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

MJ Patrick • PJ Ashton •
GC Pegram • HM Mackay

WRC Report No. KV 189/07

Water Research Commission

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

Report to the Water Research Commission by:

Marian J Patrick, Peter J Ashton, CSIR
Guy C Pegram, Pegasus
Heather M MacKay, Formerly WRC

WRC Report No.: KV 189/07
ISBN: 978-1-77005-565-0

JUNE 2007

Originally published as KV148/04 in June 2004 and updated in October 2005

The publication of this updated version of the report emanates from three consultancies 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);
"Review of the investment strategy for the crosscutting domain: Water and the Environment" (WRC Project No K8/646)

TABLE OF CONTENTS

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 is 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 meets 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 2002/3 the importance of these issues was highlighted when they emerged as major issues in the World Summit on Sustainable Development agenda and the newly developed agenda for the New Partnership for Africa's Development (NEPAD). These domains form integrating frameworks that cut across the Key Strategic Areas (KSAs) of the WRC 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 six sections plus four appendices: **Section 1** places the Water and Environment domain within the overall strategy of the WRC and outlines the context and primary focus of the domain. **Section 2** describes the conceptual framework of the domain - the imperative to integrate governance systems and ecological systems. **Section 3** describes how the domain functions within the WRC and lists proposed success criteria that form the operating model for the domain. **Section 4** describes the process undertaken to develop the domain strategy. **Section 5** presents the investment framework down to research programme level. **Section 6** presents the operational framework for thrusts one and two down to research priority issues / project level.

The appendices provide more detail and background to the project. **Appendix 1** consists of a detailed description of the process followed in drafting this strategy. **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 WRC research portfolio for the domain in the 2005/6 financial year, whilst **Appendix 4** contains a copy of a paper published in Water SA based on the original background paper on environmental governance and biodiversity written during the strategy development process.

1.2. Overview of the strategy development process

The strategy development process began in June 2002 with the preparation of the background paper for discussion (see **Appendix 2**). This background paper provided the context for the domain strategy and explored the concepts that underpin the strategy and the main focus of the domain. **Section 2** summaries this context. The background paper was circulated to a wide range of stakeholders and interested people, and a round of focus group meetings was then held. The discussions at the focus group meetings provided the basis for development of the core strategy to thrust level. The scope and descriptions of the three thrusts, contained in the initial core strategy, were published in April 2003.

Subsequently, two key review projects were commissioned to develop the strategy to project level in Thrusts 1 and 2 (Environmental functioning, and Environmental governance respectively). An updated version of the strategy was published in June 2004 (WRC report number KV148/04), containing a suite of priority research questions for Thrust 1 arising from the first of the two review projects, and articulated at project level. The second review project was completed during 2005 (WRC report number 1514/1/06), and the results of that review have been incorporated into this new version of the core strategy through the provision of priority research questions at project level for Thrust 2.

A more detailed description of the strategy development process can be found in **Appendix 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 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. INTEGRATING GOVERNANCE SYSTEMS WITH ECOLOGICAL SYSTEMS

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 2**. 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.

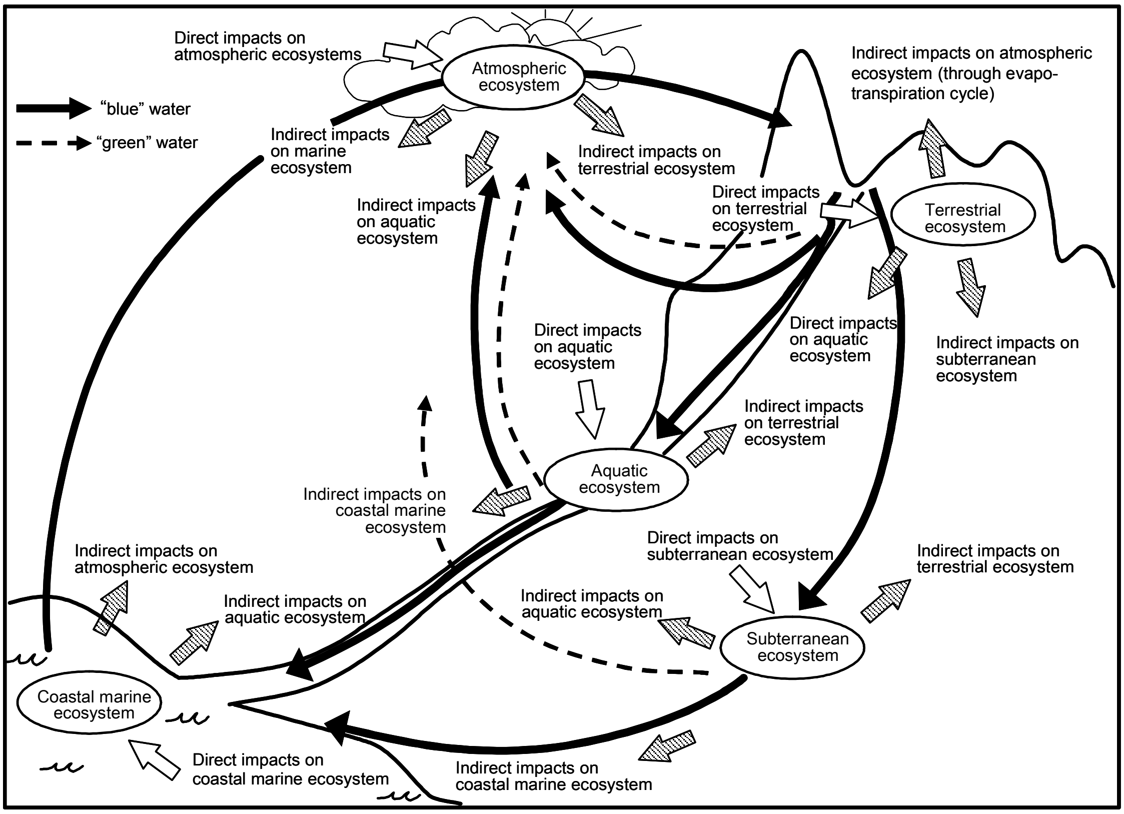

Figure 1: Phases of the Hydrological Cycle, showing the inter-relationships between environmental components and the so-called "blue" and "green" water components of the hydrological cycle, where "blue water" refers to all water that is controlled by physical processes and "green water" is the water 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; Republic of South Africa, 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.

Recent years have seen the emergence of a rapidly growing body of evidence that human domination of Earth's ecosystems has dramatically transformed large areas of the globe, causing a striking reduction in global biodiversity, and has reduced the capacity of ecosystems to provide society with a sustainable supply of essential goods and services (e.g. Vitousek et al., 1997; Tilman, 2000). This awareness of the implications of biodiversity loss has also been accompanied by increased acceptance of the philosophy that humans are an integral part of the global ecosystem, since this approach better reflects the realities of human dependence on and interdependence with ecological processes (e.g. World Commission on Environment and Development, 1987; Western, 1997; Tilman, 2000). However, for a variety of reasons, these wider philosophical developments are not always fully accepted and many government and legal institutions, at national as well as international level, still adhere to the view that while "society" is dependent upon "the environment", these should be seen as discrete entities and dealt with separately (Hirji *et al*., 2002; Acreman, 2004). Clearly, this view makes it extremely difficult for water resource management agencies to mainstream the philosophy of integrated water resource management, which requires full integration of all governance and water resource components in order to be successful.

Conceptually, the governance system can be superimposed onto both the ecological system and the economic 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, and hence through its subsequent influence on social and political interactions around resources, such as conflict or co-operation (Ashton *et al*., 2005). 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 and their sequence or timing are seldom fully predictable or appreciated. In this example, an improved understanding of the governance linkages and their implications should inform the choice between possible tradeoffs that society could make between the short- and long-term implications of biodiversity (ecosystem service) loss and economic or social gain (Ashton *et al*., 2005).

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 and sustains the livelihoods of 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 and economic systems, a governance system that is relatively better aligned with the ecological system is at least a significant step forward from the current situation. Importantly, where the available information is considered to be insufficient for a high degree of confidence in the outcome of a particular decision, then a precautionary approach is advised (Ashton *et al*., 2005).

Many scholars argue that customary legal and regulatory systems related to the use of natural resources are often closely aligned with local biophysical patterns and processes,

[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.

and are thus inherently capable of adapting to changes in resource availability (Ashton, 2004). However, since such systems tend to be highly localized and context-specific, it is often difficult, both technically and politically, to expand or upscale them to catchment, regional or even national levels (Chikozho and Latham, 2005; Van Koppen *et al*., 2005). Nevertheless, there is much to be learned from studies of both customary and conventional or state-centred approaches to natural resource management. The challenge will be to integrate the strengths of both types of approaches into a governance system for water resources, as ecosystems, that is practical, robust and administratively workable (Ashton et al., 2005).

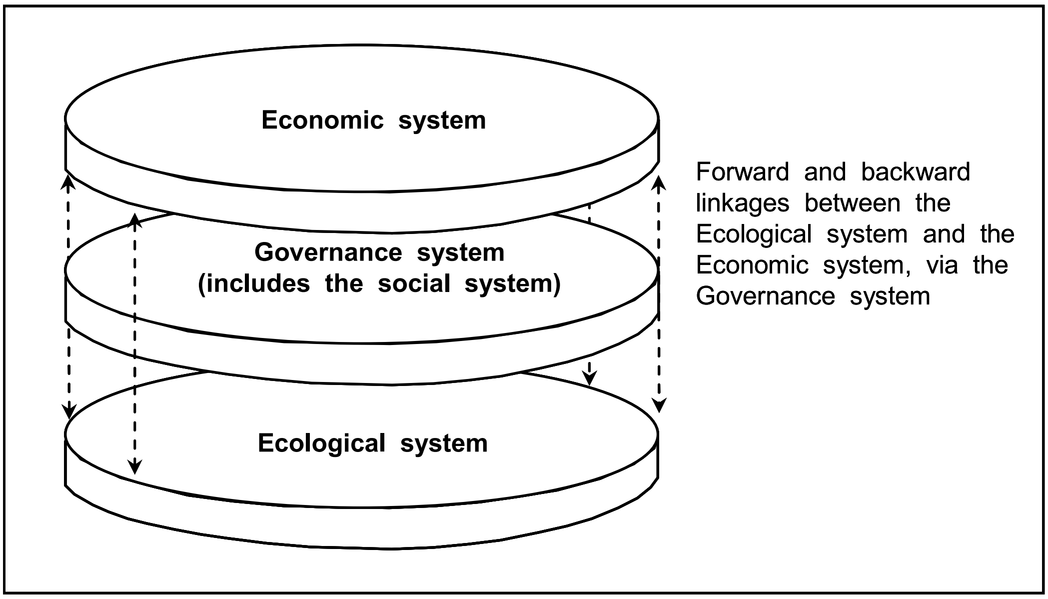

Figure 2: Conceptual diagram, showing the forward and backward linkages between the ecological system and the economic system, via a governance system, where the ecological system is represented by the hydrological cycle and the economic system represents the livelihoods and other economic benefits derived from the ecological system (as described in **Figure 1**).

3. THE CROSSCUTTING DOMAIN AND THE WRC

3.1. Background

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 transdisciplinary 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 specifically:

- Work with the Key Strategic Areas (KSAs) in a proactive manner to guide and influence their programmes in order to ensure coverage of priority domain issues, through the development of appropriate terms of reference for research projects to be commissioned in the KSAs;
- Work with the KSAs in a somewhat more retrospective manner to identify and draw out knowledge that is relevant to priority domain issues, and build on this knowledge to address priority domain issues through the preparation of review papers and the execution of higher-level integrative projects;
- Promote high-level integration across the WRC and other relevant national or international research programmes in order to address priority domain issues; and
- 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.

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.

3.2. Criteria for Success

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" were proposed (**Table 1**). These have formed the basis for the development of key performance indicators for this domain and as such, they have been incorporated into the detailed WRC business plans for successive financial years since April 2003.

Progress towards meeting the short-term criteria set out in **Table 1** is relatively easy to measure quantitatively, since these activities are almost entirely internally driven and do not depend on external factors to a very large degree. At the time of writing this report, milestone tasks have been achieved for each of the four short-term success criteria since the initial version of the domain strategy was released in April 2003.

Although progress towards meeting the medium- and longer-term criteria in **Table 1** can be measured quantitatively against suitable selected indicators, the actual contribution of WRC domain activities to this success will be difficult to resolve. This is appropriate, since the philosophy behind the domain strategy is one that promotes collaboration and integration in the generation and application of shared knowledge for the benefit of society as a whole. However, it is also important to note that individual contributions are seldom easily quantifiable in high-level integrative work. This makes it essential to develop appropriate sets of indicators that can disaggregate and identify specific individual contributions so as to improve estimates of (economic and other) returns on (research) investment. Clearly, this issue will have significant implications for intellectual property issues - these will need to be resolved at an early stage by research funders and members of the research community.

Table 1: “Criteria for success” in the 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.
Ultimate outcome	• Aligned governance systems are working effectively. • Ecosystems and governance systems are resilient to external surprises and shocks.

4. DEVELOPMENT OF THE STRATEGY

4.1. Introduction

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 investment framework (see **section 5**) 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:

1. 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 was placed on the large catchment-scale studies that were conducted from 1975 onwards. Other relevant research, and that currently in progress at the time of the review, was also included. Project numbers K8/546 and K8/584.
2. A review of the national governance system related to water in the environment. The scope of this review was the appraisal and evaluation of 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. Project number K5/1514.

The results of these reviews, plus additional inputs on this draft strategy from stakeholders, have been used to guide the revision of the domain strategy and the definition of thrusts down to project level (see **section 6**). These projects will include those supported directly within the KSAs as well as those cutting across all the KSAs and being led from the domain. The research framework has formed the basis for solicited and unsolicited project proposals for the 2005/2006 funding cycle, and for WRC business planning for the period to 2009.

4.2. Summary of the portfolio review project

This review focused on that part of the domain objective that centres on our understanding of environmental processes and functioning i.e. Thrust 1: Environmental Functioning within the Hydrological Cycle. Environmental processes and functioning have been described in the context of the components of the hydrological cycle (aquatic, terrestrial, subterranean, atmospheric and marine), in that there are biophysical, biochemical and ecological links within and between each of these components. This means that water resources are linked, via the water itself, to broader environmental processes and functioning, and respond to all forms of human activities.

Incomplete knowledge and understanding of the linkages between the components of the hydrological cycle hinders achievement of domain objectives, and prevents society from accomplishing the broader goal of sustainable water resources management.

This review evaluated the extent of our existing knowledge base related to the environmental processes and functions that occur within and between the components of the hydrological cycle, and sought to identify those knowledge gaps that preclude a complete understanding of processes within the hydrological cycle. The review was divided into two phases, where phase 1 comprised a review of the WRC's contribution to the domain objective, and phase 2 covered the contributions from the Department of Water Affairs & Forestry (DWAF). It must be recognised that the WRC and the DWAF only contribute to a segment of knowledge that comprises the domain objective. Many other institutions also participate in research that supports and contributes to the WRC achieving its domain objective.

The review took the form of developing a database from a pool of source publications relevant to the scope of the *Environmental functioning within the hydrological cycle* thrust. The list of publications from the Water Research Commission was analysed and a search using the National Inquiry Services Centre (NISC) database was undertaken. Those publications that were considered to be relevant to the domain were selected for input into a database. The database provides a brief outline or summary of the research undertaken, together with a list of referencing details, the identification of any relationships between the research and the WRC priority issues, and lists the associated components of the hydrological cycle that were studied.

The list of priority issues for thrust 1 that was identified and developed during the development of a strategy for the domain *Water and the Environment,* are believed to represent the most important current, emerging or foreseeable concerns related to water in the environment in the next 3 to 8 years. A total of 25 issues were identified and grouped into six programmes (see **Section 5 and 6**). The records that are assigned to a particular priority issue were therefore intended to form part of the literature review / compilation of background information for these future studies. Importantly, this categorization of research records does not necessarily mean that a specific issue was addressed directly by the relevant research projects. Instead, the information that is contained within the research record should be seen as being relevant to the specific issues, and potentially providing useful background inputs that could be used to guide directed research that needs to be undertaken to resolve these issues

This review provided useful insights into the contributions made by the WRC and the DWAF to the body of research that is relevant to this thrust for the last 30 years in terms of:

- The spatial distribution of research undertaken within South Africa;
- The scale of the research (i.e. research undertaken at regional, national, catchment or site specific scales);
- The level of research (i.e. research the has focused on situation assessments, process or policy related research);
- The temporal change in the focus of the level of research; and
- The relationship of research undertaken to the WRC priority issues and to components of the hydrological cycle.

A more detailed description of the review results can be found in Patrick *et al*., 2007.

4.3. Summary of the governance review project

The emerging integrated planning, economic and social development, participatory and decentralised institutional paradigm of IWRM requires a more complex understanding of governance related to all components of the hydrological cycle and the human activities that have an impact on it.

Governance in the water sector has political, administrative and economic dimensions and includes both the activities of government, as well as the interaction of civil society with these processes. Good water governance requires predictability, participation, transparency, equity, accountability, coherence, responsiveness, integrated and ethical decision making. This must be built around open policy making, a professional bureaucracy and a strong engaged civil society.

The governance review addressed international and national policy and legal frameworks.

- There are a number of political (policy) initiatives and legal instruments at the international level that have an impact on national water governance. For governance of water in the hydrological cycle, the most relevant initiatives are those related to climate change, management of transboundary water resources and environmental management.
- At the national level, policy and legislation has been generally well developed in South Africa in accordance with government policy since 1994. However, the implementation of this policy and legislation has been generally uneven, inconsistent and often inadequate to meet the challenges facing the country. The key areas for governance evaluation are the regulatory frameworks, institutional capacity and implementation practice.

The following general findings resulted from the evaluation:

- Atmospheric related governance has two elements, namely air emissions and weather modification. At a principle level, the policy and legislation is sound and reflects Constitutional and NEMA principles. Being relatively new legislation, the regulatory framework is still being established. There is very little good practice in terms of cooperation around the atmosphere as part of the hydrological cycle, either between government departments or between spheres of government, despite the severe social and economic impact air quality deterioration has in parts of the country.

- Governance around land address both the terrestrial and subterranean environments, which determines impacts on and water use associated with the water environment. The nature, impacts on water and governance of land use activities are extremely diverse and catchments are literally made up of a "tapestry" of different activities, responsibilities and associated mandates. The needs of coordination and institutional capacity to align land use management, environmental management and service delivery are the priority areas for governance related to land, while the management of communal lands and land reform pose specific challenges.

- Governance of water relates to be ground water, wetlands, rivers, lakes, impoundments, estuaries and the marine environment. It is the most visible part of the hydrological cycle and represents the "start" and "end" of the hydrological cycle.

> The policy and legal framework for water governance and its interactions with other elements of the hydrological cycle has been broadly developed in South Africa. However, delay in the development of key regulatory instruments has meant that the institutional and practical implementation of this framework is not well developed. Specific governance challenges are related to the "interfaces" between biophysical components, namely wetlands, riparian zones, estuaries and the costal zone (with the groundwater interface).

There a number of fundamental challenges to improving water governance in South Africa, namely:

- Change and maturity in the governance systems
- Institutional change and decentralisation
- Participation and democratisation
- Changing management paradigm
- Transformation
- Institutional memory
- Complexity and integration
- Information, communication and uncertainty
- Technical and management capacity
- Financial resources

Given the magnitude of these strategic challenges, it is remarkable that there is a relatively effective governance system in the water and related sectors. However, it is apparent that an institutional champion is required for promoting coherent and harmonised implementation of water governance related to the entire hydrological cycle, and it is proposed that these be catchment management agencies.

The critical requirements to ensure improved governance of water in the hydrological cycle are:

- Establishment of effective regulatory framework (and implementation plan) for water resources management, linked to other sectors activities and taking consideration of the available institutional capacity.
- Establishment of coherent institutional arrangements at a catchment level to promote alignment of water with air, land and marine management, including the development of adequate institutional capacity.
- Promotion and institutionalisation of appropriate stakeholder involvement in catchment and land management processes, taking account of the role of local government in democratic representation.

A more detailed description of the review results can be found in Pegram et al., 2006.

The results of the two above reviews plus inputs from the strategy development process are all synthesised in the investment framework of programmes and the operation framework of priority issues which are described in more detail in **Sections 5 and 6** respectively.

5. INVESTMENT FRAMEWORK: DOMAIN STRATEGY TO THRUST LEVEL

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: Governance across Biophysical Components	Water moves through all components of the natural hydrological system, namely the atmospheric, land, subterranean, freshwater and marine environments. This programme focuses on alignment and harmonisation of the different governance systems within and between these biophysical components, in order to ensure that water related issues are explicitly recognised in the planning and management frameworks for the environmental components of the hydrological cycle.
Programme 2: Governance around social, political and institutional interfaces	Management of water within the hydrological cycle is influenced by a range of social, political and institutional processes, each with their own governance systems. This programme focuses on key processes that affect the governance of water in the environment, through identification of critical gaps or conflicts in the interfaces between these national, provincial and local governance systems. This will emphasise the development of processes to promote co-operative governance or harmonization of these governance systems.
Programme 3: Policy mapping and economic governance	Other sectoral policies (e.g. agriculture, mining, etc.) and particularly economic policy 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 economic, social development, trade & industry, biotechnology and agricultural 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.
Programme 5: Institutional Strengthening for Water Governance	Effective governance of water in the environment requires that national, provincial and local government has the broad mandate and capacity to fulfil their responsibilities and that civil society (including the private sector) is empowered to participate in political and administrative governance processes. This programme focuses on research required to understand the required institutional capacity to promote cooperation between governance frameworks / systems and to enable coherent planning and management related to water in the environment.
Programme 6: Water governance building block projects	Research on water resources institutional arrangements and water-environmental governance is relatively new. In some cases it is necessary to conduct research on specific water sector governance issues before addressing the interface and alignment issues for governance of water in the entire environment (hydrological cycle). This programme focuses on (and highlights) those projects that are crucial building blocks for the other programmes within this thrust, noting that they should be conducted as part of the regular KSA programmes.

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: Integrative projects	• Design and execution of key research projects that bridge Thrusts 1 and 2, thus contributing to the overall scope and objectives of the crosscutting domain in promoting better alignment of governance systems with ecological systems to which they are related.
Programme 2: Networking, communication and capacity building	• Promoting communities of practice related to thrusts 1 and 2. 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. • 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. • 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: Strategy maintenance	• 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. • 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.

6. OPERATIONAL FRAMEWORK: DOMAIN STRATEGY TO PROJECT LEVEL

6.1. Preliminary list of priority issues for Thrust 1: Environmental Functioning within the Hydrological Cycle

Priority Issue	Rank	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?	-	Completed (WRC Project Number K5/1430: Prof R. Schulze – UKZN). Report provides broad outline of potential future changes to river flow patterns in South Africa's river basins.
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?	4	Water quality information for each river basin needs to be evaluated for projected future flow scenarios, effluent discharge patterns and the anticipated classification system. Specific water treatment technologies can be identified to suit particular situations. ToR still to be developed.
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.	1	ToR completed. Project still to be initiated. Nitrogen initiative by IPCC – can be linked to related international activities and information derived from other projects. Needs to be linked closely to research activities dealing with the causes and consequences of eutrophication.
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.	4	A lot of information should come out of the nitrogen component study (Issue 3) to support this objective, particularly in relation to eutrophication issues and their future management. ToR still to be developed.

Priority Issue	Rank	Comments
5. What are the implications of climate change for existing and new water sharing agreements?	2	The specific hydrological information (water quantity and water quality) for each of South Africa's shared river basins needs to be evaluated in the light of existing and possible future water-sharing agreements between South Africa and her neighbours. The potential future river flow scenarios derived from Project K5/1430 (see Issue 1) will provide key information. ToR still to be developed.
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?	3	The results of various regional and international initiatives need to be reviewed and evaluated for their relevance to the South African situation. Specific research gaps need to be identified for possible funding by the WRC. Specific responses will be needed at policy and regulatory levels. ToR still to be developed.
7. What are the implications of meeting the Millennium 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)	-	The background research needed for this issue can be combined with issue 25. Specific information is needed to combine the requirements of in-stream ecosystems with the needs of broader society as the basis for water allocation decision-making processes. ToR still to be developed.
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?	3	Several earlier studies have addressed specific components of this issue. These information sources need to be compiled and synthesized to allow assessment of actual (current) and potential (future) impacts on the hydrological cycle. This will allow specific research gaps to be identified, as well as appropriate policy and regulatory responses. ToR still to be developed.

Priority Issue	Rank	Comments
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?	4	This is a strategically important issue for future water management planning in every catchment. This information can complement DWAF's long-range planning. ToR still to be developed.
10. 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?	-	This issue is linked closely to the international treaty on POPs. Information is needed to inform South Africa's response and implementation of the treaty. Work is in progress on this issue via WRC Project Number K5/1561, under the direction of Prof. H. Bouwman, UNW.
11. 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?	3	This issue is a DWAF priority and some information is available. Radioactivity in the aquatic environment is a controversial topic that has fuelled much public debate. Objective information will be needed as a basis for sound decision-making and this issue offers an opportunity to source co-funding from industry. ToR still to be developed.
12. 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?	3	Several studies have been carried out on specific river systems and reservoirs, or in relation to individual industrial operations. This work needs to be compiled and synthesized and key research gaps identified, as well as the possible policy and regulatory implications. A comprehensive national assessment is needed – possibly in the form of a detailed issues paper. ToR still to be developed.
Programme 2: Biodiversity		

Priority Issue	Rank	Comments
13. 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?	3	Work on this issue has been initiated via WRC Project Number K5/1562, under the direction of Prof. B. Hewitson, UCT.
14. What are the impacts of existing and proposed inter-basin transfer schemes on structural, functional & compositional aspects of biodiversity at all scales (genetic to landscape)? What are the options for policy and regulatory responses?	2	A previous WRC project has addressed this issue to some degree. This work needs to be reviewed and synthesized as an issue paper. Specific recommendations are needed for possible new IBTs – both within South Africa and possibly also for IBTs from other countries to South Africa. Key concerns are identification of appropriate mitigation options, as well as required policy and regulatory responses.
15. 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?	1	This was announced as a Ramsar priority for 2004. It is also a DWAF priority related to the management of dams for ecological objectives (water releases to meet the needs of the Reserve. Available information needs to be synthesized. ToR still to be developed.
16. 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?	1	This issue is essential but controversial. The current trajectory of research is heavily weighted towards compositional aspects, and it will be difficult to shift due to the momentum already gathered. Work has been initiated on an issues paper via WRC Project Number K5/569 under the direction of Dr PJ Ashton at CSIR. This will provide the basis for decisions on what additional research or regulatory responses may be needed.
Programme 3: Impacts and management of introduced species		

Priority Issue	Rank	Comments
17. 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?	1	The significance of this issue is uncertain, but heated public debate about GMOs will require informed response from the water sector. The available information needs to be synthesized. ToR still to be developed.
18. 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?	-	The Working for Water (WfW) Programme has a lot of information available on this issue, but this has not been consolidated or synthesized. Need to check with WfW to source the available information.

Programme 4: Interfaces		
19. 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?	1	Work on this issue is in progress
20. 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?	-	Work that can also address this issue has been proposed for KSA1. Wait for specific research outcomes before deciding on future additional research. There is an opportunity to link this work with specific CMAs.
21. 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?	-	Work that will address this issue is being conducted in KSA1. Wait for specific research outcomes before deciding on future additional research.

22. 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?	4	Some work on this issue has been initiated under KSA1 – it will be appropriate to wait for the guidance that will be provided by the outputs of this project before deciding on specific additional research needs.
Programme 5: Resource Directed Measures (RDM)		
23. 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?	1	Knowledge on this issue is essential for future water resource planning and management at national and CMA level. Some information is available from the climate change project completed under Issue 1, but this has not been synthesized. A clear overview is needed as to the degree of influence that possible climate change scenarios may have on existing IFR methodologies, and the possible policy and regulatory responses that may be required.
24. Identification of strategic research issues and knowledge gaps related to derivation of instream water quality criteria for aquatic ecosystems (freshwater and estuarine).	3	Knowledge on this issue is essential for future water resource planning and management at national and CMA level. The current knowledge base is outdated (SA WQ Guidelines). Some work on this topic is being conducted within KSA2, though it has not been synthesized or consolidated, and there is no coherent plan that could influence policy or provide a basis for the development of new policy or regulation.
25. 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)	3	This issue is essential but also controversial, and links to issue 15. It is appropriate to wait for the appearance of documentation for RDM Version 2 (late 2005) and then link this to a directed research programme arising from RDM2, designed to address key information gaps. There is an opportunity to link this work with emerging CMAs.

6.2. Preliminary list of priority issues for Thrust 2: Environmental governance systems

Priority Issue	Rank	Comments
Programme 1: Governance Across Biophysical Components		
1 In what ways can the emerging regulatory and planning systems for atmospheric emissions be harmonised with governance systems relating to catchment based water management? What mechanisms need to be implemented to give effect to this?	6	This must focus on alignment of management / planning areas, coherence of authorisation and enforcement approaches, and fostering institutional cooperation. The implications and opportunities of the Air Emission Act should be investigated.
2 How should the emerging understanding of the subterranean environment as a complex ecosystem be reflected in water, land and environmental governance systems? Is there a need to revise the government mandates for subterranean and aquifer systems?	9	It may be that the science needs further development before governance arrangements can be addressed. Currently in progress in KSA 2.
3 What lessons can be developed from the South African experience in the governance of wetland management? How can these be expanded to the complex governance arrangements for other natural systems at the interface between biophysical components?	10	The progress with managing agricultural, environmental and water governance systems around wetlands and the role of civil society may provide important lessons for governance of riparian zones and estuaries.
4 How can governance arrangements (policy, legislation, integrated planning mechanisms) be formulated ensure integrated management of the coastal zone, between freshwater (surface and ground water) systems, estuaries and the coastal marine environment?	3	There is an opportunity to influence emerging environmental policy and legislation to ensure harmonisation in the management of the coastal zone, including the link to land management and catchment management.
5 How can the various governance systems applicable to the riparian zone of water resources be aligned in policy and practice to ensure coherent planning and management?	6	Conflicting governance around riparian zones in urban and rural areas needs to be harmonised for water, environmental and public safety purposes.

Priority Issue	Rank	Comments
6 What mechanisms can water managers realistically use to influence or control land use patterns in the interests of catchment management and its impact on water in the environment? Which types of land use are appropriate for some degree of regulatory control?	3	The science is largely in place. Questions remain about the legal, institutional and governance issues around specification of resources quality objectives, streamflow reduction activities, nonpoint sources and controlled activities to control land use, versus cooperative governance mechanisms. Governance off eutrophication management represents a particular implementation of this issue and its linkage to governance around the system response and use.
Programme 2: Governance around Social, Political and Institutional Interfaces		
7 How can governance arrangements relating to provincial growth and development plans and local integrated development plans be aligned with those for catchment management strategies, to promote coherence, coordination and cooperation in the management of aspects affecting water in the environment?	2	This alignment would focus on spatial development, service delivery and environmental management and its links with water in the environment, indicating the ways in which the CMS interfaces up with one or more PGDP/s and down into multiple IDPs.
8 What practical governance arrangements are necessary to ensure the alignment of water management (particularly water allocation reform and resource protection) with land reform processes?	2	While there is significant effort at the high policy level to ensure alignment, the practice is largely uncoordinated. The issues of sustainability need to be further developed.
9 Is it appropriate, feasible or likely for water management institutions (such as CMAs) take on any other management responsibilities from provincial or local government the interests of rationalising roles and public interaction?	8	A preliminary review / scoping may identify where possible rationalisation may be pursued explore opportunities to consolidate responsibilities for water, environmental or land management.
10 What are the implications of the evolving policy and governance systems for traditional leadership (and their responsibilities particularly around communal land) for environmental management and governance related to the hydrological cycle?	6	While this is an important issue, the dynamic nature of the policy and legislative context for traditional leadership makes this difficult to research. However, the plural nature of governance systems in communal areas must be engaged.

Priority Issue	Rank	Comments
11 What improvements can be made for governance around the use, conservation and management of biodiversity for freshwater ecosystems (including estuaries)?	7	The governance interface between environmental management (biodiversity) and water resources management (resource protection) responsibilities need to be clarified and aligned.
12 What are the priority needs for governance alignment around the control, management and removal of introduced species?	8	Contested governance between competing authorities, reflecting incompatible drives for aliens.
Programme 3: Policy mapping and economic governance		
13 What are the most effective possibilities for using the emerging environmental tax policy to support the coherent and integrated management water in the environment? What are the potential social, economic and ecological benefits of earmarking and disbursing revenues from these levies / taxes?	4	Emission / discharge charges, product / activity taxes and water levies are potentially enabled through the National Treasury environmental tax policy. Earmarking of disbursement requires demonstration of significant economic benefit.
14 To what degree and how should water and environmental governance systems be aligned / structured with macro-economic and trade policy and governance, to ensure robust water management response to global market dynamics and economic trends?	5	Issues to explore are the impacts of macro-economic & trade policy on water and environmental resources (linked to Water and the Economy Domain), and the requirements for water management. The concept of comparative advantage is relevant. The trade policy project, and econometric model project provide some insight
15 What governance arrangements are required to adopt payment for economic services in support of resource protection within a catchment management context? What governance arrangements would enable capital payments from outside a catchment to support higher levels of resource protection (classification)?	5	Valuation of and payment for environmental services within a resource protection (classification process), either as ongoing charges on “downstream” beneficiaries or capital contributions from external institutions. Opportunities within a highly regulated water environment.
Programme 4: Regional and global governance		

Priority Issue	Rank	Comments
16 What water governance arrangements at and between regional, national and catchment level are needed to enable coherent response to climate change, and how should these interact with the governance systems of other sectors?	7	As the scientific understanding of climate change improves and environmental governance is developed, water governance will need to align and interact with these other governance systems.
17 What have been / are the legal and governance implications of South Africa's ratification of international treaties and conventions with impacts on water in the environment? Where there are inconsistencies, inadequate capacity or misalignment with existing policy, how should the response be coordinated and resolved?	10	Some of these are not harmonised with each other or there is inadequate capacity to implement these. This issue relates to the practical effect of ratification of international water and environmental treaties on water in the environment and whether these are actually in South Africa's interests.

Programme 5: Institutional Strengthening for Water Governance		
18 What are the characteristics and requirements of good governance in the decentralised institutional context of water and environmental management?	1	This should address the requirements for leadership and participatory management, as well as the governance role of DWAF as sector leader.
19 What are the priorities for strengthening the institutional capacity of local government to carry out its responsibilities where these impact on water in the environment at a local catchment level?	5	The specifically relates to constitutional mandates such as land management, (water and waste) service delivery, integrated planning, air emissions, pollution control, etc
20 What is required for civil society participation to promote/ensure good governance of water in the environment, distinguishing between policy and administrative processes?	2	Typically there is reasonable involvement in policy processes by organised groups, but limited input to administrative processes or by less-capacitated groups. CMA may be a useful vehicle for mobilising participation.
21 What are the priorities and governance arrangements required to promote cooperative government around water in the environment between WMIs and Provincial Government, regionalised National Government and relevant organs of state?	4	While there has been some research on the linkage between WMI and local government, the linkages with other spheres of government have not yet been developed, particularly around the environmental, agricultural, housing, mining sectors.
Programme 6: Water Sector Governance Building Blocks		

22 What governance arrangements are required to ensure a robust process of water resource classification that balances local development priorities with resource quality requirements?	3	Governance must promote a “consensus seeking” process that results in a balance between the needs of development and protection of the resource. Leads towards a firm basis for catchment level management of water [KSA 1]
23 What governance arrangements are required to ensure that the institutional separation between water resources management and infrastructure management does not jeopardise integrated water resources management?	4	Leads towards governance around the link between infrastructure management and water in the environment [KSA 1]
24 How should the impact of significant abstraction from large (cross-boundary) or deep aquifers on water planning be managed and aligned with catchment planning?	5	Impact of abstraction from deep aquifer on marine intrusion and (requires a possible Thrust 1 project). Also fossil water abstraction and entitlement, and the impacts on trans-generational equity. Provides a basis for the Thrust 3 boundaries project. [KSA 1]
25 What should be the role of shared watercourse institutions (i.e. basin commissions) in the governance of water resources at a national level, and how should they interact with local institutions and civil society?	5	Until this is sorted out in water, the issue cannot be expanded to water in the environment at a regional level. Also needs to interrogate the implication of shared water course definition on “water in the environment”.
26 What are the priorities for strengthening the capacity of civil society to engage water resources management decisions and thereby strengthen the systems of water governance? What should WMI do to promote this?	2	Needs to be sorted out as a building block for project 20 (above)

7. REFERENCES

Acreman M (2004). Water and ecology. In: J Dooge and J Selborne (eds.) *Water and Ethics*. United Nations Educational, Scientific and Cultural Organization (UNESCO), Paris. 35 pp.

Ashton PJ (2004). Water and development: A southern African perspective. In: J Trottier and P Slack (eds.) *Managing Water Resources Past and Present – The 2002 Linacre Lectures*. Oxford University Press, Oxford. 149-174.

Ashton PJ, Patrick MJ, MacKay HM and Weaver AvB (2005). Integrating biodiversity concepts with good governance to support water resources management in South Africa. *Water SA*, **31**(4): 449-456.

Chikozho C and Latham J (2005). Shona customary practices in the context of water sector reforms in Zimbabwe. Proceedings of the International Workshop on *African Water Laws: Plural Legislative Frameworks for Rural Water Management in Africa*. Johannesburg, 26-28 January 2005. Available (online) at website: www.nri.org/waterlaw/workshop. [Accessed May 2005].

Hirji R, Johnson P, Maro P and Chiuta TM (eds.) (2002). *Defining and Mainstreaming Environmental Sustainability in Water Resources Management in Southern Africa*. SADC, IUCN, SARDC, World Bank: Maseru, Harare, Washington DC. 318 pp.

Patrick MJ, Ashton PJ, & MacKay HM. (2007). *The Development of a Strategy for the Thrust: "Environmental Functioning within the Hydrological Cycle within the Crosscutting Domain: "Water and the Environment": Final Report - Phase 1 & 2*. WRC Report.

Pegram G, Mazibuko G, Hollingworth & Anderson E. (2006). *Strategic Review of Current and Emerging Governance Systems related to Water in the Environment in South Africa*. Water Research Commission Report 1514/06.

Republic of South Africa (1998) National Water Act (Act No. 36 of 1998). Department of Water Affairs and Forestry, Pretoria.

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

Van Koppen B, Butterworth J, Juma I, Maganga F, Latham J, Chikozho C and Morris M (2005). Legal pluralism and rural water management: objectives, definitions and issues. *Proc. Int. Workshop on African Water Laws: Plural Legislative Frameworks for Rural Water Management in Africa*. Johannesburg, 26028 January 2005. Available (online) at website: www.nri.org/waterlaw/workshop. [Accessed May 2005].

Vitousek PM, Mooney HA, Lubchenco J and Melillo JM (1997). Human domination of earth's ecosystems. *Science,* **277** 494-199.

Western D (1997). In the Dust of Kilimanjaro. Island Press, Washington D.C. 297 pp.

World Commission on Environment and Development (WCED) (1987). Our Common Future. Oxford University Press, New York.

APPENDIX 1: APPROACH TO THE DEVELOPMENT OF A RESEARCH STRATEGY

In 2002 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 were used to shape, test and ratify the WRC's investment strategy in the water environment. This was effectively achieved in the beginning of 2003 through an invitation 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 (February 2003). After stakeholder comments and internal WRC review, the scope and descriptions of the three thrusts, contained in the initial core strategy, were released in April 2003.

Subsequently, two key review projects were commissioned to develop the strategy to project level in Thrusts 1 and 2 (Environmental functioning, and Environmental governance respectively). An updated version of the strategy was published in June 2004 (WRC report number KV148/04), containing a suite of priority research questions for Thrust 1 arising from the first of the two review projects, and articulated at project level. The second review project (1514/1/06) was completed during 2006, and the results of that review have been incorporated into this new version of the core strategy (this report) through the provision of priority research questions at project level for Thrust 2.

In addition to the two key reviews, priority projects that were identified during the strategy development were solicited in July 2004/5 and April 2005/6 financial years respectively. The strategy document will be (should be) regularly reviewed, updated and informed by the outcomes of commissioned domain priority projects in the KSAs. The entire strategy development process is illustrated in **Figure A1.**

Table A1: List of participants who took part in the Focal Group Meetings during the initial strategy development phase in 2003.

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

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

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

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

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

Venue: UCT, Cape Town	**Date: 20 January 2003**
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

Participants	Organisation
Venue: CSIR, Stellenbosch	**Date: 22 January 2003**
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
Freek Venter	SANP
Andrew Deacon	SANP
Harry Biggs	SANP

Venue: Rhodes University, Grahamstown	Date: 4 February 2003
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
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

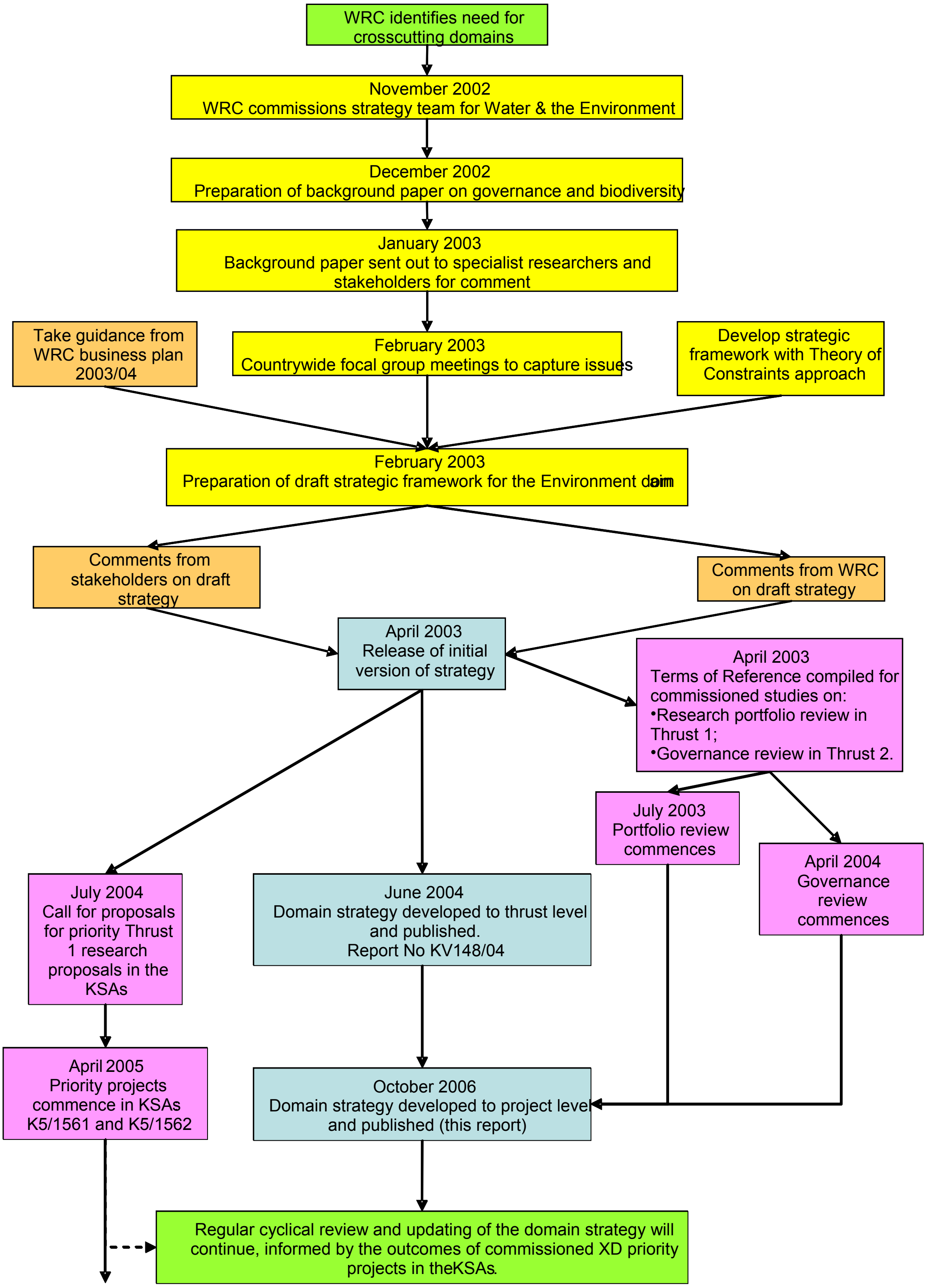

Figure A1: Flow diagram illustrating the approach to strategy development for the Water and Environment crosscutting domain, together with timescale and schedule of activities.

APPENDIX 2:
BACKGROUND INFORMATION PAPER FOR FOCAL GROUP MEETINGS

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:
Peter Ashton, Heather MacKay, Marian Neal and Alex Weaver

Date:
November 2002

CSIR

TABLE OF CONTENTS

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**).

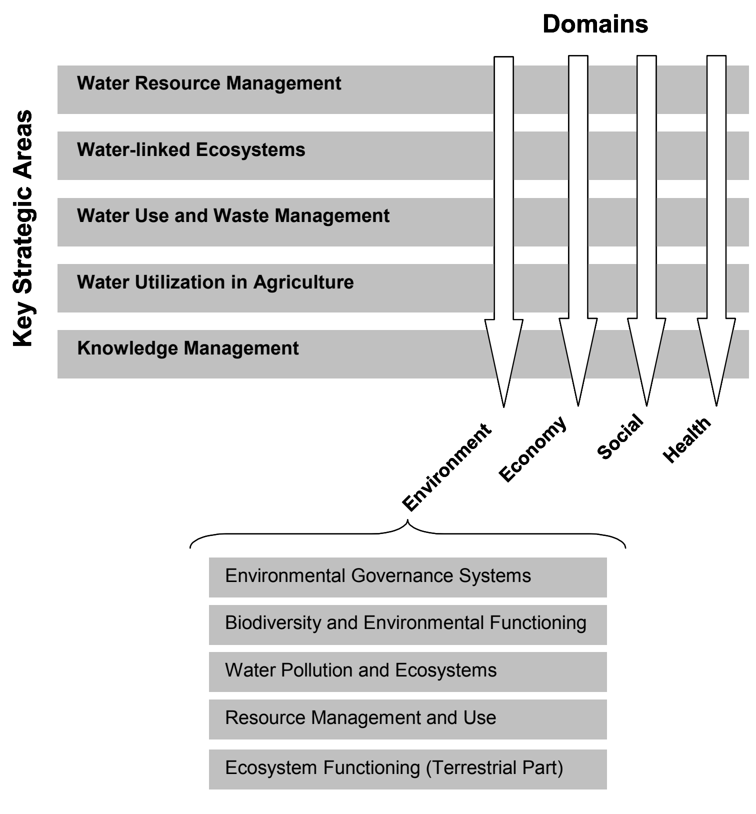

Figure 1: Key Strategic Areas and Cross-cutting Domains within the Water Research Commission

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.

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.

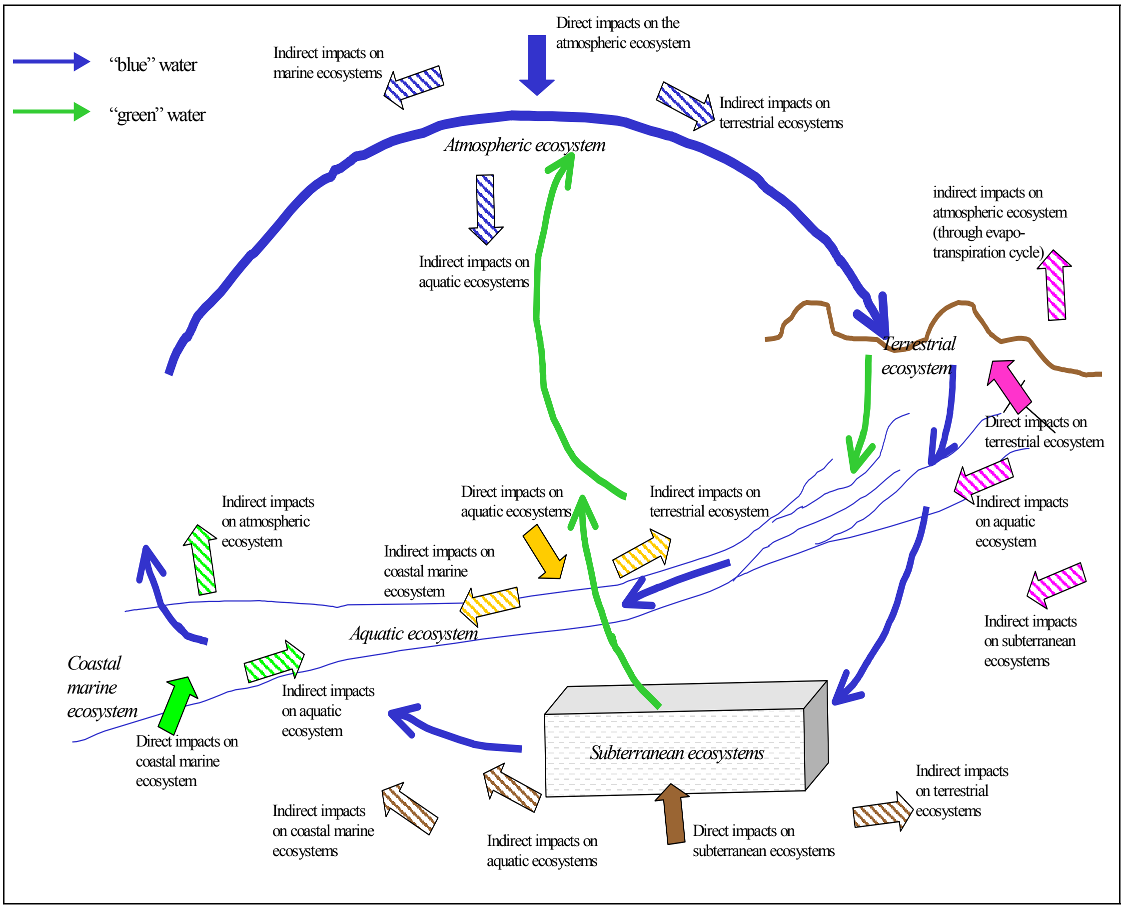

Figure 2: Phases of the hydrological cycle.

A disturbance or perturbation in the atmospheric component of the environment, for example, whether natural impact 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 (for agricultural production, industrial production or human consumption). outside the ecosystem from which it was derived, 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 if 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. So 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 <u>catchment</u> 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 abstraction or discharges of wastewater. Or, impacts 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 other 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)

			Governance element					
Environmental component	**Root cause**	**Priority issues**	**Level**	**Principles**	**Policy**	**Legisla-tion**	**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								

Environmental component	Root cause	Priority issues	Governance element Level	Principles	Policy	Legislation	Regulation	Practice
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 habitats; increased turbidity)	Global	Convention to Combat Desertification (CCD)	CCD			
			Regional		SARCCUS			
			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					

			Governance element					
Environmental component	**Root cause**	**Priority issues**	**Level**	**Principles**	**Policy**	**Legisla-tion**	**Regulation**	**Practice**
			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.

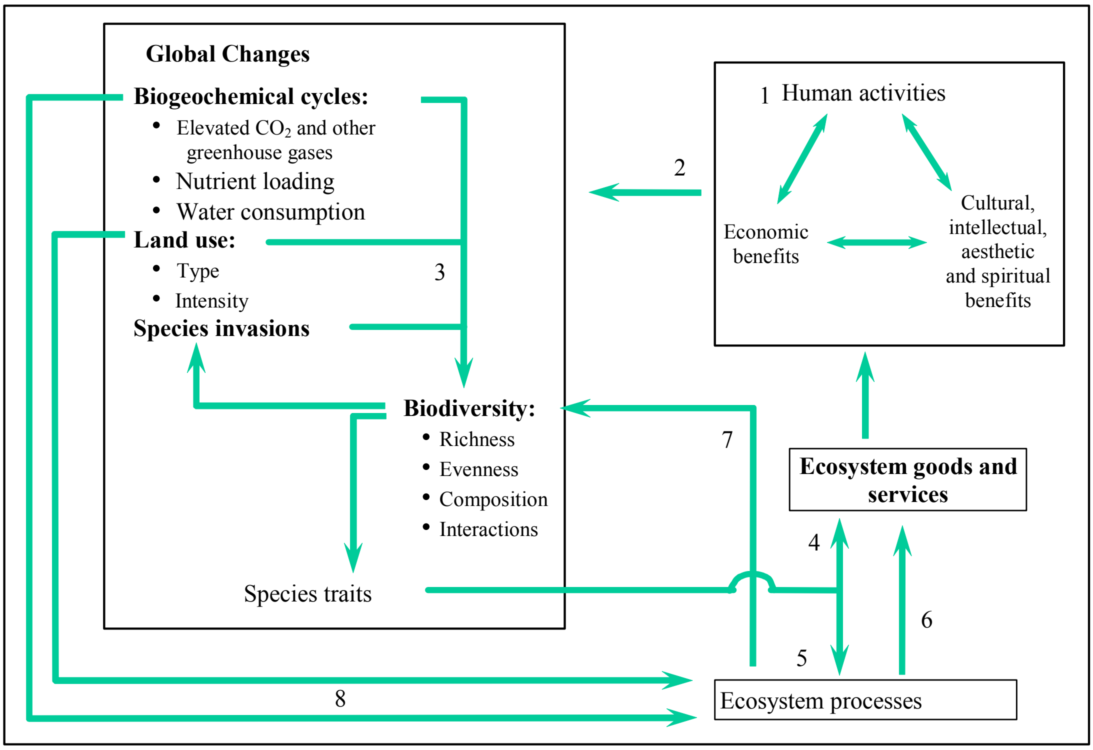

Figure 3. The role of biodiversity in global change. Redrawn from Figure 1 in Chapin *et al*., (2000). Human activities that are motivated by a diverse array of goals (1) cause ecological and environmental changes of global significance (2). These global changes contribute to changes in biodiversity 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).

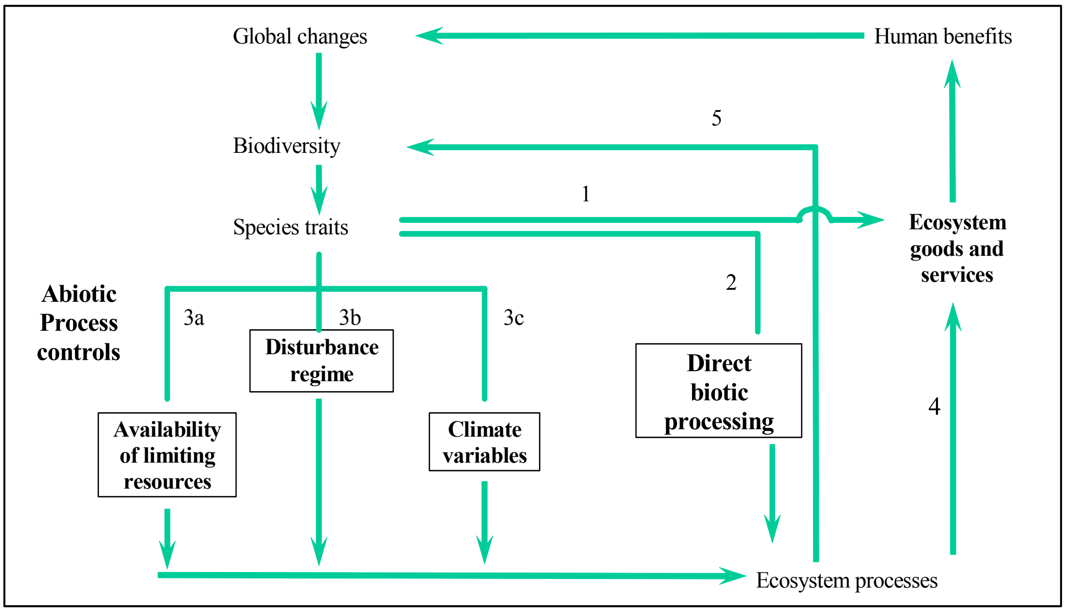

Figure 4: Mechanisms by which species traits affect ecosystem processes. Redrawn from Figure 4 in Chapin *et al*. (2000). Changes in biodiversity alter the functional traits of species in an ecosystem in ways that directly affect ecosystem goods and services (1). Changes in species traits affect ecosystem 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).

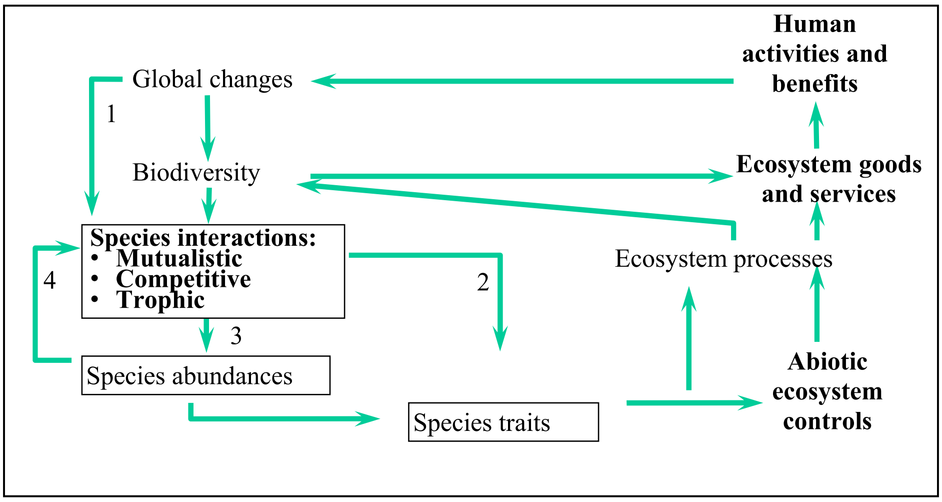

Figure 5: Mechanisms by which species interactions affect ecosystem processes. Redrawn from Figure 5 in Chapin *et al*. (2000). Global environmental change affects species interactions both directly (1), and through its effects on altered biodiversity. Species interactions may directly affect key traits 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**.

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.

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).

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 a 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 (**Addendum 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.

Addendum 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: WRC RESEARCH PORTFOLIO FOR THE CROSSCUTTING DOMAIN IN THE 2005/06 FINANCIAL YEAR

THRUST 1: ENVIRONMENTAL FUNCTIONING WITHIN THE HYDROLOGICAL CYCLE			
Project	**Title**	**KSA/XD funding**	**Due for completion**
	Programme 1: Regional and global-scale changes in the biophysical environment		
1562[1]	Secondary and tertiary impacts on water resources due to primary changes in temperature and precipitation	1	31/03/08
1561[1]	Persistent organic pollutants in the water environment	1	31/03/08
1500	Climate change and small town water resources	1	31/03/05
1467	Modelling non-point source pollution in agriculture from field to catchment scale – a scoping study	4	31/01/04
1430	Global climate change and water resources in Southern Africa: Potential impacts of climate change and mitigation strategies	1	31/03/05
1261	Regional model development for simulating atmospheric behaviour and rainfall over southern Africa	1	31/03/04
1154	The dynamical modelling of present and future climate system variability at inter-annual and inter-decadal time scales	1	30/04/04
1128	A survey of pesticide wastes in the RSA and a preliminary study of their biodegradation	3	31/03/02
1095	Tier I risk assessment of radio nuclides in selected sediments of the Mooi River	1	31/03/02
1013	Reconstruction of long-term, high-resolution records of summer rainfall and its variability in South Africa from cave speleotherms	1	31/12/02
1012	The climatology of water vapour sources, sinks and transport in the atmosphere over southern Africa, and evaluation of GCM and regional model skill in simulating the moisture characteristics	1	30/04/03
999	Evaluation of predictive models for pesticide behaviour in South African soils	4	31/03/02
953	Oceans' role in SA rainfall	1	31/12/02
938	Aerosols, recirculation and rainfall experiment	1	31/03/02
717	The impact of urbanization and industrialization on the environment	1	30/06/97
697	Modelling the long-term effect of atmospheric deposition on the salinity of catchment runoff with special reference to the Vaal Dam catchment	1	1996
	Programme 2: Biodiversity		
1588	Development of a diatom protocol for river health assessment	2	31/03/06
1567	Refining tools for evaporation monitoring in support of water resource management	1	31/03/08
1486	Conservation planning for river biodiversity	2	31/03/05
1483	Habitat use and movement of freshwater fish	2	31/03/07
1411	Determination of substrate maintenance flows in cobble and boulder bed rivers: ecological and hydraulic considerations	2	31/03/06

1409	Facilitating the free passage of migratory aquatic biota in South African rivers	2	31/03/07
1308	Development of resource monitoring procedures for estuaries	2	31/03/03
1307	Ecological impacts of reverse hydrograph releases from Albert Falls dam on instream processes	2	31/03/05
1258	A biophysical framework for sustainable management of wetlands in the NP with Nylsvley as a reference model	2	31/12/03
1256	Evaluation of the suitability of the fish assemblage integrity index (FAII) to assess river health	2	31/03/03
1213	Survey of certain persistent organic pollutants in major South African waters		2002
1065	Rule-based modelling of fish: facilitating strategic adaptive management of Kruger National Park rivers through model development and technology transfer	2	30/04/03
1063	Rule-based modelling of riparian vegetation and technology transfer to enable strategic adaptive management of Kruger National Park Rivers	2	31/03/02
975	Assessment of the implications of inter-basin water transfers for the genetic integrity of donor and recipient river basins using selected taxa	2	31/12/01
Programme 3: Impacts and management of introduced species			
1487	Integrated management of water hyacinth in SA	2	31/03/07
1407	The nature and rehabilitation of alien-invaded riparian zones	2	31/03/06
Programme 4: Interfaces			
1586	Framework development for the sampling, classification and geographical occurrences of stygobiont amphipods in South Africa	2	31/03/08
1581	The freshwater requirements of temporarily open/closed estuaries on the South Eastern and South Western Cape coasts	2	31/06/08
1565	Flow conceptualization, recharge and storativity determination in Karoo aquifers	1	31/03/09
1507	Mine water irrigation return flow	1	31/03/07
1503	Land use impacts on salinity in Western Cape Waters	1	31/03/09
1501	Field investigations to study the fate and transport of dense-aqueous liquids (DNAPLs) in groundwater	1	31/03/07

1462	Water use in relation to biomass of indigenous tree species in woodland, forest and/or plantation conditions	4	31/03/08
1330	Groundwater-dependent ecosystems	2	31/03/04
1327	Ecological and environmental impacts of large-scale groundwater development in TMG aquifer systems	1	31/03/05
1219	Improving the basis for predicting evapotranspiration from dry-land crops and veld types in South African hydrological models	1	31/03/04
1218	Use of isotope (13c) techniques to define the riparian zone in commercially afforested catchments	4	31/03/02
1168	Importance of groundwater in the hydrological cycle and the relationship to surface water bodies		2002
1122	The assessment of short-, medium- and long-term impacts on groundwater quality associated with the	1	30/04/02

	filling of dolomite cavities		
1115	Impact of groundwater abstraction on ecosystems on the Kammanassie Nature Reserve and environs	2	31/03/02
1059	Predicting the impact of farming systems on sediment yields in the context of integrated catchment management	4	30/04/03
798	Quantification of the water balance on rehabilitated mine soils under rain-fed pastures on the highveld of Mpumalanga	4	31/03/02
K3/5/ & K8/509	Freshwater requirements of the marine environment: A proposed predictive approach to assessment	2	31/03/04
Programme 5: Resource Directed Measures			
1587	Environmental water requirements in non-perennial systems	2	31/03/07
1582	Development, testing and installation of a real-time ecological Reserve implementation method for the Thukela River	2	31/03/07
1427	Pilot study: setting resource directed measures (RDM) for groundwater	1	31/03/05
1414	Environmental water requirements in non-perennial systems	2	31/03/05
1404	DRIFT methodology: Development of a Users Manual and consolidation of DRIFT software	2	31/03/05
1311	Refinement of aspects of the Reserve determination methodology for water quality	2	31/03/04
1306	Assessment of the geomorphological reference condition: application to RDM and the RHP	2	31/03/04
1257	Dealing with estuarine sedimentation – assessment of the hydraulics of estuarine sediment transport processes and the development of water reserve management guidelines	2	31/03/04
1235	Guidelines to set resource quality objectives for groundwater	1	2001
1174	Hydraulic analyses for determination of the Ecological Reserve	2	30/06/03
1160	Development of a computer-based decision support system for quantifying the components of the Ecological Reserve	2	31/12/02
1091	Groundwater reserve: delineation. Reference conditions and classification	1	2001
THRUST 2: ENVIRONMENTAL GOVERNANCE SYSTEMS			
Programme 1: Governance across biophysical interfaces			
-			
Programme 2: Governance across social political and institutional interfaces			
1511	Industry-government partnerships for development and implementation of sector-based standards for the water environment	1	30/09/06
1485	Integrated development planning for estuaries	2	31/03/07
1417	Integration of indigenous knowledge systems in the conservation and protection of wetlands in communal areas of South Africa	2	31/03/04

1410	Guidelines for integrating the protection and management of wetlands into catchment management	2	31/12/03
1215	Development of an appropriate procedure for closure of deep underground gold mines	3	2002
1018	Development of management policies, procedures and structures for Eastern Cape estuaries	2	2001
1014	The development and co-ordination of catchment forums through empowerment of rural communities	1	2001

K8/424	A legal evaluation of the South African natural resources management mechanism, towards integrated resources management	1	2003
Programme 3: Policy mapping			
1570	Econometric model to predict the effect that various water resource management scenarios would have on South Africa's economic development	1	31/03/08
1564	Trade policies and water resources	1	31/03/06
Programme 4: Regional and global governance			
1515	International freshwater agreements	1	31/03/05
Programme 5: Institutional strengthening for governance of water in the environment			
-			
Programme 6: Water sector governance building blocks			
1433	Evaluation of the requirements and mechanisms for co-operative governance between catchment management agencies and local government	1	31/03/04
THRUST 3: INTEGRATIVE KNOWLEDGE FOR ECOSYSTEM-BASED WATER RESOURCE MANAGEMENT			
Programme 1: Integrative projects			
1258	A biophysical framework for the sustainable management of wetlands in the Northern Province with Nylsvlei as a reference model	2	2003
K8/642	A model for developing cross-sectoral policy, using freshwater biodiversity as a case study	1	31/03/06
K8/591	Contributions towards constructing a socio-ecological systems (SES) view of the Sand River Catchment, South Africa	1	31/03/06
Programme 2: Networking, communication and capacity building			
1198	Strategic review of river systems research in South Africa	2	2001
K8/631	Design and establishment of a National Freshwater Biodiversity Collaboration	2	31/03/06
Mobility funding	South African interns: participation in Ramsar Convention STRP work and Conference of Parties	XDC	2005
Programme 3: Strategy maintenance			

K8/646[1]	Updating and refinement of the strategy for the crosscutting domain: Water and the environment	XDC	30/11/05
K8/546 K8/584[1]	Review of the national research portfolio related to water in the environment (Phases 1 and 2)	XDC	31/10/05
1514[1]	Strategic review of current and emerging governance systems related to water in the environment in South Africa	1	31/07/05

APPENDIX 4: INTEGRATING BIODIVERSITY CONCEPTS WITH GOOD GOVERNANCE TO SUPPORT WATER RESOURCES MANAGEMENT IN SOUTH AFRICA

Ashton P.J. [*1], Patrick M.J. [2], MacKay H.M. [3] & Weaver A.v.B. [4]

[1] CSIR-Environmentek, P.O. Box 395, Pretoria 0001, South Africa.
[2]CSIR-Environmentek, P.O. Box 17001, Congella 4013, South Africa.
[3]Water Research Commission, Private Bag X03, Gezina 0031, South Africa.
[4]CSIR-Environmentek, P.O. Box 320, Stellenbosch 7999, South Africa.

Abstract

Despite recent reforms in its water sector policies and legislation, South Africa's water governance system remains somewhat fragmented because of the need for separate management approaches to address different environmental components of the hydrological cycle. With the responsibility for different components of the hydrological cycle spread amongst several government agencies at different levels of government, integrated management of water across the hydrological cycle will require improved co-operative governance. Examination of existing governance systems and current understandings of biodiversity provides evidence to suggest that a far closer alignment between a particular governance system and the biophysical components and ecological processes comprising a specific environmental system that supports society could significantly enhance our systems of environmental governance. In turn, this would offer society the chance to design water resource management systems that better anticipate, reflect and respond to changes in environmental components and processes within the hydrological cycle. In future, greater emphasis will need to be placed on increased levels of co-operation between relevant governance systems related to water, as well as increased trans-disciplinary research that can better define the links between environmental governance systems and ecological systems.

Keywords: biodiversity; governance; ecosystem; integrated water resource management (IWRM); hydrological cycle; policy.

Introduction

The priorities and approaches to management of water resources in South Africa have undergone significant changes in recent years. Prior to 1994, water resource management focused on the development of water resources (i.e. dam construction, inter-basin transfers and irrigation schemes) and primarily supported the provision and allocation of water for development in the agricultural, urban and mining sectors (MacKay, 2003). After the first democratic elections in 1994, social equity emerged as a key political priority. In terms of water resource management, this took the form of the challenge to provide basic water and sanitation to the majority of South Africa's population, and to ensure equitable access to water for all people (De Coning and Sherwill, 2004). These political changes informed the process of reform of the policy on water resources and water services, culminating in the promulgation of the Water

Services Act (WSA: Republic of South Africa, 1997) and the National Water Act (NWA: Republic of South Africa, 1998).

The NWA recognises that water resources occur in different forms that reflect the different components of the hydrological cycle (aquatic, terrestrial, subterranean, atmospheric and marine), and that integrated management of all these components and aspects of water resources is necessary in order to achieve sustainable use of water for the benefit of all its users (Republic of South Africa, 1998). In order to fulfil this requirement, a shift in thinking is necessary, from a point where water is seen simply as a commodity to one where water resources are recognized as integral parts of a larger ecosystem. This ecosystem approach requires an understanding of the relationships between the various components of the hydrological cycle and the linkages and inter-relationships between these components. The dynamics of these complex inter-relationships and feedback loops are regulated by ecosystem processes. These ecological processes are important, from a human-needs perspective, for the goods and services they provide. Recognition of the central role that biodiversity plays in maintaining ecological processes and hence in ensuring the maintenance of the flows of ecosystem goods and services on a sustainable basis, is critical to successful water resource management (MacKay et al., 2004).

In addition to understanding biodiversity concepts as they relate to water resource management, it is important to understand the dynamics of the governance systems that are in place, which determine how water resources are managed and how water policies are implemented. Prior to 1994, most water management decisions in South Africa were undertaken by the national government via a centralised, bureaucratic system. This system was virtually inaccessible to the general public and did not allow public participation in decision-making processes (MacKay, 2003). The Constitution of South Africa (Republic of South Africa, 1996) introduced a new approach to public policy and hence to water management decision-making. Two central tenets of the constitution are that people should participate in decision-making processes that affect them, and that national government mandates are most effectively carried out by the lowest appropriate levels of government (Republic of South Africa, 1996). These principles of inclusion and subsidiarity support the generic principles of good governance: openness, participation, accountability, effectiveness, coherence, democracy, and integrity (adapted from European Union, 2001).

However, the current water governance system in South Africa is still fragmented and has deep vertical boundaries between the sectors that interact with and/or govern the various components of the hydrological cycle, as well as between scientific organisations working on different components of the hydrological cycle (MacKay and Ashton, 2004). Public sector water management agencies generally do not function in a way that can take into account a highly variable resource base such as water.

Recent years have seen growing international acceptance of a philosophy which recognises that the separation between the ecological system and the governance system is artificial, and that humans should be considered as an integral and interdependent part of the global ecological system (e.g. Western, 1997; Lochner et al., 2003; Young, 2002). From a water resource management perspective, this philosophy offers an intriguing opportunity to enhance our collective understanding of integrated water resource management in South Africa.

In this paper, we explore the potential implications of adopting such an "interdependence" philosophy as a basis for sustainable water resource management in South Africa. First, we consider the concepts of biodiversity and how these relate to ecosystem processes within the hydrological cycle. This is followed by an examination of the concepts and definition of good governance in the context of water resource management. Lastly, we discuss how our understanding of governance and of biodiversity concepts might be better aligned to ensure that water resource management approaches meet the needs of society in South Africa.

Biodiversity concepts

Introduction

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 (Tilman, 2000). The need to maintain the flows of water-related 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 (Ashton, 2004). However, the wide array of intricate linkages and inter-relationships between hydrological cycle components, and the implications of external pressures on hydrological cycle components, are seldom fully understood, further complicating the task of water resource management.

What is biodiversity?

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 (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. Biodiversity is thus an integrating 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 and Hector, 2000).

The various components, processes and linkages through which the multiple roles of biodiversity are influenced and expressed, are shown schematically in Fig. 1. This diagram demonstrates the importance of biodiversity as a determinant or regulator of biotic and abiotic process controls, in addition to energy and material fluxes, through the expression of species traits and species interactions, as well as their vulnerability to human activities (Chapin et al., 2000; Purvis and Hector, 2000; Tilman, 2000).

Figure 1 shows that human activities, motivated by a diverse array of goals and benefits (1), cause a wide range of ecological and environmental changes of global significance (2). These changes occur either directly (3A), or through the regulation of species interactions (3B). Global changes in biogeochemical cycles, land-use patterns and species invasion processes exert a direct influence on biodiversity (4) as well as indirect effects through changes in abiotic processes and ecosystem controls (5). Changes in biodiversity feed back into species invasion processes and the susceptibility of ecosystems to species invasions (6), have a direct effect on species traits (7) and regulate species interactions (8), and contribute directly to ecosystem goods and services (9). In turn, species interactions exert direct effects on species abundance (11), which then influence species traits (12) and feed back into species interactions (13) which may then give rise to a cascade of further effects on species interactions. Species traits have a direct influence on ecosystem goods and services (14), as well as indirect effects, via ecosystem processes (15) or through their influence on direct biotic processes (16A and 16B). In addition, species traits also influence abiotic processes and ecosystem controls (17), which then affect ecosystem processes (18) and ecosystem goods and services (19). Finally, ecosystem processes also feed back into biodiversity (20) to exert an array of additional influences and effects.

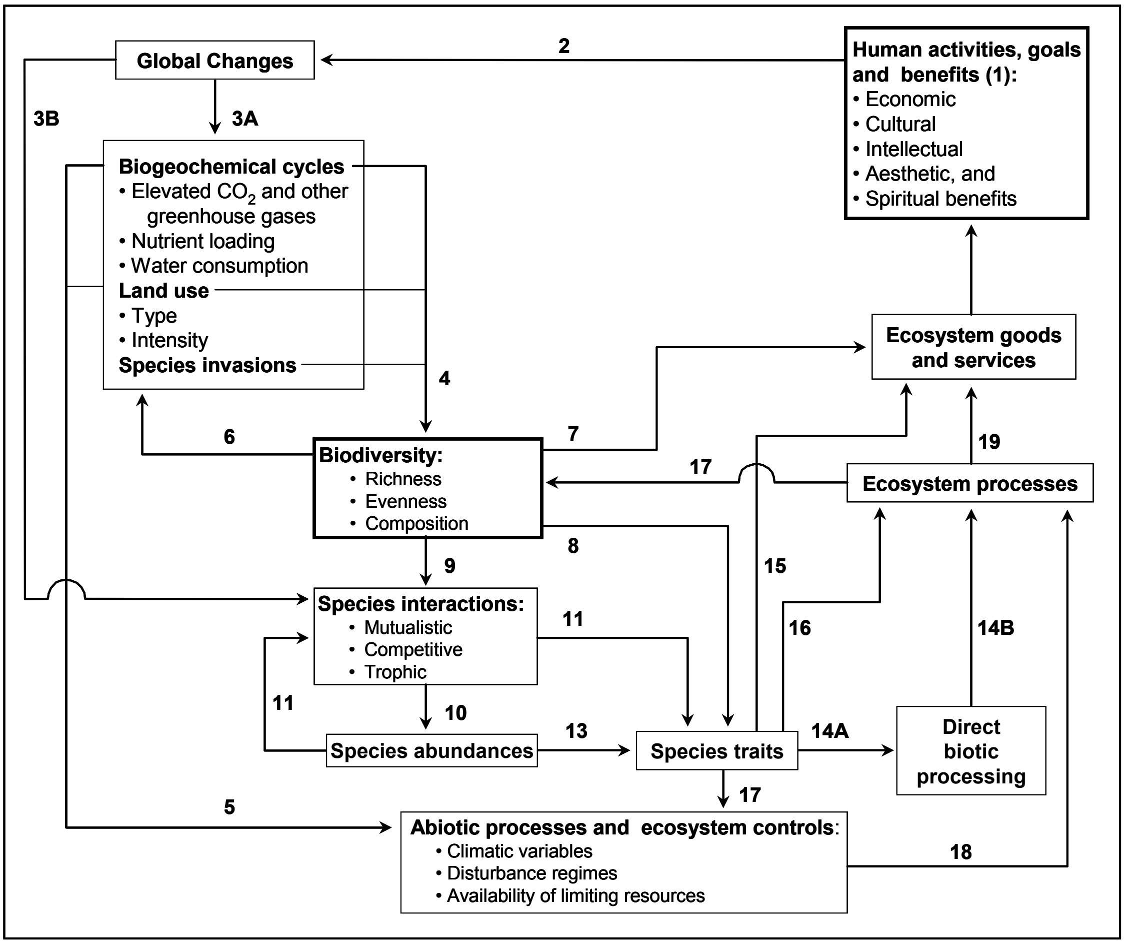

Figure 1: The role of biodiversity in expressing the influences and effects of global change, as well as the mechanisms whereby species traits and their interactions affect ecosystem processes and the delivery of ecosystem goods, services and benefits to society. Descriptive details of each interaction are outlined in the text (Diagram redrawn from a combination and rearrangement of Figs. 1, 4 and 5 in Chapin et al., 2000).

Biodiversity concepts and the hydrological cycle in South Africa

The above 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, and thence to water resource management. The linkages and inter-relationships between aquatic ecosystems and the broader environment can be explored via the hydrological cycle (Fig. 2). The hydrological cycle links all the components of the broader environment (atmospheric, marine, aquatic, terrestrial and subterranean), and this means that water resources are linked, via the water itself, to all the other components of the broader environment.

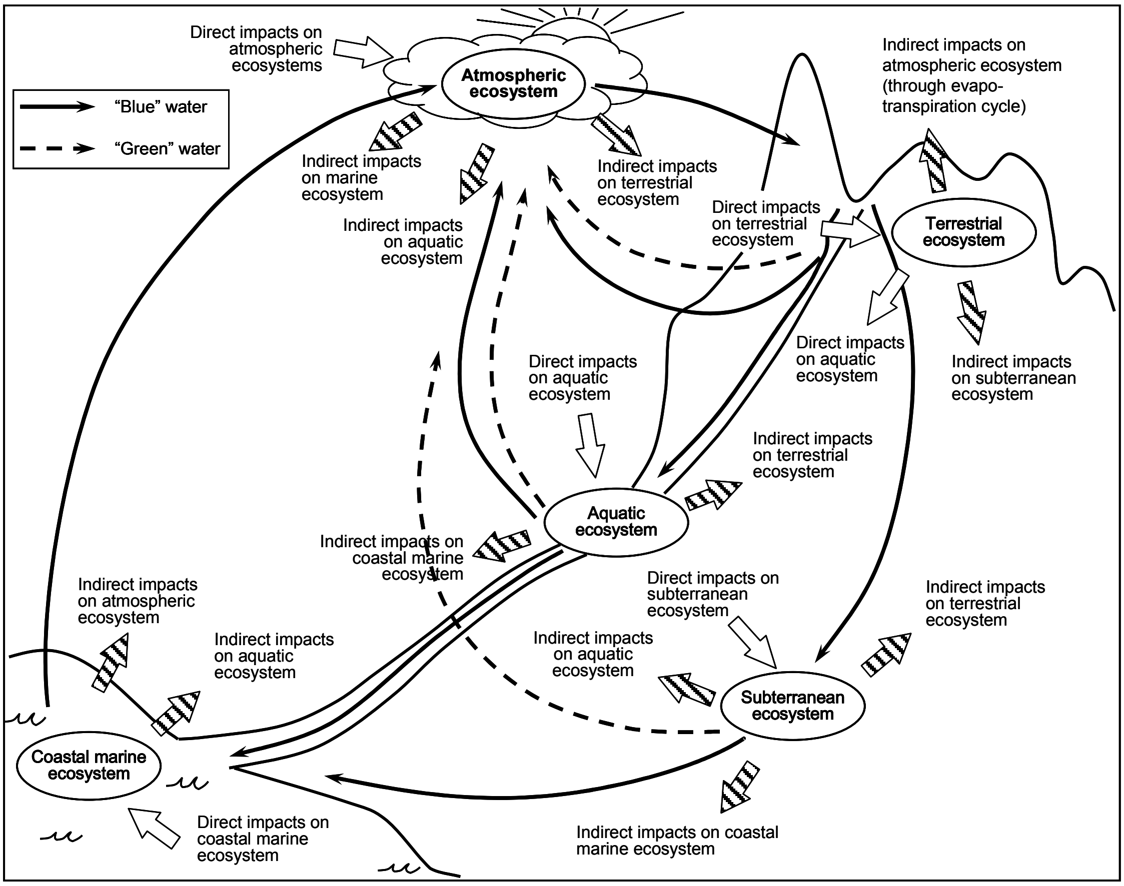

Figure 2: Phases of the hydrological cycle (redrawn from MacKay et al., 2004).

Water appears in various forms as a component of all aspects of the environment, reflecting the different phases of the hydrological cycle (Fig. 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 is held in vegetation and/or the unsaturated zone of the soil horizon and becomes part of the evapo-transpiration cycle – the term "green water" has been coined to describe water in this context (Falkenmark, 1999)
- Water in aquatic, marine and subterranean ecosystems appears in its liquid form, where it is usually termed "blue water" (Falkenmark, 1999) – this includes water held in aquifers, or in the saturated zone of the soil horizon. In the context of this 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 purpose of this 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.

A disturbance or perturbation in, for example, the atmospheric 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. 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 components can affect water, while direct impacts on water (such as water abstraction or effluent discharge) can affect the broader environment as well.

Governance concepts

Introduction

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 an associated governance system has evolved. An effective and "good" governance system is vital to the successful management of water resources, since it can determine and moderate society's response to legislation and policy, and minimise or mitigate the impacts of society on water resources, based on people's inclusion in decision-making processes and understanding of the limits of the ecological systems on which they depend.

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
- Community or civil society organisations (including the private and commercial sectors)

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

There are several levels of governance (MacKay et al., 2004):

- 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 (e.g. international agreements), national (e.g. the Constitution), or sectoral (e.g. the Water Law Principles).

- Policy at the national level is a statement of intent by government, defining what will be done in order to ensure compliance with the principles (Cloete and 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, where the three dimensions are the:

- Level of governance (from principles through to practice)

Geographic scale of applicability (global, regional, transboundary river basin, national, water management area, provincial, local and neighbourhood levels)
Responsible agent (government, non-government organisations or civil society groups/individuals)

Good governance
Given this complex, multi-layered "net" of governance, it is recognised that in order for the functioning of a governance system to be effective, efficient and socially relevant, it should be directed by the principles of ***good*** governance. Good governance is founded on the attitudes, ethics, practices and values of society. An example of "good governance" principles is provided in Box 1. It is important to note that the effectiveness of a governance system does not relate in proportion or degree to the inclusion of one or more of the individual principles themselves; rather it is the integration and inclusion of all these principles that underpins the definition of good governance.

Governance systems and the hydrological cycle in South Africa
In terms of water resource management, and more specifically legislation and regulations 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 in the environment. In part, this reflects the realities of the biophysical

environment, where different management approaches are needed for different environmental components of the hydrological cycle. However, importantly, it also reflects the administrative and functional divisions between different sectors. When a number of government agencies have regulatory responsibilities for different components of the environment, and hence for different aspects of the hydrological cycle, problems tend to occur as gaps are left or inconsistencies arise in the overall management and regulatory framework (MacKay and Ashton, 2004).

Box 1: **Principles of good governance** (adapted from European Union, 2001).

Openness: Governance institutions should work in an open manner. They should actively communicate about what they do and the decisions that are taken. They should use language that is accessible and understandable for the general public.

Participation: The quality, relevance and effectiveness of policies, legislation, regulation and practice, depend on ensuring wide participation throughout the policy chain – from conception to implementation. Improved participation is likely to create more confidence in the end result and in the institutions which deliver and implement policies.

Accountability: Roles in the legislative and executive processes need to be clear. Each institution must define and take responsibility for what it does. There is also a need for greater clarity and responsibility from all those involved in developing and implementing policy at whatever level.

Effectiveness: Policies must be effective and timely, delivering what is needed on the basis of clear objectives, an evaluation of future impact and, where available, of past experience. Effectiveness also depends on implementing policies in a proportionate manner and on taking decisions at the most appropriate level.

Coherence: Policies and actions must be coherent and easily understood. Coherence requires political leadership and a strong responsibility on the part of the institutions to ensure a consistent approach within a complex system.

Democratic: Democratic values in respect of the sharing of power, representation and participation are essential.

Integrity: Leadership that is honest, faithful and diligent, and that protects human rights and freedoms, is critical.

In South Africa, there are some critical gaps in the governance "net" as far as the whole hydrological cycle is concerned. The principal piece of water resources legislation, the National Water Act (Republic of South Africa, 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 (see Fig. 2), 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" is addressed indirectly, and then probably not adequately, by legislation and regulation in the environment, agricultural and land-use planning sectors.

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 resource management*** on a catchment basis", which is not as encompassing as "integrated catchment management". In terms of the South African Constitution, control of land-based activities falls within the responsibilities of several other government departments. In this regard, 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, but not necessarily at their origin.

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 NO_x and SO_x 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 its own sectoral legislation. However, an intervention in another component of the environment, other than water, will only be effective in terms of the water resource 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 Southern African countries, notably Malawi, South Africa and Zambia, have addressed the need for removal of sectoral boundaries by reforming their respective water sector legislation to promote or allow for an explicit ecosystem approach to management of water resources (SADC, 1998). Elsewhere in the Southern African Development Community (SADC) region, other countries are working to align their policy frameworks more closely with the environmental sustainability principles advocated by the regional Water Sector Co-ordinating Unit (SADC, 1998; Hirji et al., 2002; Acreman, 2004; Ashton, 2004). However, despite these welcome policy and legislative reforms, SADC countries still retain much of their original segmented focus on different sources or forms of water and the different sectors of water use (Ashton, 2004). Even South Africa's progressive National Water Act does not address water in all its forms in all phases of the hydrological cycle. Unless this is eventually achieved, either by improved inter-sectoral co-operation or by sectoral reform, then the full protection of water resources, as well as full protection of the environment (since the connections between water and non-water components of the environment are bi-directional), might not be feasible.

In South Africa, the governance of water in the hydrological cycle as a whole will remain distributed amongst several government agencies in different spheres of government, as well as new institutions such as catchment management agencies (CMAs) (MacKay and Ashton, 2004). Integrated management of water across the hydrological cycle will therefore need to be effected through improved co-operative governance, including the government, non-government and civil society sectors. To ensure that this approach is effective, there is a need to review the current governance "net", and where necessary, to fill critical gaps with appropriate interventions, at the appropriate levels.

Aligning the governance system with the ecological (biodiversity) system

There is a rapidly growing body of evidence that human domination of Earth's ecosystems has dramatically transformed large areas of the globe, causing a striking reduction in global biodiversity, and has reduced the capacity of ecosystems to provide society with a sustainable supply of essential goods and services (e.g. Vitousek et al., 1997; Tilman, 2000).

This awareness of the implications of biodiversity loss has also been accompanied by increased acceptance of the philosophy that humans are an integral part of the global ecosystem, since this approach better reflects the realities of human dependence on and interdependence with ecological processes (e.g. World Commission on Environment and Development, 1987; Western, 1997; Tilman, 2000). However, for a variety of reasons, these wider philosophical developments are not always fully accepted and many government and legal institutions, at national as well as international level, still adhere to the view that while "society" is dependent upon "the environment", these should be seen as discrete entities and dealt with separately (Hirji et al., 2002; Acreman, 2004). Clearly, this view makes it extremely difficult for water resource management agencies to mainstream the philosophy of integrated water resource management, which requires full integration of all governance and water resource components in order to be successful.

Conceptually, the governance system can be superimposed onto the ecological system: this highlights the linkages between these systems and the economic system (Fig. 3), although still reflecting the perceived separation of humans and ecosystems. The role of biodiversity in these linkages is not well understood, though we believe it to occur through the effects of changes in biodiversity on the flows of those goods and services that are valuable to society, and hence through its subsequent influence on social and political interactions around resources, such as conflict or co-operation. 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 and their sequence or timing are seldom fully predictable or appreciated. In this example, an improved understanding of the governance linkages and their implications should inform the choice between possible tradeoffs that society could make between the short- and long-term implications of biodiversity (ecosystem service) loss and economic or social gain.

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. Importantly, where the available information is considered to be insufficient for a high degree of confidence in the outcome of a particular decision, then a precautionary approach is advised.

Many scholars argue that customary legal and regulatory systems related to the use of natural resources are often closely aligned with local biophysical patterns and processes, and are thus inherently capable of adapting to changes in resource availability (Ashton, 2004). However, since such systems tend to be highly localised and context-specific, it is often difficult, both technically and politically, to expand or upscale them to catchment, regional or even national levels (Van Koppen et al., 2005; Chikozho and Latham, 2005). Nevertheless, there is much to be learned from studies of both customary and conventional or state-centred approaches to natural resource management. The challenge will be to integrate the strengths of both types of approaches into a governance system for water resources, as ecosystems, that is practical, robust and administratively workable.

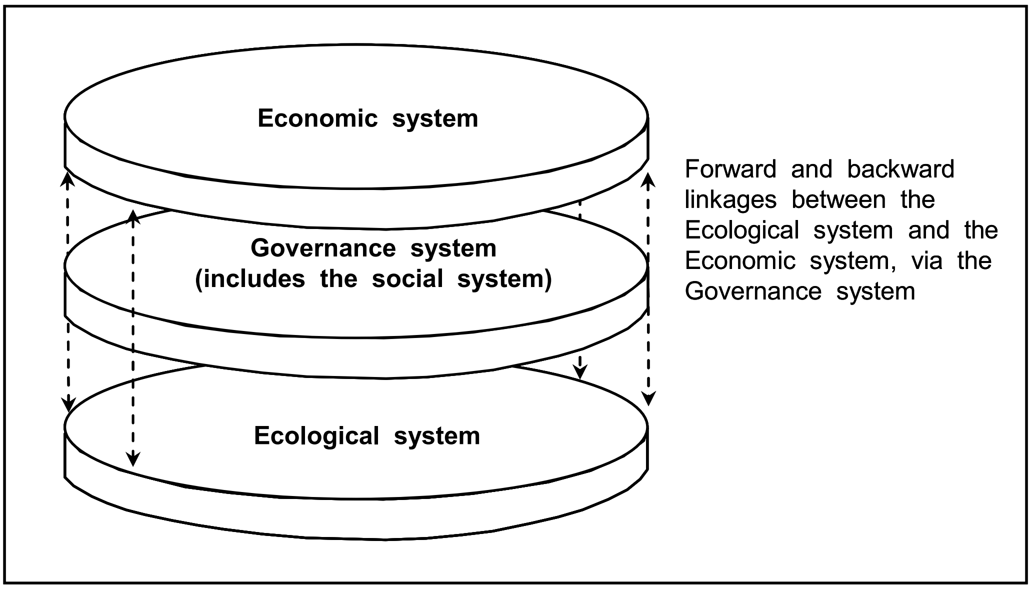

Figure 3: Conceptual diagram, showing the forward and backward linkages between a governance system and the ecological system, where the ecological system is represented by the hydrological cycle (as described in Fig.2).

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, both within and between compartments of the 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
- Encourages management interventions that sustain the long-term health of ecological systems, so that these systems can continue to provide the necessary water-related goods and services to society

Earlier in this paper it was proposed that 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, influence and impact on society's decisions and actions. Historically, ecological research has been narrowly focused on separate environmental components within the hydrological cycle, rather than the processes and relationships between them. Thus, these relationships within the hydrological cycle, as well as their role in maintaining flows of water-related goods and services to society, and their vulnerability to change in the broader environment, should be explored in future. Similarly, research on natural resource governance issues has often focused more on social, political and institutional processes within the governance system itself and, until recently, little attention has been paid to the links between associated governance systems and ecological systems (Holling, 2001; Gunderson and Holling, 2002; Folke, 2003; Pollard et al., 2003; Walker et al., 2004).

Internationally, good governance is based on principles such as openness, participation, accountability, coherence, democracy, integrity and effectiveness, as well as social equity and justice (European Union, 2001). In addition, good environmental governance should reflect our best understanding of the structure, functions, processes and variability that typify natural systems (Acreman, 2004). Although there has been considerable development within the field of public and corporate governance, little attention has been paid to the development of good environmental governance systems (Young, 2002). Thus, far greater emphasis needs to be placed on water-related governance within society, and on the design of systems that better anticipate, reflect and respond to changes in environmental components and processes within the hydrological cycle.

Conclusions

In order to strengthen the capacity to develop and apply ecosystem approaches to water resource management, and to establish and develop governance systems that are both relevant and well-matched to water resources as ecosystems, the following parallel approaches are considered to be necessary:

- 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. Interactions between these groups to enhance and promote understanding of the role of governance, in support of good environmental governance practices.

Although these interventions or approaches are characterized by a need for integrated research at a high / meta-data analysis level, it is recognized that such research is only possible on the assumption that a sound foundation (of appropriate basic research and data) is in place. This foundation needs to encompass biophysical, ecological, social, political and institutional aspects of the linked ecological-governance-economic systems (Holling, 2001; Young, 2002).

Certainly in South Africa, the foundation of basic research knowledge on aquatic ecosystems was laid during the 1970s and 1980s, when large national research programmes were in place that focused on whole-system studies, for example work done on the nutrient dynamics of Hartbeespoort Dam (NIWR, 1988). Since then, research has gradually evolved to become more multidisciplinary, where specialists from different disciplines work together on various components of the hydrological cycle, and equally on components of the governance and economic systems. However, to provide knowledge and understanding of the links between ecosystems and governance systems will require truly trans-disciplinary research, involving multiple disciplines (as opposed to specialists from different disciplines working side by side but still relatively independently of each other), and the blending of rigorous quantitative and qualitative investigatory approaches.

From a purely practical perspective, it is challenging to design and execute joint research programmes such as those outlined above. However, these potential problems are far outweighed by the likely benefits that could be gained from the new levels of insight that would underpin fresh and improved approaches and options for governance of water resources. Ultimately, good governance systems need to be aligned closely with each of the water resources that are to be managed. Ideally, this 'net' of good governance should form the core of a water resource management system so that the ideals embodied in the philosophy of integrated water resource management (IWRM) can be attained while meeting the water needs of society.

REFERENCES

ACREMAN M (2004) Water and ecology. In: J Dooge and J Selborne (eds.) *Water and Ethics*. United Nations Educational, Scientific and Cultural Organization (UNESCO), Paris. 35 pp.

ASHTON PJ (2004) Water and development: A southern African perspective. In: J Trottier and P Slack (eds.) *Managing Water Resources Past and Present – The 2002 Linacre Lectures*. Oxford University Press, Oxford. 149-174.

CHAPIN III FS, ZAVELETA ES, EVINERS VT, NAYLOR RL, VITOUSEK PM, REYNOLDS HL, HOOPER DU, LAVOREL S, SALA OE, HOBBIE SE, MACK MC and DIAZ S (2000) Consequences of changing biodiversity. *Nature Insight* 405 *(No. 6783, 11 May)* 234-242.

CLOETE F and WISSINK H (eds.) (2000) *Improving Public Policy*. Van Schaik, Pretoria. 316 pp.

CHIKOZHO C and LATHAM J (2005) Shona customary practices in the context of water sector reforms in Zimbabwe. Proceedings of the International Workshop on *African Water Laws: Plural Legislative Frameworks for Rural Water Management in Africa*. Johannesburg, 26-28 January 2005. Available (online) at website: www.nri.org/waterlaw/workshop. [Accessed May 2005].

DE CONING C and SHERWILL T (2004) An Assessment of the Water Policy Process in South Africa 1994-2003. Water Research Commission Report No. TT232/04. Water Research Commission, Pretoria. 57 pp.

EUROPEAN UNION (2001) *European Governance: A White Paper*. Commission of the European Communities, Brussels. Available (online) at website: http://europa.eu.int/comm/governance/white_paper/index_en.htm [Accessed May 2003].

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

FOLKE C (2003) Freshwater for resilience: a shift in thinking. *Phil. Trans. R. Soc. Lond.* 358 2027 – 2036.

FRANKLIN JF (1988) Structural and functional diversity in temperate forests. In: E.O. Wilson, (ed.) *Biodiversity*. National Academy Press, Washington DC. 166-175.

GUNDERSON LH and HOLLING CS (eds.) (2002) *Panarchy: Understanding Transformations in Human and Natural Systems*. Island Press, Washington. 507 pp.

HIRJI R, JOHNSON P, MARO P and CHIUTA TM (eds.) (2002) *Defining and Mainstreaming Environmental Sustainability in Water Resources Management in Southern Africa*. SADC, IUCN, SARDC, World Bank: Maseru, Harare, Washington DC. 318 pp.

HOLLING CS (2001) Understanding the complexity of economic, ecological and social systems. *Ecosyst.* 4 390 – 405.

LOCHNER P, WEAVER AvB, GELDERBLOM C, PEART R, SANDWOTH T and FOWKES S (2003) Aligning the diverse: the development of a biodiversity conservation strategy for the Cape Floristic Region. *Biol. Cons.* 112 29-43.

MACKAY HM (2003) Water policies and practices. In: D Reed and M de Wit (eds.) *Towards a Just South Africa: The Political Economy of Natural Resource Wealth*. WWF Macroeconomics Programme, Washington. 49-83.

MACKAY HM and ASHTON PJ (2004) A model for co-operative governance in the implementation of cross-sectoral policy: water policy as an example. *Water SA* 30(1) 1-8.

MacKAY HM, ASHTON PJ, NEAL MJ and WEAVER AvB (2004) Investment Strategy for the Crosscutting Domain: Water and the Environment. Water Research Commission Report No. KV148/04. Water Research Commission, Pretoria. 11 pages + appendices.

McCANN KS (2000) The diversity-stability debate. *Nature Insight* 405 *(No. 6783, 11 May)*: 228-233.

NATIONAL INSTITUTE FOR WATER RESEARCH (NIWR) (1988) Limnology of Hartbeespoort Dam. South African National Scientific Research Programmes Report No. 110, Foundation for Research Development, Pretoria. 175 pp.

NOSS RF (1990) Indicators for monitoring biodiversity. *Cons. Biol.* 4 355-364.

POLLARD S, SHACKLETON C and CARRUTHERS J (2003) Beyond the fence: people and the lowveld landscape. In: JT du Toit, KH Rogers and HC Biggs (eds.) *The Kruger Experience*. Island Press. Washington D.C. 519 pp.

PURVIS A and HECTOR A (2000) Getting the measure of biodiversity. *Nature Insight* 405 *(No. 6783, 11 May)*: 212-219.

REPUBLIC OF SOUTH AFRICA (1996) *The Constitution of the Republic of South Africa (Act No. 108 of 1996).* Government of the Republic of South Africa, Pretoria.

REPUBLIC OF SOUTH AFRICA (1997) *Water Services Act (Act No. 108 of 1997).* Department of Water Affairs and Forestry, Pretoria.

REPUBLIC OF SOUTH AFRICA (1998) *National Water Act (Act No. 36 of 1998).* Department of Water Affairs and Forestry, Pretoria.

SOUTHERN AFRICAN DEVELOPMENT COMMUNITY (SADC) (1998) Regional Strategic Action Plan (RSAP) for Integrated Water Resources Development and Management in the SADC Countries (1999-2004). Summary Report. SADC Water Sector Co-ordinating Unit, Maseru, Lesotho.

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

VAN KOPPEN B, BUTTERWORTH J, JUMA I, MAGANGA F, LATHAM J, CHIKOZHO C and MORRIS M (2005) Legal pluralism and rural water management: objectives, definitions and issues. *Proc. Int. Workshop on African Water Laws: Plural Legislative Frameworks for Rural Water Management in Africa*. Johannesburg, 26028 January 2005. Available (online) at website: www.nri.org/waterlaw/workshop. [Accessed May 2005].

VITOUSEK PM, MOONEY HA, LUBCHENCO J and MELILLO JM (1997) Human domination of earth's ecosystems. *Sci., 277* 494-199.

WALKER B, HOLLING CS, CARPENTER SR and KINZIG A (2004) Resilience, adaptability and transformability in social-ecological systems. *Ecology and Society* 9(2) 5. Available (online) at website: http://www.ecologyandsociety.org/vol19/iss2/art5. [Accessed October 2004].

WESTERN D (1997) *In the Dust of Kilimanjaro*. Island Press, Washington D.C. 297 pp.

WILSON EO (1988) The current state of biodiversity. In: E.O. Wilson (ed.) *Biodiversity*. National Academy Press, Washington D.C. 3-18.

WORLD COMMISSION ON ENVIRONMENT AND DEVELOPMENT (WCED) (1987) *Our Common Future*. Oxford University Press, New York.

YOUNG OR (2002) *Matching Institutions and Ecosystems: The Problem of Fit.* Institute on International Environmental Governance, Dartmouth College, USA. 31 pp.

Suggested citation:

Ashton PJ, Patrick MJ, MacKay HM and Weaver AvB (2005). Integrating biodiversity concepts with good governance to support water resources management in South Africa. *Water SA*, 31(4): 449-456.