10 November 1948
Reference: GUSA 1946.

United Nations Framework Convention on Climate Change

To regulate levels of greenhouse gas concentration in the atmosphere, so as to avoid the occurrence of climate change on a level that would impede sustainable economic development, or compromise initiatives in food production.
South Africa entry into force 27 November 1997
Reference: UNFCCC 1992.

United Nations Convention to Combat Desertification in Countries Experiencing Serious Drought and/or Desertification, Particularly in Africa

To combat desertification and mitigate the effects of drought in countries experiencing serious drought and/or desertification, particularly in Africa, through effective action at all levels, supported by international cooperation and partnership arrangements, in the framework of an integrated approach which is consistent with Agenda 21, with a view to contributing to the achievement of sustainable development in affected areas
South Africa entry into force 29 December 1997
Reference: UNCCD 2001.

Convention Concerning the Protection of the World Cultural and Natural Heritage

To establish an effective system of collective protection of the cultural and natural heritage of outstanding universal value, organized on a permanent basis and in accordance with modern scientific methods.
South Africa ratification 10 July 1997
Reference: UNESCO 1972.

The array of international conventions addresses all organizational levels of biodiversity (see **Table 2**) and, to some extent, implicitly addresses the three components (composition, structure and function) of biodiversity. The protection, preservation and management of (components of) water resources and biological diversity and the promotion of their sustainable use are the central messages common to all these conventions. The political goodwill and spirit of co-operation and collaboration is evident through the signing and/or ratification of these conventions by South Africa. However, where the obligations of a particular convention influence or affect neighbouring states that are not yet party to the same convention, this could lead to disputes or disagreements over resource use and management approaches that could undermine the conservation priorities of South Africa. In order to facilitate a coherent international approach to the implementation of sustainable development and therefore the concept of sustainable resource use as advocated in the conventions listed in **Table 5**, the WEHAB initiative was proposed by the United Nations Secretary-General as a contribution to the preparations for the World Summit on Sustainable Development (WSSD). This initiative seeks to provide focus and impetus to action in the five key thematic areas of water, energy, health, agriculture and biodiversity. The two themes water and biodiversity are most applicable to the issues of biodiversity and aquatic ecosystems in that the need for sustainable ecosystem management will be underpinned by the effectiveness of efforts directed at biodiversity issues (WEHAB 2002a; 2002b).

6.3 Biodiversity issues in relation to integrated water resource management

The framework of national, regional and international policies illustrates that the primary focus for conservation and management attention is correctly directed towards habitat protection, since this will help to protect both species and ecosystem functions. These policies also provide an appropriate setting for specific national legislation that recognizes the importance of aquatic ecosystems and ensures that these are afforded an appropriate level of protection. In essence, this represents a shift in the focus of water resource management towards an 'ecosystems approach' that explicitly recognizes the central role of biodiversity. This is also reflected in South Africa's new National Water Act (Act No. 36 of 1998), which formally recognizes that aquatic ecosystems are an integral part of the water resource and should not be regarded as competing users of water. Similar emphases are reflected in South Africa's National Environmental Management Act and its enabling Bills; protection of ecosystems or habitats will ensure that the key species and ecosystem functions and processes they contain will also be secured (FAO, 2000; IUCN, 2000).

The emphasis on aquatic ecosystems in the National Water Act is further supported by formal recognition of the need to manage water resources on a catchment basis, giving added impetus to measures designed to implement Integrated Water Resource Management (IWRM) over the entire hydrological cycle. Importantly, however, the National Water Act restricts the Department of Water Affairs and Forestry's activities to management of the so-called "blue water" components of the hydrological cycle (DWAF, 1998). The important "green water" components (primarily linked to evapo-transpiration processes) are specifically omitted from this legislation, since these are within the line function responsibilities of other government departments, most notably the departments of Agriculture and Environmental Affairs and Tourism (Falkenmark, 1999; FAO, 2000).

The emphasis on ecosystem protection in the National Water Act is reflected most clearly in the concept of the 'ecological reserve', where sufficient water must be retained within aquatic

ecosystems to allow these systems to continue to function, and thereby deliver the goods and services required of them. This approach also allows the relationships between aquatic and other (terrestrial, atmospheric and marine) ecosystems to be identified and helps to direct attention towards gaps in our knowledge base. By focusing on the key aspects or components of aquatic biodiversity, appropriate management attention can be directed towards conservation and rehabilitation priorities.

The incorporation of (surface water) aquatic ecosystems and their closely related riparian, terrestrial and subterranean systems into a composite view of the hydrological cycle provides a greatly improved understanding of the inter-relationships between ecosystem components (Falkenmark, 1999; FAO, 2000). Relationships with other (terrestrial, atmospheric and marine) ecosystems can be segmented into components (structure, composition and function) that explicitly identify interlinkages, vulnerabilities and responses to external impacts. In turn, information on aquatic biodiversity components and their responses to external impacts indicate the capacity or limits of ecosystems to continue providing functions, goods and services to society (Van Wilgen *et al*., 1996; Chapin *et al*., 2000; FAO, 2000; Tilman, 2000; Hirji *et al*., 2002).

There is a growing awareness that South Africa's water resources are both finite and fragile, particularly in view of the rate at which aquatic ecosystems are being degraded as a result of attempts to meet the increasing demands for water. Water scarcity is now a major issue in South Africa, whilst several of South Africa's neighbours also face similar challenges (SARDC, 1996; Ashton & Seetal, 2002; UNEP, 2002b). The pressing need to meet the steadily growing demands for water, whilst simultaneously protecting the water resources that provide critically important goods, services and benefits to society, represents an enormous challenge. To meet this challenge, South Africa's water resource managers must adopt adaptive management processes that promote principles of sustainability and ensure that appropriate corrective measures are implemented when required. Those Integrated Water Resource Management (IWRM) approaches that include, and explicitly account for, biodiversity considerations, offer the greatest likelihood of success. Theoretically, an Integrated Catchment Management (ICM) approach offers the greatest possible potential for a comprehensive and integrated approach to biodiversity management. However, in practical terms, this is not possible in South Africa (DWAF, 1998) because of the division of responsibilities for different ecosystem types between different line function government departments.

6.4 Practical issues and implementation considerations

All types of organisms – plants, animals and micro-organisms – need to be considered when attempting to understand the effects of biodiversity on ecosystem functioning (Chapin *et al*., 2000). In many cases, changes in the interactions between species alter the traits expressed by species and this, in turn, alters the effects that species have on ecosystems. As a result, knowing that a species is present or absent from a particular ecosystem is not sufficient to predict its impact on the ecosystem in question.

Biodiversity and its links to ecosystem characteristics and properties have a range of cultural, aesthetic, intellectual and spiritual values that society recognizes as being important. In addition, changes to biodiversity that may alter ecosystem functioning have an equally wide range of economic impacts through changes in the provision of goods, benefits and services to

society (Chapin *et al*., 2000; Tilman, 2000). Here, it is important to remember that the provision of ecosystem goods and benefits also depends on the abundance of species, and not merely on their presence or absence. Global and regional-scale environmental changes have a very real potential to accentuate the ecological and societal impacts of changes in biodiversity, for example through the conversion or alteration of landscapes. Several recent studies (e.g. Huntley, 1991; Van Wilgen *et al*., 1996; Tilman, 1999, 2000; Chapin *et al*., 2000; Sala, 2000; Klopper *et al*., 2002) have highlighted the likelihood and consequences of the interactions between irreversible species losses and the positive feedbacks between biodiversity changes and ecosystem processes, concluding that society is likely to incur a range of non-linear responses in terms of costs, whenever the thresholds of ecosystem resilience are exceeded. However, the extent of our understanding of these complex interactions is still relatively poor and this has led to high levels of uncertainty and a general reluctance to initiate far-reaching management actions where the outcomes are often unpredictable.

Despite the wealth of new knowledge and understanding of ecosystems and biodiversity that scientists have amassed during the last several decades, and in particular during the last decade, there remain enormous gaps in our knowledge base (Chapin *et al*., 2000; Tilman, 2000). In particular, these relate to the complex sets of interacting cause – effect relationships that characterize ecological systems and their processes and functions. However, even in the absence of detailed knowledge and an understanding of the precise causes and consequences of change, we can already see signs of the widespread alteration and degradation of aquatic ecosystems that have occurred. Fundamental changes in policies, legislation and human behaviour will be necessary for these trends to be reversed and for deleterious effects to be rehabilitated wherever possible. In this respect, South Africa's National Water Act represents a remarkably strong response that explicitly recognizes the roles and importance of aquatic ecosystems and the pressing need to confer appropriate levels of protection on them. The process of implementing this farsighted legislation is now in progress.

In South Africa, the escalating demands for water to meet the needs of social and economic development, and to remedy past inequities, highlight the urgent need to implement comprehensive and integrated management approaches to the country's water resources and their component aquatic ecosystems. This requires water resource managers to strive to attain a delicate balance between resource protection and resource utilization. The difficulties that they experience are compounded when insufficient skilled personnel are available, or the information available is inadequate or incomplete. It is these critical information "gaps" that need to be filled by carefully targeted research, whilst the development of a cadre of appropriately skilled personnel must be seen as a national priority.

Taking a more regional perspective, it is clear that South Africa's neighbours experience precisely the same types of problems in their efforts to manage their respective water resources (Ashton & Seetal, 2002; Hirji *et al*., 2002). However, in comparison to South Africa, most SADC countries have considerably less aquatic ecosystem information available, far fewer trained staff and greater difficulty in obtaining the required levels of economic support for comprehensive water resource management approaches (SARDC, 1996). This poses several potential problems, especially in those situations where more than one country shares a specific water resource or river basin. In such cases, the actions required need to be expanded to include strengthening institutional arrangements and partnerships so that each state is able to fulfil its responsibilities to its neighbours, whilst simultaneously safeguarding its own (national) water resource base.

6.5 The way forward

Future research investments need to be directed towards identifying, understanding and then solving the key problems related to biodiversity that we face in South (and southern) Africa. Here, it is important to remember that efforts to "conserve biodiversity" should not be equated with attempts to retain or protect single examples or populations of every species, or equating the species richness of a particular taxon with conserving overall biodiversity. As Purvis and Hector (2000) so eloquently state, such an action would be "… rather like having one of each note in the Mozart concerto".

The process of implementing the National Water Act provides an extremely important and useful central focus for biodiversity-related research efforts in South Africa. In particular, considerable effort will be needed if we are to fully implement the "Reserve" concepts and considerations contained within the Act.

Similarly, it is also important to remember that biodiversity *per se* is not the same as "the ecological approach". The term 'biodiversity' represents a complex and multi-dimensional scientific concept that combines the attributes of species, communities, structures, processes and functions; the so-called "ecological approach" is an analytical approach based on attempts to identify and understand the variety (or diversity) of components in a particular system as well as the range and responses of the inter-linkages between these components. Too often, the "ecological approach" is simply (and inadequately) assumed to be equivalent to the generation of a "shopping list" of species present in a particular area. The generation of such "shopping lists of species" wastes time and money, serves little purpose and provides very little in the way of information that is useful or usable. Instead, application of the ecological approach in its broadest sense, to include community structure, function and processes, offers the greatest potential for generating useful information (Tilman, 1999, 2000; IUCN, 2000).

Biodiversity has to be seen in its broadest sense with an understanding that the characteristics of populations, and of the individuals within such populations, also provide essential information. Also important are considerations of a species' (or genus') functional role in an ecosystem (e.g. predation, pollination, nitrogen fixation, habitat modification, etc.) and its functional inter-relationships with other organisms that it shares its habitat with. Because biodiversity is critically dependent on habitat type and availability, renewed efforts need to be directed towards understanding the linkages and dependencies between biotic and abiotic components of aquatic ecosystems.

In summary, therefore, future research themes and directions need to focus more attention on broader issues of aquatic ecology, particularly those that are linked to efforts aimed at implementation of the National Water Act. In addition, greater focus is needed on ecological impacts, specifically those impacts that lead to alterations in community composition and changes to wider ecosystem functions and processes. This knowledge is essential if we are to provide water resource managers and decision-makers with appropriate information to enable them to fulfil their roles as custodians of the nation's scarce water resources.

6.6 The next few steps

This document will be circulated to knowledgeable individuals who have been identified as being able to provide critical comments and suggestions for improvement, prior to engaging them in focus group discussions. These individuals have been selected on the basis of their knowledge and expertise in the arena of biodiversity and its management, and represent academic institutions, government departments and research establishments. During the focus group discussions, individuals will be asked to examine the biodiversity research priority matrix (**Appendix A**) and suggest specific priority issues or threats facing biodiversity in South Africa and the accompanying response and knowledge base (if any) for that issue. This will enable one to identify gaps that will be considered as areas of future research that the Water Research Commission should support. All responses will be collated and integrated into a final version of this document, which will then be submitted to the Water Research Commission for their consideration.

6.7 References

Ashton, P.J. & Seetal, A. (2002). Challenges of water resource management in Africa. In: (H. Baijnath & Y. Singh, eds), *Rebirth of Science in Africa: A Shared Vision for Life and Environmental Sciences.* Umdaus Press, Pretoria. Pp. 133-148.

Chapin III, F.S., Zaveleta, E.S., Eviners, V.T., Naylor, R.L., Vitousek, P.M., Reynolds, H.L., Hooper, D.U., Lavorel, S., Sala, O.E., Hobbie, S.E., Mack, M.C. & Diaz, S. (2000). Consequences of changing biodiversity. *Nature Insight, 405 (No. 6783, 11 May*: Pp 234-242.

CITES (1973). *Convention on International Trade in Endangered Species of Wild Fauna and Flora*. United Nations Environment Programme (UNEP), Washington DC, USA. Available at website: http://sedac.ciesin.org.

Cloete F. & Wissink, H. (eds.) (2000). *Improving Public Policy*. Van Schaik, Pretoria. 316pp.

DEAT (1995). *Wetlands Conservation Bill*. Department of Environmental Affairs and Tourism, Pretoria. 9pp.

DEAT (1997). *White Paper on the Conservation and Sustainable Use of South Africa's Biological Diversity*. Department of Environmental Affairs and Tourism, Pretoria. Republic of South Africa Government Gazette Notice 1095 of 1997, Vol. 385, No. 18163. 87pp.

DEAT (1998a). *National Environmental Management Act (Act No.107 of 1998).* Department of Environmental Affairs and Tourism, Pretoria. Republic of South Africa Government Gazette Notice 19519, Vol. 401, No. 1540. 37pp.

DEAT (1998b). *Marine Living Resources Act (Act No. 18 of 1998).* Department of Environmental Affairs and Tourism, Pretoria. Republic of South Africa Government Gazette Notice 18930, Vol. 395, No. 747. 34pp.

DEAT (1999). *World Heritage Convention Act (Act No. 49 of 1999).* Department of Environmental Affairs and Tourism, Pretoria. Republic of South Africa Government Gazette Notice 20717, Vol. 414, No. 1485. 28pp.

DEAT (2001). *A Bioregional Approach to South Africa's Protected Areas – 2001/2002*. Department of Environmental Affairs and Tourism, Pretoria. 24pp.

DEAT (2002a) *National Environmental Management: Biodiversity Bill, Draft 8, May 2002*. Department of Environmental Affairs and Tourism, Pretoria. 133pp.

DEAT (2002b) *National Environmental Management: Protected Areas Bill, Draft 8, May 2002*. Department of Environmental Affairs and Tourism, Pretoria. 70pp.

DWAF (1997). *White Paper on a National Water Policy for South Africa*. Department of Water Affairs and Forestry, Pretoria. 37pp.

DWAF (1998). *The National Water Act (Act No. 36 of 1998)*. Department of Water Affairs and Forestry, Pretoria. Republic of South Africa Government Gazette No. 19182, Vol. 398, No. 1091. 101pp.

DWAF (2002). *National Water Resource Strategy, Proposed First Edition, Summary*. Department of Water Affairs and Forestry, Pretoria. 40pp.

Falkenmark, M. (1999). Competing freshwater and ecological services in the river basin perspective - an expanded conceptual framework. In: *Proceedings of the SIWI/IWRA Seminar "Towards Upstream/Downstream Hydrosolidarity"*. Swedish International Water Institute, Stockholm.

FAO (1951). *International Plant Protection Convention*. United Nations Food and Agriculture Organization (FAO), Rome. Available at website: http://sedac.ciesin.org.

FAO (2000). *New Dimensions in Water Security - Water, Society and Ecosystem Services in the 21st Century*. Land and Water Development Division, United Nations Food and Agriculture Organization (FAO), Rome. FAO Report: AGL/MISC/25/2000. 82pp.

FAO (2001). *International Treaty on Plant Genetic Resources for Food and Agriculture. Commission on Genetic Resources for Food and Agriculture*, United Nations Food and Agriculture Organization (FAO), Rome. Available at website: www.fao.org/ag/cgrfa/News.htm.

FMFA (1946). *International Convention for the Protection of Birds*. French Ministry of Foreign Affairs. Paris, France. Available at website: http://sedac.ciesin.org.

Franklin, J.F. (1988). Structural and functional diversity in temperate forests. In: (E.O. Wilson, Ed.), *Biodiversity*. National Academy Press, Washington DC. Pp. 166-175.

Gleick, P.H. (2002). *The World's Water 2002-2003: The Biennial Report on Freshwater Resources*. Island Press, Washington, D.C. 334pp.

GUSA (1946). *International Convention for the Regulation of Whaling*. Government of the United States of America, Washington DC. Available at website: http://sedac.ciesin.org.

Hirji, R., Johnson, P., Maro, P. & Chiuta, T.M. (2002). *Defining and Mainstreaming Environmental Sustainability in Water Resources Management in Southern Africa*. Maseru/Harare/Washington D.C.: SADC/IUCN/SARDC/The World Bank. 317pp.

Huntley B.J. (Ed.) (1991). *Biotic Diversity in Southern Africa: Concepts and Conservation*. Oxford University Press, Cape Town.

IUCN (2000). *The Ecosystem Approach*. Report of the Fifth Meeting of the Subsidiary Body on Scientific, Technical and Technological Advice, International Union for the Conservation of Nature (IUCN). Montreal, Canada.

Klopper, R.R., Smith, G.F. & van Rooy, J. (2002). The biodiversity of Africa. In: (H. Baijnath & Y. Singh, eds), *Rebirth of Science in Africa: A Shared Vision for Life and Environmental Sciences.* Umdaus Press, Pretoria. Pp. 60-86.

Le Maitre, D.C., Euston Brown, D.I.W. & Gelderblom, C.M. (1997). Are the potential impacts on biodiversity adequately assessed in southern African environmental impact assessments? *Proceedings and Papers: Integrated Environmental Management in Southern Africa: State of the Art and Lessons Learnt.* Pp. 173-183.

MacKay, H.M. & Ashton, P.J. (in prep.). A model for co-operative governance in the implementation of cross-sectoral policy: water policy as an example.

McCann, K.S. (2000). The diversity-stability debate. *Nature Insight, (No. 6783, 11 May)*: 228-233.

NePAD (2001). *The New Partnership for Africa's Development (NePAD)*. Document of Accord drawn up on 3 July 2001. 60 pp. Available at website: http://www.nepad.org/.

Noss, R.F. (1990). Indicators for monitoring biodiversity. *Conservation Biology*, 4: 355-364.

Pallett, J. (Ed.) (1997). *Sharing Water in Southern Africa*. Desert Research Foundation of Namibia, Windhoek, Namibia. 121pp.

Purvis, A. & Hector, A. (2000). Getting the measure of biodiversity. *Nature Insight, (No. 6783, 11 May)*: 212-219.

Ramsar (1971). *Convention on Wetlands of International Importance Especially as Waterfowl Habitat*. United Nations Educational, Scientific and Cultural Organisation (UNESCO). Ramsar, Iran. Available at website: http://www.ramsar.org.

Revenga, C. & Cassar, A. (2002). *Freshwater Trends and Projections: Focus on Africa*. World Wildlife Fund for Nature (WWF), Gland. 12pp.

SADC (1992). *Declaration and Treaty of the Southern African Development Community (SADC) Region*. Southern African Development Community (SADC), Windhoek, Namibia. Available at website: http://www.sadc.int/.

SADC (1995). *Protocol on Shared Watercourse Systems in the Southern African Development Community (SADC) Region*. Southern African Development Community Council of Ministers, Gaborone, Botswana. Available at website: http://www.sadc.int/.

SADC (1996). *Policy and Strategy for Environment and Sustainable Development: Toward Equity-led Growth and Sustainable Development in Southern Africa*. Available at website: http://www.sadcelms.org.ls/

SADC (1999). *Protocol on Wildlife Conservation and Law Enforcement*. Southern African Development Community (SADC), Maputo, Mozambique. Available at website: http:// www.sadc.int/.

SADC (2001a). *Revised Protocol on Shared Watercourse Systems in the Southern African Development Community (SADC) Region*. Southern African Development Community (SADC), Windhoek, Namibia. Available at website: http:// www.sadc.int/.

SADC (2001b). *Protocol on Fisheries*. Southern African Development Community (SADC), Blantyre, Malawi. Available at website: http:// www.sadc.int/.

Sala, O.E. (2000). Global biodiversity scenarios for the year 2100. *Science*, 287: 1770-1776.

SARDC (1996). *Water in Southern Africa*. Southern African Research and Documentation Centre, Harare, Zimbabwe. 238pp.

Tilman, D. (1999). The ecological consequences of changes in biodiversity: a search for general principles. *Ecology*, 80: 1455-1474.

Tilman, D. (2000). Causes, consequences and ethics of biodiversity. *Nature Insight, 405 (No. 6783, 11 May)*: 208-211.

UNCBD (1992). *The Convention on Biological Diversity*. United Nations Conference on Environment and Development (UNCED); Rio de Janeiro, Brazil. Available at website: http://www.biodiv.org

UNCCD (2001). *United Nations Convention to Combat Desertification in Countries Experiencing Serious Drought and/or Desertification, Particularly in Africa*. United Nations Secretariat for the Convention to Combat Desertification (UNCCD), Bonn, Germany. Available at website: http://www.unccd.org.

UNCED (1992). *Agenda 21 – Earth Summit Agreement*. United Nations Conference on Environment and Development (UNCED), Rio de Janeiro, Brazil. Available at website: http://www.un.org/esa/sustdev/agenda21.htm

UNCSW (1997). *Convention on the Law of the Non-Navigational Uses of International Watercourses*. United Nations General Assembly Document A/51/869 (April 11). United Nations Publications, New York.

UNEP (1933). *Convention Relative to the Preservation of Fauna and Flora in their Natural State*. United Nations Environment Programme (UNEP), London, United Kingdom. Available at website: http://www.unep.org.

UNEP (1979). *Convention on the Conservation of Migratory Species of Wild Animals*. United Nations Environment Programme (UNEP), Bonn, Germany. Available at website: http://sedac.ciesin.org.

UNEP (2000). *The Cartagena Protocol on Biosafety*. United Nations Environment Programme (UNEP) Cartagena, Columbia. Available at website: http://www.biodiv.org.

UNEP (2002a). *Global Environment Outlook 3: Past, Present and Future Perspectives*. A Collaborative Report by United Nations Environment Programme (UNEP), Nairobi, Kenya. Earthscan Publications, London. 446pp.

UNEP (2002b). *Africa Environment Outlook: Past, Present and Future Perspectives*. A Collaborative Report by United Nations Environment Programme (UNEP), Nairobi, Kenya. Earthprint Limited, Stevenage, England. 442pp.

UNESCO (1972). *Convention Concerning the Protection of the World Cultural and Natural Heritage*. United Nations Educational, Scientific and Cultural Organization (UNESCO), Paris, France. Available at website: http://sedac.ciesin.org.

UNFCCC (1992). *United Nations Framework Convention on Climate Change*. United Nations Conference of Environment and Development (UNCED), Rio de Janeiro, Brazil. Available at website: http://www.unfcc.int/resource/conv/index.html.

United Nations Forum on Forests (1992). *United Nations Conference on Environment and Development (UNCED)*, Rio de Janeiro, Brazil. Available at website: http://www.un.org/esa/forests.

UNGA (1958). *Convention on Fishing and Conservation of the Living Resources of the High Seas*. United Nations General Assembly, Geneva, Switzerland. Available at website: http://sedac.ciesin.org.

UNGA (1961). *International Convention for the Protection of New Varieties of Plants*. United Nations General Assembly, Geneva, Switzerland. Available at website: http://sedac.ciesin.org.

Van Wilgen, B.W., Cowling, R.M., & Burgers, C.J. (1996). Valuation of ecosystem services: a case study from South African fynbos ecosystems. *BioScience*, 46: 184-189.

WEHAB (2002a). *A Framework for Action on Biodiversity and Ecosystem Management*. Water, Energy, Health, Agriculture, and Biodiversity (WEHAB) Working Group Preparatory Document for the World Summit on Sustainable Development, Johannesburg, August 2002. 36pp.

WEHAB (2002b). *A Framework for Action on Water and Sanitation*. Water, Energy, Health, Agriculture, and Biodiversity (WEHAB) Working Group Preparatory Document for the World Summit on Sustainable Development, Johannesburg, August 2002. 40pp.

Wilson, E.O. (1988). The current state of biodiversity. In: (E.O. Wilson, Ed.), *Biodiversity*. National Academy Press, Washington DC. Pp. 3-18.

WRI (2000). *World Resources 2000-2001: People and Ecosystems: The Fraying Web of Life*. World Resources Institute (WRI), United Nations Development Programme (UNDP), United Nations Environment Programme (UNEP) and The World Bank, Washington DC. 389pp.

Appendix A: Research priority matrix including examples of priority issues and accompanying responses and knowledge base information.

		Genes	**Species / Population**	**Community / Ecosystem**	**Landscape / Region**
Priority Issues		*Genetically Modified Organisms*	*Extinction of species*	*Loss of wetland ecosystems and their services*	*Loss of migration routes due to habitat fragmentation*
Responses (Legislation / Policy / Convention to address issue)	***International***	*Protocol on Biosafety*	*Convention on Biological Diversity*	*Ramsar Convention*	*Convention on the Conservation of Migratory Species of Wild Animals*
	Regional	*Protocol on Biosafety*	*Protocol on Wildlife Conservation and Law Enforcement*	*Ramsar Convention*	*Convention on the Conservation of Migratory Species of Wild Animals*
	National	*National Environmental Management: Biodiversity Bill*	*National Environmental Management: Biodiversity Bill*	*Wetlands Conservation Bill*	
Knowledge Base	**Baseline research** (Across composition, structure and function components of biodiversity)		*Relationships between hydraulics and species composition of different wetland types. Construction of artificial wetlands*	*Hydro – geomorphic classification of wetlands*	*Inventory of wetland types and their specific structure and composition*
	Applied research (Impacts on organisational levels and components of biodiversity)		*Impacts of flow modification on wetland structure, composition and functioning at specific sites / locations*	*Impacts of forestry on wetland water balance*	*Use of wetlands as "nutrient reduction filters" for wastewater and effluent treatment*

APPENDIX 3
PRELIMINARY LIST OF PRIORITY ISSUES FOR THRUST 1 (ENVIRONMENTAL FUNCTIONING WITHIN THE HYDROLOGICAL CYCLE)

This list was developed in consultation with a small group of scientists during August 2003. The initial list of issues was circulated to a range of stakeholders for comment, and for them to indicate their opinion on the relative priority of each issue, according to a simple scoring system. Scores for issues were averaged and ranked (see table below). The ranking was moderated based on priorities identified in the WRC's business planning process, and discussions with KSA directors.

	Average score	Rank	Moderated ranking	Comments
Programme 1: Regional and global-scale changes in the (biophysical) environment				
1. What are the implications of climate change for the amount, timing, variability, flow-related quality and assurance of water supply? (already in progress in KSA1)	2.00	1	2003	In progress.
2. What are the implications of climate change scenarios for background water quality in South Africa's biogeoclimatic regions, and the consequences for water treatment technologies and policies and instream water quality management policies and regulatory mechanisms?	2.67	9	2007	
3. Identify the potential impacts of global and regional climate change on nitrogen cycling processes and rates in the hydrological cycle (including the atmospheric, terrestrial, marine, surface water and subterranean components of the hydrological cycle), the implications for water resources management, and policy options for coping with possible scenarios of change.	2.00	1	2004	Nitrogen initiative by IPCC – can link to international activity & info.
4. Identify the potential impacts of global and regional climate change on phosphorus cycling processes and rates in the hydrological cycle (including the atmospheric, terrestrial, marine, surface water and subterranean components of the hydrological cycle), the implications for water resources management, and policy options for coping with possible scenarios of change.	2.33	5	2007	A lot of information should come out of the nitrogen component study to support this one.
5. What are the implications of climate change for existing and new water sharing agreements? (x-ref Thrust 2: Environmental governance systems)	2.90	10	2005	Important. Principles could be investigated, but strategies would have to wait for results of NU climate change project to understand scope and implications.

6. What are the projected rates and patterns of desertification (caused both by climate change and land use practices), and the associated impacts on components of the hydrological cycle? What are the potential impacts of current and projected water use and management scenarios on desertification processes? What might be appropriate policy and regulatory responses?	2.20	3	2006	Probably quite a lot of research going on through various regional and international initiatives. Needs to be reviewed, and possible research gaps/issues for WRC identified.
7. What are the implications of meeting the Millenium Goals for water services & sanitation on environmental functioning within the hydrological cycle, and hence for water resources management? (also x-ref WRC strategic issue 25)	3.00	11	-	Combine with issue 25.
8. What are the scope and significance of the impacts of current and projected patterns of atmospheric emissions (loads, concentrations, spatial distribution, forms {nox, sox, particulate, organics, carbon compounds}) from land-based activities for the hydrological cycle and hence for water resources management ? What are the environmental processes governing the fate and transport of these substances within the hydrological cycle? What are the options for policy responses from the water sector or in collaboration with other sectors?	2.25	4	2006	Probably quite a lot of information available, but has not been synthesised to allow assessment of impacts on hydro cycle.
9. What are the current and projected patterns of migration and urbanization? What are the potential impacts on water in the environment, either directly as a result of land use changes or discharges, or indirectly through changes in water demand patterns? (also x-ref WRC strategic issue)	2.00	1	2007	Strategic issue. Can link to & complement DWAF long-range planning.
10. What is the current and projected status of both natural and human-induced radioactivity in the components of the hydrological cycle? What are the environmental processes governing the fate and transport of radioactivity within the hydrological cycle? What are the potential impacts on water resources, in terms of use and protection? What are the possible policy and regulatory responses?	2.50	8	2006	DWAF priority. Controversial, much public debate. Objective information will be needed. Look for co-funding.
11. What are the scope and significance of past, current and projected patterns of use of persistent toxic inorganic pollutants in the environment? What are the environmental processes governing the fate and transport of persistent inorganic pollutants (PIPs) within the hydrological cycle ? What are the implications of these patterns on components of the hydrological cycle? What are the possible policy and regulatory responses?	2.67	9	2006	
11a. What are the scope and significance of past, current and projected patterns of use of persistent organic pollutants (POPs) in the environment? What are the environmental processes governing the fate and transport of POPs within the hydrological cycle? What are the implications of these patterns on components of the hydrological cycle? What are the possible policy and regulatory responses?	2.33	5	2004	International POP treaty. Information will be needed to inform SA's response/implementation

Programme 2: Biodiversity				
12. What secondary and/or tertiary effects is climate change (temperature, hydrology) likely to have on the structure, function and composition of ecosystems related to the components of the hydrological cycle? What are the implications for the quality, reliability and availability of water and associated goods and services derived from water resources? What are the options for policy responses?	2.00	1	2006	Essential, but may need to wait for baseline hydro and temperature info from NU project.
13. What are the impacts on structural, functional & compositional biodiversity at all scales (genetic to landscape) of existing and proposed inter-basin transfer schemes? What are the options for policy and regulatory responses? (x-ref programme 3)	2.25	4	2005	Addressed to some degree by previous WRC project. Needs review, and maybe a brief issues paper. Depends on how many new IBTs are proposed, and whether there are mitigation options for existing IBTs.
14. What are the upstream impacts of flow regulating structures, including dams, reservoirs and weirs? What are the potential ecological roles within the hydrological cycle of flow-regulating structures in surface water bodies? What are the implications for water resources management?	2.25	4	2004	Ramsar priority for 2004. DWAF priority related to management of dams for ecological objectives.
15. How does the current and emerging suite of WRM indicators reflect the dimensions (structure, composition and function) and scales (genetic to landscape) of biodiversity? What would be the characteristics of appropriate indicators for WRM that properly reflect all the dimensions and scales of biodiversity?	2.25	4	2004	Essential but controversial. Current trajectory of research is heavily weighted towards compositional aspects, and will be difficult to shift due to the momentum already gathered. Probably needs a short issues paper very soon to catch people's attention, then longer-term basic research.
Programme 3: Impacts and management of introduced species				
16. What are the potential impacts on water resources of the widespread or commercial introduction of GMOs into the environment, and what are the implications for policy and regulation of GMOs?	2.33	5	2004	Significance uncertain, but heated public debate likely to require informed response from the water sector.
17. What is the extent and potential impact of nuisance species (terrestrial and aquatic; fauna and flora; alien and indigenous) on environmental functioning within the hydrological cycle?	2.90	10	-	Probably quite a lot of information available, but not consolidated. Working for Water should be on this anyway. Check with WfW.
Programme 4: Interfaces				
18. What is the contribution of freshwater, derived from land, but not delivered through river mouths or estuaries, to the nearshore marine zone? What is the ecological significance of this contribution? What are the implications for water resources management?	3.00	11	2004	Needs to be assessed at a strategic level. Links to work in KSA2 on methodology for determination of marine freshwater flows. Request KSA2 to pick this up in the current estuaries programme.

19. What is the distribution and current & projected utilisation of deep (>500m) groundwater bodies in South Africa? What are the potential impacts (geochemical, geohydrological, ecological) of deep (>500m) groundwater extraction on the components of the hydrological cycle, and on environmental functioning within the hydrological cycle? What are the implications for policy and regulation?	2.50	8	-	Proposed in KSA1
20. To what extent do artificial recharge practices impact on biochemical, geochemical, hydrological and ecological processes within the hydrological cycle? What are the implications for policy and regulation?	3.50	12	-	Work in progress in KSA1
21. What is the role of groundwater-dependent ecosystems (those contained within aquifers, karst & cave systems) in regulating ecological processes between components of the hydrological cycle?	2.38	6	2007	May need to wait for outputs of GDE project in KSA1. The deliverables of the GDE project could be expanded slightly to provide guidance on this issue.
Programme 5: Resource Directed Measures (RDM)				
22. What are the implications of climate change for the philosophical basis of IFRs and the Reserve, the methodologies currently used to determine IFRs, and the status of existing environmental flow allocations? What are the options for policy responses?	2.00	1	2004	Essential.
23. Identification of strategic research issues and knowledge gaps related to derivation of instream water quality criteria for aquatic ecosystems (freshwater and estuarine).	2.40	7	2006	Essential. Current knowledge base is outdated (SA WQ Guidelines), although there is work going on, mostly through KSA2, it has not been consolidated and there isn't a coherent plan which culminates in new policy or regulation
24. Current methods for determination of IFR take little or no account of important ecosystem processes related to the integrity, functioning and resilience of those systems (e.g. oxygenation, metal sequestration, nutrient cycling, sediment-water interactions and sediment quality). How should/could existing and emerging methodologies be adapted to integrate these aspects into IFR determinations? (x-ref programme 2)	2.50	8	2006	Essential but controversial. Links to issue 15. Wait for RDM Version 2 (late 2005) and link this to directed research programme arising from RDM2.
WRC strategic issues				
26. What are the implications of HIV/AIDS scenarios for water use and water resources management (quantity and quality)? (also x-ref programme 1)	2.10	2	2005	DWAF has info on impact of HIV/AIDS on projected water demand. Not sure what is available relating to impacts of water availability & quality on HIV-affected populations. Might not need much new work, but does need consolidation and distribution of knowledge to promote wider, informed debate.

25. What are the potential impacts of national, regional and NEPAD poverty alleviation policies and strategies on the hydrological cycle, and hence on the availability, quality and reliability of water resources?	2.40	7	2005	Access international funding. There must already be possibilities within the NEPAD process for linking up.

Other related WRC reports available:

Strategic review of river research

CM Breen; D Cox; C Dickens; H Mackay; M Mander; DJ Roux; A Turton; E van Wyk

This project had its origins in the growing appreciation of the need for research on river systems to contribute more immediately and directly to improved river system management. Research is perceived as a service that leverages change in the way in which river systems are managed and so should improve our capacity to act in ways that direct behaviour towards sustainable use. This required the simultaneous addressing of 4 issues: **Perceptions** of the **state of the resource**, the **behaviour** that determines the state, and the **regulatory environment**. Research should present seamless interpretations, as this is how society experiences the real world.

If research is to improve leverage of change then it must address 'outcomes' (as well as outputs) more explicitly than has been the case. In addition, the language in which research outputs are expressed is not supportive of the leveraging of change. This is because society, by and large, perceives rivers as a resource providing goods and services (not all of which need be monetised) and through the use of these the individual experiences benefits and costs Scientists, on the other hand, usually refer to the ecological state. The proposal is made that rivers are viewed as production systems, and the environmental Reserve as the allocation to sustain this production so that society can, in perpetuity, draw on this production. In this way, it may be easier to convey the concept of the Reserve to others.

This shift of emphasis draws attention to the rights of use. Rights of use and the authority regimes underpinning these rights need to be clear if sustainable use is to become reality. Rights of water use are clear, but rights of use of the goods and services are less clear, especially where common property regimes prevail. Two strategic research needs underpinning this are discussed in the report. One is that we need to understand how to design and implement public-private compacts to promote sustainable use of river systems. The second is that we need to understand how to use the rights of access to goods and services and distribution of costs and benefits to deepen democracy. This process would promote efforts to achieve dynamic equity in resource use.

The key strategic research issues identified are:

- Establishment of an inter-organisational entity (Centre of Competence in River Management) that maintains our fitness to respond to issues pertinent to river system management.
- Strengthen our ability to leverage change based on research findings by shifting emphasis of research to outcomes and by connecting researchers and managers effectively.
- Strengthening of democracy in support of dynamic equity in apportioning costs and benefits deriving from the use of river systems and the adjacent land.
- Effective public-private compacts that empower civil society to promote sustainable use of rivers.
- A system for analysing and assessing the propagation of impacts and their consequences across scales (local to regional) whereby scenarios can be generated for decision making.

A range of interlinked products (including report 955/1/03) were produced during the project which addressed the Resource-Directed Methods and the Source-Directed Controls of DWAF, a protocol for toxicity testing in flowing water and instream toxicity monitoring.

Report Number: 1198/1/03 **ISBN: 1 86845 965 9**

TO ORDER: Contact **Publications** - Telephone No: 012 330 0340
Fax Number: 012 331 2565
E-mail: publications@wrc.org.za

1770051937

Water Research Commission
Private Bag X03, Gezina, 0031, South Africa
Tel: +27 12 330 0340, Fax: +27 12 331 2565
Web: http://www.wrc.org.za