DEVELOPMENT OF SUSTAINABILITY INDICATORS FOR CATCHMENT MANAGEMENT INFORMATION SYSTEMS

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ACRONYMS

ANC	African National Congress
ANZECC	Australia and New Zealand Environment and Conservation Council
BOD	Biological oxygen demand
BSP	Basin Sustainability Programme of the Murray-Darlin Basin Commission
CARA	Conservation of Agricultural Resources Act
COD	Chemical oxygen demand
CMA	Catchment management agency
DEAT	Department of Environmental Affairs and Tourism
DPSIR	Driving forces-Pressure-State-Impact-Response
DWA	Department of Water Affairs
DWAF	Department of Water Affairs and Forestry
EEA	European Environment Agency
EIMP	Environmental implementation and management plan
EPA	United Stated Environmental Protection Agency
FAO	Food and Agriculture Organisation
GDP	Gross domestic product
GGP	Gross geographic product
HIV/AIDS	Human Immune Virus/Acquired Immune Deficiency Syndrome
IBT	Inter-basin transfer
ICM	Integrated catchment management
IISD	International Institute for Sustainable Development
INR	Institute of Natural Resources
IP&WM	Integrated pollution and waste management
IUCN	International Union for the Conservation of Nature
IWQS	Institute for Water Quality Studies
IWRM	Integrated water resources management
LGBM	UK Local Government Management Board
MAIS	Monitoring, assessment and information system.
MAR	Mean annual runoff
MDBC	Murray-Darling Basin Commission
NEMA	National Environmental Management Act
NGO	Non-governmental organisation
OECD	Organisation for Economic Co-operation and Development

POP	Persistent organic pollutant
PPP	Purchasing price parity
PSR	Pressure-State-Response
RDM	Resource Directed Measures
RQO	Resource quality objective
SADC/HYCOS	Southern African Development Community Hydrological Cycle Observing System
TDS	Total dissolved solids
TVA	Tennessee Valley Authority
UN	United Nations
UNCED	United Nations Conference on Environment and Development
UNCSD	United Nations Commission for Sustainable Development
UNEP	United Nations Environment Programme
UNICEF	United Nations Children's Fund
WC/WDM	Water conservation and water demand management
WCED	World Commission on Environment and Development
WHO	World Health Organisation
WRC	Water Research Commission
WRI	Water Resources Institute
WSSD	World Summit on Sustainable Development
WUA	Water user association
WWF	World Wildlife Fund for Nature

PART I
BACKGROUND AND METHODOLOGY

CHAPTER 1: INTRODUCTION

1.1 BACKGROUND

The last century has seen a continuous deterioration of the bio-physical environment on a global scale, to the extent that future human survival is becoming threatened. Human populations have expanded dramatically, and development activities, intended to improve the quality of life, have exacted a high cost from the environment (Walmsley & Pretorius 1996). Consumption of the world's resources has increased considerably, with people today using approximately 12 000 times as much energy as they did 400 generations ago. In general, development activities have made use of the Earth's natural resources without adequate replenishment or cognisance of their capacity to absorb waste (Harrison 1992; Walmsley & Pretorius 1996).

There is an acknowledged need for countries to find a balance between the economic and social demands on the world's ecosystems and the need to conserve the natural resources on which the economic and social systems depend. This balance has been termed sustainable development, and is defined as "*development that meets the needs of the present without compromising the ability of future generations to meet their own needs*" (WCED 1987). *Sustainable development* refers to development that aims for equity within and between generations, and adopts an approach where the economic, social and environmental aspects of development are considered in a holistic fashion. The world's commitment to sustainable development has recently been confirmed through the recent Johannesburg Declaration on Sustainable Development (http://www.earthsummit2002.org 2002).

One of the major resources under threat globally is freshwater. The availability of water is the key to economic growth and social well-being in many countries of the world and is often over-utilised. In particular, water is recognised as a key constraint for the social and economic development in Africa, where at least 52% of the continent is arid (WISA 2001). According to WHO & UNICEF (2000) about two-thirds (273,5 million) of Sub-Saharan Africa's rural population and one-quarter (45,6 million) of the urban population are without safe drinking water. Currently, only 60% of the total population in Africa has sanitation coverage, with coverage varying from 84% in urban areas to 45% in rural areas.

To achieve sustainable development, the Earth's water resources need to be managed sustainably, in a fashion that guarantees their continued functioning. Ongoing efforts in international water policy demonstrate increasing concern for comprehensive water management including ecological, economic and social aspects. As early as 1992, Agenda 21, the international blueprint for sustainable development, defined objectives for protecting water resources, water quality and aquatic ecosystems, and advocated the sustainable management of water resources (Agenda 21, Chapter 18). Since then the protection and development of freshwater resources has attracted increasing attention and several international conferences have been convened. In 1997, the Special Session of the UN General Assembly called for a *Programme for the Further Implementation of the Agenda 21*, and decided that the Commission on Sustainable Development 6 (CSD-6) working programme for 1998 to 2002 would be to develop strategic approaches to freshwater management (http://www.un.org/esa/sustdev 2002). In early 2001, the *Second World Water Forum* in The Hague developed a *World Water Vision* and a *Framework for Action* for overcoming the threatening water crisis (http://www.earthsummit2002.org/roadmap 2002). In the same year, the *International Conference on Freshwater 2001* was held in Bonn, Germany, in preparation for the *World Summit on Sustainable Development 2002* in Johannesburg.

Many of the approaches to sustainable water resources management discussed at these world fora rely on the availability of good quality information. Although sustainability is accepted as a vision for managing water resources in an integrated manner, experts are still struggling with the practical problem of how to measure it. More often than not, they are faced with an information dilemma. On the one hand, information and information sources are proliferating. On the other hand, they seldom seem to have the specific information required for good decision-making and effective resource management (Walmsley & Pretorius 1996). One method of overcoming this dilemma is through the use of sustainability indicators. Indicators provide a means of communicating information about progress towards a goal (such as sustainable water management) in a significant and simplified manner (Hammond *et al.* 1995).

1.2 THE SOUTH AFRICAN SITUATION

South Africa faces most of the challenges mentioned above. In particular:

- South Africa is an arid country with limited freshwater resources;
- Many South Africans do not have access to water for basic needs (i.e. sanitation, drinking);
- Many of the country's freshwater ecosystems are stressed (Davies & Day 1998), and
- Future economic growth is reliant on the availability of adequate water (Basson *et al.* 1996).

In 1998 the South African government introduced the National Water Act (No. 36 of 1998), which dictates the water resource policy and practice under the jurisdiction of the Department of Water Affairs and Forestry (DWAF). A core feature of this Act is the introduction of catchment management agencies that will be responsible for integrated water resource management of catchments within specific water management areas. The Act declares that catchment management strategies are to be developed for each catchment in South Africa to ensure that the water resources are utilised in a sustainable manner. Of significance is the fact that Chapter 14 of the Act requires that DWAF establish a national monitoring and information system for water resources as soon as possible, with the objectives of (Section 140):

- Storing and providing data and information for the protection, sustainable use and management of water resources;
- Providing provide information for the development and implementation of the National Water Resource Strategy;
- Providing information to water management institutions, water users and the public for research and development; for *planning and environment impact assessments, and for public safety and disaster management.*

The monitoring and information system should provide for the collection of appropriate data to assess the quantity, quality, use and rehabilitation of water resources at catchment and national levels, as well as compliance with resource quality objectives, health of aquatic ecosystems and atmospheric conditions that may impact on water resources.

In 1999, the first National State-of-the-Environment Report for South Africa was compiled by the Department of Environmental Affairs and Tourism (DEAT1999), with a chapter of the report being devoted to the sustainability of freshwater systems and resources. *"The greatest difficulty faced in compiling the State-of-the-Environment for freshwater resources was the lack of suitable information. Originally, 45 indicators were identified as crucial to reporting on the state of the water environment at a national level in South Africa. Due to data constraints, only 30 indicators were included in the report, and often in a format different to that originally envisaged. At the time of compiling the State-of-the-Environment report, information sources were found to be fragmented and there was little evidence of a national information system being achieved in the near future"* (Walmsley *et al.* 2000).

These problems have been recognised by DWAF in the National Water Resource Strategy (DWAF 2002), which states that spatial coverage is incomplete and problems are experienced with the quality and reliability of information. The dissemination of, and access to, information is not as effective or comprehensive as it might be and access to information from other organisations is sometimes problematic. The Department is currently addressing these shortcomings by amalgamating all existing and planned monitoring and assessment systems into a coherent, structured Monitoring, Assessment and Information System (MAIS; DWAF 2002). This system includes: data acquisition; data storage, maintenance and dissemination, and data analysis, information generation and reporting. Improvements in efficiency and effectiveness are expected through sharing logistics and infrastructure in data collection and storage, by adherence to common standards and guidelines, and by refining analytical techniques to maximise the information derived from available data.

The concern with regard to the lack of adequate information is that, without that information, water resources management in South Africa is severely handicapped. Peter F Drucker, the eminent business expert, stated, "*What you measure, that you manage*" (Rainikainen 2002), and without adequate information decision-making becomes *ad hoc* and crisis management becomes common. According to the National Water Act, this implies that the information systems at catchment level should be comprehensive, easily accessible and useful to decision makers. Indicators of sustainable development are ideal tools to provide this information, and fulfil the requirements of the MAIS.

1.3 AIMS AND OBJECTIVES

The main aim of this thesis is to assess the current availability and quality of information at catchment level in South Africa using sustainability indicators.

Null Hypothesis

Adequate information is readily available at catchment level for decision-making on the sustainable management of South Africa's water resources.

The hypothesis is based on the understanding that DWAF, as prescribed by the National Water Act, is required to have information to manage the water resources of the country in a sustainable, equitable and efficient manner (DWAF 2002). This should be achieved at catchment level under the management of catchment management agencies, whose role is currently being undertaken by nine regional offices. In essence, information for sustainable water resources management at catchment level should be available from these regional offices if the mandate of the Department is to be upheld.

Several key questions will be examined in this study, including:

- What is the role of indicators of sustainable development in developing an understanding of the strategic issues in catchment management? This will require the development of an understanding of sustainable water resources management and its measurement using indicators
- What core indicators are required to provide information on sustainable water resource management at catchment level? The development of a set of sustainability indicators that

adequately describe aspects of sustainability, including social, economic and biophysical elements is crucial for the success of the study.

- Are the current systems that South Africa has in place at catchment level adequate to manage the country's water resources sustainably? This will include an assessment of the information available at catchment level to populate the indicators.

1.4 REFERENCES

BASSON MS, VAN NIEKERK PH & VAN ROOYEN JA. 1997. *Overview of Water Resources Availability and Utilisation in South Africa*. DWAF, Pretoria. Report PRSA/00/0197. 72pp.

DAVIES BR & DAY JA. 1998. *Vanishing Waters*. University of Cape Town Press, Cape Town. 487 pp.

DEPARTMENT OF ENVIRONMENTAL AFFAIRS AND TOURISM (DEAT). 1999. *State of the Environment South Africa*. DEAT, Pretoria. http://www.ngo.grida.no/soesa.

DEPARTMENT OF WATER AFFAIRS AND FORESTRY (DWAF). 2002. *Proposed First Edition National Water Resource Strategy: Summary*. DWAF, Pretoria. 37 pp. http://www.dwaf.gov.za.

HAMMOND A, ADRIAANSE A, RODENBURG E, BRYANT D and WOODWARD R. 1995. *Environmental Indicators: A Systematic Approach to Measuring and Reporting on Environmental Policy Performance in the Context of Sustainable Development*. World Resources Institute, Washington. 42 pp.

HARRISON P. 1992. *The Third Revolution*. IB Taurus/Penguin Books, London. 359 pp.

REINIKAINEN T. 2002. *Working Core Set of Indicators for Namibia*. Ministry of Environment and Tourism, Windhoek. 26 pp.

WALMSLEY JJ, WALMSLEY RD, PRETORIUS RJ & MARAIS D. 2000. *Information Management and State-of-the-Environment Reporting for Water Resources in South Africa*. Poster Presentation, WISA Conference 2001. Mzuri Consultants, Pretoria.

WALMSLEY RD & PRETORIUS JPR. 1996. *Environmental Indicators. Report No. 1. State of the Environment Series*. Department of Environmental Affairs and Tourism, Pretoria. 76pp.

WATER INSTITUTE OF SOUTH AFRICA. 2001. *Draft Position Paper by the Water Sector for South Africa: Draft 2*. WISA, Midrand. 12 pp.

WORLD COMMISSION ON ENVIRONMENT AND DEVELOPMENT (WCED). 1987. *Our Common Future*. Oxford University Press, Oxford. 430pp.

WORLD HEALTH ORGANISATION (WHO) & UNITED NATIONAL CHILDREN'S FUND (UNICEF). 2000. *Global Water Supply and Sanitation Assessment 2000 Report*. http://www.who.int.

CHAPTER 2: OVERVIEW - SUSTAINABILITY, ITS MEASUREMENT AND THE USE OF INDICATORS IN CATCHMENT INFORMATION MANAGEMENT

2.1 INTRODUCTION

Traditionally water resources management centred around the provision of water through water resources development, and the control of water quality, with little emphasis on the environment (Pigram & Hooper 1991; DWA 1986). Over the last two decades, this view has changed, to the extent that the concept of sustainability has become the cornerstone of water resources management in many countries in the world, including South Africa. With it has come the requirement of measuring and managing for sustainability.

This chapter provides the context for indicator development for sustainable catchment management in South Africa, by outlining of some of aspects that influence the management and measurement of sustainability. It is not the intention to provide a comprehensive review of all the literature, but rather to highlight and discuss some of the key principles and issues relating to sustainability, its measurement and the implications for water resources management, particularly catchment information management.

2.2 SUSTAINABLE DEVELOPMENT

2.2.1 Definition and understanding of sustainable development

Security of existence is a concern facing all living entities. In the case of humans, the issue has always been a priority, and in attempting to create security through socio-economic development there has been an escalation in environmental damage. Population growth, increased sophistication of human needs, creation of domestic infrastructure and technology have all contributed to an increase in the consumption of natural resources throughout the world. This trend has been accompanied by a general deterioration in the quality of the global environment and a loss in its long-term potential to sustain life. Despite wide recognition that these trends should not be allowed to continue, nations of the world have been unable to reverse the situation (WCED 1987; Harrison 1992). Alerting the world to the dimensions of the problem has been one of the pre-occupations of an international effort over the last 30 years. The implementation of effective programmes to reverse undesirable trends has proved largely unsuccessful, mainly because of the high inertia required to alter the social, cultural, economic and political approaches of the world's diverse societies (Harrison 1992).

In the last decade-and-a-half the concept of *sustainable development* has been promoted as the most appropriate approach to achieving long-term security for the human race. Originally introduced by the WCED (1987), and endorsed by the majority of the World's nations at the United Nations' Conference on Environment and Development in Rio de Janeiro in 1992 and recently at the Johannesburg Summit (September 2002; http://www.earthsummit2002.org 2002), there are major international programmes attempting to implement the concept. However, there is still poor understanding of its meaning, and in particular how it should be approached.

The term " sustainable development " was first defined by the WCED (1987) as "*development that meets the needs of the present without compromising the ability of future generations to meet their own needs*". This definition has generated much debate and criticism and many other interpretations have subsequently been put forward. One of the most innovative approaches was that taken by the IUCN/UNEP in collaboration with the WWF who, building on the WCED concepts, generated a document entitled *Caring for the Earth: A Strategy for Sustainable Living* (Monro & Holdgate 1991). This document provided both an analysis of the situation and a plan of action for the Earth's nations to follow. It represented a milestone in providing a better understanding of what is meant by sustainable development and how to go about achieving it. The definition that was proposed by Monro & Holdgate (1991) was "*improving the quality of life while living within the carrying capacity of supporting ecosystems*". In this definition, carrying capacity covers the issues of resource use, pollution and biodiversity while quality of life deals with meeting human needs.

The term *sustainable development* describes an intended approach to development that provides solutions to all current and future social, economic and environmental problems (e.g. poverty, disease, unemployment, violence, environmental pollution and loss of biodiversity). In essence, sustainable development refers to a kind of development that aims for equity within and between generations, and adopts an approach where the economic, social and environmental aspects of development are considered in a holistic fashion (Figure 2.1). The definition of sustainable development in South Africa's National Environmental Management Act (Act No. 107 of 1998) emphasises this requirement: *"sustainable development means the integration of social, economic and environmental factors into planning, implementation and decision-making so as to ensure that development serves present and future generations."*

In many cases the term has either been used inappropriately or misinterpreted by the audiences who have been exposed to it. Throughout the world many people are confused by the term, mainly because it represents a still as yet unknown and unproven conceptual approach. There are numerous perspectives that have to be incorporated within a general understanding of the term.

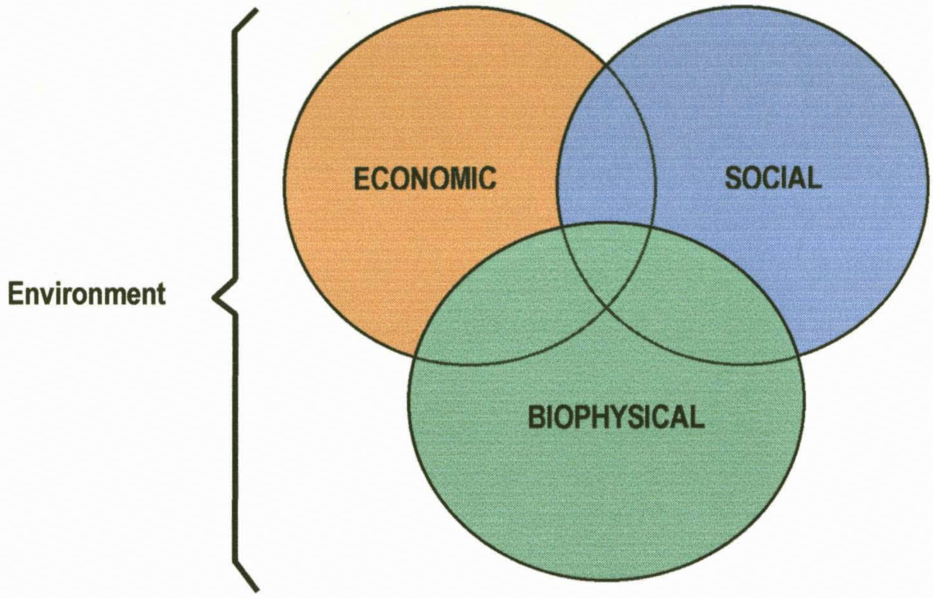


Figure 2.1: Inter-linkage between the three recognised aspects of sustainability.

An important distinction, which should be stressed, is the difference in definition between *growth* and *development*. To grow means "*to increase in size by the assimilation or accretion of materials*". To develop means "*to expand or realise the potential of; to bring to a fuller, greater, or better state*" (Walmsley *et al.* 1999). Thus, when something grows it gets physically bigger, whilst when it develops it gets qualitatively better. Sustainable development is, therefore, about the qualitative improvement of society and is not necessarily associated with physical size unless this forms part of the qualitative characteristics.

One of the major problems with understanding the concept of sustainable development is the fact that it is difficult to visualise the concept being implemented in any practical way because of the absence of real-life model situations where it has been achieved or evidence that it can be measured. The concept thus stands as an ideal situation or *state* that societies should strive for. Lankester (Director of the UN Sustainable Development Networking Programme), summarised sustainable development as *"development that does not merely generate growth, but also distributes benefits equitably; it regenerates the environment rather than destroying it: it empowers people rather than marginalising them; enlarges their choices and opportunities and it provides for people's participation in decisions affecting their lives. Sustainable development is pro-poor, pro-nature, pro-jobs, and pro-women. It stresses growth, but growth with employment, growth with environment, growth with empowerment and growth with equity"* (Walmsley *et al.* 1999).

In terms of the **biophysical** environment, sustainability involves the maintenance of the stability of ecosystems, by limiting stress on them (Sullivan *et al.* 2002). The idea of conservation is central to maintaining ecosystem stability as it means the protection of the resilience of fragile ecosystems (Sullivan *et al.* 2002). Monro & Holdgate (1991) identify three essential components to maintaining the capacity of ecosystems:

- Conserving the life-support systems that nature provides;
- Conserving the diversity of life on Earth (biodiversity), and
- Ensuring that all uses of renewable resources are sustainable.

From an **economic** perspective, sustainability can only be achieved if the use of natural resources, the natural capital, is accounted for. In many countries natural capital is depleted as financial capital increases and, while some financial capital can be converted to human gain (i.e. human, social and physical capital) it is inevitably at the expense of the environment. The idea of constant natural capital stock promotes inter-generational and intra-generational equity, and economic and ecological resilience, and it limits uncertainty (Sullivan *et al.* 2002). However, this requires that the natural capital remain constant.

Social sustainability relies on both biophysical and economic sustainability. According to the Local Government Management Board of the United Kingdom (LGMB 1995) characteristics or properties of a "sustainable local society" include:

- Resources are used efficiently and waste is minimised by closing cycles;
- Pollution is limited to levels that natural systems can cope with without damage;
- The diversity of nature is valued and protected;
- Everyone has access to good food, water, shelter, and fuel at reasonable cost;
- Everyone has the opportunity to undertake satisfying work in a diverse economy;
- The value of unpaid work is recognised, whilst payments for work are fair and fairly distributed;
- People's health is protected by creating safe, clean, pleasant environments and health services which emphasise prevention of illness as well as care for the sick;
- Access to facilities, services, goods and other people is not achieved at the expense of the environment or limited to those with motor vehicles;
- People live without fear of personal violence from crime or persecution because of their personal beliefs, race, gender or sexuality;
- Everyone has access to the skills, knowledge and information needed to enable them to play a full part in society;
- All sections of the community are empowered to participate in decision-making;

- Opportunities for culture, leisure and recreation are readily available to all, and
- Places, spaces and objects combine meaning and beauty with utility. Settlements are "human" in scale and form. Diversity and local distinctiveness are valued and protected.

The IUCN/UNEP/WWF *Strategy for Sustainable Living* (Monro & Holdgate 1991), provides principles for achieving a sustainable society, which include:

- Respecting and caring for the community of life and nature;
- Improving the quality of human life;
- Conserving the Earth's vitality and diversity;
- Minimising the depletion of non-renewable resources;
- Keeping within the Earth's carrying capacity;
- Changing personal attitudes and practices;
- Enabling communities to care for their environment;
- Providing frameworks for integrating development and conservation; and
- Creating a global alliance at all levels.

2.2.2 International response to achieving sustainable development

Following the WCED (1987) report, there has been an escalation in efforts aimed at promoting sustainable development on a global scale. This has involved numerous governmental and non-governmental agencies. The United Nations (UN) has been the main agency involved with setting and implementing the concept. The activities to implement sustainable development have included the following:

- **Recognition of the problem and commitment from nations of the world** - One of the major contributions of the UN was the successful convening of the 1992 UNCED Earth Summit in Rio de Janeiro. The Summit was attended by more than 30 000 people, including 103 heads of state and had many positive outcomes (Quarrie 1992; Wynberg 1993). The meeting succeeded in launching Agenda 21, a programme that has provided guidelines and principles for countries to follow, as well as forums to monitor and discuss progress. Numerous agreements and treaties were tabled and nations of the world were urged to accept and endorse them as an approach to achieving a sustainable world. It was understood that each country would devise its own approach to these agreements and treaties. The treaties and agreements that were tabled and generally accepted at Rio included:
    - The Rio Declaration on Environment and Development;
    - Declaration of Principles on Forests;

- ➢ The Framework Convention on Climate Change;
- ➢ The Convention on Biological Diversity; and
- ➢ Agenda 21.

Each of the above has been highly significant in terms of stimulating both international and national approaches to sustainable development. The most important document to emerge from Rio was Agenda 21, a non-binding programme for on how individual countries should achieve sustainable development. Countries have been encouraged to participate in the international forums that have been set up to deal with Agenda 21, forests, climate change and biodiversity. At the same time they have also been encouraged to initiate internal programmes that deal with each issue at a national level. Of the above agreements, it was accepted that Agenda 21 should form the basis of all national development programmes (Quarrie 1992).

- o **Implementation of Agenda 21 by UN member countries** - The UN set up a Commission on Sustainable Development (UNCSD), which has the task of monitoring the implementation of Agenda 21. A programme has been set and member nations regularly report to the UN on the progress that has been made towards sustainable development.
- o **Development of Local Agenda 21 programmes** - Agenda 21 is a programme aimed at national level. It was recognised that little progress would be made unless action was taken at the local level. To this end there has been considerable effort put in to promote the development of Local Agenda 21 programmes involving cities and local authorities (see DEAT 1998). In South Africa several cities (Durban, Johannesburg, Cape Town and Pretoria) have initiated such programmes.
- o **Implementation of international treaties** - Most of international environmental treaties have well-established secretariats that arrange meetings to discuss progress, outstanding issues, and compliance with meeting the objectives of each treaty. Some treaties have been extremely successful (e.g. Law of the Sea, London Dumping Convention and the Montreal Protocol; see Walmsley & Tosen 1994) whereas others have not yet been able to achieve objectives and it will take many years before the desired progress will be made (e.g. Framework Convention on Global Climate Change; http://www.unep.org 2002; http://www.un.org 2002).
- o **Evaluation and re-commitment** – Ten years after the Earth Summit in Rio de Janeiro, the nations of the World recommitted themselves to strive towards sustainable development, at the World Summit for Sustainable Development in Johannesburg in September 2002. The *Plan of Implementation* drafted at the Johannesburg Summit states that it *"will further build on the achievements made since UNCED and expedite the realisation of the remaining goals"*. It identifies several areas where effort is required, including: poverty eradication; changing unsustainable patterns of consumption and production; protecting and managing the natural resource base of economic and social development; globalisation; health and sustainable development; sustainable

development of small island developing states; sustainable development for Africa and other regional initiatives.

2.2.3 Sustainable water resource management

It has become apparent that the ability of nations and societies to develop and prosper is linked directly to their ability to develop, utilise and protect their water resources (DWAF & WRC 1996). Water resources are the cornerstone of industrial development and agricultural production, as well as being useful in the transportation of goods, production of energy and enhancement of the quality of life through recreational opportunities (DWAF & WRC 1996). Thus most economies rely on their river systems and underground water resources for their development.

The 1991 Dublin Conference, in preparation for UNCED 1992, concluded that, "*since water sustains all life, effective management of water resources demands a holistic approach, linking social and economic development with protection of natural ecosystems*". Since then, it has been recognised that sustainable use and holistic management of freshwater resources is key to achieving the overall goal of sustainable development (e.g. UNCED 1992; Second World Water Forum in The Hague 2001; International Conference on Freshwater 2001 in Bonn; Johannesburg World Summit on Sustainable Development 2002; see Figure 2.2).

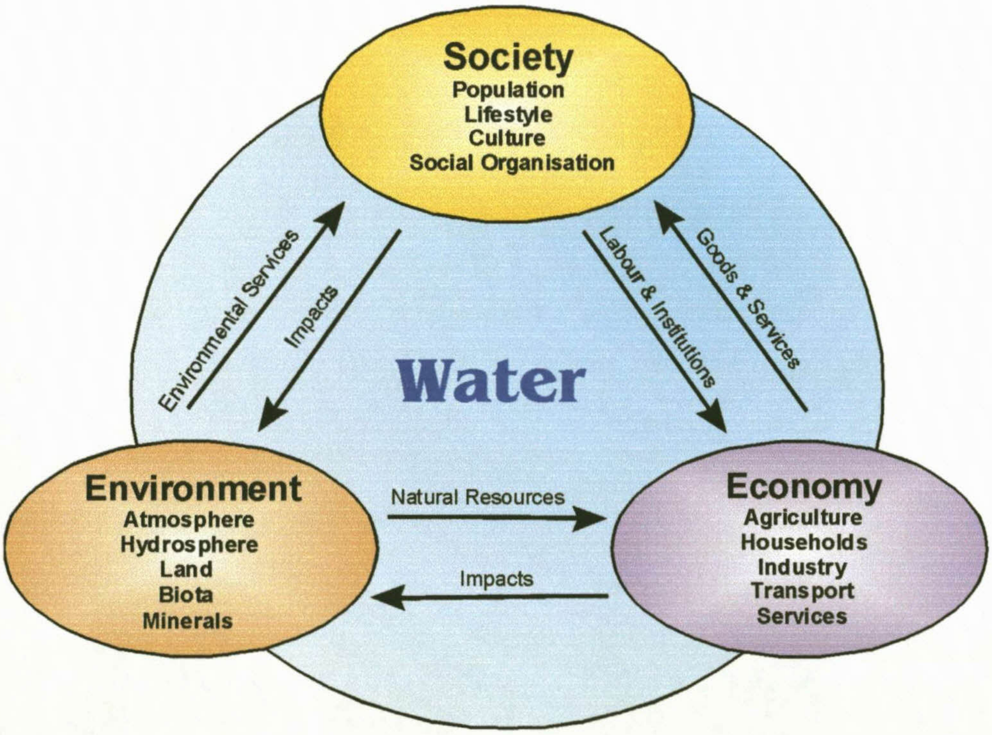


Figure 2.2: Social, economic and environmental aspects affecting water resource sustainability (from http://www.dwaf.gov.za 2002)

An internationally-accepted approach to sustainable water resources management, and one that is advocated by *Agenda 21* and the Johannesburg Summit *Plan of Implementation*, is integrated water resources management (IWRM) on a catchment basis (e.g. Syme *et al.* 1994; Pomeroy 1995; Serageldon 1995; Vicory 1995; Abu-Zeid 1998; DWAF & WRC 1996; DWAF & WRC 1998; Görgens *et al.* 1998).

A catchment, or drainage basin, is the total land area from which a river system receives its water, and the boundaries are demarcated by the points of highest altitude in the surrounding landscape (Hutchinson 1957; Reid & Wood 1981; DWAF & WRC 1996). A catchment encompasses the entire hydrological cycle, including atmospheric water (quantity, quality and distribution of precipitation); subsurface water (soil moisture and groundwater reserves); surface water (rivers, lakes, wetlands, impoundments); the estuarine zone and the costal marine zone. DWAF & WRC (1996) define a catchment as a *living ecosystem* in which there is a large, interconnected web of land, water, vegetation, structural habitats, biota and the many physical, chemical and biological processes that link these. Minshall (1988) states that spatial and temporal dimensions provide the basis of river ecosystem structure. River systems, and thus catchment areas, have a four-dimensional structure, with changes occurring longitudinally, laterally, vertically and with time (Ward 1989). Super-imposed upon this is the human system, which utilises the water as an essential resource.

Integrated water resources management represents an sustainable approach to managing the resources of a catchment by integrating all environmental, economic and social issues within a catchment into an overall management philosophy, process and plan (DWAF & WRC 1996). It is aimed at deriving the optimal mix of sustainable benefits for future generations, whilst protecting the natural resources, particularly water, and minimising the possible adverse social, economic and environmental consequences (DWAF & WRC 1996). In essence, it is *managing for sustainable development at the catchment level*, where water resources are viewed as the limiting factor.

According to *Agenda 21* (DEAT 1998), four actions should be pursued to successfully implement integrated catchment management:

- Promote a dynamic, interactive, iterative and multi-sectoral approach to water resources management, including the identification and protection of potential sources of freshwater supply, which integrates technological, socio-economic, environmental and human health considerations;
- Plan for the sustainable utilisation, protection, conservation and management of water resource ecosystems based on community needs and priorities within the framework of national economic development policy;

- Design, implement and evaluate projects and programmes that are both economically efficient and socially appropriate within clearly defined strategies, based on an approach of full public participation, including that of women, youth, indigenous people and local communities in water management policy-making and decision-making, and
- Identify and strengthen or develop, as required, in particular in developing countries, the appropriate institutional, legal and financial mechanisms to ensure that water policy and its implementation are a catalyst for sustainable social progress and economic growth.

2.3 MEASUREMENT OF SUSTAINABILITY USING INDICATORS

Sustainable development is accepted as a vision for managing the interaction between the natural environment and social and economic progress, but experts are still struggling with the practical problem of how to measure it. The Centre d'Estudis d'Informació Ambiental (2001) stated that *"the move towards sustainability would entail minimising the use of energy and resources by maximising the use of information and knowledge"*. In effect, in order to manage natural resources in a sustainable manner, decision- and policy-makers need to improve the application of knowledge gained from information. There is generally a large communication gap between the provision of data and the application of knowledge.

One method of providing information in a format that is usable by policy- and decision-makers, is through the use of sustainability indicators. An indicator is a parameter that provides information about an environmental issue with a significance that extends beyond the parameter itself (OECD 1993; Reinikainen 2002). Indicators have been used for many years by economists to explain economic trends, a typical example being Gross National Product. More recently there have been efforts aimed at developing indicators that are suitable for measuring sustainable development. As well as national initiatives (see DEAT 2001), there have been several international initiatives by, most notably:

- The World Resources Institute (Hammond *et al.* 1995);
- The World Conservation Union-IUCN (Trzyna 1995);
- The OECD (1993; 2000) and its member countries;
- United Nations Environment Programme (Bakkes *et al.* 1994);
- The UN Commission on Sustainable Development (Moldan & Billharz 1997);
- European Environment Agency (EEA 2000, 2002);
- The International Institute of Sustainable Development (IISD 2002), and
- The World Bank (1995).

Agenda 21 (Chapter 40) states that *"indicators of sustainable development need to be developed to provide solid bases for decision-making at all levels and to contribute to the self-regulating sustainability of integrated environmental and development systems"*. This has led to the acceptance of sustainability indicators as basic tools for facilitating public choices and supporting policy implementation (Von Meyer 2000). They provide information on relevant issues; identify development-potential problems and perspectives; analyse and interpret potential conflicts and synergies, and assist in assessing policy implementation and impacts (Von Meyer 2000). In essence, they allow us to better organise, synthesise and use information.

The main goal of establishing indicators is to measure, monitor and report on progress towards sustainability. Within this, indicators have numerous uses and potential for improving environmental management. Some of these include (Hammond *et al.* 1995; Walmsley & Pretorius 1996):

- Monitoring and assessing conditions and trends on a national, regional and global scale;
- Comparing situations;
- Assessing the effectiveness of policy-making;
- Marking progress against a stated benchmark;
- Monitoring changes in public attitude and behaviour;
- Ensuring understanding, participation and transparency in information transfer between interested and affected parties;
- Forecasting and projecting trends, and
- Providing early warning information.

Even though indicators are often presented in statistical or graphical form, they are distinct from statistics or primary data (Hammond *et al.* 1995). Indicators, which may include highly-aggregated indices, top an information pyramid, whose base is primary data derived from monitoring and data analysis (Figure 2.3).

2.3.1 Indicator criteria and possible pitfalls

Indicators should have three essential qualities; they should be *"simple, quantifiable and communicable"* (Walmsley & Pretorius 1996). Criteria for selection of indicators vary according to the needs of users and may differ for each indicator selection process (see LGMB 1995; Meadows 1998; Walz 2000; DEAT 2002). However, the following criteria, as proposed by the OECD (1993), provide a comprehensive guide to the selection of appropriate indicators:

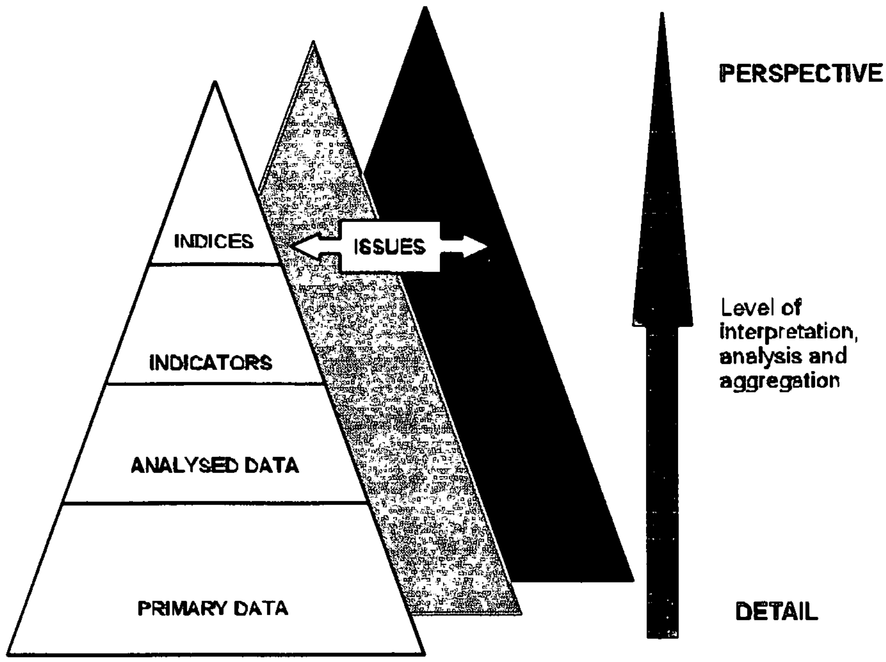


Figure 2.3: Information pyramid (adapted from Walmsley & Pretorius 1996).

With respect to *policy relevance and utility for users*, an indicator should:

- Provide a representative picture of environmental conditions, pressure on the environment or society's response;
- Be simple, easy to interpret and be able to show trends over time;
- Be responsive to changes in the environment and related human activities;
- Provide a basis for comparisons;
- Be either national in scope or applicable to issues of national significance (e.g. catchment management), and
- Have a target or threshold against which to compare it so that users are able to assess the significance of the values associated with it.

With respect to *analytical soundness* an indicator should:

- Be theoretically well-founded in technical and scientific terms;
- Be based on international standards and consensus about its validity, and
- Lend itself to be linked to economic models, forecasting and information systems.

With respect to *measurability of the data* required to support the indicators should be:

- Readily available or made available at a reasonable cost;
- Adequately documented and of known quality, and

- Updated at regular intervals in accordance with reliable procedures.

Meadows (1998) outlines several pitfalls in the choice and use of indicators, including:

- Over-aggregation – if too many parameters are joined together, the message presented by the indicator may become indecipherable;
- Measuring what is measurable or for which there is information, rather than what is important;
- Dependence on a false model or misunderstanding the true meaning of an indicator;
- Deliberate falsification if an indicator carries bad news;
- Diverting attention from direct experience, and increasing the reliance on data rather than knowledge;
- Overconfidence, particularly in indicators where interpretation is important, and
- Incompleteness – indicators are not the real system, and they may miss some of the subtleties, possibilities and warnings of the real system.

The International Institute for Sustainable Development has developed a set of ten principles for the measurement of sustainable development, which take into account many of the criteria and pitfalls mentioned above (http://www.iisd.org/measure/ 2002). Known as the Bellaglio Principles, they are valuable in the determination of sustainability indicators and are useful to ensure that the vision of sustainability is maintained throughout the process of indicator development (Table 2.1).

2.3.2 Indicator frameworks

One of the problems in the development of indicator sets is the over-abundance of possible indicators. The use of sustainability frameworks overcomes this by assisting in the development indicators in a logical fashion so that key issues can be readily identified and summarised, thus making them more understandable to non-experts. They suggest logical groupings of related sets of information and, thus, promote interpretation and integration. They can also help identify data collection needs and data gaps. Finally, indicator frameworks can help to spread reporting burdens, by structuring the information collection, analysis and reporting process across the many issues that pertain to sustainable development (Gouzee *et al.* 1995; Walmsley & Pretorius 1996).

Table 2.1: Bellaglio Principles (from (http://www.iisd.org/measure/ 2002)

1. Guiding vision and goals	∘ Be guided by a clear vision of sustainable development and goals that define that vision.
2. Holistic perspective	∘ Include review of the whole system as well as its parts; ∘ Consider the well-being of social, ecological, and economic sub-systems, their state as well as the direction and rate of change of the state, of their component parts, and the interaction between parts; ∘ Consider both positive and negative consequences of human activity, in a way that reflects the costs and benefits for human and ecological systems, both in monetary and non-monetary terms
3. Essential elements	∘ Consider equity and disparity within the current population and between present and future generations, dealing with such concerns as resource use, over- consumption and poverty, human rights, and access to services, as appropriate; ∘ Consider the ecological conditions on which life depends; ∘ Consider economic development and other, non-market activities that contribute to human/social well-being
4. Adequate scope	∘ Adopt a time horizon long enough to capture both human and ecosystem time scales thus responding to needs of future generations as well as those current to short-term decision making; ∘ Define the space of study large enough to include not only local but also long distance impacts on people and ecosystems; ∘ Build on historic and current conditions to anticipate future conditions - where we want to go, where we could go;
5. Practical focus	∘ An explicit set of categories or an organizing framework that links vision and goals to indicators and assessment criteria; ∘ A limited number of key issues for analysis; ∘ A limited number of indicators or indicator combinations to provide a clearer signal of progress; ∘ Standardising measurement wherever possible to permit comparison; ∘ Comparing indicator values to targets,-reference values, ranges, thresholds, or direction of trends, as appropriate;
6. Openness	∘ Make the methods and data that are used accessible to all; ∘ Make explicit all judgements, assumptions, and uncertainties in data and interpretations;
7. Effective communication	∘ Be designed to address the needs of the audience and set of users; ∘ Draw from indicators and other tools that are stimulating and serve to engage decision-makers; ∘ Aim, from the outset, for simplicity in structure and use of clear and plain language;
8. Broad participation	∘ Obtain broad representation of key grass-roots, professional, technical and social groups, including youth, women, and indigenous people - to ensure recognition of diverse and changing values ∘ Ensure the participation of decision-makers to secure a firm link to adopted policies and resulting action.
9. Ongoing assessment	∘ Develop a capacity for repeated measurement to determine trends; ∘ Be iterative, adaptive, and responsive to change and uncertainty because systems are complex and change frequently; ∘ Adjust goals, frameworks, and indicators as new insights are gained ∘ Promote development of collective learning and feedback to decision-making.
10. Institutional capacity	∘ Clearly assigning responsibility and providing ongoing support in the decision-making process; ∘ Providing institutional capacity for data collection, maintenance, and documentation; ∘ Supporting development of local assessment capacity.

There are numerous frameworks or models of sustainability that have been proposed over the last twenty years (see OECD 1995). However, not all of them are appropriate for the development of indicators. This section briefly outlines only those frameworks that could be used to assist in the identification of indicators (published in a project document as part of the South African National Environmental Indicators Programme, DEAT 2001; see Appendix E). They can be split into four main types: issue-based, physical, economic and societal.

Issue-based frameworks

Issue-based frameworks, as their name suggests, are based upon the identification of strategic issues that will influence the sustainability of a system (country, province, region etc.). They rest upon the premise that not all issues are equally important at any given time. Thus, they are dynamic and will change over time as the priority issues are dealt with and other issues emerge.

- ***Thematic frameworks*** - Thematic frameworks are the basis for all state-of-the-environment reports (see UNEP/GRID-Arendal 2002). Indicators are designed and used to describe the status surrounding a specific aspect of the environment. Every society and community will have its own themes and issues that it feels are important. It thus follows that indicators can be aggregated within themes or issues that they describe (Bakkes *et al.* 1994). It is essential to define key areas (themes) of concern and identify indicators that can be used to monitor and measure conditions (issues) within these priority areas. In some cases, the themes are chosen in accordance with a specific policy framework, such as a Sustainability Charter. An example of this is the use by the UN Commission for Sustainable Development using *Agenda 21* as its framework to develop themes and issues for which indicators could be chosen.

- ***Dashboard of Sustainability*** - The Dashboard of Sustainability, developed by the Consultative Group on Sustainable Development Indicators of the International Institute of Sustainable Development (IISD), uses an analogy of the dashboard of a car to develop a visual presentation of the elements of a sustainable system (IISD 2002; Figure 2.4). The dashboard has three displays, corresponding to three clusters of indicators that measure the status of the *environment* (Environmental Quality), the *economy* (Economic Performance) and the *social* well-being (Social Health) of a nation. Each dial has: a needle pointing to a value that reflects the current performance of that system; a graph reflecting the change in performance over time, and a gauge showing the amount remaining of certain critical stocks. Beneath each of the three dials is a display area for alert lights. Indicators crossing critical thresholds or experiencing rapid change, trigger warning lights that call special attention to those indicators. The overall state-of-the-environment is reflected in the composite status indicator labelled "Overall Sustainability". The IISD has developed a simple set of indicators and indices that fit into this framework (IISD 2002), and it is currently being testing at a national level in several countries, including South Africa.

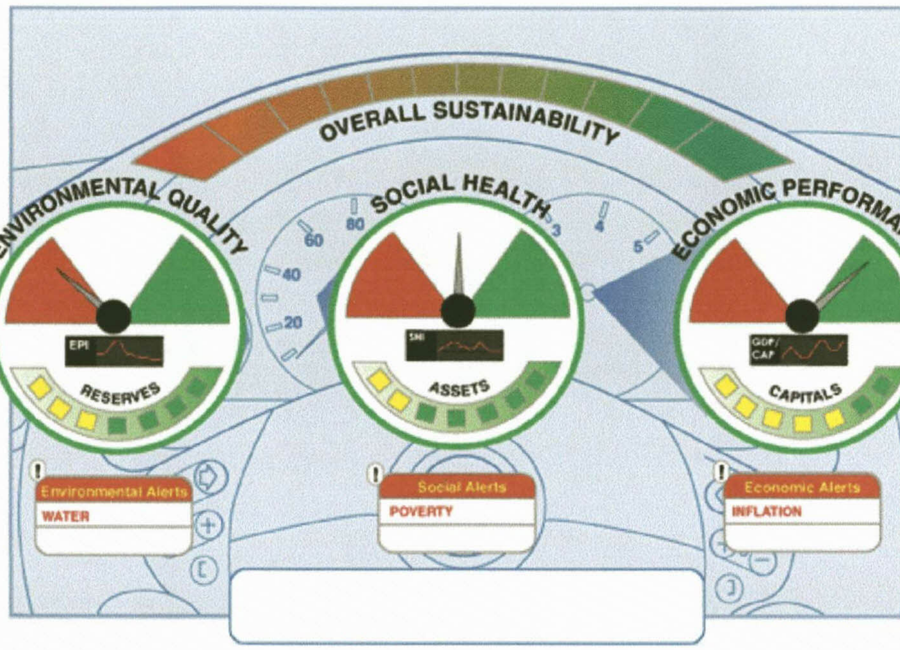


Figure 2.4: Dashboard of sustainability (from IISD 2002).

- ***Impact-Probability framework*** - The impact-probability framework is based on two strategic considerations. The first is the impact of a particular problem and the second is the probability or risk that the issue will cause a problem. This can be represented graphically using a simple business-school model (Figure 2.5). This framework identifies four types of issue that are of concern when making a strategic sustainability analysis. They are (Walmsley *et al.* 1999):
  - *Latent issues* of low impact and low probability. These issues are of concern because they are important as part and parcel of long-term management. Because impact and risk at the present time is relatively low there is only a need for monitoring.
  - *Emerging issues* of increasing impact and increasing probability. These are issues that have the potential to emerge as problems or are beginning to emerge as problems. These issues have the potential to cause problems in the near future. There is, therefore, a need to have them monitored as a priority.
  - *Action issues* of high impact and high probability. These are issues that should occupy most management time as they require solutions. They not only require monitoring but also the setting of objectives for problem-solving to reduce the risk.

> *Solved issues* of high impact and low probability. These are issues where the management problem has been solved through the successful implementation of an intervention. Monitoring of performance is ongoing to ensure that the intervention has been successfully implemented (performance indicators).

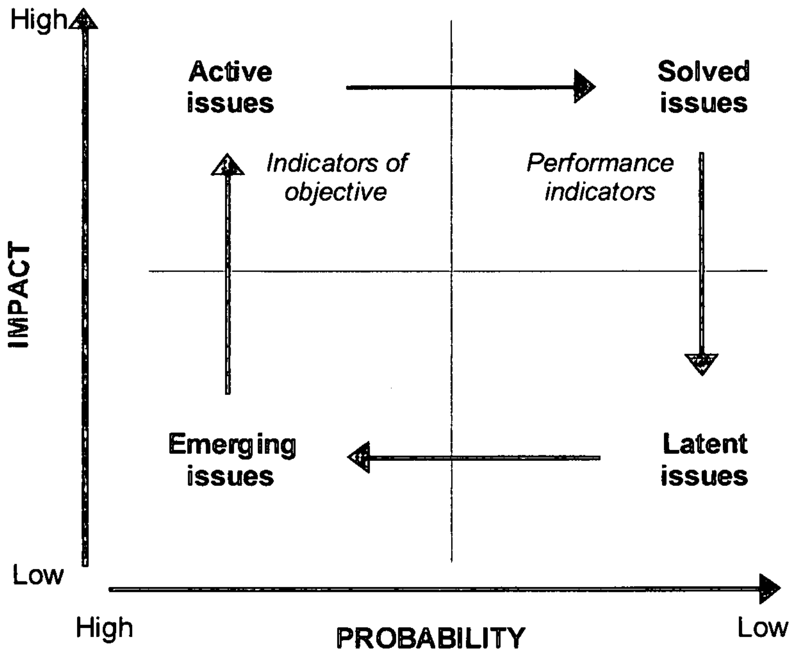


Figure 2.5: Impact-probability framework (adapted from Walmsley *et al.* 1999).

Physical frameworks

Some frameworks are based on the physical interaction between humans and the environment, and the impact of this interaction. They take into account both the static elements of a system, as well as the dynamic elements such as physical flow etc. These physical frameworks are designed to ensure that the environmental aspects of sustainability are reflected, as well as the economic and social aspects. The most commonly-used of these frameworks are the Pressure-State-Response (PSR) framework and the Driving-Forces-Pressure-State-Impact-Response (DPSIR) framework, which is based on the PSR framework.

- ***PSR Framework*** - The pressure-state-response (PSR) framework (Figure 2.6) was originally developed by the OECD programme on environmental indicators during the late 1980's from earlier work by the Canadian Government (Friend & Rapport 1979). This framework is based on a cause-effect-societal-response logic, where human activity causes *pressure* on the environment, whose *state* (quality and quantity) is changed, resulting in a societal *response* to reduce or eliminate the problem (Carlsson Reich & Åhman 2000). Pintér *et al.* (2000) expand upon the three categories of the PSR framework as follows:

- *Pressures* are classified into underlying forces such as population growth, poverty consumption or pollution. The pressures on the environment are often considered from a policy perspective as the starting point for addressing environmental problems. Information on pressures tends to be the most readily available since they are often derived from socio-economic databases. They include primary pressures such as population growth and economic development, and secondary pressures such as consumption patterns and pollution;
- *State* refers to the condition of the environment resulting from pressures (e.g. level of air pollution, land degradation or deforestation). The state of the environment will, in turn, affect human health and well-being as well as the socio-economic fabric of society. Knowing both the state of the environment and its indirect effect is critical for decision-makers and the public.
- *Response* corresponds to societal action taken collectively or individually to ease or prevent negative environmental impacts, correct environmental damage or conserve natural resources. Responses may include regulatory action, environmental or research expenditure, public opinion and consumer preferences, changes in management strategy, and provision of environmental information. Satisfactory indicators of societal response tend to be the most difficult to develop and interpret.

The framework was originally developed as a simple model used for isolated chains of cause and response. Because of the complexity of environmental relationships, in practice identification of causal chains is difficult. Thus, the framework has been developed to take into account more complex interactions (see Figure 2.6), where societal response is shown to impact on both the pressures and the state of the environment. Some indicators can be placed in more than one category, so the framework should be used for analysis rather than for rigid categorisation of indicators. This framework forms the basis for indicator development for several organisations including the Organisation for Economic Co-operation and Development (OECD), the UNCSD, the US Environmental Protection Agency (EPA) and the Australian and New Zealand governments (Zinn 2000; ANZECC 1998).

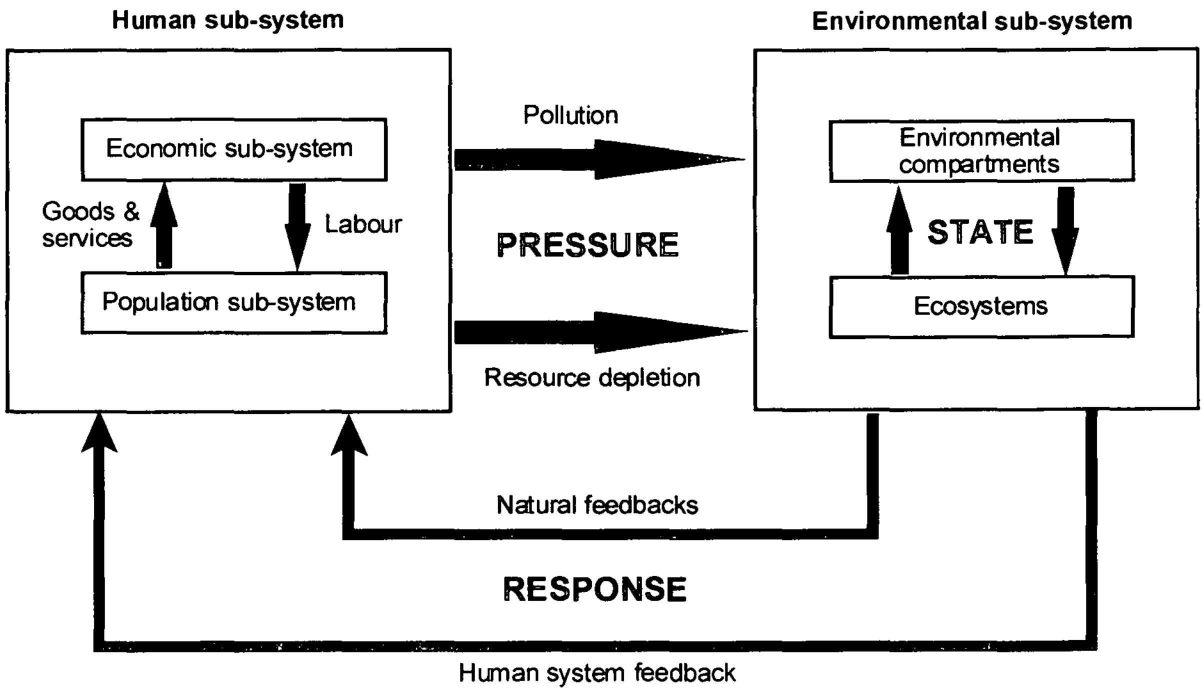


Figure 2.6: Schematic diagram of the Pressure-State-Response framework (Walmsley & Pretorius 1996).

- ***DPSIR and PSIR frameworks*** - The PSR framework was further developed by the United Nations and the European Environment Agency into the Driving-forces-Pressure-State-Impact-Response (DPSIR) framework (Figure 2.7). The DPSIR framework is viewed as providing a systems-analysis view of the relations between the environmental system and the human system (Smeets & Weterings 1999) rather than a direct cause-and-effect approach like the PSR. According to this view, social and economic developments (*driving forces*) exert *pressure* on the environment and, as a consequence, the *state* of the environment changes (e.g. provision of adequate conditions for health, resources availability and biodiversity). This leads to *impacts* on human health, ecosystems and materials that may elicit a societal *response* that feeds back on all the other elements (Smeets & Weterings 1999).

The development of this framework was based on the premise that from a policy point-of-view there was need for clear and specific information on: *driving forces* and the resulting environmental *pressures*; the *state* of the environment and the *impacts* resulting from changes in environmental quality, and the societal *response* to these and its effectiveness. Thus, two additional categories were added to the original PSR framework:

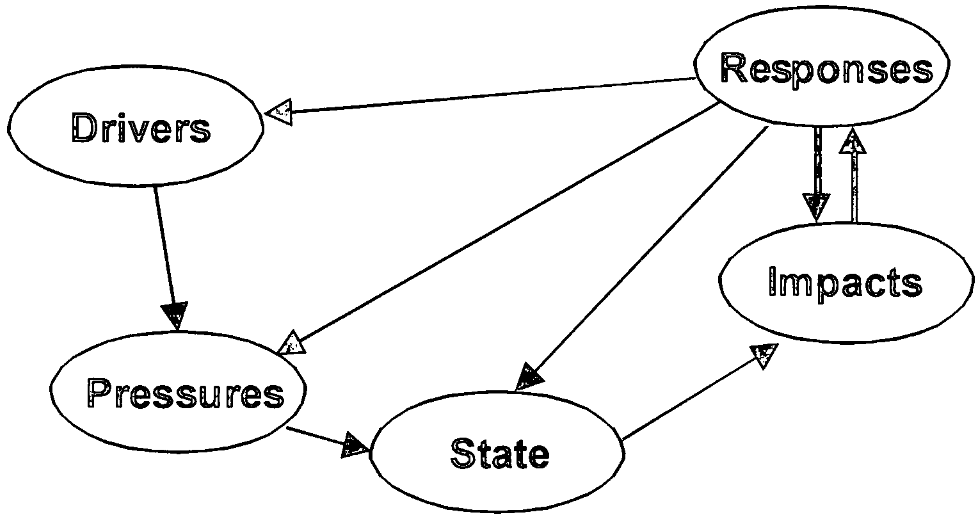


Figure 2.7: Schematic diagram of elements of the DPSIR framework and their interactions (EEA 2000).

- ***Driving forces*** are the human influences and activities that, when combined with environmental conditions, underpin environmental change. Indicators for driving forces describe the social, demographic and economic developments in societies and the corresponding changes in lifestyles, overall levels of consumption and production patterns. Primary driving forces are population growth and development in the needs and activities of individuals. These primary driving forces provoke changes in the overall levels of production and consumption, and thus exert pressure on the environment (Smeets & Weterings 1999).
- ***Impacts*** are the results of pressures on the current state of the environment, and which occur in a certain sequence. For instance, air pollution may cause global warming (primary effect), which may in turn cause an increase in temperature (secondary effect), which may provoke a rise of sea level (tertiary impact), which could result in a loss of biodiversity and thus impact on human health and well-being (Smeets & Weterings 1999).

Driving forces are often seen as those forces that are most difficult to change through the various response mechanisms. For this reason, the DPSIR framework is sometimes modified to include driving force and pressures in one category. This is referred to as the Pressure-State-Impact-Response framework (see Pintér *et al.* 2000). Although the DPSIR framework was developed as an extended cause-effect-response model, the framework is most useful in describing the origins and consequences of environmental problems. In developing linkages between the various categories the dynamic relationships within a system can be analysed. The DPSIR framework is currently being used by many countries in the development of their state-of-the-environment report, including South Africa (UNEP/GRID-Arendal 2002; http://www.ngo.grida.no/soesa), and is the preferred framework of the European Environmental Agency (EEA 2000, 2002).

Economic frameworks

Several economic frameworks have been developed, including frameworks such as the System of Integrated Environmental and Economic Accounting (SEEA); measures of wealth; and genuine savings (see OECD 2000). These economic frameworks are based on the concept of attempting to place a financial value on resources and assets. The basic framework on which all the others rest, is that of the National System of Accounts, which may be extended to include environmental resources and assets, and human and social capital (Obst 2000). However, although valuable in assessing sustainability, not all these frameworks are appropriate for developing indicators. The only economic framework that may be used for indicator development is the capital-based framework.

- ***Capital-based framework*** - The capital-based framework is founded on the concept of capital conservation, which is based on the idea that sustainability means living off the income derived from the stock of wealth or *capital* rather than living off the capital itself. The capital conservation approach broadens the traditional economic theory to include natural and human/social capital, as well as built capital (OECD 1995). Thus, the capital-based framework includes three basic capital types, which need to be accounted for when measuring sustainability. They are (OECD 1995):
  - *Built capital*, which is the human-built physical capacity (factories, tools and technologies) that provides a steady stream of economic output without being directly consumed.
  - *Natural capital*, which consists of the natural resource stocks and energy flows from which the human economy takes its raw material and energy, and the natural sinks into which we throw these materials and energy.
  - *Human or social capital*, which is defined as labour (including unpaid labour such as housework), education, nutrition, health and well-being of a population. Social capital is sometimes distinguished from human capital and reflects the institutional and cultural basis for society to function, which in turn reflects the richness and diversity of civil society.

For a system to be sustainable all these types of capital need to be accounted for. For an economist this would mean including natural and human capital into the System of National Accounts. In terms of the development of indicators, it would mean ensuring that there were indicators reflected in each category. Manitoba Environment (1997) used this concept to develop its state-of-the-environment report, allowing that the different types of capital were included in the equity of the province (Figure 2.8).

Figure 2.8: Framework of issues used by Manitoba Environment (1997), developed from the capital - based framework.

Societal frameworks

Societal frameworks are founded on the premise that the ultimate goal of sustainability is the fulfillment of human needs, which requires the maintenance of the system that can provide this. There are two main societal frameworks, Daly's triangle and the orientor framework. Both of these arose from the Balaton Group, an international network of scholars and activists who work on sustainable development in their own countries and regions.

- ***Daly's Triangle*** - The Daly's Triangle framework was developed at a Balaton Group workshop and later expanded upon by Meadows (1998). The concept is based on the model outlined by Herman Daly more than twenty years previously (Daly 1973). It relates natural wealth to ultimate human purpose through technology, economics, politics and ethics, by integrating the four aspects: ultimate means, intermediate means, intermediate ends and ultimate ends (Figure 2.9).

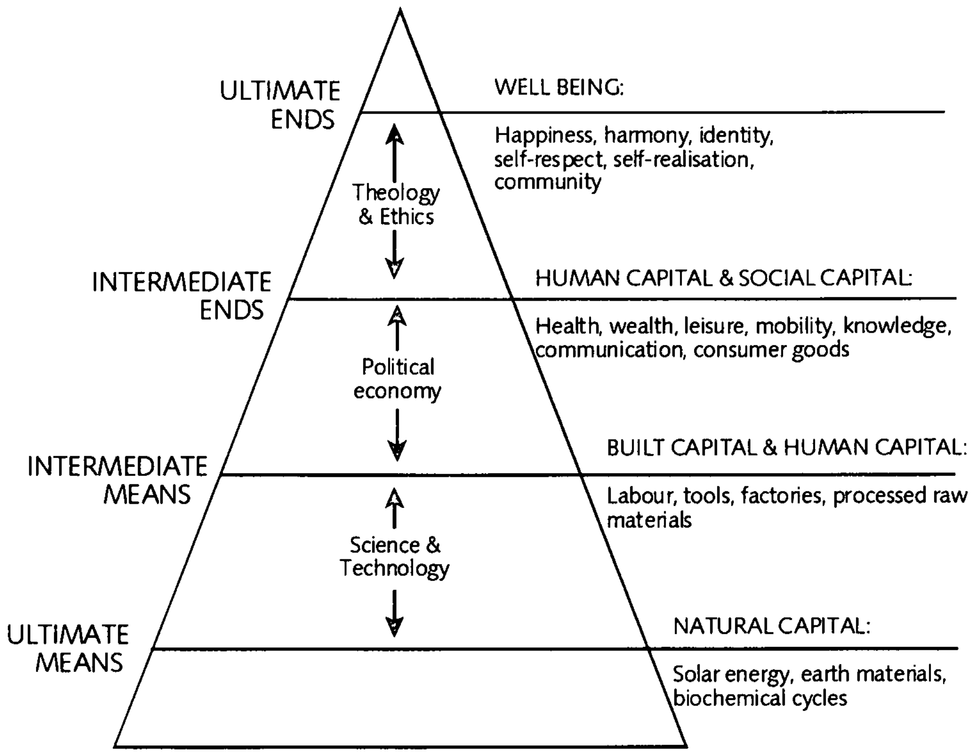


Figure 2.9: Daly's triangle (adapted from Meadows 1998)

The details of these four aspects are outlined by Meadows (1998) as follows:

- *Ultimate means* are the elements upon which all life and economic transactions are built and sustained. This is the natural capital (the matter of the planet, the sun's energy, biochemical cycles, ecosystems and genetic information).
- *Intermediate means* are built capital, human capital and raw material (e.g. tools, machines, factories, skilled labour, processed material and energy) that have been developed through science and technology from ultimate means. These intermediate means define the productive capacity of the economy, and are referred to by economists as input.
- *Intermediate ends* are the goals that governments promise and economies are expected to deliver (e.g. consumer goods, health, wealth, knowledge, leisure, communication, transportation), and are referred to by economists as output. They are what everyone wants, but do not guarantee satisfaction.
- *Ultimate ends* are desired for themselves and are not means to achieving other goals. They are the fulfillment of all needs and include nebulous concepts such as happiness, harmony, fulfillment, self respect etc.

- ***Orientors*** - The orientation theory on which the orientor framework is based, was developed in the 1970s to understand the divergent interests and visions for the future of various stakeholders in the environmental field, and to define criteria and indicators for sustainable development (Bossel 1977). Orientors, which form the basis of the framework, are defined by Bossel (1999) as the "*important interests that orient most of our decisions and actions, directly or indirectly*". If basic orientors can be identified for environmental systems, then all aspects of system viability should be covered. Bossel (1999) has identified seven basic orientors that can be used to define sustainability indicators. They include:

- *Existence* – The system must be compatible with and able to exist in the normal environmental state. The information, energy and material inputs necessary to sustain the system must be available.
- *Effectiveness* – The system should, over the long term, be effective in its efforts to secure scarce resources (information, matter, energy) and the exert influence on its environment.
- *Freedom of action* – The system must have the ability to cope in various ways with the challenges posed by environmental variety.
- *Security* – The system must be able to protect itself from the detrimental effects of environmental variability; i.e. variable, fluctuating and unpredictable conditions outside the normal environmental state.
- *Adaptability* – the system should be able to evolve, adapt and self-organise to generate more appropriate responses to challenges posed by environmental change.
- *Co-existence* – The system must be able to modify its behaviour to account for behaviour and interests of other systems in its environment.
- *Psychological needs* – In the case where sentient beings are part of the system, they have psychological needs that should be met

The basic orientors resulting from fundamental environmental properties are identical across all self-organising systems, irrespective of the functional type or physical nature. Viable systems, with adequate minimum satisfaction of all basic orientors, may differ in their basic orientor emphasis. However, sustainable systems should have a balance between all the basic orientors. The method of developing indicators using this framework is not explicit, and there are no records of this framework being used to develop indicators for any specific country or organisation.

Framework comparison

All the frameworks described above have both positive and negative aspects that need to be taken into account when choosing the most appropriate framework for indicator development (Table 2.2). However, the frameworks presented here are not necessarily mutually exclusive. A combination of frameworks can be used to develop a set of indicators that meet the requirements of the organisation or country that is developing them. In essence, a framework is a means to develop indicators that fulfil their purpose. The DPSIR and PSR frameworks are the most commonly used frameworks, mainly for state-of-the-environment reporting, but there is no universally accepted framework for developing indicators.

Table 2.2: Comparison of reviewed sustainability frameworks, identifying positive and negative characteristics of each framework.

FRAMEWORK	POSITIVE ASPECTS	NEGATIVE ASPECTS
	PHYSICAL FRAMEWORKS	
PSR	∘ Ensures integration of indicators in a specific theme (Walmsley & Pretorius 1996) ∘ Promotes a cause-effect-response logic to policy-setting and environmental management theme (Walmsley & Pretorius 1996) ∘ Provides information on key interactions between nature and society (Pintér *et al.* 2000) ∘ Can be used in conjunction with other frameworks	∘ Neglects the systemic and dynamic nature of environmental processes (Bossel 1999) ∘ Does not necessarily include all aspects of sustainability
DPSIR and PSIR	∘ Describes the relationships between the origins and consequences of environmental problems (Smeets & Weterings 1999) ∘ Provides a systems analysis based on a cause and response logic ∘ Identifies dynamic links between elements in an environmental system ∘ Includes social and economic elements into the analysis, thus readily analysing all aspect of sustainability ∘ Ease of identification of key indicators ∘ Can be used in conjunction with other frameworks	∘ Difficult to identify indicators in each category of the DPSIR causal chain ∘ Can become highly complex
	ISSUE-BASED FRAMEWORKS	
Thematic frameworks	∘ Identify key areas of concern ∘ All aspects of sustainability can be included ∘ Can be used in conjunction with other frameworks ∘ Ensures stakeholder and expert input	∘ Difficulty in deciding on themes ∘ Difficulty in addressing cross-cutting issues
Impact-probability	∘ Has practical application ∘ Focuses attention on priority areas ∘ Good environmental management tool ∘ Stakeholder and expert input is ensured ∘ Excellent for identifying key performance indicators (Walmsley *et al.* 1999)	∘ Does not necessarily ensure sustainability
	ECONOMIC FRAMEWORKS	
Capital-based	∘ Deals with all aspects of sustainability • Can be used in conjunction with other frameworks	∘ Tends to favour "weak sustainability" (Zinn 2000) ∘ Not holistic
	SOCIETAL FRAMEWORKS	
Daly's Triangle	∘ Theoretically elegant way of measuring human fulfilment ∘ Organises links between aspects of development (Meadows 1998) ∘ Lends itself to dynamic modelling (Meadows 1998) ∘ Can be used in conjunction with other frameworks	∘ Anthropocentric (Meadows 1998) ∘ Based on an economic model that was developed before the concept of sustainability was introduced. ∘ Too hierarchical (Meadows 1998)
Orientors	∘ Systematic and takes into account the dynamic nature of environmental processes	∘ Application is vague

2.4 CATCHMENT MANAGEMENT INFORMATION SYSTEMS IN SOUTH AFRICA

2.4.1 Catchment management information systems

The availability of reliable data and information is fundamental to sustainable water resources management as it provides input to decision-making processes (Figure 2.10; DWAF 2002). One of the freshwater programmes advocated by *Agenda 21* is *Water Resources Assessment*, which requires that "*the assessment of information is fully utilised in the development of water resource management policies*" and that "*all countries establish the institutional arrangements needed to ensure the efficient collection, processing, storage, retrieval and dissemination to users of information about the quality and quantity of available water resources at the level of catchments and groundwater aquifers in an integrated manner*".

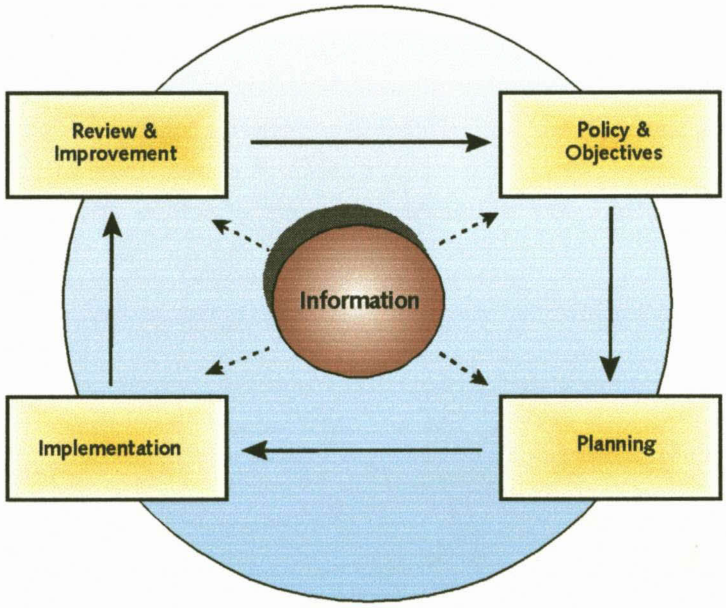


Figure 2.10: Role of information in the management cycle.

Catchment information systems should be a tool to integrate, exchange and deliver information to catchment managers in a way that is easy to understand and pertinent. The basic definition of an information system is "*a method to deliver and transform information into a form we can use*" (Economist Intelligence Unit 1991). An information system is formed through the co-ordinated functioning of people, equipment, procedures, data and other resources to provide uniform, reliable and accurate information. It should provide information in a technologically-appropriate and comprehensive manner.

Information systems can be broadly divided into two categories: formal systems (e.g. libraries and databases) and informal systems (e.g. personal knowledge and contacts). Formal information systems provide descriptive information, mapping the real world in a systematic way. Questions regarding such things as production quality, geographical information, statistical observations and variances between data sets may be answered by formal systems. However, the question as to why the variances occur, for instance, is often qualitative and requires a value judgement (Walmsley & Walmsley 1993).

With the advent of the "Information Age" and improvement in information technology (i.e. computers and communications technology), managers rely less on informal, knowledge-based systems and more on formal, computer-based systems (Walmsley & Walmsley 1993). This is also true of catchment management information systems, where there is an increasing dependence on Geographic Information Systems and large databases. The result of this is that there is a reliance on electronically-stored information to make decisions.

2.4.2 Use of indicators in catchment management information systems

According to DWAF & WRC (1996) integrated water resources management requires:

- *Analysis* of aspects of the catchment system that affect use and condition of the water resource;
- *Assessment* of the prevailing environmental, economic and social values, together with the values arising from beneficial uses of the water resource and the related impacts of management actions, and
- *Monitoring* of the environmental conditions and related socio-economic factors.

This should provide the basis for a management information system for catchments.

Indicators of sustainable development are a tool for ensuring that the correct information is provided in a manner that complements the integrated water resources management approach. A physical framework for identifying environmental indicators, such as the PSR or DPSIR frameworks, assists in the *analysis* of catchment systems; the indicators provide a method for *assessing* the current situation; and, once developed, the indicator system is ideal for both short- and long-term *monitoring*. The literature indicates that this approach has not yet been implemented in the catchment context.

The strategic value of indicators is in their ability to summarise pertinent information in an easily understood format. Additionally, the process of developing indicators highlights policy issues and strategic decisions that are required to ensure sustainability of the system. Figure 2.11 shows the position of indicators in establishing an information system for integrated water resource management at a catchment level.

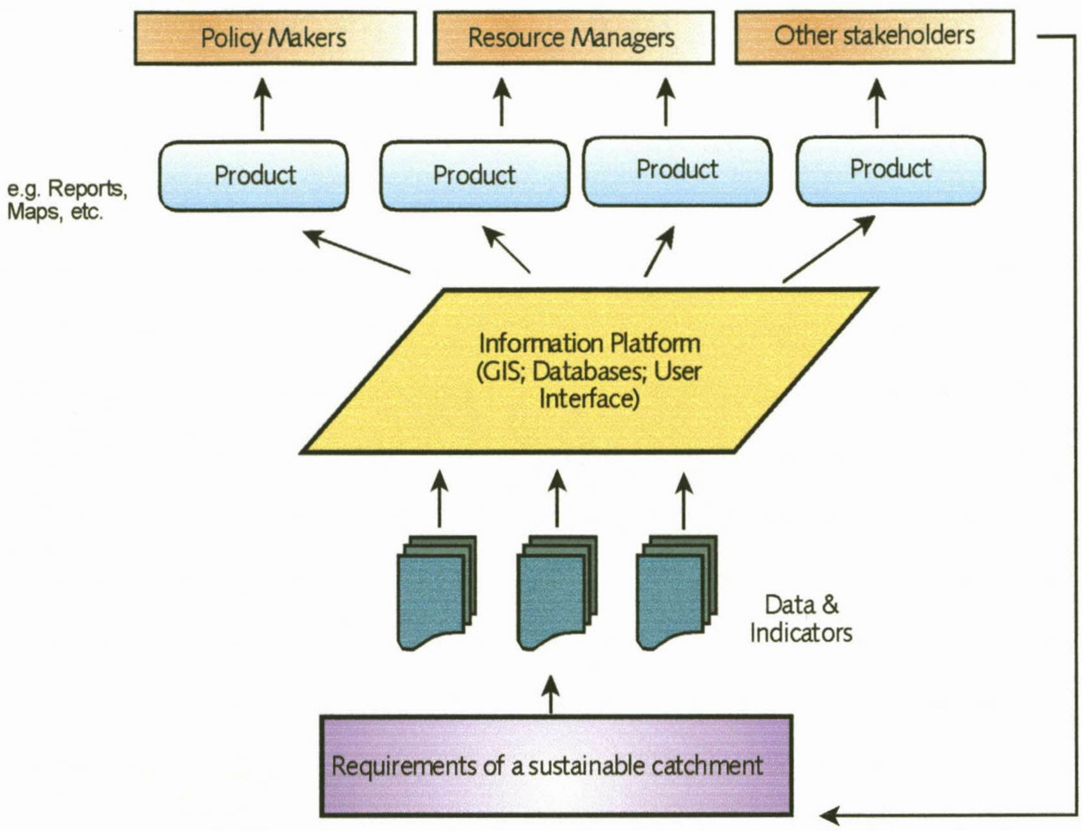


Figure 2.11: Role of indicators in information management.

2.4.3 Monitoring, Assessment and Information System (MAIS) of the Department of Water Affairs and Forestry

According to the National Water Resource Strategy (DWAF 2002), the Department is currently reviewing all data-acquisition, monitoring and information systems. It will amalgamate all existing and planned monitoring and assessment systems into a coherent, structured Monitoring, Assessment and Information System (MAIS). National systems will be designed so that catchment management agencies, can take responsibility for information management in their water management areas, as well as have access to information from adjacent areas. The national information system for water services required by the Water Services Act will be linked to information systems for water resources.

Monitoring systems

The Department operates several monitoring systems that collect some of the data and information required by the National Water Act:

- Flow in rivers is monitored at 800 national monitoring stations, and 625 sites where flow is measured at reservoirs, in transfer schemes or at major irrigation schemes. This is expected to increase by an additional 500 national monitoring points over the next 20-25 years.
- Groundwater levels are currently only monitored at 150 boreholes throughout the country. It is estimated that there should be 460 groundwater monitoring points (DWAF 2002).
- The National Chemical Water Quality Monitoring Network comprises approximately 850 ambient monitoring points in rivers and at reservoirs.
- The National Microbial Monitoring Network is operational in eight water management areas and will be expanded to cover all nineteen areas by 2007.
- The National Eutrophication Monitoring Programme, which includes cyanobacterial surveys, is operational in 50 reservoirs and will be expanded to 250 reservoirs by 2012.
- The National River Health Programme operates in seven provinces and is expected to be operational in at least one major catchment per province by 2006, and to produce state-of-the-rivers reports for all major river systems in the country by 2008.

Programmes that have not been implemented yet include the National Toxicity Monitoring Programme, the National Radioactivity Monitoring Programme and the National Estuarine Monitoring Programme (DWAF 2002).

Information systems

The National Water Act of 1998 requires the Minister to establish national information systems, including:

- A hydrological information system;
- A water resource quality information system,
- A groundwater information system; and
- A register of water use authorisations.

The Department currently has a mainframe-based **Hydrological Information System**, which stores all the flow data for the country as well as ambient water quality data (DWAF 2002). It contains in excess of 17 million days of primary data, which reduces to almost 380 000 months of processed secondary flow data. Information and access to this data is available on the departmental website (http://www-dwaf.pwv.gov.za/directorate/hydrology 2002). This is due to be replaced with a new system (HYDSYS), which is a server-based, commercial system developed in Australia. It has extensive graphics capabilities, supports data analysis, provides a variety of information, and makes use of GIS mapping to display systems and networks. After installation in the Department's National Office during 2002, transferring data from the existing system, and extensive staff training, the new system is expected to be operational in all departmental regional offices by 2004, six years after the promulgation of the Act.

The **Water Management System (WMS)** is a computer-based system being developed specifically for DWAF to support decision-making and to provide the necessary information, particularly about water quality, needed to manage water resources, potential pollution sources and monitoring in South Africa. The vision of the WMS is to have a working integrated computer system where different directorates and regions, with different mandates and functions, can support each other, sharing information and the workload, and in this way help DWAF to be consistent in all its decisions and actions in the management of water quality. The principal features of the system are (DWAF 2002):

- The consolidation of monitoring activities to reduce or eliminate duplication;
- The results of analyses can be captured, audited and quality assured.
- Monitoring networks can be displayed graphically, together with details of the water quality standards and resource quality objectives for the resource;
- The extent to which users comply with standards and objectives can be monitored;
- Results can be statistically analysed, and presented graphically, diagrammatically or in report form. Results can also be exported in a range of electronic formats for subsequent use in, for instance, spreadsheets;
- Documents, photographs, video and audio clips can be stored, and
- Incorporation of a user or stakeholder database.

As the system is developed, the completed and useable components of the system are implemented. The Water Management System is being implemented in one region or directorate at a time. It is currently functional at the Department of Water Affairs and Forestry Head Office and one regional office.

Groundwater information is currently stored in the mainframe-based **National Groundwater Database**, which will be replaced with a server-based, web-enabled National Groundwater Archive by 2004. It is envisaged that the Archive will be linked to REGIS (Regional Geohydrological Information System) Africa, a proprietary system that provides management information by modelling groundwater recharge, impacts of abstraction, and impacts of aquifer contamination (DWAF 2002). REGIS Africa is expected to be installed in the Department's National Office and three Regional Offices by the end of 2002.

The **Water Use Authorisation and Registration Management System** (WARMS) is a comprehensive system designed to manage the process of registering water use and the authorisation of water use (by licensing), as well as manage administrative components of the water charge system. It is designed to (DWAF 2002):

- Manage the process of registering water use by storing the information to identify a water user, and characterise the location, nature and extent of the use.
- Manage the authorisation of water use by incorporating the workflow requirements for the licensing process from application, through evaluation, issue or refusal, to review.
- Invoice water users based on established tariff structures, issue receipts and statements, account for revenue received, and track outstanding water use charges;
- Establish links with other national databases (such as the National Deeds Register) to facilitate validation of data and information, and
- Produce reports on all of the above dimensions.

The registration component of the system and the cost recovery functions are operational, while the licensing capabilities will be operational in 2003 and links to other national databases should be established by 2004.

The Water Situation Assessment Model (WSAM) is an information system in the broader sense of the word. It is essentially a water resources planning model for the analysis of future water requirements and supply scenarios. It provides information on numerous of water resources management such as:

- Water availability from major and minor dams, off-channel surface storage and rivers;
- Potentially sustainable groundwater abstraction;
- Water and effluent transfers;
- Runoff enhancement and losses by evaporation (from reservoirs and lakes);
- Detailed water use grouped as urban, irrigation, bulk and rural;
- Return flow and its reuse;
- Ecological and human reserve requirements;
- Impact of hydropower use;
- Stream flow reduction activities (forestry, dry land agriculture and alien vegetation), and
- The loss of storage capacity as a result of sedimentation.

The model incorporates a comprehensive database for the whole of South Africa, including shared catchments between South Africa and neighbouring states. Data have already been collected for more than two thousand interlinked catchments.

It is evident from the above that, although the MAIS includes water quality and quantity indicators and information, it does not appear to be based on any conceptual sustainability framework; i.e. it does not integrate social and economic information with the biophysical information that is monitored.

2.5 CONCLUSIONS

This overview has discussed several aspects of sustainability and its measurement, especially with regard to catchment systems. It has been recognised that:

- Sustainable development is a concept that is difficult to implement, especially considering the complexity of environment systems;
- Indicators of sustainable development are useful to provide a measure of progress towards achieving sustainability, although an absolute measurement of sustainability is impossible;
- Indicators should be developed within a framework, which allows for the logical structuring of indicator sets and assists in understanding the environmental system being assessed;
- Integrated water resources management at a catchment level is internationally accepted as the primary requirement for ensuring that freshwater resources are managed sustainably;
- Without information at a catchment level, water resources managers will be unable to make informed operational and strategic decisions.

From the above, it is obvious that indicators have a role to play in ensuring the sustainable management of catchment water resources. However, it also emphasises the importance of the quality of the indicator set that has been chosen. It is recognised that the key to testing the hypothesis in this study is the development of a set of indicators that adequately describes the sustainability of water resources at catchment level. Important aspects of indicator development include:

- **Knowledge on how indicators have been applied to catchment systems elsewhere in the world**. A review of the indicator sets used around the world should be a first step in the development of the indicator set for South Africa. This will provide an indication of the methods used elsewhere, as well as the indicators that have been developed.
- **The framework used to development the indicator set.** From the review it is apparent that the most appropriate frameworks for the development of catchment management indicators are the biophysical frameworks. In particular, the DPSIR framework lends itself to a functional analysis of catchment processes. This, in conjunction with an issues-based approach, is considered to be most appropriate for this study.
- **Understanding of stakeholders, their policies and their requirements**. For any indicator set to become established, it requires acceptance by the stakeholders. This will not only include DWAF, but also water providers, provincial authorities, local authorities and research organisations.

Once the indicators have been developed, the hypothesis that the information is available for sustainable water resources management in South Africa at the catchment level can be tested. Not all organisations that might have a monitoring system within a catchment can be approached with regards to the data availability. Thus, this study is based on the assumptions that DWAF, in accordance with the National Water Act, should have the information required to manage the water resources sustainably, and that this information should be available at the level at which management of catchments is taking place (i.e. DWAF Regional Offices).

2.6 REFERENCES

ABU-ZEID MA. 1998. Water and sustainable development: the vision for world water, life and the environment. *Water Policy* **1**: 9-19.

AUSTRALIAN AND NEW ZEALAND ENVIRONMENT AND CONSERVATION COUNCIL (ANZECC). 1998. *Core Environmental Indicators for Reporting on the State of the Environment: Discussion paper for public comment.* ANZECC, Canberra. 63 pp.

BAKKES JA, VAN DEN BORN GJ, HELDER JC, SWART RJ, HOPE, CW & PARKER JDE 1994. *An Overview of Environmental Indicators: State of the Art and Perspectives.* Environmental Assessment Sub-Programme. Nairobi. 73pp.

BOSSEL H. 1977. *Concepts and Tools of Computer-Assisted Policy Analysis.* Birkhäuser, Basel.

BOSSEL H. 1999. *Indicators for Sustainable Development: Theory, Method and Applications. A Report to the Balaton Group.* IISD, Winnipeg. 123 pp.

CARLSSON REICH M & ÅHMAN M. 2000. *Survey of Sustainability Indicator Projects.* Framkom, Stockholm. 97 pp.

CENTRE D'ESTUDIS D'INFORMACIÓ AMBIENTAL. 2001. *A New Model of Environmental Communication for Europe from Consumption to Use of Information.* European Environment Agency, Copenhagen. 65 pp.

DALY HE. 1973. *Towards a Steady-State Economy.* W Freeman & Co., San Francisco.

DEPARTMENT OF ENVIRONMENTAL AFFAIRS AND TOURISM (DEAT). 1998. *Agenda 21: An Agenda for Sustainable Development into the 21st Century.* DEAT, Pretoria. 70 pp.

DEPARTMENT OF ENVIRONMENTAL AFFAIRS AND TOURISM (DEAT). 2001. *National Core Set of Environmental Indicators for State of Environment Reporting in South Africa. Phase 1: Scoping Report. Volumes 1 & 2.* DEAT, Pretoria. 237 pp.

DEPARTMENT OF ENVIRONMENTAL AFFAIRS AND TOURISM (DEAT). 2002. *National Core Set of Environmental Indicators for State of Environment Reporting in South Africa. Phase 2: Identification of Issues and Criteria.* DEAT, Pretoria. 75 pp.

DEPARTMENT OF WATER AFFAIRS (DWA). 1986. *Management of the Water Resources of the Republic of South Africa.* Government Printer, Pretoria. 1020 pp.

DEPARTMENT OF WATER AFFAIRS AND FORESTRY (DWAF). 2002. *Proposed First Edition National Water Resource Strategy: Summary.* DWAF, Pretoria. 37 pp. http://www.dwaf.gov.za.

DEPARTMENT OF WATER AFFAIRS AND FORESTRY (DWAF) & WATER RESEARCH COMMISSION (WRC). 1996. *The Philosophy and Practice of Integrated Catchment Management: Implications for Water Resource Management in South Africa.* WRC Report No TT 81/96. WRC, Pretoria. 139 pp.

DEPARTMENT OF WATER AFFAIRS AND FORESTRY (DWAF) & WATER RESEARCH COMMISSION (WRC). 1998. *A Strategic Plan for the Department of Water Affairs and Forestry to Facilitate the Implementation of Catchment Management in South Africa.* WRC, Pretoria, Report No KU/107/98. 66pp.

ECONOMIST INTELLIGENCE UNIT. 1991. *Executive Information Systems.* EIU, London. 127 pp.

EUROPEAN ENVIRONMENT AGENCY (EEA). 2000. *Environmental Signals 2000.* EEA, Copenhagen. 109 pp.

EUROPEAN ENVIRONMENT AGENCY (EEA). 2002. *Environmental Signals 2002: Benchmarking the New Millennium.* EEA, Copenhagen. 147 pp.

FRIEND A & RAPPORT D. 1979. *Towards a Comprehensive Framework for Environmental Statistics: A Stress-Response Approach.* Statistics Canada, Ottawa.

GÖRGENS A, PEGRAM G, UYS M, GROBICKI A, LOOTS L, TANNER A & BENGU R. 1998. *Guidelines for Catchment Management to Achieve Integrated Water Resources Management in South Africa.* WRC Report No. KV 108/98. WRC, Pretoria. 40 pp.

GOUZEE N, MAZIJN B and BILLHARZ S. 1995. *Indicators of Sustainable Development for Decision-Making.* Federal Planning Office of Belgium, Brussels. 34pp.

HAMMOND A, ADRIAANSE A, RODENBURG E, BRYANT D and WOODWARD R. 1995. *Environmental Indicators: A Systematic Approach to Measuring and Reporting on Environmental Policy Performance in the Context of Sustainable Development.* World Resources Institute, Washington. 42pp.

HARRISON P. 1992. *The Third Revolution.* IB Taurus/Penguin Books, London. 359 pp.

HUTCHINSON GEF. 1957. *A Treatise on Limnology. Vol 1: Geography, Physics and Chemistry.* John Wiley and Sons, New York. 1015 pp.

INTERNATIONAL INSTITUTE OF SUSTAINABLE DEVELOPMENT (IISD). 2002. IISDnet, Measurement and Indicators for Sustainable Development. http://iisd1.iisd.ca/measure.

LOCAL GOVERNMENT MANAGEMENT BOARD (LGMB). 1995. *The Sustainability Indicators Research Project: Consultant's Report of the Pilot Phase.* The Local Government Management Board, UK. 164pp.

MANITOBA ENVIRONMENT, 1997. *State of the Environment Report for Manitoba: Moving Towards Sustainable Development.* Manitoba Environment, Winnipeg.

MEADOWS DH. 1998. *Indicators and Information Systems for Sustainable Development. A Report to the Balaton Group*. September 1998. The Sustainability Institute, Hartland Four Corners, VT 78pp.

MINSHALL GW. 1988. Stream ecosystem theory: a global perspective. *J. N. Am. Benthol. Soc.* 7(4): 263-288.

MOLDAN B and BILLHARZ S (eds). 1997. *Sustainability Indicators: A Report on the Project on Indicators of Sustainability*. John Wiley and Sons, New York. 415pp.

MONRO D & HOLDGATE M (eds). 1991. *Caring for the Earth: A Strategy for Sustainable Living.* IUCN, UNEP, WWF, Gland, Switzerland. 228 pp.

OBST C. 2000 Report of the September 1999 OECD expert workshop on the measurement of sustainable development. In: Organisation for Economic Co-operation and Development. 2000. *Frameworks to Measure Sustainable Development*. OECD, Paris. pp 7-17.

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT (OECD). 1993. *Environmental Indicators: Basic Concepts and Terminology*. Background Paper No.1. OECD, Paris. 150 pp.

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT (OECD). 1995. *Background Paper to the OECD Workshop: Sustainable Consumption and Production: Clarifying the Concepts, Rosendal, Norway, 2-4 July, 1995.* OECD, Paris.

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT (OECD). 2000. *Frameworks to Measure Sustainable Development*. OECD, Paris. 164 pp.

PIGRAM JJ & HOOPER BP. 1991. *Water Allocation for the Environment: Proceedings of an International Seminar and Workshop, 27-29 November 1991.* Centre for Water Policy Research, University of New England, Armidale. 282 pp.

PINTÉR L, ZAHEDI K & RESSMAN DR. 2000. *Capacity Building for Integrated Environmental Assessment and Reporting. Training Manual*. IISD, Winnipeg & UNEP, Nairobi. 142 pp.

POMEROY WM. 1995. The Fraser River Basin – Towards Sustainability. *Wat. Sci. Tech.* **31(8):** 33-39.

QUARRIE J. 1992. *Earth Summit '92: The United Nations Conference on Environment and Development, Rio de Janiero 1992.* Regency Press, London. 257 pp.

REID GK & WOOD RD. 1981. *Ecology of Inland Waters and Estuaries*. Van Nostrand, New York. 485pp.

REINIKAINEN T. 2002. *Working Core Set of Indicators for Namibia.* Ministry of Environment and Tourism, Windhoek. 26 pp.

SERAGELDIN I. 1995. Toward Sustainable Management of Water Resources. World Bank, Washington DC. 33 pp.

SMEETS E & WETERINGS R. 1999. *Environmental Indicators: Typology and Overview. Technical Report No. 25.* European Environment Agency, Copenhagen. 19 pp.

SULLIVAN C, MEIGH J & O'REGAN D. 2002. *Evaluating Your Water: A Management Primer for the Water Poverty Index.* DFID and NERC, Wallingford. 95 pp.

SYME GJ, BUTTERWORTH JE & NANCARROW BE. 1994. National Whole Catchment Management: A Review and Analysis of Processes. Research & Development Corporation and Murray-Darling Basin Commission, Canberra. 39 pp.

TRZYNA TC (ed). 1995. *A Sustainable World.* IUCN, The World Conservation Union. 272pp.

UNITED NATIONS ENVIRONMENT PROGRAMME (UNEP)/GRID-ARENDAL. 2002. UNEP/*GRID-Arendal SOE Reports.* http://www.grida.no/soe.

VICORY AH. 1995. Making the case for managing water on a basinwide basis. *New World Water* **1995:** 39-41.

VON MEYER H. 2000. Territorial indicators for sustainable development. Why? And how? In: Organisation for Economic Co-operation and Development. 2000. *Frameworks to Measure Sustainable Development.* OECD, Paris. pp 150-157.

WALMSLEY JJ & WALMSLEY RD. 1993. *A Research Information System for the Department of Environment Affairs.* Unpublished Report, DEAT, Pretoria. 38 pp.

WALMSLEY RD & PRETORIUS JPR. 1996. *Environmental Indicators. Report No.1. State of the Environment Series.* DEAT, Pretoria. 76pp.

WALMSLEY RD, RAMBALIE K & NELSON P. 1999. *A Scan and Discussion Document: Sustainable Development and the Environmental Performance of Eskom.* Corporate Environmental Affairs, Eskom, Johannesburg. 59 pp.

WALMSLEY RD & TOSEN G (eds). 1995. *International Treaties and Protocols: Implications for South Africa.* DEAT, Pretoria. 167 pp.

WALZ R. 2000. Development of Environmental Indicator Systems: Experiences from Germany. *Environ. Man.* **25(6):** 613-623.

WARD JV. 1989. The four-dimensional nature of lotic ecosystems. *J. N. Am. Benthol. Soc.* **8(1):** *2-8.*

WORLD BANK. 1995. *Monitoring Environmental Progress.* The World Bank, Washington DC. 84pp.

WORLD COMMISSION ON ENVIRONMENT AND DEVELOPMENT (WCED). 1987. *Our Common Future.* Oxford University Press, Oxford. 430pp.

WYNBERG R. 1993. *Exploring the Earth Summit.* Penrose Press, Johannesburg. 136 pp.

ZINN E. 2000. *Sustainable Development Indicators for Urban Water Systems.* MSc Thesis for Chalmers University of Technology, Götenborg, Sweden. 58 pp.

CHAPTER 3: METHODOLOGY

3.1 PROCESS OUTLINE

In order to meet the objectives of this study, i.e. the assessment of the current availability and quality of information at catchment level in South Africa, a two-phased approach was taken (Figure 3.1):

- **Phase 1:** Development of a set of sustainability indicators, which describes aspects of sustainability, including social, economic and biophysical elements (Part II of this thesis), and
- **Phase 2:** Testing of the hypothesis by assessing the information available at catchment level to populate the indicators (Part III of this thesis).

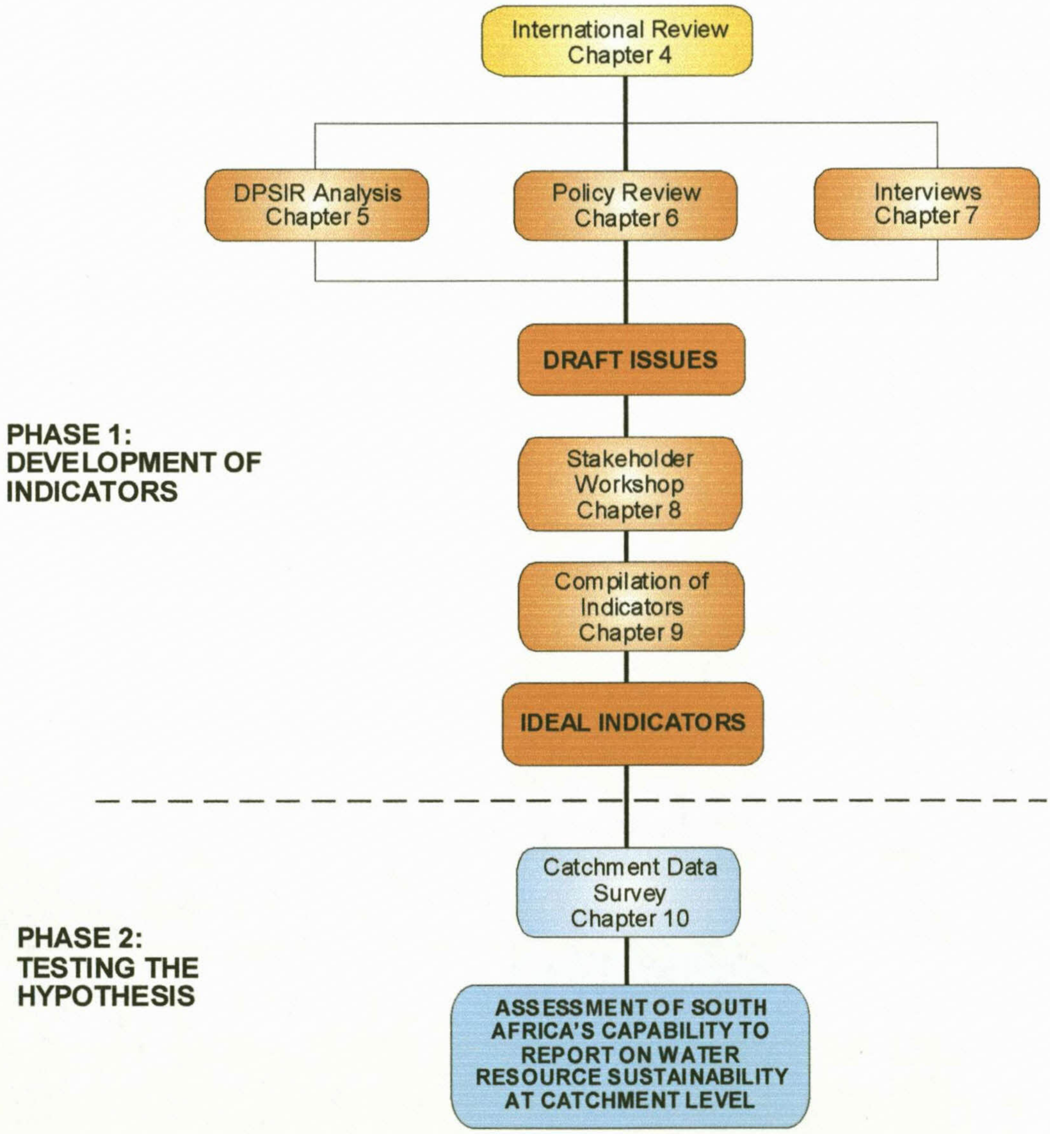


Figure 3.1: Process followed to assess the current availability and quality of sustainability information at catchment level in South Africa.

The methodology used was progressive, so that each step in the study built on the results of the previous step. The methods used in each of these steps are described below.

3.2 PHASE 1: DEVELOPMENT OF INDICATORS

The aim of Phase 1 of the project was to develop a set of *ideal indicators* that reflected sustainability in the catchment context, but that were not reliant on data availability. Mention should be made here that, although the indicators may be *ideal*, it is recognised that the indicator set as a whole cannot be perfect and there will always be debate as to completeness of the set. The indicator set established should be a set of *core* indicators that adequately describes sustainability in South Africa's catchments.

The initial step in the development of the indicators was an international review, which provided guidelines to indicator development. Thereafter, the indicators were developed using an issues-based approach, by:

- Identifying key sustainability issues that were important at catchment level in South Africa, and
- Identifying indicators that pertained to each of the key issues.

3.2.1 International review

A literature and internet search was conducted to identify organisations around the world that might be involved in catchment management directly, or which might have addressed the problem of information management at a catchment level. Four types of organisation were identified:

- *Catchment management agencies* (CMAs), which were directly involved in catchment management and had an official mandate to manage the water resources of the catchment areas for which they were responsible. These were identified through recognition of the catchment areas for which they were responsible (i.e. Tennessee River; Vaal River; Murray-Darling River).
- *Non-governmental organisations* (NGOs) and *international basin commissions*, which were associated with specific catchment areas, but did not have an official mandate to manage any of the catchment areas. In most cases, they were advisory bodies that were established to provide insight into catchment management issues. As with the CMAs, they were identified through recognition of the catchment areas for which they were responsible (e.g. Rhine River; Fraser River; Danube River).
- *Government agencies and departments*, which were *not* related to a specific catchment areas, but which had an interest in catchment management as part of their mandate or complementary to their mandate. For example, the Commonwealth Scientific and Industrial Research Organisation (CSIRO) of Australia has a research responsibility as part of its Sustainable Catchment Management

Programme, the UK Environment Agency has a responsibility to the environment, including river basins and the South African Department of Water Affairs and Forestry (DWAF) has a legal responsibility to ensure sustainable catchment management.

- *International organisations*, which were involved in the management of the environment and natural resources, including water resources.

Although it was recognised that these organisations were at different levels of governance, they all had an interest in managing catchments sustainably. Because catchments can be defined by similar characteristics (see Chapter 2; Wells 1992), it was accepted that there was a basis for comparison. Additionally, water resource management is not only based on management objectives, but is largely dependent on the condition of the catchment, which can be assessed using sustainability indicators.

In all, 21 organisations were approached with regards to whether they had developed indicators of sustainable development for catchment management (five CMAs; six NGOs and international basin commissions; seven government agencies and departments, and three international organisations). A contact person was identified for each organisation and requested to provide information on any programme or programmes to develop indicators for catchment management, including:

- The policy requirements and mandate of the organisation;
- The process followed to develop indicator sets, and
- Lists of indicators that might depict catchment health; catchment management; condition of water resources in the catchment, and sustainability of catchment systems.

The information provided by the response organisations was reviewed and indicator sets were compared to each other (Appendix A). Common indicators were identified, and the differences between indicator sets established. The different approaches to the establishment of indicators were noted and commented upon where possible. Lessons to be learnt for development of catchment management indicators in South Africa were extracted and commented upon.

3.2.2 Identification of key issues

The process to identify the key issues was designed to ensure that all aspects identified in the international review (Chapter 4) were taken into account, including:

- The issues, and thus indicators, must reflect the physical characteristics of catchments and the human influences on these;

- The issues, and thus indicators, must be relevant in terms of the current catchment management policy, and
- The indicator set developed must be useful for major stakeholders involved in catchment management.

The methodology for developing the issues was based on three requirements mentioned above, and included (see Figure 3.1):

- A Driving Forces-Pressure-State-Impact-Response (DPSIR) analysis, in which the functional characteristics of a catchment were superimposed upon the DPSIR sustainability framework developed by the European Environment Agency (see Chapter 2);
- A policy review of all the national legislation and policy for environmental and water resources management in the country, and
- Personal interviews of water resource managers in DWAF head office, DWAF regional offices, water providers and local authorities.

DPSIR analysis

The aim of the DPSIR analysis was to use the indicator framework to better understand the functional relationships in a catchment.

For development of catchment indicators, the DPSIR categories for catchment management were defined as follows:

- *Driving force* indicators reflect pressures exerted by natural phenomena and anthropogenic activities that are not easily manipulated or managed within the catchment context, but provide essential information to understanding catchment processes;
- *Pressure* indicators measure the pressures that are exerted on the water resources of a catchment as a result of the driving forces (e.g. increased pollution from domestic waste due to increased population and poor sanitation; increased consumption due to increasing economic activity);
- *State* indicators assess the current status of the water resource, in terms of quantity and quality for each habitat or ecosystem type;
- *Impact* indicators assess the effect that a pressure has on the state of the water resource or on water-user groups;
- *Response* indicators relate to the social response via policies, laws, programmes, research etc.

Within this framework a flow diagram was developed showing conceptual links and inter-relationships between the DPSIR categories for a catchment-based situation. This provided the framework within which the South African situation could be analysed, as well as identifying issues that needed to be taken into consideration when developing the indicators.

Review of national legislation and policy

The aim of the legislation and policy review was to identify issues of national importance to water resources management in the country. The legislation and policies that were reviewed included those pertaining to water resources management, as well as the environment:

- The Constitution (Act No. 108 of 1996);
- National Water Act (Act No. 36 of 1998);
- Water Services Act (Act No. 108 of 1997);
- National Environmental Management Act (Act No. 107 of 1998);
- Environmental Conservation Act (Act No. 73 of 1989);
- Minerals Act (Act No. 50 of 1991);
- Minerals Development Draft Bill (2000);
- Conservation of Agricultural Resources Act (Act No. 43 of 1983);
- Mountain Catchment Areas Act (Act No. 63 of 1970);
- White Paper on Integrated Pollution and Waste Management for South Africa (March 2000), and
- White Paper on the Conservation and Sustainable Development of South Africa's Biological Diversity (1997).

Key issues were identified for each policy or Act and a combined list compiled to facilitate integration at a later stage.

Interviews with major stakeholders

Interviews with major stakeholders were held over a three-month period between September 2001 and November 2001. The aim was to collect information on the mandates and policies of the operational directorates in DWAF and other water authorities, as well as to identify key water management priorities for each stakeholder group. The interviews were structured in such a way as to:

- Introduce stakeholders to the use of indicators in catchment management;

- Receive comment from them on the identification of issues from the DPSIR analysis and from the national legislation and policy review;
- Identify issues within the different areas of competency of each stakeholder, from both the interview and internal policy documents accessed during the interview.

Interviews were aimed at managers at director level and above, in order to ascertain the strategic concerns of water resource managers in the country. For practical reasons, not all stakeholders (i.e. all regional offices, water providers and local authorities) could be interviewed. However, twenty-four individuals, representative of the different authorities, were interviewed from the following DWAF directorates, DWAF regional offices, water providers and local authorities:

DWAF Head Office

- Chief Directorate: Water Services
- Chief Directorate: Planning
  - ➢ Directorate: Strategic Planning
  - ➢ Directorate: Water Resources Planning
- Chief Directorate: Scientific Services
  - ➢ Directorate: Hydrology
  - ➢ Directorate: Geohydrology
  - ➢ Directorate: Social and Ecological Services
- Chief Directorate: Water Use and Conservation
  - ➢ Directorate: Water Conservation
  - ➢ Directorate: Water Quality Management
  - ➢ Directorate: Catchment Management
  - ➢ Directorate Water Utilisation

DWAF Regional Offices

- KwaZulu-Natal
  - ➢ Water Resources
  - ➢ Catchment Management
- Western Cape
  - ➢ Water Resource Protection
  - ➢ Water Resources Management

Water Providers

- Umgeni Water, Hydrology
- Rand Water, Catchment Management

Local Authorities

- Cape Town Metropolitan Council
- Durban Metropolitan Council

Each of the people interviewed were requested to provide any policy documentation that was pertinent to the mandate of their directorate or, in the case of water providers and local authorities, organisation.

3.2.3 Identification of ideal indicators

The process to identify ideal indicators included:

- Compilation of issues identified from the DPSIR analysis, policy review and stakeholder interviews;
- Confirmation of the issues identified, through a stakeholder workshop;
- Identification of possible indicators for each issue, through a stakeholder workshop, and
- Compilation of a list of indicators.

Compilation of issues

Prior to the workshop, the issues identified during the DPSIR analysis, policy review and stakeholder interviews were compiled, using a mind-mapping technique (http://www.mindjet.com 2002). This method allowed for a multi-dimensional presentation of all the issues identified, and combining of similar issues.

Stakeholder workshop

A stakeholder workshop was held on 21 January 2002 (Appendix B). The workshop was aimed particularly at water resource managers at director level and below who had not necessarily been involved in the interview process. In this way a wider audience was exposed to the development of the indicators, and the issues identified could be tested by an impartial audience.

The aims of the workshop were threefold:

- To inform water resource managers of the use of sustainability indicators in catchment management;
- To evaluate the issues identified through the DPSIR analysis, national policy review and the interview process, and
- To identify possible key indicators for each issue.

Through a combination of questionnaires, group discussion and plenary discussion, the workshop participants were required to evaluate the previously-identified issues, and provide a single key indicator to describe each issue. The workshop was designed in such a way that the participants were required to work slightly outside their comfort zones, and to provoke some lateral thought in terms of indicator development.

Evaluation of Issues

The mindmap of all the issues was presented to workshop participants. They were requested to provide input on the issues identified through:

- **Completion of a questionnaire** (Issues Questionnaire; Appendix B), in which they were asked to evaluate the issues listed, by answering the following questions:
  - Is this issue important at a catchment level?
  - Do water resources managers need information on this issue?
  - Is this issue critical to the sustainability of the water resource?

  On analysis, each issue could obtain a high score of three per participant if all three questions were answered positively. The sum of positive answers from all participants provided an importance rating for each issue.
- **A plenary discussion**, which allowed debate on critical or controversial issues.

Identification of Indicators

Two exercises were undertaken to obtain the input of stakeholders in the identification of indicators at the workshop:

- **Completion of a questionnaire** (Indicators Questionnaire; Appendix B), to get an indication of the opinions of individuals. Prior to the workshop, a list of possible indicators was compiled for each issue from other indicator initiatives. Workshop participants were requested to rate each indicator as one of the following:
  - An *excellent* reflection of the issue;
  - A *good* reflection of the issue;
  - A *poor* reflection of the issue;
  - A *very poor* reflection of the issue.

  Issues that had been discarded previously during the workshop, were omitted from the questionnaire. Input from the participants was analysed according to a maximum score that could be obtained for each indicator, reflected as a percentage of the total.

- **A group exercise and a plenary discussion**. The participants were split into five groups according to the five DPSIR categories. Each group was requested to identify a *single* indicator that best described each issue in that category. The aim of this exercise was to encourage group discussion and try to identify the most appropriate indicator for each issue, on the understanding that most issues required more than one indicator, and that some indicators could be included in more than one issue. It provided an indication of the best single indicators for each issue. This was followed by plenary discussion to consolidate the group findings.

It was not envisaged that the final set of indicators would be determined at the workshop, but rather that the process would assist in the decision-making process in selecting final set of *ideal indicators*.

Compilation of ideal indicators

The results of the workshop were integrated into a final list of issues. For each of these issues, indicators were identified by choosing the most appropriate indicator to represent each issue, using the results of the workshop, as well as previous experience (Rand Water 2000). In some cases, more than one indicator was chosen to represent an issue, and some indicators covered more than one issue, Criteria for selection of the indicators included:

- All indicators must be current (i.e. indicators not relevant now, e.g. *CMA viability*, were omitted);
- All indicators must relate to issues that have been identified through stakeholder interviews and the stakeholder workshop;
- All indicators must be scientifically valid and analytically sound;
- All indicators must be easily understandable.

The indicators were grouped into five traditional water management categories for ease of understanding: i.e. socio-economic; water balance; waste and pollution; resource condition, and management. For each indicator, the following information was provided in the form of fact sheets (Appendix C):

- Definition;
- Purpose of the indicator;
- Relevance to sustainable water resource management;
- Linkages with other indicators;
- Limitations and potential problems, and
- Calculation of the indicator and data requirements.

The use of the indicators to describe different aspects of sustainability, and the linkages between indicators to describe various issues were explored. The intention was to provide the reader with a greater understanding of how the indicator set could be used to describe different aspects of catchment sustainability.

3.3 PHASE 2: ASSESSMENT OF CATCHMENT MANAGEMENT INFORMATION

An evaluation was made of the information availability and estimated accuracy for a selected pilot catchment within each of the nine regional jurisdictions: Gauteng, North-West, Limpopo, Mpumalanga, KwaZulu-Natal, Eastern Cape, Western Cape and Northern Cape. The methodology included:

- Compilation of a list of data requirements;
- Identification of a pilot catchments by each of the nine regional offices, and
- Completion of a questionnaire by the regional catchment managers with respect to data availability and accuracy, for each pilot catchment.

3.3.1 Data requirements

As a preliminary step in the assessment, a list of data requirements was compiled from the indicator fact sheets. In cases where several indicators were calculated using the same parameter (e.g. catchment area), the duplicate parameters were removed from the list.

3.3.2 Identification of pilot catchments

A contact person for each of the DWAF regional offices was identified through the Directorate of Social and Ecological Services. Each contact person was requested to identify a pilot catchment within their area of jurisdiction, using the following criteria as a guideline:

- The catchment should fall within a water management area under the region's jurisdiction, and
- The catchment could be a quaternary, tertiary or secondary catchment, but should be considered as a management unit by the Department.

3.3.3 Assessment of information availability and accuracy

The list of data requirements was used as a basis to develop a questionnaire that was completed by the regional catchment managers for each of the pilot catchments selected (Appendix D). The questionnaire requested managers to provide the following information for each indicator parameter:

- Whether there was information available;
- If the information was available, at what estimated confidence level was it available (high, medium, low);
- If information was not available, where it could be sourced.

The data from the questionnaires was analysed to provide an assessment of the information available for each of the pilot catchments, as well as an integrated assessment for South Africa.

Pilot catchment assessment

The replies received from the questionnaires were analysed for each pilot catchment in two ways. The first was an assessment of the **parameters** (elements making up each indicator) for which information was available. This provided an indication of the overall level of data availability for each pilot catchment. For each parameter the data availability was categorised as:

- Available at a low, medium or high confidence level;
- Not available;
- Not known whether it was available or not, and
- Not applicable (in rare instances where certain activities were not taking place).

The second was an assessment of the number of **indicators** that could be populated for each pilot catchment. In cases where the indicator was made up of more than one parameter, the lowest confidence level was assumed. If it was unknown whether a parameter was available, it was assumed that the indicator could not be populated.

Integrated assessment

In addition to the above analysis, each indicator was assessed with respect to how many regions were able to populate each. This provided an indication of the ability of South Africa in general to populate the indicators.

Regional catchment managers were also required to identify possible data sources for parameters for which information was not available at catchment level. An analysis of this provided an assessment of the most common data sources outside of the regional offices.

Conclusions regarding the South Africa's capability to report on water resources sustainability at catchment level were drawn, and recommendations for the future made.

3.4 REFERENCES

RAND WATER. 2000. *Catchment Diagnostic Framework: Prototype Catchment Diagnostic Index – User's Manual.* Rand Water, Johannesburg. 53 pp.

WELLS JJ. 1992. *A Pre-Impoundment Study of the Biological Diversity of the Benthic Macro-Invertebrate Fauna of the Sabie-Sand River System*. MSc Thesis, University of Cape Town. 207 pp.

PART II
DEVELOPMENT OF INDICATORS

CHAPTER 4: INTERNATIONAL REVIEW

4.1 INTRODUCTION

Most indicator initiatives in the world have been aimed at providing information at a national level for state-of-the-environment reporting (e.g. Ward 1990; OECD 1991; ANZECC 1998; UNEP/GRID-Arendal 2002) or for answering specific policy questions at national and international levels (e.g. UNEP & WHO 1988; FAO 1992; Eeronheimo *et al.* 1997). Few initiatives have been aimed at developing sectoral indicators, although some attempt has been made to develop sectoral indicators for agriculture, forestry, transport and energy (Obst 2000). In South Africa, indicators have been developed for national state-of-the-environment reporting (DEAT 2001, 2002) and for forestry (INR 2001). At the start of this study, it was uncertain as to what extent an attempt has been made to develop indicators for catchment or water basin management, either within South Africa or internationally.

This chapter provides the results of a review to establish what progress has been made towards development of indicators that assist in catchment management around the world. The focus is on the approach taken by various organisations throughout the world; the indicator sets developed by them, and the lessons that can be learn from these for the development of sustainability indicators for catchments.

This chapter formed the basis of a paper published in *Water SA* (Walmsley *et al.* 2001; see Appendix E).

4.2 PARTICIPATING ORGANISATIONS

In 2001, a literature and Internet search was conducted to identify organisations around the world that might be involved in catchment management directly, or which might have addressed the problem of information management at a catchment level, including: catchment management agencies (CMAs); non-governmental organisations; international basin commissions; government agencies and departments, and international organisations. (see Chapter 3 for details). Although it was recognised that these organisations were at different levels of governance, they all had an interest in managing catchments sustainably. Because catchments can be defined by similar characteristics (see Chapter 2; Wells 1992), it was accepted that there was a basis for comparison.

In all, 21 organisations were approached with regards to whether they had developed indicators of sustainable development for catchment management or not (five CMAs; six NGOs and international basin commissions; seven government agencies and departments, and three international organisations). Of these, eighteen replied. Twelve (67%) had not developed a set of indicators for catchment management, and six (33%) had either developed a set or were in the process of developing a set (Table 4.1). The organisations for which indicators were available for review, included:

- Fraser Basin Council, Canada;
- Murray-Darling Basin Commission, Australia;
- Tennessee Valley Authority, USA;
- US Environmental Protection Agency;
- World Resources Institute.

Each of these and their approaches to developing indicators are described briefly below.

Table 4.1: Organisations approached for information and summary of results

ORGANISATION	CATCHMENT	REPLY	INDICATORS DEVELOPED
Catchment Management Agencies			
Colorado River Commission	Colorado River, United States of America	Yes	None
Murray Darling Basin Commission	Murray-Darling River, Australia	Yes	Yes
Rand Water	Vaal Barrage Catchment, South Africa	Yes	Yes, but not publicly available at the time
Ruhrverband	Ruhr River, Germany	Yes	None
Tennessee Valley Authority	Tennessee River, USA	Yes	Yes
NGOs and International Commissions			
Advisory Committee for the St Lawrence Vision 2000	St Lawrence River	Yes	None
Fraser Basin Council	Fraser River, Canada	Yes	Draft
Georgia Basin Conservation Authority	Georgia Basin, Canada	Yes	see Fraser Basin Council
Grand River Conservation Authority	Grand River, Canada	Yes	None
International Commission for the Protection of the Danube	Danube River, Europe	Yes	None
International Commission for the Protection of the Rhine	Rhine River, Europe	Yes	None
Government Agencies and Departments			
Bureau of Reclamation, USA		Yes	None
Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia		No	-
Department of Water Affairs and Forestry, South Africa		Yes	None
Rijksinstituut voor Integraal Zoetwaterbeheer en Afvalwaterbehandeling (RIZA), Netherlands		Yes	None
UK Environment Agency		Yes	None
US Environmental Protection Agency		Yes	Yes
Washington State Water Resources Association		Yes	None
International Organisations			
IUCN		No	-
UNEP		No	-
World Resources Institute		Yes	Yes

4.2.1 Fraser Basin Council

The Fraser River Basin in Canada covers a quarter of British Columbia's landmass, with an area of 240 000km^2. The river itself is 1 375 km long from the headwaters to the mouth and is the fifth longest in Canada. It supports two-thirds of the province's population and accounts for 80% of its Gross Domestic Product. The economy of the Basin has historically been dependent on the natural resource base with fishing, forestry, mining, and hydro-electric development being important activities. In addition, the Basin supports a diverse agricultural sector.

The Fraser Basin Council is a non-governmental, not-for-profit organisation. It was established in 1997 as the successor to the Fraser Basin Management Program, an intergovernmental co-ordination program that focused on the sustainability of the Fraser River Basin between 1992 and 1997. The Council is guided by a 36-person Board of Directors that represent all four orders of Canadian governance (i.e. federal, provincial, local government and First Nations), as well as non-government and private sector interests. The work of the Council is carried out by co-ordinators in each of the five regions of the Basin.

The mandate of the Council is to enable individuals, organisations and governments of the Fraser Basin to work together to advance the sustainability of the Basin. The Council's work is guided by its Charter for Sustainability, with its vision that states, "*the Basin is a place where social well-being is supported by a vibrant economy and sustained by a healthy environment*" (Fraser Basin Council 1997). The Charter contains 26 goals related to social, economic, environmental and institutional systems in the Basin. The goals are organized under four directions or themes: understanding sustainability; caring for ecosystems; strengthening communities and improving decision-making.

The constitution of the Council requires that it report to the residents of the Fraser Basin at regular intervals on the progress towards sustainability. The use of sustainability indicators was recognised as an important tool to accomplish this. The Council was in the process of identifying a set of sustainability indicators and had, thus far, developed a draft set of 40 indicators using the Council's Charter for Sustainability (Fraser Basin Council 1997) as a framework.

The indicators chosen were goal-oriented towards the 26 goals of the Charter under the four directions specified by the Charter. A discussion document in the form of a workbook (Fraser Basin Council 2000) had been developed. This would form the basis of a participatory process (including workshops and an on-line indicators questionnaire) to refine and further develop the indicators presented in the workbook.

4.2.2 Murray-Darling Basin Commission

The Murray-Darling River system drains about 14% of the Australian continent, covering a catchment area of 1 061 469 km^2 (Crabb 1997). It is a highly-utilised basin, with about 81% of the divertible water having been developed (Commonwealth of Australia 1996). The Murray-Darling Basin Commission (MDBC) was established in 1988 and is responsible for co-ordinating the efforts of the governments (Commonwealth, New South Wales, Victoria, South Australia and Queensland) and communities involved in the management of the Basin.

As part of its mandate to manage the natural resources of the Murray-Darling system, the MDBC has developed the Basin Sustainability Plan (BSP; prior to 2001 this was entitled the Basin Sustainability Programme), the aim of which is "*to promote and co-ordinate effective planning and management for the equitable, efficient and sustainable use of the water, land and other environmental resources of the Murray-Darling*" (MDBC 2000a). The BSP is largely administered through three programmes:

- Riverine Environment Management;
- Irrigated Regions Management, and
- Dryland Regions Management.

The BSP also has four key result areas:

1. Water quality;
2. Sustainable agricultural production;
3. Nature conservation and
4. Cultural heritage (introduced in late 1999).

Each programme is required to address specific objectives within each key result area. In addition, the BSP has a set of direction-setting objectives that are shared by all programs. These relate to: government and community capacity development; community empowerment, and development of co-ordinating frameworks.

In 1998, the Commission attempted to develop a set of indicators for assessing progress towards the BSP objectives. Given the multi-jurisdictional nature of the administration of the Murray-Darling Basin it was essential that data sets in each jurisdiction were sufficiently compatible (or capable of being made so) to generate basin-wide indicators.

An initial set of 130 indicators generated by the Commission, was reduced to 30 (MDBC 1999). These were tested to evaluate their efficacy, the cost of generating data, and the administrative requirements to align existing data sets in the six jurisdictions. Of the 30, only sixteen were recommended for use in the Basin and, of these, only five were suitable for rapid implementation due to the general lack of compatible basin-wide data sets. The majority of the sixteen indicators recommended dealt with the quality, state and use of aquifers and surface water. The evaluation of indicators in this chapter includes all 30 indicators tested by the MDBC.

The Commission is working towards implementing a goal-oriented framework within which indicators will be further developed. In particular, the partners of the MDBC are in the process of agreeing to a new Integrated Catchment Management Policy (ICM) Framework (MDBC 2000b). When finalised and approved by the partner governments this framework will commit all stakeholders in the Basin to:

- Developing a range of basin-wide strategies regarding the management of salinity, water quality, water sharing, riverine ecosystem heath, and terrestrial biodiversity;
- Establishing and further developing the capacities of catchment management organisations across the Basin;
- Strengthening links between land-use planning legislation and processes and catchment planning and management;
- Establishing a range of basin-wide and catchment-level targets, initially these will be for water quality, water sharing, terrestrial biodiversity and river ecosystem health, and
- Developing a set of core indicators of catchment health to complement the targets as a means of assessing progress and directing investments and effort to achieve major benefits for the Basin.

In terms of indicators, the development of this ICM Framework represents a shift from previous attempts to utilise only pre-existing data sets and interpretive models such as Pressure-State-Response (PSR) framework. Instead, the ICM Framework will:

- Identify the data and indicators needed for catchment management, investment targeting, and accountability purposes, and
- Provide the structure for the development of basin-wide and regional-level reporting processes.

4.2.3 Tennessee Valley Authority

The Tennessee River Valley in the Eastern United States is the 5th largest river in the country, covering an area of about 103 600 km^2 within seven states. The Tennessee Valley Authority (TVA), created by the United States Congress in 1933 to manage the system, has three main goals:

- Supplying low-cost, reliable power to the nearly eight million people living in the region;
- Stimulating economic growth, and
- Supporting a thriving river system.

As part of the environmental stewardship of the river, the TVA has established a citizen advisory council (the Regional Resource Stewardship Council) as well as twelve Watershed Teams whose aim is to improve watershed conditions in the Tennessee Valley.

The TVA has established a set of core performance indicators for each of the three main goals mentioned above, including *"supporting a thriving river system"*, as part of the Strategic Plan for 2000 to 2005 (TVA 2000). The indicators supporting this goal provide the basis for catchment management within the Tennessee River. The main objectives within the thriving river system goal are to minimise flood damage, maintain navigation, support power production, improve water quality, protect public health, protect the environment and support recreational uses.

Within this Strategic Plan, the TVA has developed a set of indicators that primarily deal with watershed condition in terms of water quality. The approach that they have taken is twofold:

1. A Watershed Condition Index is used to assess the overall water quality conditions as an outcome measure. It is based on four physical elements: i.e. reservoir ecological health; stream ecological health; water quality assessments, and reservoir shoreline vegetation condition.
2. A planning framework used by the Watershed Teams is aimed at meeting the outcome by focusing on four core stewardship areas of the TVA, i.e. shoreline management, water resource condition, public lands management, and stakeholder or customer interests. This framework allows for development project evaluation based on natural resource conditions (13 measures) and public interests (16 measures), which build toward overall watershed sustainability.

4.2.4 United States Environmental Protection Agency

The EPA is a United States federal government organisation, which was established in 1970. Its mission is "*the establishment and enforcement of environmental protection standards consistent with national environmental goals...The conduct of research on the adverse effects of pollution and on methods and equipment for controlling it; the gathering of information on pollution; and the use of this information in strengthening environmental protection programmes and recommending policy changes...assisting others, through grants, technical assistance and other means, in arresting pollution of the environment...assisting the Council on Environmental Quality in developing and recommending to the President new policies for the protection of the environment.*" (EPA 2001).

The EPA has established a set of 12 national environmental goals, of which two are "safe drinking water" and "clean waters". To check progress towards the national goals, the EPA developed a series of milestones for each goal that set a 10-year target to be reached by 2005. In addition five objectives for meeting the goals have been set. These are: conserve and enhance public health; conserve and enhance ecosystems; support uses designated by the states and tribes in their water quality standards; conserve and improve ambient conditions, and prevent or reduce pollutant loadings and other stressors. In 1996 the EPA, in collaboration with other government organisations, developed a set of indicators to meet the goals, milestones and objectives of the organisation (EPA 1996). Eighteen indicators were chosen; these were used as a basis for the current Index of Watershed Indicators (EPA 2001; http://www.epa.gov).

Development of the Index of Watershed Indicators was aimed at providing a complete descriptive technique for characterising the condition and vulnerability of water resources at a catchment level; establishing a national baseline on the condition and vulnerability of aquatic resources, and making information readily available (EPA 2001). The 15 indicators chosen to achieve these aims have been split into "condition indicators" (i.e. state indicators) and "vulnerability indicators" (pressure indicators). There is ongoing development of these indicators, especially with regard to policy and institutional indicators that will eventually be added to the set (EPA 2001).

4.2.5 World Resources Institute

The World Resources Institute, established in 1982, is an environmental "think-tank" based in Washington DC. Its mission is *"to move human society to live in ways that protect Earth's environment and its capacity to provide for the needs and aspirations of current and future generations"* (WRI 2001). Its goals are to reverse the rapid degradation of ecosystems; to halt the changes in the earth's climate; to catalyse the adoption of policies and practices that expand prosperity, while reducing the use of materials and generation of wastes, and to guarantee people's access to information and decisions regarding natural resources and the environment (WRI 2001).

Within the information programme of the WRI, a set of 15 indicators have been developed that characterise catchments in terms of their ecological value, current condition and vulnerability to potential degradation from human activities. The indicators have been developed as a preliminary set to provide information about major watersheds on a global scale. The set of 15 indicators incorporates 23 data sets that measure catchment characteristics and human activities that potentially affect rivers and lakes. The global data sets include such variables as land use, land cover, aridity, forest extent and loss, erosion, endemic bird species distributions, population density, and protected areas. Additional statistical databases on surface water runoff, location of major dams, and fish species diversity, were included when they could be geo-referenced or linked to major rivers or lakes. The WRI has also recently completed additional indicators on the condition of the world's freshwater systems, where condition is defined as the current and future capacity of the systems to continue providing the full range of goods and services needed or valued by humans (Revenga *et al.* 2000).

4.3 COMPARISON OF INDICATOR SETS

The information provided by the response organisations was reviewed and a direct comparison was made of the catchment indicators developed by each organisation (see Appendix A). Although the governance level of the organisations differed, the level of information required was the same (i.e. catchment level). The differences between the organisations make identification of the common issues for which indicators need to be developed all the more important, whilst the variations may be considered less relevant. Thus, this analysis concentrates on the similarities rather than the differences.

The indicators were split into five water management themes; that is, socio-economic, water balance, waste and pollution, resource condition, and policy and management (Rand Water 2000; Walmsley 2001). Within each of these categories, the indicators were split into categories, which were felt best reflected their aim. The categories that were represented in the five indicator sets under review included:

Socio-economic

- *Population and demographics*, which includes population growth and demographic changes within catchments, and can include birth and mortality rates, gender ratios and race ratios;
- *Education* of the catchment population, which includes levels of education and literacy;
- *Employment*, including sectoral and regional changes in employment and the job market;
- *Community development*, which includes issues such as community participation, charitable works, as well as crime rates;
- *Economic development*, which includes economic growth within the catchment, strategies for development, energy consumption and transportation.

Water balance

- *Water availability*, which is the amount of water available for use from surface and ground water sources. It includes climate as well as forms of hydrological modification and storage systems;
- *Water use*, is the sectoral and regional use of water, which includes abstraction of water as well as exporting of water from the basin.

Waste and pollution

- *Waste production*, which is the amount of waste produced within the catchment area. In this case it includes waste that enters waste treatment plants and landfill sites, as well as polluted runoff. It also includes compliance with pollution and water quality standards.
- *Water quality*, which is the condition of the water in terms of the possible chemical and physical pollutants that enter it.
- *Contamination*, which is the level of contamination of the natural system due to waste and water quality problems (e.g. bioaccumulation).

Resource condition

- *Biodiversity and ecosystem integrity*, which includes aquatic ecosystem and species diversity, as well as changes in habitat and aquatic ecosystem health;
- *Land use change*, which includes changes to the terrestrial ecosystems which may impact on the catchment water resources;
- *Resource use*, which is the consumptive and non-consumptive use of resources that rely on aquatic systems for their continued existence. Consumptive uses include the harvesting of reeds, fish etc, whilst non-consumptive uses include shipping and recreation.

Policy and management

- *Policy*, which provides legislated and non-legislated guidelines for management, as well as determining the interaction between various political entities;
- *Management*, which determines the day-to-day running of the catchment within the policy framework;
- *Research and training*, which provides the knowledge on which further management steps will be taken.

Using these categories, it was possible to compare the indicator sets at three levels:

1. Number of organisations that had developed at least one indicator in each category (Figure 4.1);
2. Total number of indicators that had been developed by the five organisations in each category (Figure 4.2), and
3. Identification of common indicators (Table 4.2).

Figure 4.1 shows that the most common categories, which were included in the indicator sets of the five organisations, were *biodiversity and ecosystem integrity, water quality and water availability.* These were followed by *population, resource use, land use change, contamination* and *waste production*, which were included in three of the sets.

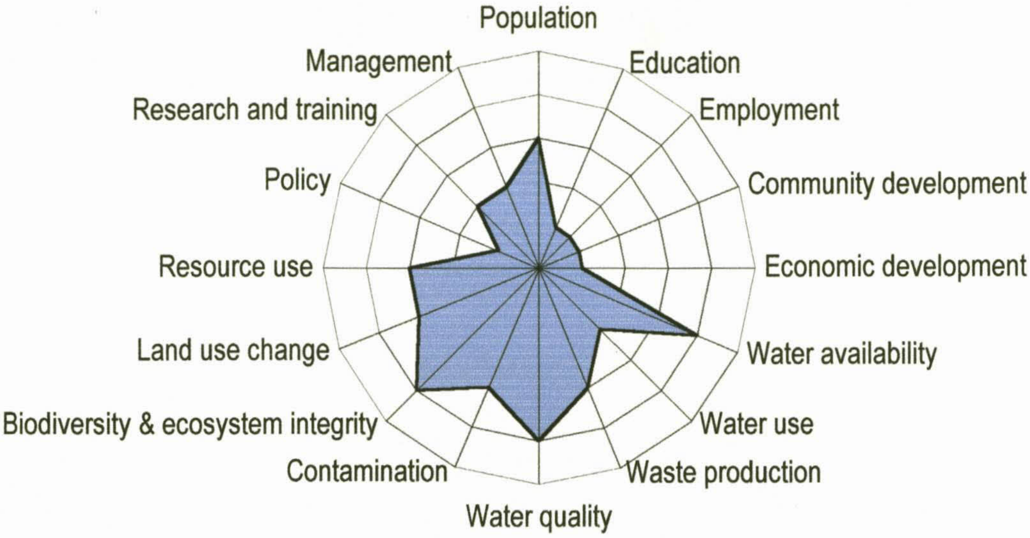


Figure 4.1: Number of organisations (0-5) that had indicators within each category.

A similar pattern was observed with the number of indicators per category (Figure 4.2), with *biodiversity and ecosystem integrity* having the highest number of indicators (fifteen), followed by *land use change* (twelve), *waste production* (ten), *water quality* (nine), *resource use* (eight) and *water availability* (eight). *Population, economic development, contamination* and *management* had six indicators in each, whilst *education*, *community development*, *research and training* and *water use* had the fewest indicators (three).

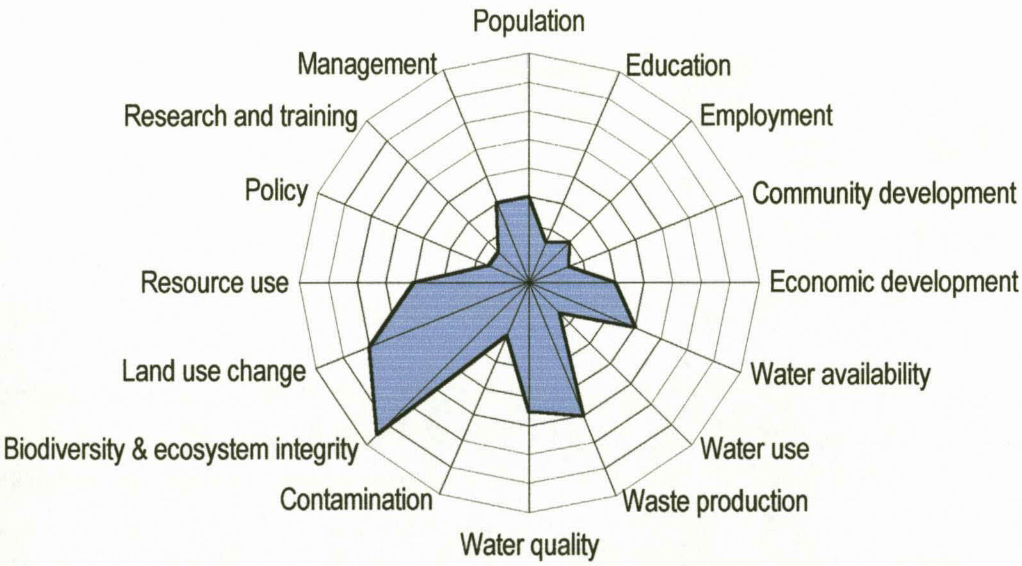


Figure 4.2: Number of indicators (0-10) within each category

The level of importance of each category can be assessed by summing the scores from the above two analyses to provide an index of importance (Figure 4.3). Figure 4.3 shows that *biodiversity and ecosystem integrity, land use change, water quality, waste production, water availability* and *resource use* are common categories, and are valuable at all levels of governance.

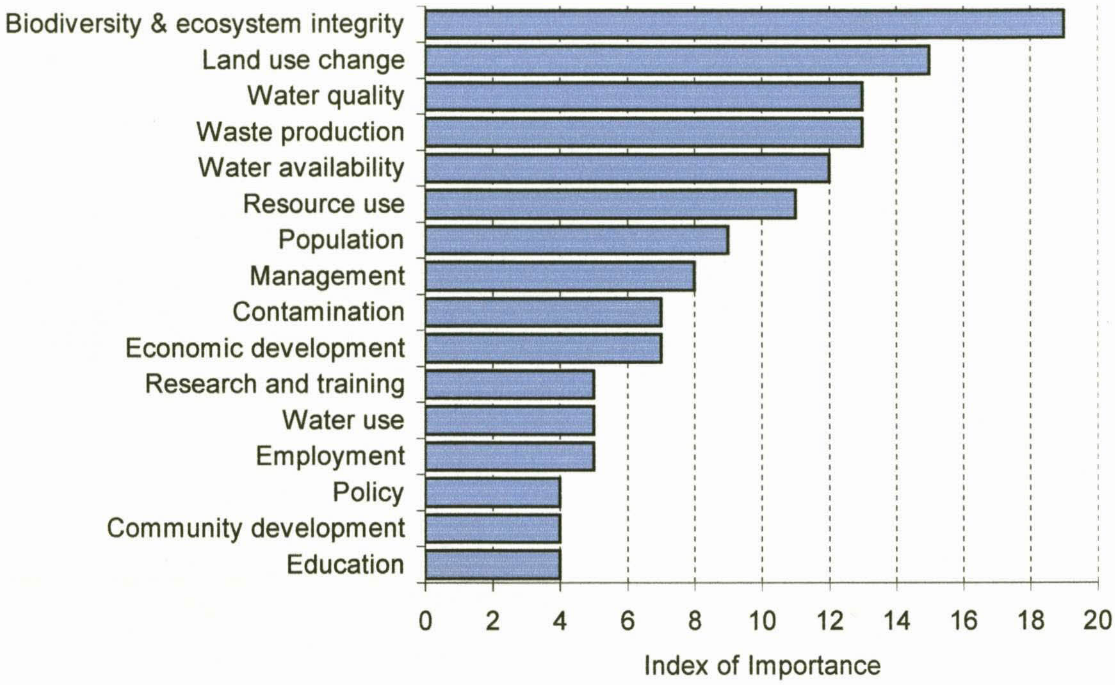


Figure 4.3: Index of importance for the various indicator categories.

Common indicators were also identified (Table 4.2). In each case, the indicator of one organisation did not have to be identical to a similar one in another organisation. However, if the sense behind the indicator was considered similar, it was assumed that there was commonality.

Table 4.2: List of indicators found in more than one indicator set

SOCIO-ECONOMIC	WATER BALANCE	WASTE AND POLLUTION	RESOURCE CONDITION	POLICY AND MANAGEMENT
Population growth Community involvement	Water availability Water use	Water quality trends Soil contamination Non-compliance	Species at risk Key species assessment Change in vegetation Agricultural impact Access to recreational opportunities Ecosystem health	None

4.4 GENERAL DISCUSSION

From the response to the survey by the 21 organisations approached (see Table 4.1), it is apparent that not many had developed sets of indicators for catchment management purposes. This was unexpected as the need for integrated catchment and water resources management is recognised throughout the world (DWAF & WRC 1996), and indicators are the ideal means by tracking changes in catchment conditions, and thus providing information for decision-making. There were a variety of reasons for this, including: the complexity of developing indicator sets for international catchments (e.g. Danube River; Mr H Fleckseder, Danube Programme Co-ordination Unit, *pers. comm.*), the lack of resources, and the lack of understanding of the use of indicators in catchment water resource management. However, even the five sets of indicators that were available provided an indication of some of the issues that need to be taken cognisance of while developing indicator sets for catchment management, as discussed below.

4.4.1 Frameworks

Indicators need to meet the requirements of the physical system under inspection. For instance, the functional aspects of the Fraser River and Murray Darling differ considerably, and certain key physical characteristics need to be taken into account to ensure that these are represented. In the Fraser River this may mean understanding the ecological requirements of the sockeye salmon and the influence of the natural forests on the system, whilst in the Murray-Darling system salinity is a major problem that requires understanding. These should be reflected in the indicators chosen. Therefore, a clear understanding of the physical environmental interactions and their socio-economic importance is required to develop a coherent set of indicators.

Walmsley (2001) has shown that one method of doing this is through the use of indicator frameworks such as the Pressure-State-Response (PSR) framework (Hammond *et al.* 1995; Gouzee *et al.* 1995; see Chapter 2) or the Driving-forces-Pressure-State-Impact-Response (DPSIR) framework (Smeets & Weterings 1999; see Chapter 2). Both the PSR and DPSIR frameworks have been used extensively in the development of state-of-the-environment reports (DEAT 1999). More recently, issues-based frameworks have been used to identify indicators (DEAT 2001, 2002).

Of the five indicator sets under review, the only one for which there was an obvious framework for development was the Fraser Basin set. These were developed from the Council's Sustainability Charter, which caters for all sustainability issues in the basin. It, therefore, provides an adequate framework for a set of sustainability indicators. The lack of an obvious framework in the other sets of indicators may stem from the indicators being developed primarily from a needs analysis, leading to issue-based indicators.

The use of one framework, does not preclude the use of another. It is recommended for South Africa that the physical and issues-based frameworks used in conjunction with each other to develop indicators that not only take into account the characteristics of the physical system, but also concentrate on current or emerging issues that will affect the future sustainability of any catchment.

4.4.2 Themes and indicators

The indicator sets evaluated in this chapter were different from each other. However, there were several recurring themes and indicators (see Figures 4.1, 4.2 and 4.3; Table 4.2). These give an indication of the common problems with regards to sustainability of water resources, and some of the key issues that need to be addressed for adequate catchment management. If the common themes are combined with the common indicators (Table 4.3), certain key issues emerge that should be considered for inclusion in a catchment sustainability indicator set for South Africa. These include:

- The *destruction of ecosystem integrity*, which may lead to biodiversity and habitat loss. These can be assessed through monitoring of high-risk species and key species or community assessments;
- *Waste production*, which is recognised as a major problem in both developing and developed countries. It leads to pollution of the environment and a deterioration in water quality;
- *Water quality* problems derived from excess pollutants entering freshwater systems. In South Africa these may include eutrophication, salinisation, microbiological deterioration, toxic pollutants and sedimentation;
- *Resource use*, in particular access to the resource for recreational purposes, although in South Africa, harvesting of the resources may be as important;
- *Terrestrial ecosystem condition*, which will have an impact on the water resource of the catchment, and
- *Population growth*, which has far-reaching repercussions in terms of development requirements, resource use and sustainability of a system.

All of the themes and indicators presented in Table 4.3 can be applied to the South African situation, and could provide a basis against which to assess a South African indicator set.

Table 4.3: Key themes and common indicators within these themes.

THEME	INDICATOR
Biodiversity and ecosystem integrity	Species at risk Key species assessment
Waste production	Amount of waste produced Compliance levels
Water quality	Water quality trends
Water balance	Amount available Water use
Resource use	Access to recreational opportunities
Land-use change	Change in vegetation Agricultural impact
Terrestrial ecosystem condition	Soil contamination Ecosystem health
Social issues	Population change Community involvement

4.4.3 Policy requirements of indicator sets

One of the reasons for the differences in indicator sets in general is that they are a reflection of policy, both national and organisational, upon which they have been based. In this instance:

- The Fraser Basin indicators focus on the need for sustainability, and are the best reflection of Integrated Catchment Management in the true sense of the term;
- The MDBC indicators reflect a policy of integrated water resource management and are based primarily on the management of the water resources, rather than the integration of all resources;
- The TVA indicators reflect mainly the anthropocentric needs, and
- The US EPA indicators reflect their mandate to concentrate primarily on pollution control and management, rather than integrated catchment management.

One of the essential requirements of developing catchment indicators for South Africa, is to ensure that they reflect the water resources and environment policies of the country. South Africa has recently undergone major transition in terms of both the water and environmental law in the country. The new legislation is underpinned by the concept of sustainability and any indicators based on the legislation could provide information on the progress towards environmental sustainability within the catchment context.

Indicators developed for catchment management should, thus, take into consideration the key environmental legislation. In the case of South Africa this includes the National Water Act (Act No. 36 of 1998) and the National Environmental Management Act (Act No. 107 of 1998). Other legislation and policy that may influence the choice of indicators will be: the National Forests Act (Act No. 84 of 1998);

the Mountain Catchment Areas Act (Act No. 63 of 1970); the Minerals Act (Act No. 50 of 1991) and the Minerals Development Draft Bill (2000); the Conservation of Agricultural Resources Act (Act No. 43 of 1983); the White Paper on Integrated Pollution and Waste Management (March 2000), and the White Paper on the Conservation and Sustainable Use of South Africa's Biological Diversity Policy (July 1997).

4.4.4 Stakeholder involvement

A common thread to all the indicator sets, was the participation of stakeholders (who influence or will be affected by management of the catchment) in their development. Although expert opinion is required to develop a set of indicators, the core indicators that are finally decided upon, should meet the requirements of stakeholders in the catchment. Obviously indicator sets cannot meet all the needs of all the stakeholders, but an attempt should be made to include the requirements of stakeholders in general. In South Africa, structures have been set up in many catchments for the involvement of stakeholders. Catchment management forums have either been set up, or are being set up for most of the highly-developed and sensitive catchments (e.g. the Upper Olifants River, Mpumalanga and the Palmiet River, Western Cape). Likewise, management of the water resources of South Africa at catchment level has been delegated to regional offices of the DWAF. Stakeholders who should be approached with regards to the development of indicators for sustainable catchment management include DWAF regional offices; water service providers such as Umgeni Water and Rand Water; local authorities; catchment management agencies and water forums.

4.4.5 Data availability

One of the issues that arose in the development of the indicator sets under review is that the development of indicator sets is often limited by data availability, and indicators are selected for data availability rather than for validity. The WRI indicator set, for instance, was largely based on the amount of data available world-wide, and is limited by some fairly gross-scale indicators. If, however, a core indicator set is developed that takes into account the physical system as well as the policy and management goals, the collection of data should be important enough that monitoring programmes be put in place. The selection of indicators should not rely on data availability, but rather be guided by what is available, or what can be collected within reasonable cost, effort and timeframe.

4.5 CONCLUSIONS

From this review, it was apparent that, around the World, the development of indicators for catchment management is uncommon, and can be considered as a relatively new science. There are, thus, no universally accepted methodologies for indicator development and use.

The indicator initiatives reviewed in this chapter showed bias towards the biophysical nature of catchment systems, with most of the indicators falling in the categories of biodiversity and ecosystem integrity, land use change, waste production and water quality, whilst few indicators were developed in the social categories of policy, community development and education (see Figures 4.2 and 4.3). Indicators of sustainability for catchment systems need to reflect the economic and social components of sustainability (see Figure 2.1, Chapter 2), and the methodologies for developing indicators should ensure their inclusion.

Each situation is unique, and that no two indicator sets will be alike. It is, however, possible to identify, from this review, some broad criteria for the development of sustainability indicators for catchments in South Africa:

- Indicators should reflect the physical characteristics of catchments and the human influences on these (i.e. integrated water resource management);
- Indicators should be relevant in terms of the current policy and management issues that affect catchment sustainability;
- The selection of indicators should not rely on data availability, but rather be guided by what is available, or what can be collected within reasonable cost, effort and timeframe.
- The indicator set developed should be useful for major stakeholders involved in catchment management, such as the DWAF, catchment management agencies, local authorities and service providers.

4.6 REFERENCES

AUSTRALIAN AND NEW ZEALAND ENVIRONMENT AND CONSERVATION COUNCIL (ANZECC). 1998. *Core Environmental Indicators for Reporting on the State of the Environment: Discussion Paper for Public Comment*. ANZECC, Canberra. 63 pp.

COMMONWEALTH OF AUSTRALIA. 1996. *Australia State of the Environment.* CSIRO Publishing, Collingwood.

CRABB P. 1997. *Murray-Darling Basin Resources: Murray-Darling Basin by Numbers.* MDBC, Canberra.

DEPARTMENT OF ENVIRONMENTAL AFFAIRS AND TOURISM (DEAT). 1999. *State of the Environment South Africa.* DEAT, Pretoria. http://www.ngo.grida.no/soesa.

DEPARTMENT OF ENVIRONMENTAL AFFAIRS AND TOURISM (DEAT). 2001. *National Core Set of Environmental Indicators for State of Environment Reporting in South Africa. Phase 1: Scoping Report. Volumes 1 & 2.* DEAT, Pretoria. 237 pp.

DEPARTMENT OF ENVIRONMENTAL AFFAIRS AND TOURISM (DEAT). 2002. *Environmental Indicators for National State of the Environment Reporting, South Africa 2002.* DEAT, Pretoria. 37 pp.

DEPARTMENT OF WATER AFFAIRS AND FORESTRY (DWAF) & WATER RESEARCH COMMISSION (WRC). 1996. *The Philosophy and Practice of Integrated Catchment Management: Implications for Water Resource Management in South Africa.* WRC Report No TT 81/96. WRC, Pretoria. 139 pp.

EERONHEIMO O, AHTI A & SAHLBERG S. 1997. *Criteria and Indicators for Sustainable Forest Management in Finland.* Ministry of Agriculture and Forestry, Helsinki. 70 pp.

ENVIRONMENTAL PROTECTION AGENCY (EPA).1996. *Environmental Indicators of Water Quality in the United States.* EPA, Washington DC. 25 pp.

ENVIRONMENTAL PROTECTION AGENCY (EPA). 2001 *United States Environmental Protection Agency.* http://www.epa.gov.

FOOD AND AGRICULTURE ORGANISATION (FAO). 1992. *Yearbook Fishery Statistics.* FAO, Rome.

FRASER BASIN COUNCIL. 1997. *Fraser Basin Council Charter for Sustainability.* Fraser Basin Council, Vancouver, BC.

FRASER BASIN COUNCIL. 2000. *Fraser Basin Council Sustainability Indicators Workbook.* Fraser Basin Council, Vancouver, BC. 45 pp.

GOUZEE N, MAZIJN B & BILLHARZ S. 1995. *Indicators of Sustainable Development for Decision-Making.* Federal Planning Office of Belgium, Brussels. 34 pp.

HAMMOND A, ADRIAANSE A, RODENBURG E, BRYANT D and WOODWARD R. 1995. *Environmental Indicators : A Systematic Approach to Measuring and Reporting on Environmental Policy Performance in the Context of Sustainable Development.* World Resources Institute, Washington. 42pp.

INSTITUTE OF NATURAL RESOURCES (INR). 2001. *Preparing Criteria, Indicators and Standards for Sustainable Forest Management in South Africa: A Set of Draft Indicators for Discussion. Committee for Sustainable Forest Management.* DWAF, Pretoria.

MURRAY-DARLING BASIN COMMISSION (MDBC). 1999. *Performance Indicators for the Murray-Darling Basin Sustainability Program: Final Project Report.* Murray-Darling Basin Commission, Canberra.

MURRAY-DARLING BASIN COMMISSION (MDBC). 2000a. The Basin Sustainability Program. In: *Basin Sustainability Program Reporting Guidelines Kit, August 2000.* Murray-Darling Basin Commission, Canberra.

MURRAY-DARLING BASIN COMMISSION (MDBC). 2000b. *Integrated Catchment Management in the Murray-Darling Basin 2001-2010: Delivering sustainable development.* Murray-Darling Basin Commission, Canberra.

OBST C. 2000. Report of the September 1999 OECD expert workshop on the measurement of sustainable development. In: Organisation for Economic Co-operation and Development. 2000. *Frameworks to Measure Sustainable Development*. OECD, Paris. pp. 7-17.

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT (OECD). 1991. *The State of the Environment*. OECD, Paris.

RAND WATER. 2000. *Catchment Diagnostic Framework. Report No. 5: Development of the Catchment Diagnostic Index*. Mzuri Consultants, Pretoria. 91 pp.

REVENGA C, BRUNNER J, HENNINGER N, KASSEM K & PAYNE R. 2000. *Pilot Analysis of Global Ecosystems: Freshwater Systems.* World Resources Institute, Washington, DC, 83 pp.

SMEETS E & WETERINGS R. 1999. *Environmental Indicators: Typology and Overview. Technical Report No. 25.* European Environment Agency, Copenhagen. 19 pp.

TENNESSEE VALLEY AUTHORITY (TVA). 2000. Government Performance and Results Act (GPRA): *Strategic Plan FY 2000-2005.* Tennessee Valley Authority, Chattanooga. 27 pp.

UNITED NATIONS ENVIRONMENT PROGRAMME (UNEP)/GRID-ARENDAL. 2002. UNEP/*GRID-Arendal SOE Reports*. http://www.grida.no/soe.

UNITED NATIONS ENVIRONMENT PROGRAMME (UNEP) and WORLD HEALTH ORGANISATION (WHO). 1988. *Assessment of Urban Air Quality Worldwide*. UNEP, Nairobi, Geneva.

WELLS J. 1992. *Pre-Impoundment Study of the Biological Diversity of the Benthic Macro-invertebrate Fauna of the Sabie-Sand River System.* MSc Thesis, University of Cape Town. 207 pp.

WALMSLEY JJ. 2001. Framework for measuring sustainable development in catchment systems. *Environ. Manage.* **29(2):** 195-206.

WALMSLEY JJ, CARDEN M, REVENGA C, SAGONA F & SMITH M. 2001. Indicators of sustainable development for catchment management in South Africa – Review of indicators from around the world. *Water SA* **27(4):** 539-550.

WARD CJ. 1990. Environment Indicators for State of the Environment Reporting. *Information Paper No. 21*. Centre for Resource Management, Canterbury, New Zealand.

WORLD BANK. 1995. *Monitoring Environmental Progress*. The World Bank, Washington DC. 84pp.

WORLD RESOURCES INSTITUTE (WRI). 2001. *World Resources Institute.* http://www.wri.org.

CHAPTER 5: DPSIR FRAMEWORK FOR IDENTIFICATION OF CATCHMENT MANAGEMENT ISSUES

5.1 INTRODUCTION

The Driving-Forces-Pressure-State-Impact-Response (DPSIR) concept has been used here as a framework to identify and develop indicators for catchment management. The advantages of this framework include its ability to describe the relationship between the origins and consequences of environmental problems, as well as identifying the dynamic links between elements in an environmental system. It also ensures that the social, economic and biophysical elements of sustainability are given equal weighting in the development of indicators. It is used in this chapter to characterise functional aspects of catchments by identifying the cause-and-effect relationships and, in doing so, identify key issues for sustainable catchments in South Africa.

Within this framework a linkage diagram has been developed showing conceptual links and inter-relationships between the DPSIR categories for a catchment-based situation (Figure 5.1). If core (or key) indicators for catchment management are identified within each of the categories present in the diagram, most major catchment-based management issues will be covered. Each of the elements within this causal diagram and there relevance to South Africa are discussed below.

This chapter formed the basis of a paper published in *Environmental Management* (Walmsley 2001; see Appendix E), although the conceptual foundation for it was developed over several projects prior to this study (see Walmsley *et al.* 1999; Rand Water 2000).

5.2 DRIVING FORCES

5.2.1 Natural conditions

The European Environment Agency (EEA) definition of driving forces (Smeets & Weterings 1999; http://glossary.eea.eu.int/EEAGlossary/D/driving_force 2002) excludes natural phenomena, and only includes human influence and activities. However, DEAT (1999) in the South African National State-of-the-Environment Report, recommends that natural conditions be included as driving forces. Certainly, in the catchment context, driving forces in the form of climate, geology and topography etc. determine the underlying character of a catchment and its water resources. Without knowledge of these aspects, any anthropogenic impacts and changes cannot be monitored and managed.

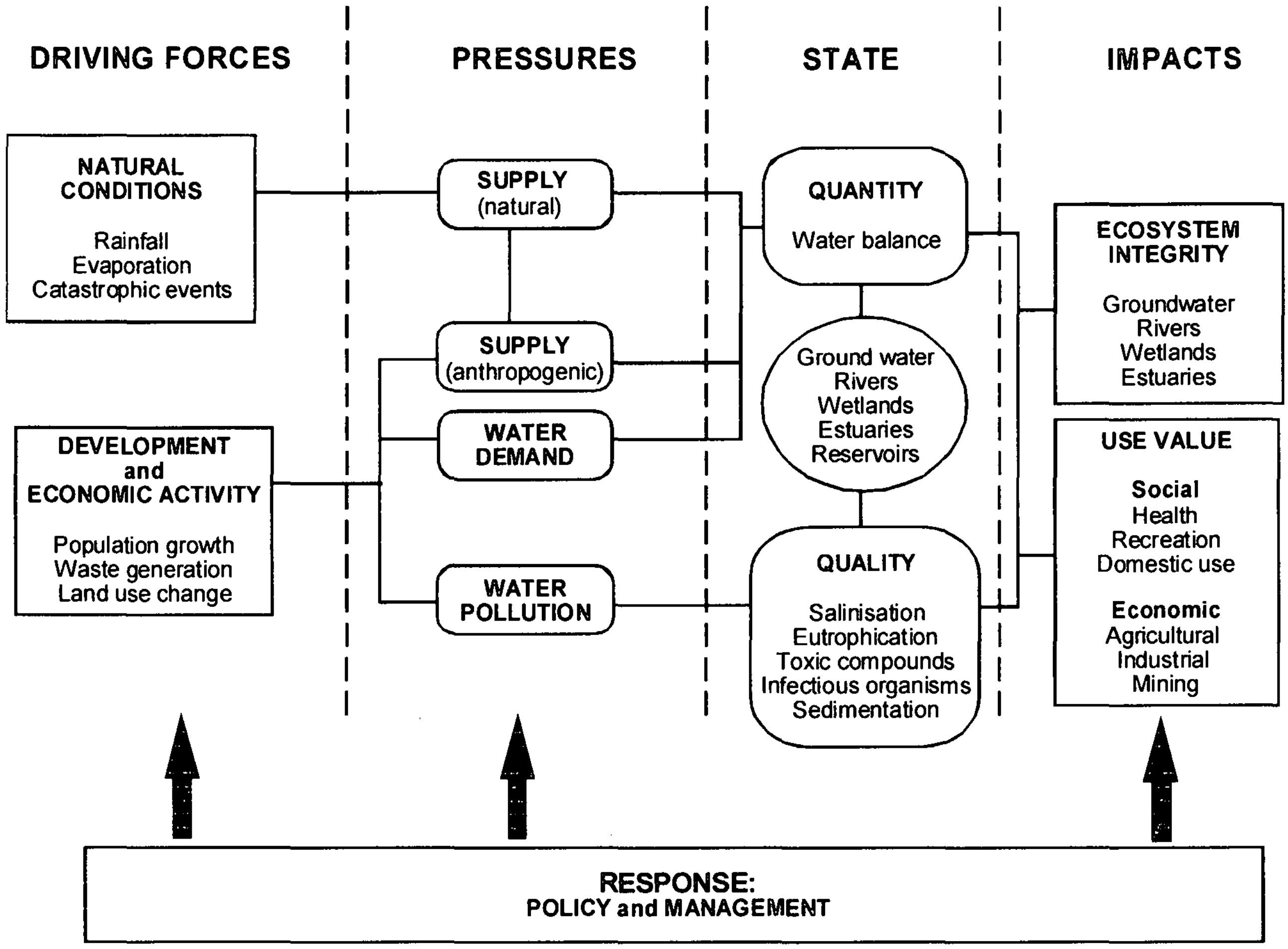


Figure 5.1: DPSIR diagram showing the functional inter-relationships of water resource issues at a catchment level.

In the catchment context, the most important of these natural conditions is the climate, which directly affects the amount of water in the system. High precipitation and low evaporation ensures an abundance of water, whilst low precipitation and high evaporation will create arid conditions. Catastrophic events such as droughts and floods also have a major influence on the character of the catchment.

For South Africa, the warm Agulhas current on the east coast, the cold Benguela current on the west, coupled to the topography of the sub-continent, have created an overall theme of aridity (Preston-Whyte & Tyson 1988). Climatic features affecting South Africa's aquatic environment include (Walmsley 1991; Walmsley *et al.* 1999):

- Low precipitation - with an average rainfall of 497 mm, the country is well below the world average of 860 mm;
- High temporal climatic variability with distinct seasonal rainfall patterns;

- High spatial climatic variability - the country has six rainfall regions with higher rainfall occurring on the east coast, and the country becoming progressively more arid towards the west;
- High evaporation rates - except for small areas on the coast and certain escarpments, evaporation exceeds rainfall;
- Prolonged droughts, which are often terminated by severe floods. During any one season certain areas may be experiencing drought whereas others severe flooding.

5.2.2 Development and economic activity

Over the last 50 years, the world has experienced an unprecedented growth in economic activity (Walmsley & Pretorius 1996), resulting in humans today using approximately 12 000 times more energy, mainly in the form of fossil fuels, than they did 400 generations ago (Munasinghe & Shearer 1995). For the purposes of developing indicators for catchment management, population growth, waste generation and land-use change have been identified as the key consequences of development and economic growth within catchments. These, in turn, place pressures on the environment that have direct effects on the water resources.

Some people may argue that population growth is not a consequence of economic development, but a cause. However, most will agree that population growth and economic development are closely inter-related and both have a direct effect on the quantity and waste produced and on the type of land use that the catchment is experiencing.

Some important socio-economic characteristics of South Africa that affect the use of water resources include (DEAT 1999):

- The South African population has grown from 5,17 million people in 1904 to approximately 43,3 million in 2000 (DEAT 1999; UNDP 2002), and has been growing by roughly 2% each year. With the advent of HIV/AIDS (affecting 20,1% of the adult population in South Africa), however, this growth rate is estimated to drop to 0,2% for the next decade (UNDP 2002).
- In South Africa, as elsewhere in the world, the major trend has been movement from rural to urban areas. In 1904, more than 75% of the South African population was living in rural areas, whereas today almost 57% of South Africans live in urban areas (DEAT 1999; UNDP 2002).
- In 2000, South Africa was ranked 107^{th} out of 173 countries in the international Human Development Index of the United Nations Development Programme (UNDP 2002), as opposed to 89^{th} in 1998 (UNDP 1998). This index attempts to measure the overall achievement of a country in three dimensions of human development, namely longevity, educational status and standard of living.

- In 2000, South Africans had an average life expectancy of 52,1 years (as opposed to 64,1 years in 1998) and a per capita income (purchasing price parity, PPP) of US$ 9 401 (UNDP 2002), an increase from the 1998 figure of PPP US$ 4 334. These figures indicated the dramatic effect of HIV AIDS on South African society.
- Poverty permeates all social sectors and is reflected in all aspects of life, with 22% of the South African population living below the national poverty line (UNDP 2002). Households in the lowest income group (15% of the population) only contribute 1,2% to national expenditure, whilst households in the highest income group spend nearly 35 times as much per year (DEAT 1999). This indicates a skewed income distribution, with a Gini coefficient of 0,593 (UNDP 2002).
- In 2000, the GDP for South Africa was US$125,9 billion, showing and annual growth of approximately 1% since 1990 (DEAT 1999; UNDP 2002).
- The South African macro-economy is characterised by high and increasing levels of unemployment and low but positive levels of economic growth, giving rise to the phenomenon called *jobless-growth* (DEAT 1999). The high growth that took place in the early 1990s was financed by long-term, risky, foreign investment, and recent disturbances in the capital market suggest that such a situation is not sustainable.
- It has been estimated that the informal sector accommodates approximately 1,8 million people, 12% of the labour force, which is approximately 15 million people in total. Their contribution to GDP was approximately R32 billion in 1997 or 7% of GDP (DEAT 1999).

5.3 PRESSURES

5.3.1 Natural supply

Like the driving forces, pressures on a resource can be either positive or negative. The natural supply of water to a catchment area is considered to be positive, although certain natural phenomena such as droughts and floods may have a negative effect on the quality of life of the human population in a catchment. From a natural environment point-of-view, the ecosystem is adapted to handle these fluctuations. The natural supply of water in a catchment is provided by the precipitation on the catchment, which is stored as surface water in rivers lakes, reservoirs, wetlands and estuaries, and as groundwater in aquifers.

The quantity of the surface water available is reflected in the mean annual runoff (MAR), which is the amount of water that reaches the river after evaporation and soil absorption. South Africa's hydrological regime is characterised by high variability, due to climatic conditions, and low water runoff, due to high evaporation and absorption by soils (Walmsley 1991). The country has a mean annual precipitation (MAP) to mean annual runoff (MAR) ratio of 8,6%; that is, only 8,6% of the rainfall is available as surface water. This is one of the lowest conversion ratios in the world. Canada and Australia, which have similar MAP figures, have ratios of 65,7% and 9,8% respectively. The resultant MAR for South Africa is estimated at 50 150 million m^3 a^{-1}. This is not distributed evenly throughout the country, with the eastern seaboard having high runoff, whilst the western regions tend to have low runoff.

Similar to surface waters, groundwater is relatively limited in South Africa compared to world averages (Walmsley *et al.* 1999). There are no aquifers or groundwater sources large enough to act as a sole supply for any of the larger urban areas or irrigation schemes (Basson *et al.* 1997). Of critical nature is the relationship between groundwater and surface water. Groundwater can only be abstracted on a sustainable basis at a rate less than, or equal to, the long-term average recharge of the resource through infiltration of rainwater. There are an estimated 50 000 new boreholes drilled in South Africa per year by the private sector, but the majority are dry or low yielding (Walmsley *et al.* 1999).

5.3.2 Anthropogenic supply

In many countries in the world, the natural water supply in a catchment needs to be supplemented with water from outside. In most cases this is due to the development in a catchment outstripping the water resource availability. Importation of water takes different forms, the cheapest of which is inter-basin transfer (IBT), where water is transferred via pipelines from one catchment to another (even one country to another). This has a negative effect on the water supply in one catchment, whilst fulfilling a need in another catchment. Other forms of water importation are desalinisation of sea-water, and transportation of icebergs.

Inter-basin transfers (IBTs) of water have had an important role to play in the development of South Africa. In all provinces, except the Limpopo Province, at least 50% of the provincial gross geographic product (GGP) is reliant on IBTs (Walmsley *et al.* 1999). Increased demand through population growth and economic activity will lead to an increase in IBTs, probably from international sources (e.g. Okovango River, Namibia).

In determining indicators of anthropogenic supply one must be careful of the syntactic difference between *availability* and *supply*. The term *supply* is used specifically by hydrologists as the amount of *water available for use*, and includes return flows. Although there is a fixed amount of water available in the catchment (availability = groundwater + MAR + IBTs), there is more available for use due to re-use of water in the form of return flows (supply = groundwater + MAR + IBTs + return flows). This can be confusing to the non-hydrologist and should be taken cognisance of when indicators are being developed.

Another source that falls under anthropogenic supply is the water made available through return flows. In effect this water can be utilised more than once. In South Africa the previous Water Act (Act No. 54 of 1956), which has now been repealed, required that all unused water be returned to source. This no longer applies, although the reuse of water is still considered to be an important aspect of water balance in the country.

5.3.3 Water demand

Water demand is the amount of water required by all water use sectors, including the mining, agriculture, industry, domestic and environmental sectors. Previously the environment was not considered as a legitimate water user, but there is an international trend in recognising the environmental as a legitimate water user. In South Africa, water for the environment (Ecological Reserve) and for basic human needs (drinking, cooking and hygiene; Basic Human Needs Reserve) is given priority in terms of water allocation. Sectoral water demand may be particularly important when considering policy development or catchment management issues.

As with the supply of water, both surface and groundwater demands should be taken into account. Some countries may rely heavily on their groundwater supplies, whilst others may rely on surface water resources. In both cases the demand for water needs to be seen in conjunction with supply to have any relevance.

The sectoral water requirements for surface water in South Africa for 1996 and 2000 are presented in Table 5.1. There was an estimated overall increase in water requirements of 3,5% between 1996 and 2000, mostly due to an increased awareness of the needs for environmental water. Discounting environmental demand, there was a drop in water requirements by about 4,4% per annum in that period. The environment is presently the largest sector, followed by the urban and rural domestic sector. Groundwater demand has increased, from approximately 1 790 million $m^3 a^{-1}$ in 1980 to over 2 000 million $m^3 a^{-1}$ in 1999. Seventy-eight percent of this water is utilised by the irrigation sector (Walmsley *et al.* 1999).

Table 5.1: Summary of sectoral water requirements for 1996 and 2000 (from Walmsley *et al.* 1999; DWAF 2002a).

SECTOR	1996 (million m^3 a^{-1})	2000 (million m^3 a^{-1})	% INCREASE PER ANNUM
Urban & domestic	2 171	3 904	19,9
Mining & industrial	1 598	1 052	-8,5
Irrigation & afforestation	12 344	8 324	-8,1
Environmental	3 932	9 544	35,7
TOTAL	20 045	22 824	3,5

In South Africa, the demand for water does not necessarily coincide with the spatial distribution of water. The country's urban and industrialised areas (Cape Town, Port Elizabeth, East London, Durban, Pietermaritzburg, Bloemfontein, Kimberley, Polokwane, and Gauteng Province) are the most water stressed, and will become more so as the population increases and the demand for water in the urban and domestic sector increases. Because of the spatial variability of water resources and the scarcity of water throughout the country, in many catchments the need for water exceeds the supply (e.g. the Vaal, Lower Orange, Sundays, Great Fish, Olifants (Mpumalanga) and Crocodile/Limpopo rivers).

5.3.4 Water pollution

Pollution is one of the greatest threats to water resources throughout the world. It is defined by as the *presence of any substance that impairs the usefulness of water* (adapted from Dallas & Day 1993). Freshwater pollutants originate mainly from industrial, mining, domestic and agricultural sources. Those of greatest concern include organic and inorganic chemicals, plant nutrients, oxygen-demanding wastes, radioactive materials, sediment and microbiological contaminants (DEAT 1996). The type and amount of pollution will vary from catchment to catchment, depending on the land-use and development patterns within each catchment. It is impossible to monitor all forms of pollution and indicators will have to be chosen keeping in mind the dominant land use of a catchment.

Typical pollutants of South Africa's freshwater aquatic environment include industrial effluents; domestic and commercial sewage; acid mine drainage; agricultural runoff, and litter. However, the total amount of waste-water (industrial, mining and domestic effluent, and agricultural and urban runoff) entering South Africa's surface waters is unknown (Walmsley *et al.* 1999). Diffuse sources of pollution are difficult to quantify and, although point sources can be identified and measured, the data are fragmented. A survey by the University of Pretoria (1996) indicated that the total volume of domestic and commercial waste-water treated at water care works throughout the country was about 2 600 Mℓ d^{-1}.

Of concern to water resource managers are the diffuse sources of pollution that are difficult to quantify. In the past, agricultural runoff, including nutrients, pesticides and herbicides, was of major concern. However, the increase in informal settlements, with high poverty levels and inadequate sanitation, may become one of the greatest localised pressures for water quality in South Africa (Walmsley *et al.* 1999).

To give an indication of the type of pollution pressures on South Africa's water resources, the Vaal Barrage catchment is taken as an example. Water from the Vaal Barrage catchment supplies the whole of Gauteng, which contributes about 37,6 % of the country's GNP and contains about 18,1% of the population (Stats SA 1998). The pollution pressures on the catchment include (Walmsley *et al.* 1999):

- Thirty-three water care works, which treat commercial and domestic effluents, discharge an average volume of 859 Mℓd^{-1}. Problems caused by these effluents are ortho-phosphates, COD, ammonium, suspended solids and faecal coliforms. Only 60% of these water care works comply to the 1 mg $ℓ^{-1}$ phosphate standard (see section 3.6).
- Fifteen extant gold mines and 29 closed mines are distributed on the North side of the catchment. Acid drainage from these mines is a recognised problem, increasing sulphate, suspended solids and metals (manganese, aluminium, iron) and decreasing the pH of the receiving water resources. An average of 240 MRd^{-1} of polluted water has to be pumped to the surface from these mines (Wingrove *et al.* 1998).
- The volume of return flows into streams from industrial plants is not known, although it is estimated that this figure would not exceed 100 Mℓd^{-1}. Problem elements are arsenic, COD, BOD, manganese and suspended solids.
- Litter from informal settlements and recreational visitors is also a problem, although no figures can be given.

5.4 STATE

The state of water resources in a catchment should be described in terms of both quantity and quality. Both the amount of water in the system and the quality of that water are essential in terms of ecosystem viability, as well as use value. It should be remembered that descriptions of *state* should provide information on the current status of a catchment. The three spatial dimensions of river systems need to be taken into account (longitudinal, vertical and lateral), as well as short-term variations (i.e. seasonal changes).

5.4.1 Quantity

The state of a catchment's water resources is dependent on the right amount of water being available at the right time. All catchments undergo seasonal and long-term variations in water quantity. The natural system relies on these variations, to which they are adapted (including catastrophic events such as floods and droughts), to maintain ecosystem integrity. For instance, breeding seasons of the fauna are dependent on seasonal changes in the water level, whilst floods clear the system of weeds such as water hyacinth. On the other hand, humans prefer the system to be constant. To ensure sustainability, there should be a balance between the regulation of rivers and their natural flow regime.

All the ecosystems that make up the freshwater resources of a catchment need to be taken into account when describing water quantity. These include groundwater, rivers, wetlands, lakes, reservoirs and estuaries. Wetlands, estuaries, lakes and reservoirs all form an important part of the whole river ecosystem, while the groundwater is continually replenished by surface waters. The balance between the availability of water and water removed from the system (supply and demand) will be crucial in the viability of these ecosystems. As with all the other categories, there are a large number of indicators that could describe the state of each ecosystem, and the choice will depend on the importance and character of the ecosystems within each catchment.

The South African landscape contains several types of aquatic ecosystem (Noble & Hemens 1978; Walmsley 1991), including:

- **Wetlands** - Wetlands are some of the most threatened aquatic habitats in South Africa (Walmsley 1991). Threats to wetlands include human development activities, canalisation, drainage, crop production, effluent disposal and water abstraction; that is, most land-use changes. Begg (1986) states that "*wetlands formerly occupied between 10 and 15% of every catchment in Natal. Within the last fifty years wetlands in these same areas have been reduced to a few scattered remnants, and in certain catchments virtually eliminated*". This probably applies to the rest of South Africa, but little is known about the extent of previously-existing wetland areas.
- **Endorheic pans and lakes** - The drier parts of the country contain numerous endorheic (have no outlet) pans that are semi-permanently or periodically filled with water. Their value is largely to provide habitats for organisms within arid areas. However, several of the larger systems (e.g. Lake Chrissie, 1 000 ha; Barberspan, 2 000 ha) are more permanent and have been used as a water supply for irrigation (Walmsley 1991).

- **Coastal and estuarine lakes** – South Africa has a unique set of coastal and estuarine lakes that either are not normally not influenced by the sea and contain fresh or brackish water (e.g. Lake Sibaya, Mzingazi, Zeeloeivlei), or are temporarily connected to the sea (e.g. Wilderness Lakes, Kosi system, St Lucia) (Walmsley 1991).
- **Estuaries** – There are about 200 estuarine systems in South Africa, having a total area of between 500 and 600 km^2, of which 400 km^2 are in KwaZulu-Natal. Heydorn (1990) reported that the general ecological condition of estuaries was poor, with more than 70% displaying adverse symptoms caused by deprivation of freshwater inputs, increased sediment deposition and pollution.
- **Reservoirs** - The scarcity of freshwater resources and highly variable hydrological conditions have led to every river in South Africa being regulated in order to ensure water supply for development (Walmsley *et al.* 1999). Water budgets for South Africa generally take into account the amount of water that can still be stored in reservoirs, without permanently destroying riverine environments. Often this figure does not take into account farm dams, which, although small have a cumulative effect on the functioning of river systems. A graph of the cumulative capacity of both large and small dams (Figure 5.2) indicates that by 1990 the maximum utilisable MAR in South Africa had already been exceeded.

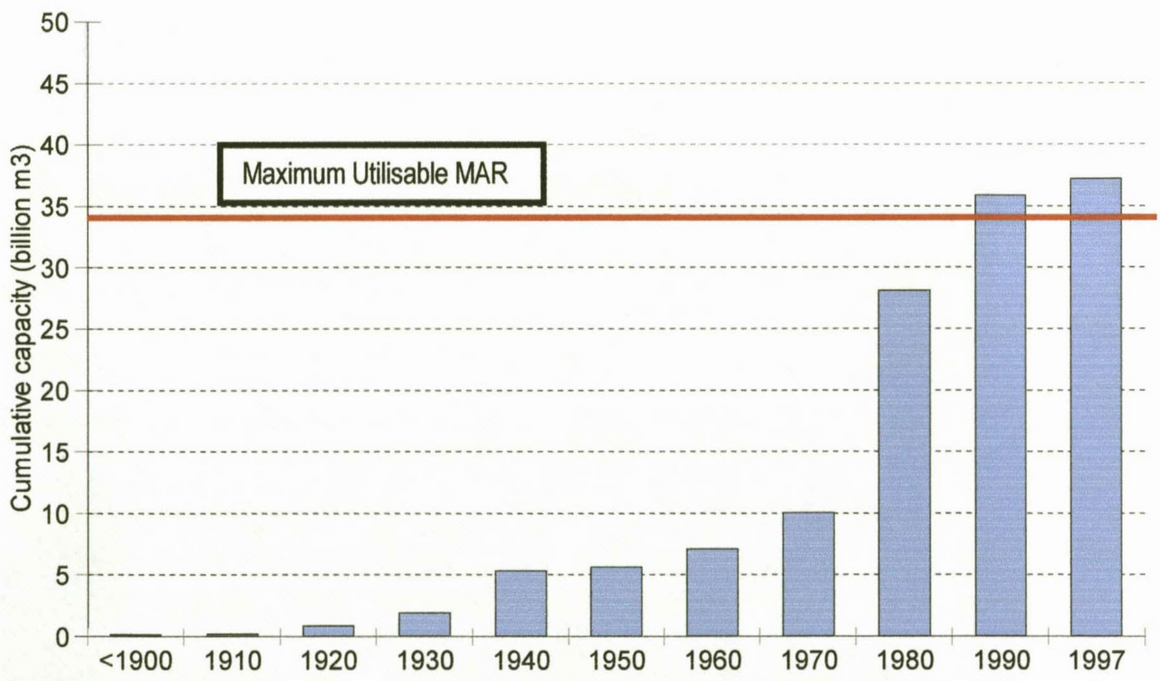


Figure5.2: Cumulative capacity of both large and small reservoirs in South Africa.

- **Rivers** - There are 22 primary drainage regions in South Africa, each containing river systems of various lengths and MAR. Despite a high ecological and recreational value in a generally arid landscape, the major concern of policy-makers and resource managers has been the role of rivers in supplying water (through impoundment and inter-basin transfer), and in their ability to assimilate urban and industrial effluents.

- **Groundwater –** Although groundwater supplies in South Africa are limited, most rural inhabitants are reliant on groundwater. The largest aquifers are in the east of the country and in the coastal region of the Western Cape. Many of the groundwater resources of the country have been over-utilised, leading to drying up of springs and boreholes (Basson *et al.* 1997).

5.4.2 Water quality

The quality of water in a catchment obviously depends on the level and sources of pollution. The type of water quality problems will obviously vary from catchment to catchment, but several generic problems have been identified, all of which apply to the South African situation (DEAT 1996; Walmsley *et al.* 1999):

- *Salinisation* reduces crop yields, leads to salinisation of irrigated soils, increases scaling and corrosion, and increases the need for pre-treatment of water for industrial purposes. Sources include municipal, mining and industrial effluents, irrigation return water, runoff from urban settlements and seepage from waste disposal sites.
- *Eutrophication* causes taste and odour problems, limits recreational use and can limit stock watering due to the presence of toxic algae. Sources of plant nutrients, which cause eutrophication, include agricultural and urban fertilisers, sewage and effluent discharges.
- *Sedimentation* reduces the storage capacity of reservoirs, as well as affecting the ecological functioning of a system. Activities promoting erosion and increasing sedimentation include agriculture, forestry, construction activities, open-cast mining and other disturbances of vegetation.
- *Toxic inorganic compounds* include heavy metals (e.g. mercury, lead, tin, cadmium), highly toxic elements (e.g. selenium, arsenic) and inorganic substances such as acids, nitrates and chlorine compounds that become toxic in high concentrations. Sources include industrial processes like metal finishing, mineral refining, plastics and chemical industries, and household solvents.
- *Toxic organic compounds* include pesticides, plastics, paints, colourants, pharmaceuticals and many other products. Many are persistent and bio-accumulative toxins. The largest source of these is improper disposal of household and industrial waste.
- *Infectious organisms*, such as disease-causing micro-organisms and parasites, are a major cause of health problems. Human settlements are the main source of these pollutants, which enter the water in the form of partially-treated or untreated sewage, seepage from pit latrines and runoff

from settlements with inadequate sanitation and waste disposal facilities.

- *Oxygen-demanding wastes*, including sewage, paper and pulp effluent and food-processing wastes, increase the oxygen consumption of bacteria and reduce the availability for other aquatic life.

5.5 IMPACTS

Changes in water quality and quantity have two major impacts, one on the environmental sub-system, in the form of *ecosystem integrity*, and one on the human sub-system, in the form of *use value*.

5.5.1 Ecosystem integrity

Any anthropogenic changes to a natural ecosystem, may have a negative impact on the balance of that ecosystem, i.e. it will affect the functional integrity of the system. This may take the form of invasion by alien species, increase in the numbers of pest species, decrease in biodiversity, and inability of the system to clean itself etc. In most of these cases, the result will have direct or indirect economic consequences. Once again, the type of environmental impact that is experienced will vary from catchment to catchment, depending on the sensitivity of the catchment and the level of disturbance.

Typical ecological changes that have occurred in the South African freshwater environment include:

- **Habitat loss** - A good example of extensive habitat loss is that of natural wetlands. Kotze *et al.* (1995) hypothesized the extent of natural wetland loss in South Africa, based on isolated reports and climatic and physiographic information. It is estimated that parts of the Western Cape, Eastern Cape and KwaZulu/Natal have less than 50 % of the natural wetlands left. Additionally, riverine habitats have been so changed, that little remains of natural systems in South Africa. Many perennial rivers have become seasonal (e.g. Limpopo, Levuvhu, Letaba); floodplains that rely on regular flooding have become less productive (e.g. Pongola), and some estuaries can no longer rely on natural opening of the estuary mouth (e.g. Umfolozi).
- **Biodiversity loss** - Loss of or changes in habitat have resulted in changes in biotic composition and loss of biological diversity. Unfortunately the freshwater fauna (especially invertebrates) of South Africa are not well documented, although attempts have been made over the last decade to remedy this. Although outdated, a list of threatened freshwater and estuarine plant and animal species is available in Noble & Hemens (1978). Little information is available on loss of aquatic invertebrates (represented by a single dragonfly species), but 24 plant species, 25 fish species, 6

amphibians, 2 reptiles, 24 birds and 2 mammals are included in the Red Data Book list. Of these, one fern, *Christella altissima* is extinct.

- **Invasive species** - Invasive or pest species, detrimental to the natural environment or to human populations, may be alien to an area, introduced either accidentally or deliberately, or indigenous to an area, but become invasive when habitat changes create perfect conditions for their habits and life cycles. De Moor & Bruton (1988) have compiled an atlas of all alien and translocated indigenous aquatic animals in South Africa. There are 42 known alien species (16 invertebrates, 23 fish, 1 reptile and 2 birds) in South African waters and at least 74 translocated indigenous species (74 fish, unknown number of invertebrates). Of these, 37 have a known detrimental effect on the environment (De Moor & Bruton 1988). Some alien aquatic macrophytes have flourished because of changes in flow regime and hypertrophic conditions. This has severe economic implications for South Africa as they cover and choke vast areas of standing and slow-running waters. Of special concern are water hyacinth (*Eichhornia cassipes*), parrot's feather (*Myriophyllum aquaticum,*) Kariba weed (*Salvinia molesta*) and the water fern, *Azolla filiculoides*.

5.5.2 Use value

If the resource is to be maintained for the purpose of human development on a sustainable basis, then the use value of the resource should not decline. Uses that need to be taken into account include social elements such as health, recreation and domestic use, and economic elements such as agricultural, industrial (including power generation) and mining use.

The use value of a system is directly related to ecosystem integrity. If the ecosystem is not functioning properly, this will have a direct effect on use value. For instance, the introduction of plant nutrients will lead to eutrophication, which creates and imbalance in the system, causing algal blooms, which decrease the use value for industrial purposes that require clean water and for domestic use. In both cases, treatment costs will rise, negatively affecting the economic value of the water in the system. It may or may not be possible to pin a financial cost on a drop in use value.

The National Water Resource Strategy of the Department of Water Affairs and Forestry (2002) recognises water as a national asset for South Africa. The resource should, therefore, be used to the best benefit of all the people of the country. Although it is recognised that local needs should be catered for, the use value of South Africa's water resources are generally viewed in the national context.

In general local impacts of a declining use value are related to inequitable access to the resource, which is still prevalent in South Africa. This is particularly true in poor communities that rely on freshwater ecosystems to fulfil their needs. Secondary impacts include an increase in water-borne diseases, as well as loss of cultural usage (e.g. creative and religious use).

5.6 RESPONSES

Responses to a catchment problem may be applied anywhere in the causal chain outlined above. Generally, responses aim at adjusting anthropogenic pressures caused by development or by mitigating impacts. They are rarely able to make an impact on the driving forces.

Responses in the context of the DPSIR framework generally apply to more long-term management actions, rather than emergency measures. They may include policy development in the form of international treaties, national and local legislation, and catchment management plans. A more indirect response may be the expansion of the knowledge base, in the form of research and monitoring.

International treaties, protocols and policies that influences South Africa's water resources management at catchment level include:

- Helsinki Rules on shared water-courses, which state that each basin state has a right to the reasonable and equitable share of the water in the basin and that the greatest benefit should be achieved with the least disadvantage to other states;
- SADC Protocol on Shared Water Course Systems, which has been ratified by South Africa, Lesotho, Botswana and Mauritius, and
- Convention on Wetlands of International Importance, especially as Waterfowl habitat (Ramsar Convention 1971).

Several commissions, committees and organisations ensure that there is co-operation between South Africa and her neighbours where international rivers are concerned including:

- Botswana-RSA Joint Permanent Technical Water Committee;
- Lesotho Highlands Water Commission (Lesotho, RSA);
- Limpopo Basin Permanent Technical Committee;
- Mozambique-RSA Joint Water Commission;
- Orange-Senqu River Basin Commission (RSA, Namibia, Lesotho and Botswana);
- Permanent Water Commission (RSA, Namibia);
- Swaziland-RSA Joint Water Commission, and
- Swaziland-Mozambique-RSA Tripartite Permanent Technical Committee.

In terms of South African legislation and policy, most legislation and policy pertaining to the environment affects water resources, either directly or indirectly. These include:

- **Water Services Act 108 of 1997** - provides for the rights of access to basic water supply and basic sanitation and the institutional structures required to provide water.
- **National Water Act 36 of 1998** - provides for the reform of the water law relating to water resources.
- **Environment Conservation Act 73 of 1989** - provides for the effective protection and controlled utilisation of the environment.
- **National Environmental Management Act 107 of 1998** - provides for co-operative environmental governance by establishing principles for environmental decision-making; identifies institutions that will promote co-operative governance and determines procedures for co-ordinating environmental functions of state departments.
- **National Forests Act 84 of 1998** – provides for sustainable forest management, which impacts on water resources use.
- **Minerals Development Draft Bill 2000** - regulates prospecting for and exploitation, processing and utilization of minerals, taking into account the National Environmental Management Act and the National Water Act.
- **Mountain Catchment Areas Act 63 of 1976** - recognises mountain catchments as sensitive areas and makes provision for their conservation.
- **Conservation of Agricultural Resources Act 43 of 1983** - provides control over the utilisation of the natural agricultural resources in order to promote the conservation of the soil, the water sources and the vegetation and to combat weeds and invader plants.
- **White Paper on Integrated Pollution and Waste Management in South Africa 2000** - provides the policy framework for pollution prevention, waste minimisation, impact control and remediation for all media (air, water, land) in South Africa.
- **White Paper on the Conservation and Sustainable Use of South Africa's Biological Diversity 1997** – provides the foundation for South Africa's fulfilment of the country's international obligation to the UN Convention on Biological Diversity.

5.7 IDENTIFICATION OF ISSUES IN SOUTH AFRICA

Figure 5.3 summarises the main characteristics of the South African water environment in the context of the DPSIR framework. These core characteristics can be applied at any catchment level, from large basin catchments (such as the Orange and Vaal River Basins), to quaternary catchments or hydrological units.

In other words, it can be applied to any appropriate management unit, and also provides the basis for identifying sustainability issues for the identification of indicators.

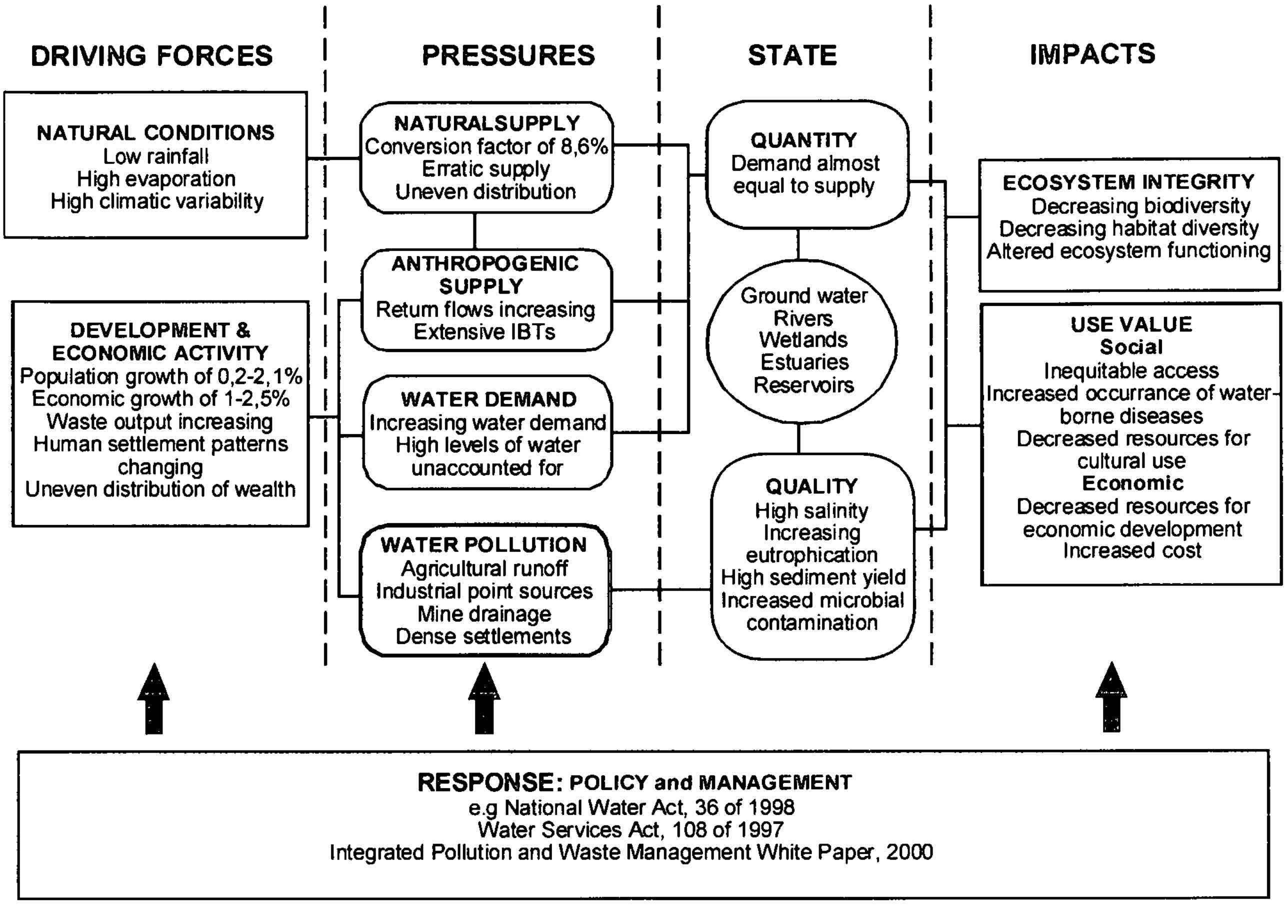


Figure 5.3: DPSIR diagram for South Africa, showing key issues for the management of the country's freshwater resources.

Issues identified through the use of the DPSIR framework include (not necessarily in order of importance):

- Population growth;
- Economic growth;
- Increased waste output;
- Changing human settlement patterns (especially urbanisation);
- Uneven distribution of wealth (and other resources);
- Variable water supply in time and spatially;
- Extensive IBTs and river regulation;
- Increased return flows;
- Increasing water demand;
- High levels of unaccounted-for water;

- Inequitable access to water and water-based resources;
- Increased occurrence of water- borne diseases;
- Decreased resources for cultural use;
- Decreased resources for economic development, and
- Increased cost of supplying enough water of the right quality.

The DPSIR framework has provided an adequate foundation to characterise catchment functioning and identify some of the issues that are relevant to water resource management in South Africa today. However, the issues identified here are fairly broad and need to be placed in the policy context (Chapter 6) and then further refined (Chapters 7 and 8).

5.8 REFERENCES

ALLANSON BR, HART RC, O'KEEFFE JH & ROBARTS RD. 1990. *Inland Waters of Southern Africa: An Ecological Perspective*. Kluwer Academic Publishers, Dordrecht. 457 pp.

BASSON PH, VAN NIEKERK PH & VAN ROOYEN JA. 1997. *Overview of Water Resources Availability and Utilisation in South Africa*. DWAF, Pretoria. Report PRSA/00/0197. 72pp.

BEGG GW. 1986. *The Wetlands of Natal. Part I. An Overview of Their Extent, Role and Present Status.* Natal Town and Regional Planning Report No. 68. Pietermaritzburg. 115 pp.

DALLAS HF &. DAY JA. 1993. *The Effect of Water Quality Variables on Riverine Ecosystems: A Review.* Water Research Commission, Pretoria. 240 pp.

DE MOOR IJ & BRUTON MN. 1988. *Atlas of alien and translocated indigenous aquatic animals in southern Africa.* South African National Scientific Programmes Report No. 144. CSIR, Pretoria. 310 pp.

DEPARTMENT OF ENVIRONMENTAL AFFAIRS AND TOURISM (DEAT). 1996. *Integrated Pollution Control and Waste Management: The Need for Integrated Pollution Control in South Africa.* DEAT, Pretoria, 57 pp.

DEPARTMENT OF ENVIRONMENTAL AFFAIRS AND TOURISM (DEAT). 1999. *State of the Environment South Africa.* DEAT, Pretoria. http://www.ngo.grida.no/soesa.

DEPARTMENT OF WATER AFFAIRS AND FORESTRY (DWAF). 2002. *Proposed First Edition National Water Resource Strategy: Summary.* DWAF, Pretoria. 37 pp. http://www.dwaf.gov.za.

HEYDORN AEF. 1989. The conservation status if South African estuaries. In: BJ Huntley (Ed), *Biotic Diversity in Southern Africa.* Oxford University Press. Pp. 51-77.

KOTZE DC, BREEN CM & QUINN N. 1995. Wetland losses in South Africa. In: GI Cowan (Ed), *Wetlands of South Africa.* DEAT, Pretoria. pp. 263-272.

MUNASINGHE M & SHEARER W (eds). 1995. *Defining and Measuring Sustainability: The Biophysical Foundations.* World Bank, Washington, 440 pp.

NOBLE RG & HEMENS J. 1978. *Inland water ecosystems in South Africa - a review of research needs* . South African National Scientific Programmes Report No. 34. CSIR, Pretoria.150 pp.

PRESTON-WHYTE RA & TYSON PD. 1988. *The Atmosphere and Weather of Southern Africa.* Oxford University Press, Cape Town. 375 pp.

RAND WATER. 2000. *Catchment Diagnostic Framework. Report No. 5: Development of the Catchment Diagnostic Index*. Mzuri Consultants, Pretoria. 91 pp.

SMEETS E & WETERINGS R. 1999. *Environmental Indicators: Typology and Overview. Technical Report No. 25.* European Environment Agency, Copenhagen. 19 pp.

STATISTICS SOUTH AFRICA (STATS SA). 1998. *The People of South Africa Population Census, 1996.* Report No.1:03-01-11. Stats SA, Pretoria.

UNITED NATIONS DEVELOPMENT PROGRAMME (UNDP). 1998. *Human Development Index*. UNDP, Nairobi. http://www.undp.org/hdr1998 .

UNITED NATIONS DEVELOPMENT PROGRAMME (UNDP). 2002. *Human Development Index*. UNDP, Nairobi. http://www.undp.org/hdr2002/.

UNIVERSITY OF PRETORIA. 1996. *Survey of Water Treatment in South Africa.* University of Pretoria, Survey Division, Pretoria.

WALMSLEY JJ. 2001. Framework for measuring sustainable development in catchment systems. *Environ. Manage.* **29(2):** 195-206.

WALMSLEY JJ, WALMSLEY RD & SILBERBAUER M. 1999. Chapter 3: Sustainability of Freshwater Systems and Resources. In: Department of Environmental Affairs and Tourism (Ed), *State of the Environment in South Africa*, DEAT Pretoria. http://www.ngo.grida.no/soesa.

WALMSLEY RD. 1991. Stream environments and catchment processes - a South African perspective. In: JJ Pigram & BP Hooper (eds), *Water Allocation to the Environment - Proceedings of an International Seminar and Workshop*. The Centre for Water Policy Research, University of New England, Armidale. pp 45-57.

WALMSLEY RD & PRETORIUS JPR. 1996. *Environmental Indicators. Report No. 1. State of the Environment Series*. Department of Environmental Affairs and Tourism, Pretoria. 76pp.

WINGROVE A, PATERSON B & MCEWAN L. 1998. *The Amanzi Water Treatment Venture: Briefing Paper for Interested and Affected Parties*. JCI, Johannesburg.

CHAPTER 6: POLICY REQUIREMENTS OF INDICATORS FOR CATCHMENT MANAGEMENT IN SOUTH AFRICA

6.1 INTRODUCTION

As part of the transformation process, the policy and legislation in South Africa has been completely revised since 1994. The current ANC-led Government has taken the opportunity not only to repeal past apartheid legislation, but also to introduce legislation and policy that is innovative and forward thinking in terms of sustainable development. Most of the key legislation, including that mentioned in this chapter, has been developed in a participatory manner with stakeholders, communities and interested parties throughout South Africa. Although this has lengthened the process of developing the required legislation, it ensures that the policy of the country reflects the needs of South African citizens.

This chapter discusses the key policy and legislation that impacts on water resources management in the country. This includes environmental legislation as well as the water law. The relationship between these key policies and Acts is shown in Figure 6.1. The implication here is that the essential legislation includes the National Water Act and the Water Services Act (water law) at the same level as the National Environmental Management Act and the Environmental Conservation Act (environmental law) for the purpose of managing a catchment. The National Forests Act, Minerals Act, Minerals Development Bill, Conservation of Agricultural Resources Act and biodiversity policy will impact on water resources management at a catchment level, but will not drive it. The integrated pollution and waste management policy will ultimately become a driving force once it is legislated, but currently it has no legislative power. Overarching all the legislation and policy is the Constitution, which forms the basis of South Africa's legal system.

Legislation and policy affect the development of indicators in several ways:

1. The policy of a country tends to highlight key areas of concern, or current issues that require management. This is particularly so in South Africa where the policy has recently been developed through a participatory process;
2. Legislated reporting requirements might show which indicators would be valuable, and
3. Policy might indicate how indicators could best be used to be of benefit to the country.

Likewise indicators can prove to be an invaluable tool for analysing and reporting on the effectiveness of policy, and as a basis for information management.

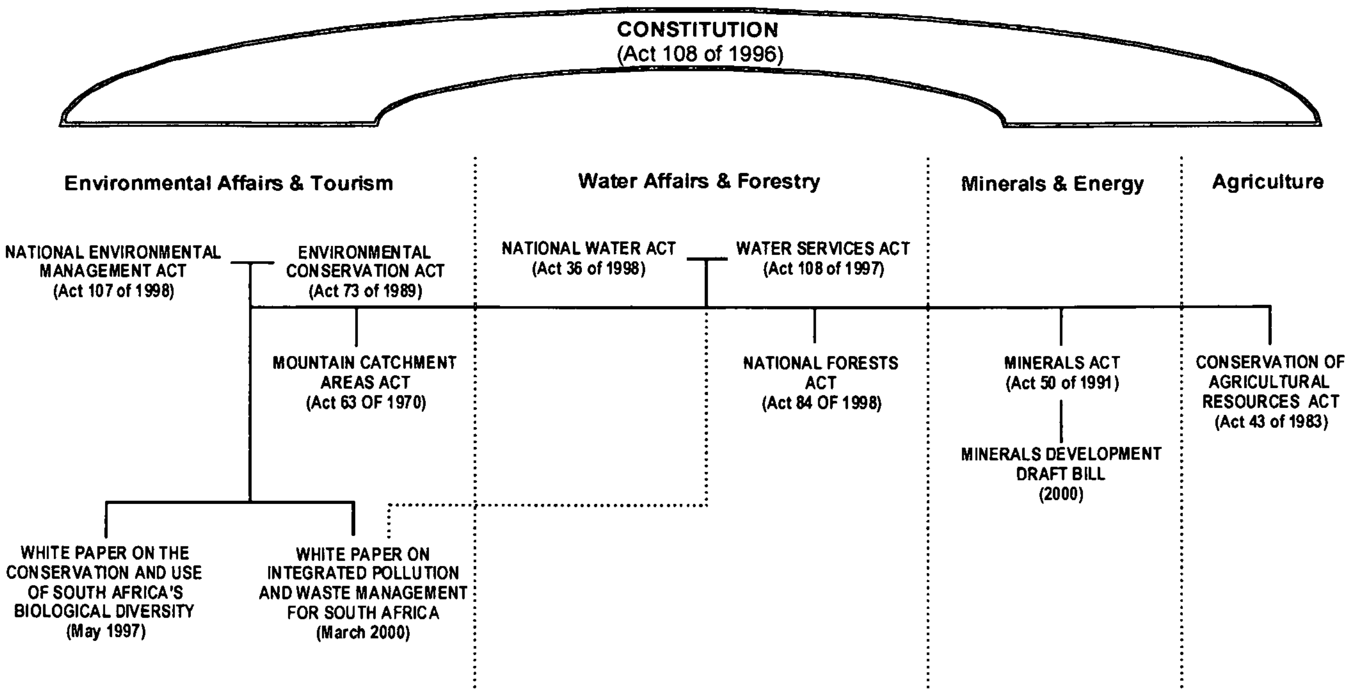


Figure 6.1: National policy and legislation that affect water resources management in South Africa.

The aim of this chapter is identify the key issues that affect water resource management at the catchment level as outlined in the legislation and policy of the country.

6.2 THE CONSTITUTION (ACT NO. 108 OF 1996)

The Constitution (Act No. 108 of 1996) provides the basic principles to which all other policies and legislation are subsidiary. The most significant aspect pertaining to sustainability is Section 24, which specifies the Environmental Right of the people of South Africa, as:

"Everyone has the right

- *(a) to an environment that is not harmful to their health or well-being; and*
- *(b) to have the environment protected, for the benefit of present and future generations through reasonable legislative and other measures that –*
  - *(i) prevent pollution and ecological degradation;*
  - *(ii) promote conservation; and*
  - *(iii) secure ecologically sustainable development and the use of natural resources while promoting justifiable economic and social development."*

The Bill of Rights also includes the right of access to information held by the State, or any other person, which is required for the exercise of any right (Section 32). The section imposes a duty on the State to enact legislation to give effect to the right. This right forms part of most current legislation and policy in South Africa.

6.3. NATIONAL WATER ACT (ACT NO. 36 OF 1998)

6.3.1 Content

The National Water Act, 1998, is a complete revision of the previous water law of South Africa. It legislates many of the concepts that have been proposed previously for integrated management of South Africa's water resources, but have never been implemented up until now.

The underlying principles behind the Act are those of: sustainability of the resource, and equity of use. Both these aspects are influenced by the character of the water resource. The Act recognises that water is a scarce and unevenly distributed resource, which is further complicated by water quality aspects. These need to be taken into account if sustainable water resource use is to be successful. The Act recognises the need for integrated management of all aspects of water resources, at the lowest possible level (preferably catchment level) to ensure participation of all, whilst the Government still retains overall responsibility over the nation's water resources.

The purpose of this Act is clearly outlined in Chapter 1 of the Act. It is to ensure that the nation's water resources are protected, used, developed, conserved, managed and controlled in such a way that:

- Basic human needs of present and future generations are met;
- Equitable access to water is promoted;
- Results of past racial and gender discrimination are redressed;
- Efficient, sustainable and beneficial use of water are promoted;
- Social and economic development are facilitated;
- The growing demand for water is provided for;
- Ecosystem integrity and biodiversity are protected;
- Pollution and degradation of water resources are reduced and, where possible, prevented;
- International obligations are met, and
- Floods and droughts are effectively managed.

In order to attain these aims and ideals certain approaches have been specified including:

- **Development of National Water Resource Strategy (Chapter 2 of the Act)**

  The National Water Resource Strategy provides the implementation framework for water management throughout the country. The Strategy is currently in draft form, available for public comment (DWAF 2002), but has not been ratified by Parliament. According to the Act, it is required to:

  - Provide for the requirements of the Reserve (that water set aside for basic human and ecosystem needs);
  - Provide for international rights and obligations;
  - Provide for future water needs;
  - Provide for water use of strategic importance;
  - Establish water management areas and the amount of water available within each area;
  - Estimate current and future water requirements, and determine surpluses or deficits within each water management area;
  - Provide for inter-basin transfers between areas of surplus and those of deficit;
  - Set out the principles relating to water conservation and water demand;
  - Provide a classification system for water resources and state the water quality objectives for each type;
  - Provide the objectives for establishing institutions for water resource management, and
  - Promote catchment management within water management areas in a holistic, integrated manner.

- **A catchment management approach to water resources (Chapters 2 & 7 of the Act)**

  This approach requires the establishment of catchment management agencies (CMAs), as well as the development of a catchment management strategy for each catchment. This should be achieved within the framework provided by the National Water Resource Strategy. Each catchment management strategy will be based on the characteristics of the catchment and should take into account the class of water resources and their resource quality objectives, as well as the requirements of the Reserve and international obligations (if any). It should contain water allocation plans and take into account the needs and expectations of existing and potential water users. Both the establishment of the CMAs and the development of the catchment management strategies will need to be done in consultation with the public.

- **Classification of water resources for the purpose of protection and development of resource quality objectives (Chapter 3 of the Act)**

  The water resources of the country will need to be classified according to a procedure determined by the Minister. The current system is based on the ecoregion classification of Kleynhans (1999).

For each of the water resource types procedures will be outlined for establishing the Reserve; satisfying water users without significantly altering the natural water quality characteristics, and determining which instream and land-based activities must be regulated in order to protect the water resource. Once the classification system is in place resource quality objectives will be determined. These objectives may relate to: the Reserve; the instream flow; the water level; the presence and concentration of particular substances in the water; the characteristics and quality of water resources and the instream and riparian habitat; the characteristics and distribution of aquatic biota, and the regulation of instream or land-based activities that may affect the quantity or quality of the water resource.

- **Determination of the Reserve (Chapter 3 of the Act)**

  The Reserve consists of two elements, the Basic Human Needs Reserve and the Ecological Reserve. The basic human needs reserve provides for essential needs of individuals, such as water for drinking, cooking and personal hygiene. The Ecological Reserve relates to the water required to protect the functional integrity of aquatic ecosystems. The Reserve will need to be determined for each catchment management area according to the class of water resource. The methodologies are currently being revised by DWAF.

- **Pollution prevention (Chapter 3 of the Act)**

  The Act deals mainly with the problem of land-based pollution. It specifies that the owner, or person in control of the land, is required to take reasonable measures to prevent pollution occurring. These may include: controlling the cause of the pollution; complying with prescribed waste standard and management practice; containing or preventing the movement of pollutants; eliminating the source of pollution; remedying the effects of pollution; remedying the effects to the watercourse (bed or banks), and minimising the effects of emergency spills.

- **Regulation of water use (Chapters 4 & 8 of the Act)**

  The principle underlying the regulation of water use in the Act is that the National Government has overall responsibility for water resource management, including the equitable allocation and beneficial use of water. In general a water use must be licensed if it is for an industrial concern or large-scale stream-flow reduction activity. Water for domestic use and recreation do not need licenses. In some cases the Act permits the continuation of an existing water use derived from a law repealed by the Act.

The Act provides for the use of economic instruments for regulation of water use. The Minister may, after public consultation, set a differential pricing strategy. Water use charges will be used to fund direct and related costs of water resource management, development and use, and may also be used to achieve an equitable and efficient allocation of water. It may also be used to ensure compliance with prescribed standards and water management practices according to the user-pays and polluter-pays principles. Water use charges will be used as a means of encouraging reduction in waste for efficient and effective water use.

- **Implementation of international agreements (Chapter 10 of the Act)**

  South Africa is obliged to uphold any international agreements to which it is a signatory. The Minister has the power to establish bodies to implement international agreements in respect of the management and development of water resources shared with neighbouring countries. These must be in accordance with the Convention on the Law of the Non-navigational Uses of International Watercourses (May 1997) and the Protocol on Shared Watercourses in the Southern African Development Community, to which South Africa is a signatory. In accordance with these, several international bodies have been established to further the development and management of international river basins that South Africa shares with neighbouring countries (see Chapter 5).

- **Monitoring, assessment and information (Chapter 14 of the Act)**

  One of the key chapters in terms of indicator development is Chapter 14, which specifies the national legislation concerning national monitoring and information systems for water resources in the country. The Minister is required to develop a national information system that contains information on:

  - Quantity of water in the various water resources;
  - Quality of water resources;
  - Use of water resources, including water use authorisations;
  - Rehabilitation of water resources;
  - Compliance with resource quality objectives;
  - Health of aquatic ecosystems;
  - Atmospheric conditions that may influence water resources, and
  - Floodlines, floods and droughts.

  This information must be made available to the public in an appropriate manner.

6.3.2 Implications for indicator development

The National Water Act integrates environment into all aspects of water resources management, through its emphasis on sustainability. Because of this it provides clear focus on issues that are nationally important for water resources management and, thus, a firm foundation on which to base indicator development.

In terms of the National Water Act, indicators will need to be developed for the following issues:

- *Scarce and uneven distribution of natural water resources*, including:
  - Water use and allocation;
  - Provision of water for basic human and ecosystem requirements;
  - Supply and demand management;
  - Meeting international requirements;
- *Deteriorating water quality*, including:
  - Pollution prevention;
  - Waste management;
- *Deteriorating water resource and ecosystem quality*, including:
  - Attaining resource quality objectives;
  - Atmospheric conditions;
- *Increase in natural catastrophic events*, including:
  - Floods and droughts.

6.4 WATER SERVICES ACT (ACT NO. 108 OF 1997)

6.4.1 Content

The Water Services Act has the specific aim of providing access to basic water supply and sanitation to all South Africans in a manner that is efficient, equitable and sustainable. It was promulgated specifically to deal with a problem created by the previous Government of the country.

The Act complements the National Water Act in that the provision of water supply and sanitation services should be undertaken in a manner consistent with the broader goals of water resource management. It is founded on the basis that everyone has the right of access to basic water supply and sanitation, and if water is scarce these are the minimum requirements that should be met.

The main objectives of the Act are given as (Section 2):

- The right of access to basic water supply and the right to basic sanitation necessary to secure sufficient water and an environment not harmful to human health or well-being;
- The setting of national standards and norms and standards for tariffs in respect of water services;

- The preparation and adoption of water service development plans by water services authorities;
- The regulatory framework for water services institutions and water services intermediaries;
- The establishment and disbanding of water boards and water service committees and their duties and powers;
- The monitoring of water services and intervention by the Minister or by the relevant Province;
- Financial assistance to water services institutions;
- The gathering of information in a national information system and the distribution of that information;
- The accountability of water services providers, and
- The promotion of effective water resource management and conservation.

The implementation of this Act relies on water service authorities and providers. Water services authorities are required to submit a services development plan the Department of Water Affairs and Forestry by November 1998 (subject to extension).

The Minister must ensure that there is a national information system on water services (Chapter 10), which may form part of the larger system relating to water generally. This information should be provided in an accessible format.

6.4.2 Implications for indicator development

Implementation of this Act is at a local level, rather than a national level. It relies on the efficient and effective management of water services institutions, both water providers and distributors. In terms of indicator development, it identifies issues that are more socio-economic in nature including:

- *Proportion of the population without adequate facilities*, including:
  - Water supply
  - Sanitation facilities;
- *Increased incidence of water-borne disease* (due to poverty, overcrowding and inadequate sanitation).

6.5 NATIONAL ENVIRONMENTAL MANAGEMENT ACT (ACT NO. 107 OF 1998)

6.5.1 Content

The National Environmental Management Act, commonly referred to as NEMA, is based on the concept of sustainability and that both present and future generations have a right to an environment that is not harmful to their health. It recognises that everyone has the right to have the environment protected through reasonable legislative and other measures that prevent pollution and ecological degradation; promote conservation, and secure ecologically sustainable development and the use of natural resources while promoting justifiable economic and social development.

"Environment" is defined in this Act as "*the surroundings within which humans exist and that are made up of –*

(i) the land, water and atmosphere of the earth;

(ii) micro-organisms, plant and animal life;

(iii) any part or combination of (i) and (ii) and the interrelationship among and between them; and

(iv) the physical, chemical, aesthetic and cultural properties and conditions of the foregoing that influence human health and well-being."

The Act outlines an extensive list of principles in Chapter 1. Those that may affect water resources management include:

- Environmental management must place people and their needs at the forefront of its concern, and serve their physical, psychological, developmental, cultural and social interests equitably;
- Development must be socially, environmentally and economically sustainable;
- Environmental management must be integrated, acknowledging that all elements of the environment are linked and inter-related;
- Environmental justice must be pursued so that no one person is unfairly discriminated against. There should be equitable access to environmental resources, benefits and services to meet basic needs;
- Participation of all interested parties in environmental governance must be promoted and decisions must take into account the interests, needs and values of all interested and affected parties, and this includes recognising all forms of knowledge (traditional and ordinary);
- The social, economic and environmental impacts of activities, including disadvantages and benefits, must be considered, assessed and evaluated, and decisions made accordingly;

- The environment is held in public trust for the people, the beneficial use of environmental resources must serve the public interest and the environment must be protected as the people's common heritage;
- The costs of remedying pollution, environmental degradation and consequent health effects and of minimising or controlling these must be paid for by those responsible for harming the environment;
- Sensitive, vulnerable and highly dynamic or stressed systems (e.g. wetlands) require specific attention in management and planning procedures.

In terms of this Act, sustainable development will be ensured if the following factors are considered:

- Disturbance of ecosystems and loss of biological diversity are avoided or, where they cannot be altogether avoided, minimised and remedied;
- Pollution and degradation of the environment are avoided or, where they cannot be altogether avoided, minimised and remedied;
- Disturbance of landscapes and sites that constitute the nation's cultural heritage is avoided or, where they cannot be altogether avoided, minimised and remedied;
- Waste is avoided or, where they cannot be altogether avoided, minimised and recycled where possible, or disposed of in a responsible manner;
- Use and exploitation of non-renewable natural resources is responsible and equitable, and takes into account the consequences of the depletion of the resource;
- Development, use and exploitation or renewable resources and the ecosystems of which they are part do not exceed the level beyond which their integrity is jeopardised;
- A risk-averse and cautious approach is applied, which takes into account the current knowledge about the consequences of decisions and actions, and
- Negative impacts on the environment and on people's environmental rights are anticipated and prevented or, where they cannot be altogether avoided, minimised and remedied.

Implementation of the Act is dependent on co-operative governance. Although the Department of Environmental Affairs and Tourism is the lead agency where the Act is concerned, all other departments share responsibility for implementation of the Act within their sectors through the establishment of the Committee for Environmental Co-ordination (sections 7 and 8). Each department that exercises functions that may affect the environment (Environmental Affairs and Tourism, Land Affairs, Agriculture, Housing, Trade and Industry, Water Affairs and Forestry, and Defence), are all obliged to prepare regular environmental implementation plans. Likewise, departments exercising functions involving the management of the environment (Environmental Affairs and Tourism, Water Affairs and Forestry, Minerals and Energy, Land Affairs, Health and Labour) must prepare environmental management plans regularly.

Integrated Environmental Management (IEM) is recognised as essential in the implementation of this Act. This is based on the recognition of certain activities that require permission from the Minister to be carried out. Permission can only be obtained once an Environmental Impact Assessment (EIA) has been undertaken. This is done in conjunction with other organs of state. As part of the process to identify activities that may not be commenced without permission, or geographical areas for which the same applies, the Department of Environmental Affairs and Tourism is obliged to prepare compilations of information and maps that specify the attributes of the environment in particular geographical areas, including the sensitivity, extent, interrelationship and significance of such attributes. These must be taken into account by every organ of state charged by law with authorising, permitting or allowing the implementation of a new activity, or for assessing and evaluating an existing activity.

The Act also deals with the remediation of environmental damage, and the control of emergency incidents. Every person who causes significant pollution or environmental degradation is required to take reasonable measures to prevent this occurring. Prosecution may occur if the person liable is not willing to take remedial action as specified in the Act. Additionally, any worker may refuse to do work that they consider hazardous to the environment. In the case of emergency incidents, provision is made for minimising environmental damage through emergency intervention, as well as ensuring that steps are taken to prevent future incidents.

6.5.2 Implications for indicator development

NEMA provides the basic framework for sustainable management of South Africa's environmental resources. By implication this means that any legislation that is based on sustainable use or development of resources is required to complement NEMA, including the National Water Act. The Department of Water Affairs and Forestry is also required to submit an environmental management plan.

The main issues arising from NEMA, which need to be taken into account for indicator development at a catchment level are:

- *Loss of habitat and ecosystem integrity*, including:
  - Instream and riparian habitat;
  - Aquatic communities;
  - Loss of wetlands;

- *Exceedance of carrying capacity*, including:
  - Water use;
  - Water pollution;
- *Inequitable allocation of resources*, including:
  - Water supply and sanitation;
  - Inequitable access to freshwater resources (recreation; harvesting);
- *Lack of participation in water resource management*, including:
  - Status of water fora and CMAs;
  - Participation in EIAs;
- *Increasing economic and social development impacting on the environment*, including:
  - Increased need for EIAs.

6.6 ENVIRONMENTAL CONSERVATION ACT (ACT NO. 73 OF 1989)

6.6.1 Content

Most of the Environmental Conservation Act has been repealed by NEMA, with the exception of sections 1, 16-20, 23-27 (excl 27A), 28-37 and 39-46. The most important aspects of this Act that are still relevant include:

- The declaration of a protected natural environment to protect certain ecological processes, natural systems, natural beauty, species of indigenous wildlife or the preservation of biodiversity in general (e.g. nature reserves, conservation areas, marine reserves);
- Declaration of limited development areas;
- Control of pollutants (particularly litter) and waste management, which relies on a permitting system implemented by the Department of Water Affairs and Forestry (Section 20), but regulated by the Minister of Environment Affairs (now Minister of Environmental Affairs and Tourism);
- Declaration of regulations by the Minister regarding waste management; littering; noise, vibration and shock; environmental impact reports and limited development areas, and
- General provisions relating to the powers of the Minister.

6.6.2 Implications for indicator development

Much of the legislation laid down by this Act has been repealed by NEMA. Additionally there is currently a process in place to amend NEMA to include the remaining sections of the Environmental Conservation Act. Either way, the issues that should be included in the development of indicators include:

- *Areas of protected natural environment are limited*, including:
  - Management of such areas to ensure ecosystem integrity;
- *Increasing pollution*, including:
  - Water quality problems.

6.7 MOUNTAIN CATCHMENT AREAS ACT (ACT NO. 63 OF 1970)

6.7.1 Content

The Mountain Catchment Areas Act was promulgated to provide for the conservation, use management and control of land situated in a declared mountain catchment area. In terms of the Act, any area where the environment is considered to be sensitive and water yield is of great importance can be declared a mountain catchment area by the Minister of Environmental Affairs and Tourism (with devolved power now resting with provincial environmental authorities). Within declared areas, land owners are required to manage the soil, vegetation and water in an integrated and sustainable manner according to the directive provided by the legislated authority (currently the provincial government).

The importance of this Act is elevated by the fact that South Africa's mountain catchments comprise only 10% of the total area of the country, but yield over 50% of the water (Fuggle & Rabie 1992). Thusfar an estimated 15% of the mean annual runoff of the main river systems originates from declared mountain catchments.

6.7.2 Implications for indicator development

According to Fuggle & Rabie (1992) the Mountain Catchment Areas Act was promulgated as a tool to promote co-operative governance for the conservation of sensitive mountain areas. Although provision for the protection of mountain areas existed in other Acts at the time (Water Act 54 of 1956, Forest Act 72 of 1968 and Soil Conservation Act 76 of 1969), co-ordinated action by the various responsible authorities was not always achieved. Although the new legislation, as discussed above, makes provision for better co-operation, the Mountain Catchment Areas Act can still be considered important in terms of integrated resource management. With this in mind, the main issues that should be included in the development of indicators include:

- *Lack of co-operative governance*, and
- *Mismanagement of the terrestrial environment influencing water resources.*

6.8 NATIONAL FORESTS ACT (ACT NO. 84 OF 1998)

6.8.1 Content

The National Forests Act (84 of 1998) cannot be considered a key act in terms of catchment management legislation. It does, however, impact on one of the major water users in the country, that of commercial forestry. The Act takes this aspect into account in terms of the principles behind forest management in South Africa. Section 3(3) states that "*forests must be developed and managed so as to—*

- *(i) conserve biological diversity, ecosystems and habitats;*
- *(ii) sustain the potential yield of their economic, social and environmental benefits;*
- *(iii) promote the fair distribution of their economic, social, health and environmental benefits;*
- *(iv) promote their health and vitality;*
- *(v) conserve natural resources, especially soil and water;*
- *(vi) conserve heritage resources and promote aesthetic, cultural and spiritual values; and*
- *(vii) advance persons or categories of persons disadvantaged by unfair discrimination.*"

In terms of water allocation for forestry it is subsidiary in that in the issuing of a license, or other authorisation relating to the use of water for afforestation or forestry, is determined by sections 39(1) and 40(1) of the National Water Act, 1998.

What is of interest to catchment management is that the Minister is given the power to set criteria, indicators and standards for assessing and enforcing sustainable forest management through legislated regulations. This means that the Minister may determine criteria on the basis of which it can be determined whether or not forests are being managed sustainably; indicators that may be used to measure the state of forest management; and appropriate standards in relation to the indicators, which can then be regulated. This has been an ongoing process since the Act was brought into effect. The principle and related criteria proposed in accordance with this legislation, which impact on freshwater resources include (INR 2001):

Principle: The protective and environmental functions of forests are promoted and maintained.

Criteria: Potential yield of water is maintained.

Quality of water discharged from forested catchments is maintained.

6.8.2 Implications for indicator development

The forestry sector in South Africa is mainly commercial forestry of non-indigenous trees, although the value of woodlots is now being recognised. In areas where forestry is possible (in the East of the country where there is high rainfall) the forestry industry is recognised as one of the major water users. With this in mind, the main issue of concern with regard to water resources management is the *high levels of water use by the commercial forestry sector.*

6.9 MINERALS ACT (ACT NO. 50 OF 1991)

6.9.1 Content

Although the Mineral Act is currently in the process of being repealed (see Section 6.10 below), it is currently the main legislation controlling prospecting and mining in South Africa. The aim of the Act is to *"regulate the prospecting for and the optimal exploitation, processing and utilisation of minerals; to provide for the safety and health prospects of persons concerned in mines and works; to regulate the orderly utilisation and the rehabilitation of the surface of the land during and after prospecting and mining operations; and to provide for matters connecting therewith".* It falls under the jurisdiction of the Department of Minerals and Energy.

The Minerals Act does not deal extensively with the protection of the environment external to mining areas. The main environmental requirements of the Act concern the development and implementation of Environmental Management Programmes (EMPs), and rehabilitation.

EMPs for part of the integrated environmental management of mines and their impacts and, in most cases, water resource management and aquatic ecosystem conservation form part of EMPs. Approval of EMPs might require that an Environmental Impact Assessment (EIA) be carried out by a professional body designated by the Director-General of the Department of Minerals and Energy. Once and EMP Report (EMPR) has been submitted and approved, the mine is obliged to carry out its responsibilities.

According to the Act, all mines are obliged to rehabilitate the surface land where is had been disturbed by prospecting and mining. This has obvious implications for water pollution and quality control, particularly in areas where surface runoff is high.

6.9.2 Implications for indicator development

Like forestry, the mining sector has a large impact on South Africa's water resources. Of particular concern is the impact that mining has on the terrestrial environment that might influence water resources integrity. Thus, the issue that can be identified from this Act is:

- *The level of impact of mining on the water resources*, including:
  - Terrestrial resources;
  - Waste management and water pollution.

6.10 MINERALS DEVELOPMENT DRAFT BILL (2000)

6.10.1 Content

The Minerals Development Draft Bill (2000) outlines the new minerals and mining policy for the country and is aimed at repealing the Minerals Act (50 of 1991). Obviously the main thrust of the Bill is the mining sector, but it includes proposed legislation that upholds both the national Environmental Management Act (107 of 1998) and the National Water Act (36 of 1998). In terms of environmental legislation, the Draft Bill states that the aim is to ensure that *"the development of mineral resources will take place within the framework of sustainable development and environmental management and will be regulated in accordance with national environmental management policy, norms and standards"* (Section 64 (2)).

This approach includes the following:

- The social, economic and environmental impacts of activities must be evaluated, and decisions must be appropriate according to such assessment;
- The use and exploitation of non-renewable natural resources is responsible and equitable and takes into account the consequences of the depletion of the resource;
- The development, use and exploitation of renewable resources and the ecosystems of which they are part do not exceed the level beyond which their integrity is jeopardised;
- The disturbance of ecosystems and loss of biological diversity are avoided, or, where they cannot be avoided, are minimised and remedied;
- Pollution and degradation of the environment are avoided, or, where they cannot be avoided, are minimised and remedied;
- The disturbance of landscapes and sites that constitute the nation's cultural heritage is avoided, or where it cannot be avoided, is minimised and remedied;

- The generation of waste is avoided, or where it cannot be avoided, is minimised, re-used or recycled where possible and disposed of in a responsible manner;
- A risk-averse and cautious approach is applied, which takes into account the limits of current knowledge about the consequences of decisions and actions; and
- Negative impacts on the environment and on people's environmental rights be anticipated and prevented and where they cannot be prevented, are minimised and remedied.
- The costs of remedying pollution, environmental degradation and consequent adverse health effects and of preventing, controlling or minimising further pollution; environmental damage or adverse health effects must be paid for by those responsible for harming the relevant environment.
- The philosophy of integrated environmental management must be pursued during the process of environmental impact assessment and the management of all environmental impacts resultant from prospecting and mining activities.
- Environmental Management Programmes are required for all mining operations. These will be assessed on a regular basis.

6.10.2 Implications for indicator development

Although the Draft Bill has not yet been legislated it highlights that there are numerous environmental concerns that the mining sector has to deal with. From a water resources perspective the main issue is:

- *The level of impact of mining on the water resources*, including:
  - Water use
  - Waste management and water pollution.

6.11 CONSERVATION OF AGRICULTURAL RESOURCES ACT (ACT NO. 43 OF 1983)

6.11.1 Content

The Conservation of Agricultural Resources Act (CARA) provides for the control over the utilisation of the natural agricultural resources of South Africa, and falls under the auspices of the Department of Agriculture. It includes the use and protection of land, soil, wetlands and vegetation and the control of weeds and invader plants. The Act covers all land in South Africa (including land situated in urban areas) except for areas declared under the Mountain Catchment Areas, 1970.

From a water resources perspective, this Act is the only legislation that is directly aimed at the conservation of wetlands. Land-users are forbidden to drain or cultivate any vlei, marsh, water sponge or a portion of these, or to cultivate anything within the flood area of a watercourse without written permission. The regulations also forbid the use of vegetation in wetlands that would cause deterioration or damage to agricultural resources (e.g. overgrazing; Fuggle & Rabie 1992).

Indirectly, conservation of the soil and vegetation also has a positive impact on water resources, due to maintenance of riparian habitats, control of soil erosion and control of water pollutants.

6.11.2 Implications for indicator development

The Conservation of Agricultural Resources Act is based on the integrated management of resources for the benefit of agriculture in South Africa. In this way it complements the National Water Act that promotes integrated water resources management. The issues that need to be taken into account for indicator development include:

- *Loss of habitat and ecosystem integrity*, particularly
  - Loss of wetlands;
- *Impact of agriculture on water resources*, including:
  - Terrestrial resources;
  - Waste management and water pollution.

6.12 WHITE PAPER ON INTEGRATED POLLUTION AND WASTE MANAGEMENT FOR SOUTH AFRICA (MARCH 2000)

6.12.1 Content

The White Paper on Integrated Pollution and Waste Management (IP&WM) provides the policy framework for pollution prevention, waste minimisation, impact control and remediation for all media (air, water, land) in South Africa. It is considered to be a subsidiary policy of the overarching environmental management policy legislated in NEMA.

The vision of the South African government with regard to this is: "*to develop, implement and maintain an integrated pollution and waste management system which contributes to sustainable development and a measurable improvement in the quality of life by harnessing the energy and commitment of all South Africans for the effective prevention, minimisation and control of pollution and waste*". It aims to:

- Encourage the prevention and minimisation of waste generation, and thus pollution at source;
- Encourage the management and minimisation of the impact of unavoidable waste from its generation to its final disposal;
- Ensure the integrity and sustained "fitness for use" of all environmental media, i.e. air, water and land;
- Ensure that any pollution of the environment is remedied by holding the responsible parties accountable;
- Ensure environmental justice by integrating environmental considerations with the social, political and development needs and rights of all sectors, communities and individuals, and
- Prosecute non-compliance with authorisations and legislation.

In the case of freshwater pollution several key issues have been identified as critical for South Africa, including salinisation; enrichment of fresh water bodies by nutrients; microbiological quality of water, sediment and silt migration, and harmful inorganic and organic compounds. Diffuse water pollution is also recognised as a major challenge to ensuring sustainable use of South Africa's freshwater resources.

The policy on water pollution management covers inland waters, both surface and groundwater, as well as estuarine and marine waters. Issues that will be considered in relation to policy implementation include:

- River catchments as basic management units;
- Land uses affecting catchment water quality;
- Water quality requirements as specified by the catchment water users;
- Management of storm water from industrial and urban areas;
- Point sources of pollution, e.g. sewage treatment works and industrial waste-water treatment works;
- Diffuse sources of pollution, e.g. polluted base flow originating from industrial areas, leachate from waste disposal sites, polluted base flow originating from informal settlements, and leakage from sewage reticulation systems and sewage works.
- The agricultural and domestic use of herbicides, pesticides and poisons, and their contribution to the contamination of storm water run-off;
- Soil erosion resulting in siltation of reservoirs and high silt loads in rivers;
- Atmospheric deposition on land and the indirect impact on surface and groundwater, and
- Wind-blown dust and solids from tailing deposits and their impact on water quality.

The government will also be required to provide information, in a format that can be used by the general public on:

- Pollution levels in the ambient environment;
- The amounts and types of pollution generated and released into the various media from point sources;
- Estimates of the total release of non-point source pollutants of concern;
- Cleaner technology, best available technologies for pollution control and other information that can assist in integrated pollution and waste management.

6.12.2 Implications for indicator development

Pollution and waste management have been recognised as cross-cutting issues in the development of environmental indicators in South Africa (DEAT 2001, 2002). In terms of water resources, the issues that are identified from this policy are:

- *Increased amounts of waste produced*, including:
  - Domestic waste;
  - Industrial waste;
  - Agricultural waste;
- *Increased water pollution*, including:
  - Point sources;
  - Non-point sources;
- *Deterioration of water quality*, including:
  - Eutrophication;
  - Salinisation;
  - Microbiological quality;
  - Sedimentation;
  - Harmful inorganic and organic compounds;
  - Decreasing fitness-for-use.

6.13 WHITE PAPER ON THE CONSERVATION AND SUSTAINABLE USE OF SOUTH AFRICA'S BIOLOGICAL DIVERSITY (1997)

6.13.1 Content

The development of South Africa's policy on biodiversity was initiated as part of the country's international obligation to the UN Convention on Biological Diversity. It recognises the benefits derived from ecosystems and ecological services and the ongoing the threat to the national biological diversity.

The biodiversity policy has six major goals, including:

1. Conserving South Africa's biodiversity;
2. Using biological resources sustainably and minimising adverse impacts on biodiversity;
3. Ensuring that benefits from the use and development of the country's genetic resources serve national interests;
4. Expanding the human capacity to conserve biological diversity, to manage its use, and to address the factors threatening it;
5. Creating conditions and incentives that support the conservation and sustainable use of biodiversity;
6. Promoting the conservation and sustainable use of biodiversity at the international level.

The goals most applicable to catchment management are conserving biodiversity; using biological resources sustainably and minimising adverse impacts, and expanding the human capacity to conserve biological diversity.

To conserve biological diversity, the following steps are recognised as necessary:

- Identifying important components of biodiversity and threatening processes;
- Maintaining and strengthening existing arrangements to conserve indigenous biodiversity, in and out of protected areas;
- Establishing and managing efficiently a representative and effective system of protected areas;
- Promoting environmentally sound and sustainable development in areas adjacent to or within protected areas;
- Restoring and rehabilitating degraded ecosystems and developing species recovery plans where appropriate;
- Controlling, eradicating and preventing the introduction of harmful alien species that threaten biodiversity;
- Regulating the transfer, handling, use and release of genetically modified organisms, and
- Strengthening measures for *ex-situ* conservation.

The major concerns recognised for the water sector with regard to the sustainable use and minimisation of adverse impacts are:

- The introduction of alien fish species for aquaculture enterprises;
- Habitat loss and fragmentation through construction of dams and water transfer schemes;
- Water pollution and the concentration of pollutants through excess abstraction of water, and
- Introduction of harmful alien species through inter-basin transfer schemes.

6.13.2 Implications for indicator development

Although the White Paper was accepted by Parliament in 1997, the legislation on the conservation of South Africa's biodiversity has not progressed further. The conservation of biodiversity is included as a component of NEMA, although not in the detail provided in the White Paper. The essential issue identified in this policy is:

- *Decline in biological diversity*, including:
  - Freshwater ecosystem diversity;
  - Diversity of freshwater habitats and communities;
  - Species diversity.

6.14 CONCLUSIONS

The common theme throughout the legislation and policy is that of sustainability, and providing for the needs of future generations. Another common element is the need for relevant and adequate information. In most cases the relevant departments are required to establish and maintain an information base that meet the legislated requirements. Sustainability indicators are the perfect tool to combine these two elements; they can provide a framework for data collection, monitoring and research requirements, while at the same time providing a method to report on progress towards sustainability.

By combining the issues identified for each of the Acts and policy documents, it is possible to develop a list of key issues, or areas of concern that should be included in a set of sustainability indicators.

The issues that have been identified during this review include:

- *Scarce and uneven distribution of natural water resources*, including:
  - Water use and allocation (forestry, mining, agriculture, industry, domestic);
  - Provision of water for basic human and ecosystem requirements;
  - Supply and demand management;
  - Meeting international requirements;
- *Deteriorating water quality*, including:
  - Amount of waste produced (domestic, industrial and agricultural);
  - Increased water pollution (point and non-point sources);
  - Water quality (eutrophication, salinisation, microbiological quality, sedimentation, harmful inorganic and organic compounds, decreasing fitness-for-use);
- *Deteriorating water resource and ecosystem quality*, including:
  - Increasing economic and social development impacting on the environment;

- ➢ Attaining resource quality objectives;
- ➢ Atmospheric conditions;
- ➢ Exceedance of carrying capacity (water use, pollution);
- ➢ Terrestrial environment (especially mountain catchment areas);

- *Loss of habitat and ecosystem integrity*, including:
  - ➢ Instream and riparian habitat;
  - ➢ Loss of wetlands;
  - ➢ Loss of biological diversity (ecosystem, communities, species);
  - ➢ Areas of protected natural environment.
- *Inequitable allocation of resources*, including:
  - ➢ Water supply (lack of facilities);
  - ➢ Sanitation (lack of facilities; increase in water-borne disease);
  - ➢ Inequitable access to freshwater resources (recreation; harvesting);
- *Lack of participation in water resource management*, including:
  - ➢ Status of water fora and CMAs;
  - ➢ Participation in EIAs;
- *Increase in natural catastrophic events*, including:
  - ➢ Floods and droughts.

6.15 REFERENCES

DEPARTMENT OF ENVIRONMENTAL AFFAIRS AND TOURISM (DEAT). 2001. *National Core Set of Environmental Indicators for State of Environment Reporting in South Africa. Phase 1: Scoping Report. Volumes 1 & 2.* DEAT, Pretoria. 237 pp.

DEPARTMENT OF ENVIRONMENTAL AFFAIRS AND TOURISM (DEAT). 2002. *Environmental Indicators for National State of the Environment Reporting, South Africa 2002.* DEAT, Pretoria. 37 pp.

DEPARTMENT OF WATER AFFAIRS AND FORESTRY (DWAF). 2002a. *Proposed First Edition National Water Resource Strategy: Summary.* DWAF, Pretoria. 37 pp. http://www.dwaf.gov.za.

FUGGLE RF & RABIE MA (Eds). 1992. *Environmental Management in South Africa.* Juta & Co, Cape Town, Johannesburg. 823 pp.

INSTITUTE OF NATURAL RESOURCES (INR). 2001. *Preparing Criteria, Indicators and Standards for Sustainable Forest Management in South Africa: A Set of Draft Indicators for Discussion. Committee for Sustainable Forest Management.* DWAF, Pretoria.

KLEYNHANS CJ. 1999. Preliminary Ecoregion Classification System for South Africa. Institute for Water Quality Studies, DWAF, Pretoria. 20 pp.

CHAPTER 7: PRIORITY ISSUES OF THE DEPARTMENT OF WATER AFFAIRS AND FORESTRY AND OTHER WATER MANAGEMENT AUTHORITIES

7.1 INTRODUCTION

The international review (Chapter 4) concluded, and recent indicator development initiatives in South Africa (DEAT 2001, 2002) indicate, that stakeholder participation is essential in the development of indicators. The participation process has two main outcomes. The first is capacity building in the area of indicator use and development; the second is to ensure that current issues that are important to water resource managers are incorporated into the indicator development process.

Although the National Water Act provides for the establishment of several different water management authorities (e.g. catchment management agencies; water user associations; advisory committees; water forums; infrastructure development institutions and international management institutions; DWAF 2002a), many of these have not yet been established. The key stakeholders currently in water resources management in South Africa have, therefore, been identified as the Department of Water Affairs and Forestry (DWAF), water providers and local authorities.

This chapter outlines the mandates of these stakeholders, policies that has been developed by them that support their mandates, and the priority water management issues identified during the interview process. Emphasis is placed on DWAF as the custodian of South Africa's water resources.

7.2 DEPARTMENT OF WATER AFFAIRS AND FORESTRY

DWAF is mandated to ensure effective water resources management in South Africa (DWAF 2002a). Its mission is to serve the people of South Africa by (http://www.dwaf.gov.za 2002):

- *"Conserving, managing and developing our* (South Africa's) *water resources and forests in a scientific and environmentally sustainable manner in order to meet the social and economic needs of South Africa, both now and in the future;*
- *Ensuring that water services are provided to all South Africans in an efficient, cost-effective and sustainable way;*
- *Managing and sustaining our* (South Africa's) *forests, using the best scientific practice in a participatory and sustainable manner;*
- *Educating the people of South Africa on ways to manage, conserve and sustain our water and forest resources;*

- *Co-operating with all spheres of Government, in order to achieve the best and most integrated development in our country and in our region;*
- *Creating the best possible opportunities for employment, the eradication of poverty and the promotion of equity, social development and democratic governance."*

At present the Department is responsible for administering all aspects of the Act on the Minister's behalf. The Department's role will progressively change, as regional and local water management institutions are established and the responsibility and authority for water resources management are delegated and assigned to them. Its eventual role will be to provide the national policy and regulatory framework within which other institutions will directly manage water resources, and to maintain general oversight of the institutions' activities and performance (DWAF 2002a).

An abbreviated organisational structure, showing the chief directorates and directorates that were included in the interview process is provided in Figure 7.1.

7.2.1 Chief Directorate: Water Services

The mission of the Chief Directorate of Water Services is *"to ensure, through a programme of support to local government, that all South Africans have access to sustainable, effective, equitable and economical water supply and sanitation services"* (DWAF 2000a). The chief directorate was formed in 1994 with the primary aim of implementing the rural infrastructure aspect of the Reconstruction and Development Programme (Dr F van Zyl, DWAF, *pers. comm.*). Since the introduction of the Water Services Act (Act 108 of 1997) it has continued to focus on rural infrastructure, but with a greater emphasis on supporting appropriate government and other institutions. The chief directorate supports regional offices of DWAF in implementing water services programmes, and provides support to water services institutions (local government and water boards) in providing access to clean water and sanitation facilities (DWAF 2000a).

A Consolidated National Business Plan for the Water Services Programme describes the methodology that will ensure that water services projects are implemented in accordance with the Department's current policy and strategy and that of the government as a whole, specifically in respect of the Water Services Act (Act No. 108 of 1997), the National Water Act (Act No. 33 of 1998), the Municipal Structures Act (Act No. 33 of 2000), the Municipal Systems Act (Act No. 32 of 2000) and, the National Environment Management Act (Act No. 107 of 1998) (DWAF 2000a; DWAF 2002b). Policy on and strategy for local institutional development, operations, macro-planning, integrated rural development and implementation have been updated, and strategies for water conservation and use, environmental impact management, water quality, and groundwater management have been incorporated.

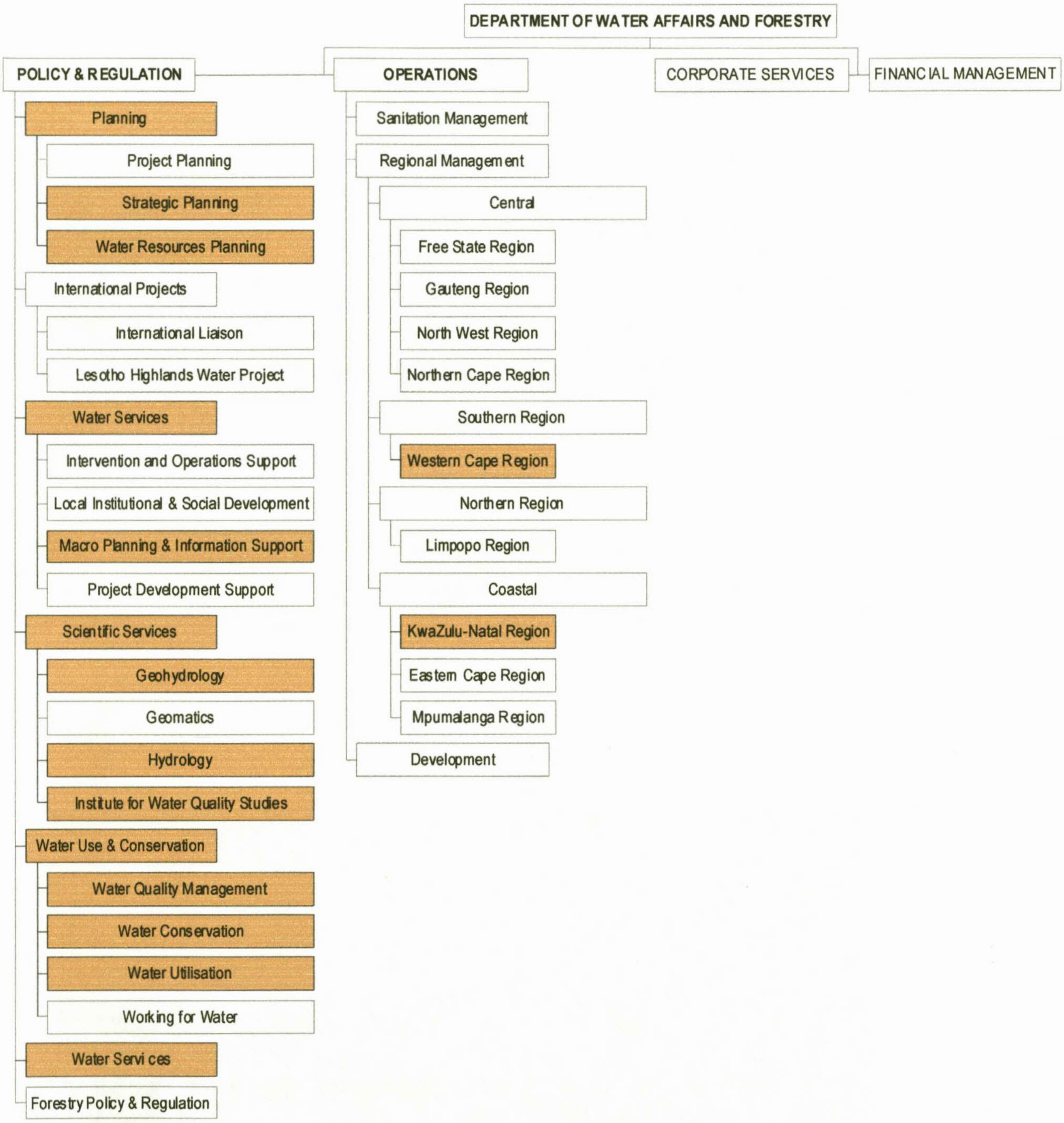


Figure 7.1: DWAF organisational structure. Chief directorates and directorates interviewed are highlighted.

The main departmental programmes that fall under this chief directorate include the Community Water Supply and Sanitation Programme and the National Sanitation Programme. These programmes are aimed at ensuring that all South Africans have equitable access to water and sanitation, particularly where local government is unable to fulfil its mandate, and at meeting the minimum standards for water supply and sanitation as specified by the *Regulations Relating to Compulsory National Standards and Measures to Conserve Water (April 2001)*, i.e.:

- The minimum standard for basic sanitation services is:
  - (a) the provision of appropriate health and hygiene education; and
  - (b) a toilet that is safe, reliable, environmentally sound, easy to keep clean, provides privacy and protection against the weather, well ventilated, keeps smells to a minimum and prevents the entry and exit of flies and other disease-carrying pests.
- The minimum standard for basic water supply services is:
  - (a) the provision of appropriate education in respect of effective water use; and
  - (b) a minimum quantity of potable water of 25 litres per person per day or 6 kilolitres per household per month -
    - (i) at a minimum flow rate of not less than 10 litres per minute;
    - (ii) within 200 metres of a household; and
    - (iii) with an effectiveness such that no consumer is without a supply for more than seven full days in any year.

Priority issues identified by this chief directorate included:

- Balance between customer service and availability and quality;
- Prosperity planning (strategic use of water as an economic good);
- Rural development;
- Adequate water services;
- Health;
- Cost effectiveness in terms of quality;
- Positive effect of urbanisation on runoff, and
- Urban rivers.

7.2.2 Chief Directorate: Planning

The mission of the Chief Directorate of Planning is *"to meet the growing water needs of all the inhabitants of the country with a limited supply of water, and to provide information technology services to the Department as a whole"* (DWAF 2000a). The functions of this chief directorate are (DWAF 2000a):

- To plan water resources management and development options and, if required, new national water resources infrastructure to meet the country's future water needs and sustain the economic and social well-being of its people;
- To provide guidelines for regional water resources management and development, taking into account social and economic objectives as well as the hydro-geographical characteristics of the country;
- To assess the need to adapt or change departmental strategies and policies, given the dynamic environment in which the department operates, and
- To help the department to develop and maintain information systems and to supply information technology infrastructure.

The Directorate of Strategic Planning is responsible for the development of strategies for implementation of policies pertaining to the Department. The current emphasis is on the National Water Resources Strategy, as specified in the National Water Act (Act 36 of 1998, see Chapter 6). The *Proposed First Edition National Water Resources Strategy* (DWAF 2002a; http://www.dwaf.co.za 2002) has recently been released for public comment. It provides the legally-binding framework within which the water resources of South Africa will be managed in the future. It outlines the goals and objectives of water resources management for the country and provides the plans, guidelines and strategies to achieve these goals.

Elements of the strategy include:

- Protection of water resources by resource-directed measures and source-directed measures;
- Water use and the allocation of water;
- Water conservation and demand management as a methodology to improve water use efficiency;
- Water pricing (and financial assistance) to ensure the financial viability of the resource and its management in the future;
- Institutional arrangements, particularly with regard to catchment management;
- Monitoring and information systems required to support the strategy;
- Public safety with regard to flood and droughts, dam safety and water pollution;
- Implementation programme and timeframe, and
- Financial requirements for implementation.

Complementary to the strategy are the recognised need for capacity building and education, as well as co-operative governance at local, national and international levels.

Priority issues for this chief directorate identified during the interviews were:

- The affect of HIV/AIDS on the population and its affect on water use in the future;

- The affect of climate change on the water resources of the country in the future;
- Rural development and poverty;
- Capacity building at all levels (user education to catchment management capacity);
- Scarce and uneven distribution of water (allocation of water to meet basic human needs and ecosystem requirements; international requirements; strategic requirements and other user requirements)
- Public safety with regard to dam safety and flood management;
- Financial viability of water resources, and
- Efficiency of use.

7.2.3 Chief Directorate: Scientific Services

The mission of the Chief Directorate of Scientific Services is *"to develop water resource monitoring and assessment methodologies, based on multidisciplinary scientific and technical principles; and to provide an extensive range of water resource quality, quantity, and related information to support the department's mandates for providing water services, and developing and protecting water resources* "(DWAF 2000a).

The **Directorate of Hydrology** is responsible for the monitoring of the country's water resources, as well as flood management and warnings. Hydrological monitoring networks are being extended and, according to the National Water Resource Strategy (DWAF 2002a), the spatial density of national monitoring points will be expanded to one national monitoring point in less than 1 000 km^2 (currently one station per 1 500 km^2). An additional 500 national monitoring points will be established during the next 20-25 years. The number of meteorological stations will need to be increased from 275 to at least 350. Additionally, hydrological databases are also being extended to neighbouring states through the Southern African Development Community/Hydrological Cycle Observing System (SADC/HYCOS) initiative. The flood management system, which formerly addressed the Orange-Vaal system only, will in future also incorporate smaller catchments.

The **Directorate of Geohydrology** is responsible for the management of South Africa's groundwater resources. Both quality and quantity aspects of groundwater are dealt with by the directorate. For some time, geohydrological exploration has concentrated on developing small-scale systems for use by rural communities. A continuing awareness campaign has been launched, teaching communities that rely on groundwater how to protect these resources against contamination and misuse (Mr E Braune, DWAF *pers. comm.*). Of importance to the directorate has been the development of the *Policy and Strategy for Groundwater Quality Management in South Africa* (DWAF 2000b).

The groundwater quality management mission, as stated in the Strategy is *"to manage groundwater quality in an integrated and sustainable manner within the context of the National Water Resource Strategy and thereby to provide an adequate level of protection to groundwater resources and secure the supply of water of acceptable quality"*. The Department will achieve its mission by (DWAF 2000b):

- Implementing source-directed controls to prevent and minimise the impact of development on groundwater quality by imposing regulatory controls and by providing incentives;
- Implementing resource-directed measures in order to manage impacts that occur in a way that protects the Reserve and ensures suitability for beneficial purposes recognised by the National Water Act, and
- Remedying groundwater quality where practical, to protect the Reserve and ensure fitness-for-use.

These will require (DWAF 2000b):

- Establishing an understanding of the vulnerability of the country's groundwater resources to pollution;
- Establishing an understanding of the relationship between polluting activities (sources) and quality effects in the groundwater;
- Regulating and prohibiting land-based activities that may affect the quantity and quality of water, i.e. the location and nature of development in relation to its impact on groundwater quality;
- Controlling practices and using measures to lessen the polluting effects of activities that threaten groundwater quality, and
- Controlling the aggregate impact of certain prescribed activities.

The **Directorate of Social and Ecological Services** is a relatively new directorate set up in 1999 (Dr C Ruiters, DWAF, *pers. comm.*). It deals mainly with environmental management issues, including the social and ecological components. The most prominent policy document to be developed by this directorate is the *Environmental Implementation and Management Plan* (EIMP), in compliance with the National Environmental Management Act (DWAF 2001; see Chapter 6). The EIMP is mainly for the purpose of assisting the Committee for Environmental Co-ordination (an inter-departmental co-ordinating committee) in aligning DWAF's environmental management policies and functions with other departments, in order to promote sustainability. Its value to DWAF is its assessment of the Department's environmental functions and strategies and its success in complying with NEMA principles and promoting environmental management.

The use of water for recreational purposed also falls under the Directorate of Social and Ecological Services, which has developed a policy framework for the recreational water use of government waterworks (DWAF 1999a). The purpose of the policy is to provide clear direction on the management and control of recreational water use of State-owned dam basins. The policy will be implemented through (DWAF 1999a):

- Zoning of State-owned dam basins (i.e. the compilation of zoning plans and their subsequent implementation);
- Licensing of recreational water use;
- Establishing regulations regarding the management, control and use of government waterworks, and
- Establishing management bodies (e.g. water user associations; provincial authorities or contractors).

The **Institute for Water Quality Studies (IWQS)** also falls under the Chief Directorate of Scientific Services. Its mission is *"to provide the national water resource management function with resource quality and technical information, guidelines and procedures necessary to address the strategic and operational requirements for the protection and assessment of water resource quality"* (IWQS 2000). The core operational business areas of the IWQS are (IWQS 2000):

- *Monitoring and assessment* of water resources, which includes the co-ordination and operation of national and regional resource quality monitoring programs and the provision of chemical, microbiological and biological (microbiological, hydrobiological and toxicological) analytical services for the assessment of water resource quality;
- *Development*, which includes the development of strategies, procedures, guidelines, information systems and capacity for the monitoring, assessment and protection of water resource quality, and
- *Technical support*, which includes the development and provision of technical and scientific support for the national water resource management function.

The major task of the chief directorate, which impacts on most directorates, and other chief directorates, is the determination of the Reserve (water for basic human needs and ecological requirements). The **Resource Directed Measures (RDM) Office**, established in the Chief Directorate of Scientific Services, is the central national co-ordinating office for Reserve determinations (IWQS 2000). The techniques for determining ecological water requirements are critical to the achievement of sustainable water use, and are currently being compiled into user manuals for rivers, estuaries, wetlands and groundwater. Linked to the Reserve determination is the development of a system for managing water use licensing and registration under the Chief Directorate of Water and Conservation.

Priority issues for this chief directorate identified during the interviews were:

- Equity of allocation, under conditions of scarcity and uneven distribution of the water resources;

- Capacity to manage the surface- and ground-water resources;
- Economic, social and ecological sustainability of the water resources, and monitoring of this (state-of-the-water-resources)
- Floods and droughts;
- Status of storage dams as a supply-side management intervention;
- Recognition of the strategic social value of groundwater;
- Knowledge and assessment of groundwater use;
- Conjunctive use of groundwater and surface water in development planning, and
- Groundwater protection (well-head protection; Mountain Catchment Areas Act).

7.2.4 Chief Directorate: Water Use and Conservation

The mission of the Chief Directorate of Water Use and Conservation is *to promote the equitable allocation, beneficial use and sustainability – in terms of quality as well as quantity – of water resources via policy development, regulation, facilitation and monitoring* (DWAF 2000a). Its four directorates all have direct operational significance for integrated water resource management at catchment level.

The **Directorate of Water Conservation's** core function is to facilitate the development and implementation of appropriate policies, strategies, projects and initiatives that will promote and institutionalise water conservation and demand management among water institutions and end users. The directorate has been involved in the development of the National Water Conservation/Demand Management (WC/WDM) Strategy, as part of the National Water Resource Strategy (DWAF 2002a).

The National WC/WDM Strategy is based on the premises that many water users can reduce their water use without materially affecting their quality of life, and significant reductions in use can be achieved by changes in behaviour and the adoption of water-saving technologies. The foundation of the WC/WDM Strategy is the creation of a WC/WDM culture within all water management and water services institutions and among water users.

It is based on three fundamental principles:

- Water institutions should strive to supply water efficiently and effectively, minimise water losses, and promote WC/WDM among their consumers.
- Users should not waste water, and should strive to use it efficiently.
- WC/WDM should be an integral part of water resources and water services planning processes. In situations of water shortage the appropriateness and cost effectiveness of demand-side solutions must be considered alongside supply-side augmentation options.

The role of the **Directorate of Water Quality Management** is to ensure the integrated and sustainable management of the quality of water resources in South Africa. Water quality management in this country has evolved from a pollution control approach, which concentrated on source-directed management measures; through a receiving water quality objectives approach, which recognised the water quality requirements of receiving water users as well as the aquatic ecosystem; to the current integrated source, remediation and resource-directed management approach as adopted in the National Water Act (36 of 1998). As part of the implementation of the National Water Act, the directorate has developed new water quality policies and various regulatory instruments as part of the *Water Quality Management Framework Policy* (DWAF 2002c).

The Water Quality Management Framework Policy applies to all components of the water resource, including watercourses, surface and groundwater bodies, wetlands, estuaries and marine resources. The water quality management goal of the strategy is *"achieving water quality that is 'fit for use' and maintaining aquatic ecosystem health on a sustainable basis by protecting the country's water resource, in a manner allowing justifiable, social and economic development."*

The key strategies that give effect to the water quality management policy include:

- Establishment and enhancement of the water quality aspects that underpin sustainable water use;
- Maintenance and improvement of the quality of the country's water resource;
- Creation and maintenance of partnerships with outside parties who could aid the water quality management effort;
- Communication with stakeholders to create awareness of the water resource and the factors affecting it and its management, and
- Building capacity of stakeholders to contribute meaningfully towards water resource management.

One of the key areas of concern for the directorate is the management of the water quality of dense settlements, which include densely populated residential areas in urban, peri-urban and rural areas. The *National Strategy for Managing the Water Quality Effects of Densely Populated Settlements* has been developed and is currently being implemented as a response to this concern (DWAF 1999b). This strategy is based on the understanding that the size, density and siting of the settlement largely determine the risk to the water environment. As settlement density increases, the amount of waste produced per unit area increases and the natural assimilation of waste during the delivery process decreases. The strategy is based on limiting the production of waste in dense settlements (waste prevention); limiting the amount of waste that can be delivered to the water resource (waste minimisation), and managing and removing the waste once it has been mobilised in the delivery pathway (impact minimisation) (DWAF 1999b). Remediation is only considered a strategy for emergency situations.

The **Directorate of Catchment Management** aims to support effective water resources management via the establishment of water management institutions. Under the Act, a water management institution may be a catchment management agency, a water user association, a body responsible for international water management or any person who fulfils the functions of a water management institution (DWAF 2002a).

South Africa has been divided into nineteen Water Management Areas (October 1999 by Government Notice No. 1160) within which water resources management will occur at catchment level. Within these areas, water management institutions need to be established under the auspices of the directorate in the form of (DWAF 2002a):

- Catchment management agencies (CMAs), which provide the second tier of the water management structure under the Act (the first being the Department of Water Affairs and Forestry). They operate within the broader framework provided by the Minister and the National Water Resource Strategy, and are required to develop and implement catchment management strategies in line with this.
- Water user associations (WUAs), which are statutory bodies and form the third tier of water management under the Act. The role of WUAs is to enable people to pool their resources to more effectively carry out water-related activities (e.g. irrigation, effluent and waste disposal, recreational water use). They can represent one sector or more than one sectors and will normally have a local interest.

Other water management institutions, which include international water management bodies and water services institutions, advisory committees and the Water Tribunal, do not fall under this directorate. The directorate interacts strongly with regional offices to reach a common understanding of catchment management approaches and processes and ensure that a joint effort is made to address key issues.

The **Directorate of Water Utilisation** deals with water abstraction and storage allocations; authorisation of afforestation development; control of noxious weeds; support and guidelines for systems operations of government water schemes; raw water pricing; irrigation, and water loss control in bulk raw water supply distribution systems. It has been responsible for the strategies for implementing water allocation as specified in the National Water Resource Strategy (DWAF 2002a).

Water allocation, and the issuing of water use authorisations, is viewed as one method to reconcile the amount of water available with the needs of the people and economic development of the country. Authorised water use includes:

- Schedule 1 use that has no significant impact on water resources;
- Existing lawful uses, which were authorised under any law during the period 1 October 1996 and 31 September 1998;
- Generally authorised use, published in the Government Gazette (e.g. General Authorisations in Terms of Section 39 of the National Water Act, 1998, No. 1191, October 1999);
- Licensed water use entitling a person to use water within the terms and conditions of the licence.

This directorate is responsible for water allocation and the compulsory licensing procedures required by the Act.

The directorate was also responsible for the development of the *Pricing Strategy for Water Use Charges* (DWAF 1999c). The pricing strategy applies only to the use of raw (untreated) water, and to the setting of tariffs by the Department and water management institutions established in terms of the Act. The Pricing Strategy is based on the principles of social equity, ecological sustainability, financial sustainability and economic efficiency, and aims to *"achieve the efficient and cost-effective allocation of water, equity and fairness in the allocation mechanism, and long-term sustainability of the natural environment"* (DWAF 1999c). Water use charges will be determined using a set approach established in the strategy, taking cognisance of the need to fund:

- *Water resource management activities*, such as monitoring, information management, controlling water resources and their use, water resource protection and conservation;
- *Water resource development and the use of waterworks* including all costs from design through to operation, and
- *Achieving equitable and efficient allocation of resources* through the value of water to users.

Priority issues identified for this chief directorate during the interviews included:

- Public participation in integrated water resources management at catchment level;
- Institutional capacity, including the social and economic viability of CMAs and local government;
- Reconciliation of demand and supply, and demand side management (pricing, co-regulation and wise use);
- Efficient and effective use of water given the climatic and distribution constraints (re-allocation of water);
- Financial viability and cost recovery, including least-cost planning;
- Infrastructure development and operation (premature development of infrastructure and transfer to CMAs, water user associations etc.;

- Rural development and poverty (particularly emerging farmers);
- Waste management in general and where it impacts on the water resources;
- Water quality problems related to dense settlements;
- Water quality problems, including salinisation, eutrophication, micro-biological contamination and sedimentation;
- Disparity in awareness of water issues and rights between the various users, and
- Integration of groundwater into catchment management;

7.2.5 Chief Directorate: Regional Implementation

The mission of the Chief Directorate of Regional Implementation is *"the effective provision of water services and water resource management in regions throughout the country"*. It operates as the executive arm of the department and focuses on implementing water services functions and projects as well as effectively managing the country's water resources at a regional level (DWAF 2000a).

This directorate comprises of a head office and nine regional offices: Northern Cape; Gauteng; Eastern Cape; Mpumalanga; Free State; KwaZulu-Natal; North West; Western Cape, and Limpopo Province. The regional offices are currently carrying out the responsibilities of catchment management agencies for the Department until such time as catchment management agencies can be formally established. This includes the management of water resources and co-ordination of the water-related activities of water users and other water management institutions within water management areas; development of catchment management strategies and implementation of water management strategies developed by the Department.

Priority issues identified for regional offices during the interviews included:

- Lack of institutional capacity and resources;
- Lack of integration with other government departments;
- Estuarine health;
- Economic viability of water use, and
- Water allocation and licensing.

7.3 WATER PROVIDERS

Water providers (water boards) are autonomous, legislated organisations whose core business is the provision of bulk water to local authorities and other bulk water users (e.g. certain industries and mines). There are currently fifteen water providers in South Africa, including: Albany Water, Bloem Water, Goudveld Water, Magalies Water, Overberg Water, Rand Water, Umgeni Water, Mhlatuze Water, North West Water Authority, Western Transvaal Water Company, Kalahari West Water, Kalahari East Water and Northern Water. The most significant of these are Rand Water, which supplies mainly Gauteng, and Umgeni Water, which supplies Durban, Pietermaritzburg and the surrounding areas.

Although the primary activity of water providers is the provision of bulk water, according to the Water Services Act (Act 108 of 1997) other activities that it may perform include, but are not limited to:

- Provision of management services, training and other support services to water services institutions, in order to promote co-operation in the provision of water services;
- Supply of untreated or non-potable water to end users who do not use the water for household purposes;
- Provision of catchment management services on behalf of the responsible authority (DWAF or CMAs);
- With the approval of the water services authority or in a joint venture, supply water directly for industrial use, accept industrial effluent and act as water service providers to customers, and
- Perform water conservation functions.

The more prominent water providers, in particular Rand Water and Umgeni Water, have become increasingly involved in catchment management activities, including amongst others:

- Participation in catchment forums;
- Development of catchment management plans and strategies;
- Provision of information on catchment status (e.g. hydrological, chemical, physical and socio-economic;
- Participation in and promotion of environmental education;
- Research into catchment functioning and management strategies, and
- Co-operation with national and local government to ensure integrated environmental management.

Priority issues identified by water providers during the interviews included:

- Deteriorating geomorphology, due to overgrazing (destruction of the terrestrial environment);
- Sedimentation;

- Loss of riparian vegetation;
- Loss of wetlands;
- Unaccounted for water;
- Eutrophication;
- Sedimentation;
- Microbiological contamination;
- Impact of demographic change;
- Water balance (meeting demand);
- Cost of water treatment, and
- Cost effective water management.

7.4 LOCAL AUTHORITIES

Local authorities, including municipalities, metropolitan councils and district councils, are constitutionally responsible for the delivery of a range of services to residents. They must provide democratic and accountable government; provide services in a sustainable manner; promote social and economic development; promote a safe and healthy environment, and encourage the involvement of communities in matters of local government (http://www.localelections.org.za 2002).

The *Local Government White Paper* of 1998 emphasises local government's responsibility for the provision of household infrastructure and a basic level of services as part of local economic development. In terms of water resources, local authorities have the executive authority to administer the following matters (http://www.localelections.org.za 2002):

- Municipal planning;
- Municipal public works, such as water care works and distribution systems;
- Stormwater management;
- Waste and sanitation services for potable and domestic waste water and sewage disposal;
- Water quality management and monitoring;
- Amusement facilities, which may include lakes and water-recreation facilities, and
- Refuse removal, refuse dumps and solid waste disposal (under the authority of the Department of Water Affairs and Forestry).

The Municipal Systems Act (Act 32 of 2000) establishes a legal framework for municipal systems, including the development of Integrated Development Plans. These include water services planning, which is overseen as part of the duties of the Chief Directorate of Water Services in DWAF. With the promotion of co-operative governance some metropolitan councils have become more pro-active in terms of water resources management (e.g. Cape Town, Johannesburg, Ethekwini - Durban, Tshwane - Pretoria).

Priority issues identified by local authorities during the interviews included:

- City planning is along the line of ward boundaries rather than catchments;
- Service provision;
- Fragmentation of effort, due to political intervention;
- Lack of a sustainability of open spaces;
- Flooding of urban rivers;
- Densification;
- Inappropriate use of groundwater, and
- Water quality management and community health.

7.5 CONCLUSIONS

This chapter provides an overview of some of the priorities of water resources managers in South Africa. Combining the issues identified by the various organisations during the interviews, the following list provides an overview of issues as identified by the stakeholders:

- *Financial viability of water resources*, including:
  - ➢ Prosperity planning (strategic use of water as an economic good);
  - ➢ Cost effectiveness (least cost planning);
  - ➢ Rural development and poverty;
  - ➢ Efficiency of use;
- *Social viability of water resources*, including:
  - ➢ Balance between customer service and availability and quality;
  - ➢ The affect of HIV/AIDS on the population and its affect on water use in the future;
  - ➢ Recognition of the strategic social value of groundwater;
  - ➢ Rural development and poverty;
  - ➢ Public participation in integrated water resources management at catchment level;
  - ➢ Disparity in awareness of water issues and rights between the various users;
  - ➢ Densification in urban areas;
- *Political viability*, including:
  - ➢ Fragmentation of effort, due to political intervention;
- *Human resource capacity*, including:
  - ➢ User education;

- Capacity to manage the surface- and ground-water resources;
- *Scarce and uneven distribution of natural water resources*, including:
  - Water use and allocation (forestry, mining, agriculture, industry, domestic);
  - Provision of water for basic human and ecosystem requirements;
  - Reconciliation of demand and supply;
  - Demand side management (pricing, co-regulation, unaccounted for water and wise use);
  - Meeting international requirements;
  - Positive effect of urbanisation on runoff;
- *Affect of climate change*, including:
  - Increase in catastrophic events (floods and droughts);
- *Inequitable allocation of resources*, including:
  - Water supply (status of storage dams as a supply-side management intervention; lack of facilities);
  - Lack of sanitation facilities, leading to health problems;
  - Inadequate water services;
- *Public safety*, including:
  - Dam safety and flood management;
  - Flooding of urban rivers;
- *Lack of co-operative governance and integrated planning*, including:
  - Conjunctive use of groundwater and surface water in development planning;
  - Integration of groundwater into catchment management;
  - City planning is along the line of ward boundaries rather than catchments;
- *Institutional capacity*, including:
  - The social and economic viability of CMAs and local government;
  - Infrastructure development and operation (premature development of infrastructure and transfer to CMAs, water user associations etc.);
- *Research and monitoring*, including:
  - Knowledge and assessment of groundwater use;
- *Deteriorating water quality*, including:
  - Waste management in general and where it impacts on the water resources;
  - Water quality problems related to dense settlements;
  - Water quality problems, including salinisation, eutrophication, micro-biological contamination and sedimentation;
- *Deteriorating water resource and ecosystem quality*, including:
  - Deteriorating geomorphology;
  - Loss of riparian vegetation;

- Loss of wetlands;
- Groundwater protection (well-head protection; Mountain Catchment Areas Act).

7.6 REFERENCES

DEPARTMENT OF ENVIRONMENTAL AFFAIRS AND TOURISM (DEAT). 2001. *National Core Set of Environmental Indicators for State of Environment Reporting in South Africa. Phase 1: Scoping Report. Volumes 1 & 2.* DEAT, Pretoria. 237 pp.

DEPARTMENT OF ENVIRONMENTAL AFFAIRS AND TOURISM (DEAT). 2002. *Environmental Indicators for National State of the Environment Reporting, South Africa 2002.* DEAT, Pretoria. 37 pp.

DEPARTMENT OF WATER AFFAIRS AND FORESTRY (DWAF). 1999a. *Policy Framework on the Recreational Use of Government Waterworks.* Report No. 26/P/I. DWAF, Pretoria. 15 pp.

DEPARTMENT OF WATER AFFAIRS AND FORESTRY (DWAF). 1999b. Managing the Water Quality Effects of Settlements: The National Strategy, First Edition. Water Quality Management Series U.2. DWAF, Pretoria. 65 pp. http://www.dwaf.co.za.

DEPARTMENT OF WATER AFFAIRS AND FORESTRY (DWAF). 1999c. *Establishment of a Pricing Strategy for Water Use Charges inn Terms of Section 56(1) of the National Water Act, 1998. Government Gazette 20615,12 November 1999.* Government Printers, Pretoria.

DEPARTMENT OF WATER AFFAIRS AND FORESTRY (DWAF). 2000a. *Department of Water Affairs and Forestry Annual Report 1999-2000.* DWAF Pretoria. 59 pp.

DEPARTMENT OF WATER AFFAIRS AND FORESTRY (DWAF). 2000b. *Policy and Strategy for Groundwater Quality management in South Africa, First Edition.* DWAF, Pretoria. 47 pp.

DEPARTMENT OF WATER AFFAIRS AND FORESTRY (DWAF). 2001. *Environmental Implementation and Management Plan. First Edition. DWAF, Pretoria.* 70 pp.

DEPARTMENT OF WATER AFFAIRS AND FORESTRY (DWAF). 2002a. *Proposed First Edition National Water Resource Strategy: Summary.* DWAF, Pretoria. 37 pp. http://www.dwaf.gov.za.

DEPARTMENT OF WATER AFFAIRS AND FORESTRY (DWAF). 2002b. *The Development of a Sanitation Policy and Practice in South Africa. Preliminary Draft Paper.* DWAF, Pretoria. 13 pp. http://www.dwaf.co.za.

DEPARTMENT OF WATER AFFAIRS AND FORESTRY (DWAF). 2002c. *National Water Quality Framework Management Policy.* Water Quality Management Series MS 7. DWAF, Pretoria. 68 pp. http://www.dwaf.co.za.

INSTITUTE FOR WATER QUALITY STUDIES (IWQS). 2000. *Annual Report – January 1999 to March 2000.* DWAF, Pretoria. 32 pp.

CHAPTER 8: STAKEHOLDER OPINION ON ISSUES AND INDICATORS

8.1 INTRODUCTION

One of the recognised problems in indicator development is choosing a limited set of relevant indicators, which still represents the important aspects of sustainable development. The DPSIR analysis (Chapter 5), policy review (Chapter 6) and stakeholder interviews (Chapter 7) identified numerous issues surrounding integrated water resources management in South Africa. It was necessary to limit these to issues that have the largest impact on water resources management at catchment level before indicators could be chosen for each issue.

This was achieved through a workshop in January 2002, to which DWAF Head Office, DWAF Regional Offices, the Water Research Commission, provincial environmental departments, local authorities and water providers were invited. The full proceedings of the workshop and a list of attendees are provided in Appendix B. The workshop was, primarily, aimed at representatives of the stakeholder organisations that had not been involved in the interview process. In this way, people working in the same field, with the same mandate, could act as reviewers for what had taken place previously.

8.2 COMPILATION OF ISSUES

In preparation for the workshop, the issues identified through the DPSIR analysis, policy analysis and stakeholder interview were compiled, using a mind-mapping technique (http://www.mindjet.com 2002). The results are provided in Figure 8.1.

From this, 40 main issues were identified, and placed within the DPSIR framework (see Figure 8.1). Sub-issues were included in some of the issues (e.g. *frequency of droughts* as a sub-issue of *catastrophic events*), as a guide to developing the final indicator set. It was recognised that some issues might be linked to others and that the DPSIR categories were not absolute, but should be viewed as a guide.

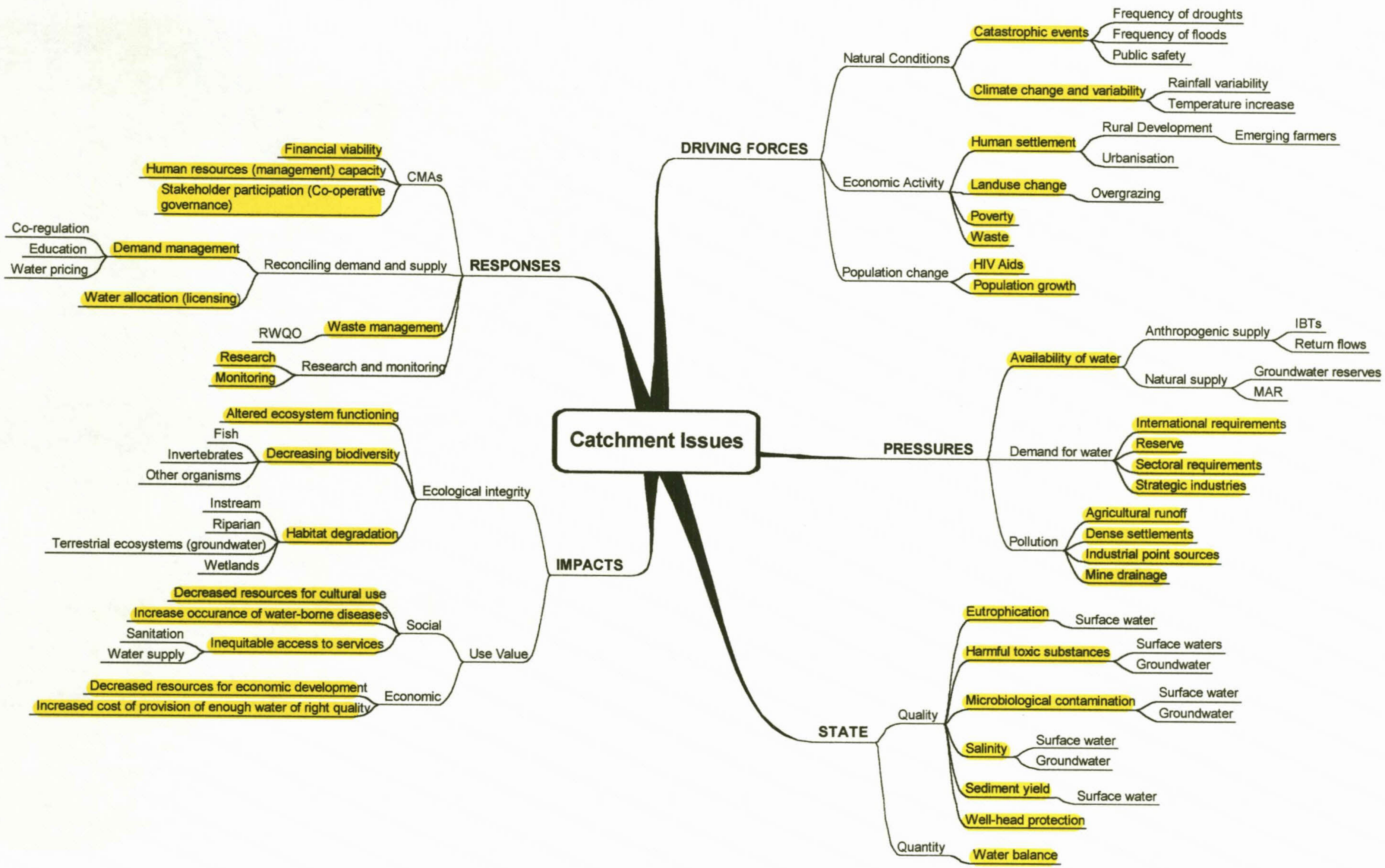


Figure 8.1: Mindmap of the issues identified during the DPSIR analysis, policy review and stakeholder inteviews. The main issues are highlighted.

8.3 EVALUATION OF ISSUES

The mindmap of all the issues (Figure 8.1) was presented to workshop participants. They were requested to provide input on the issues identified through:

- Completion of a questionnaire (see Appendix B), which provided an indication of the opinions of individuals, and
- A plenary discussion, which would allow debate on critical or controversial issues.

8.3.1 Questionnaire

Twenty-one workshop participants completed the questionnaire on the identified issues (see Appendix B). The participants were asked to evaluate the issues listed, by answering the following questions:

- Is this issue important at a catchment level?
- Do water resources managers need information on this issue?
- Is this issue critical to the sustainability of the water resources?

On analysis, each issue could obtain a high score of three per participant if all three questions were answered positively. The sum of positive answers from all participants provided an importance rating for each issue (Figure 8.2).

The issues considered less important at a catchment level (scoring 47 or less; < 75%) were:

- Well-head protection;
- HIV/AIDS;
- International requirements;
- Decreased resources for cultural use;
- Change in climate and variability;
- Increased cost of provision of water;
- CMA financial viability;
- Decreased resources for cultural use, and
- Decreased resources for economic use.

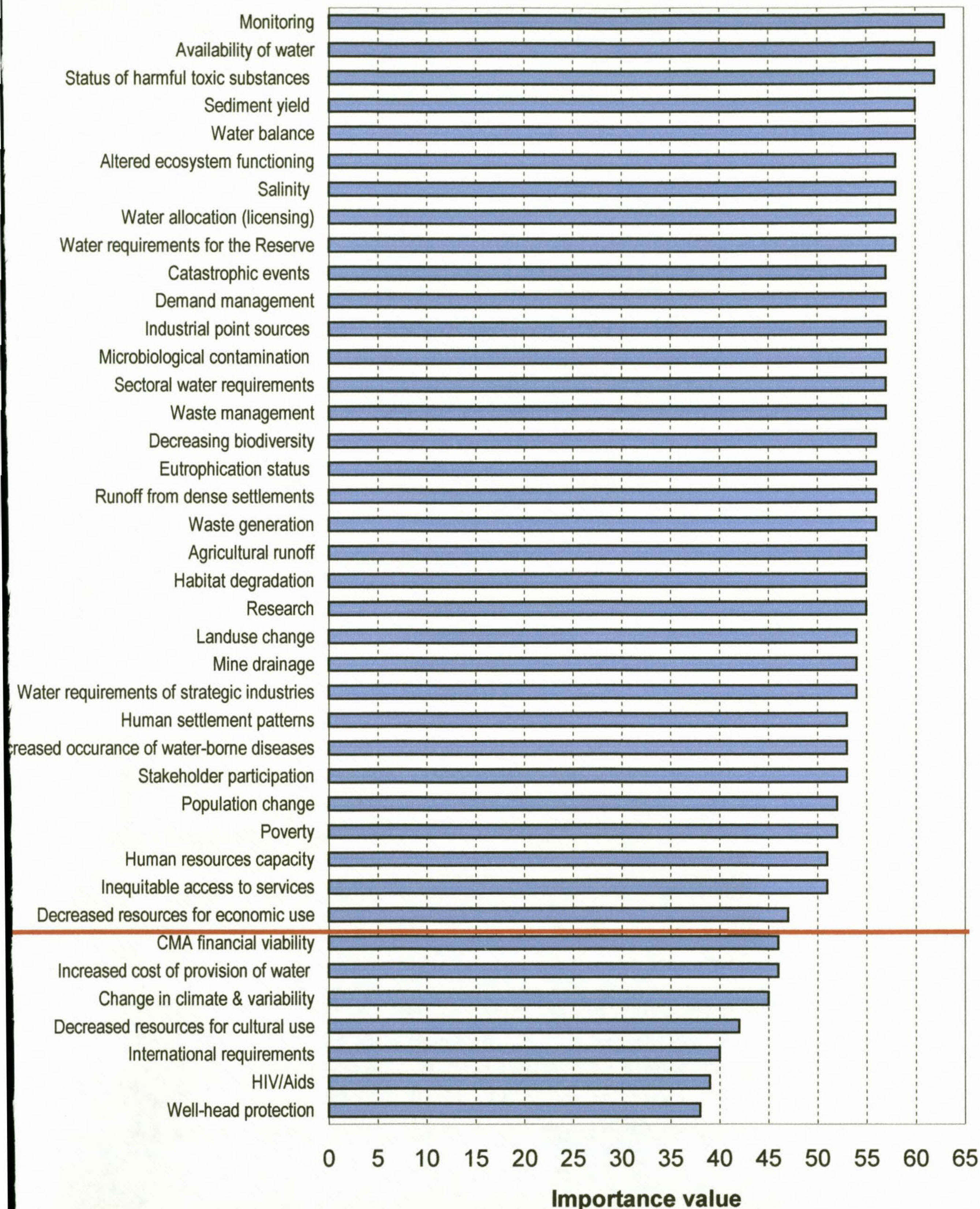


Figure 8.2: Ranking of issues by individual workshop participants (maximum value that could be obtained = 63).

8.3.2 Workshop plenary discussion

During the plenary discussion, it was agreed:

- *HIV/AIDS* could be incorporated into *population change*;
- *Climate change and variability* could form part of *catastrophic events*
- *Availability of water, demand for water, water balance* and *water allocation* were linked;
- *Waste generation, water quality management* and *waste management* were linked;
- *Sectoral water requirements* included *water requirements for strategic industries* and *international requirements*;
- All the water quality issues could be combined into one issue or listed seperately;
- *Water for food* was an issue that should be dealt with under poverty;
- *Eradication of past discrimination (inequity)* was an issue that should be included;
- *Inequitable access to resources* would be more appropriate as an issue than *inequitable access to services*;
- *Auditing (monitoring and reporting)* should be included as a response issue;
- *Water resources management capacity* should be included as a response issue;
- *CMA viability* should take the place of *CMA financial viability*;
- *Decreased resources for cultural use* would be excluded;
- *Decreased resources for economic development* would be excluded,
- *Increased cost of provision of enough water of the right quality* would be excluded
- *Inclreased occurrence of water-borne diseases* would be excluded, and
- *Research* should be viewed as predominantly a national function, although it may contribute to catchment understanding.
- Where possible, issues should be described in neutral terms (i.e. *biodiversity change*, not *biodiversity loss*).

These comments were included in the development of the final mindmap of issues as presented in Figure 8.3.

8.4 IDENTIFICATION OF INDICATORS

Two exercises were undertaken to obtain the input of stakeholders in the identification of indicators at the workshop:

- Completion of an indicators questionnaire (see Appendix B), in order to get an indication of the opinions of individuals, and
- A group exercise, which also included plenary discussions.

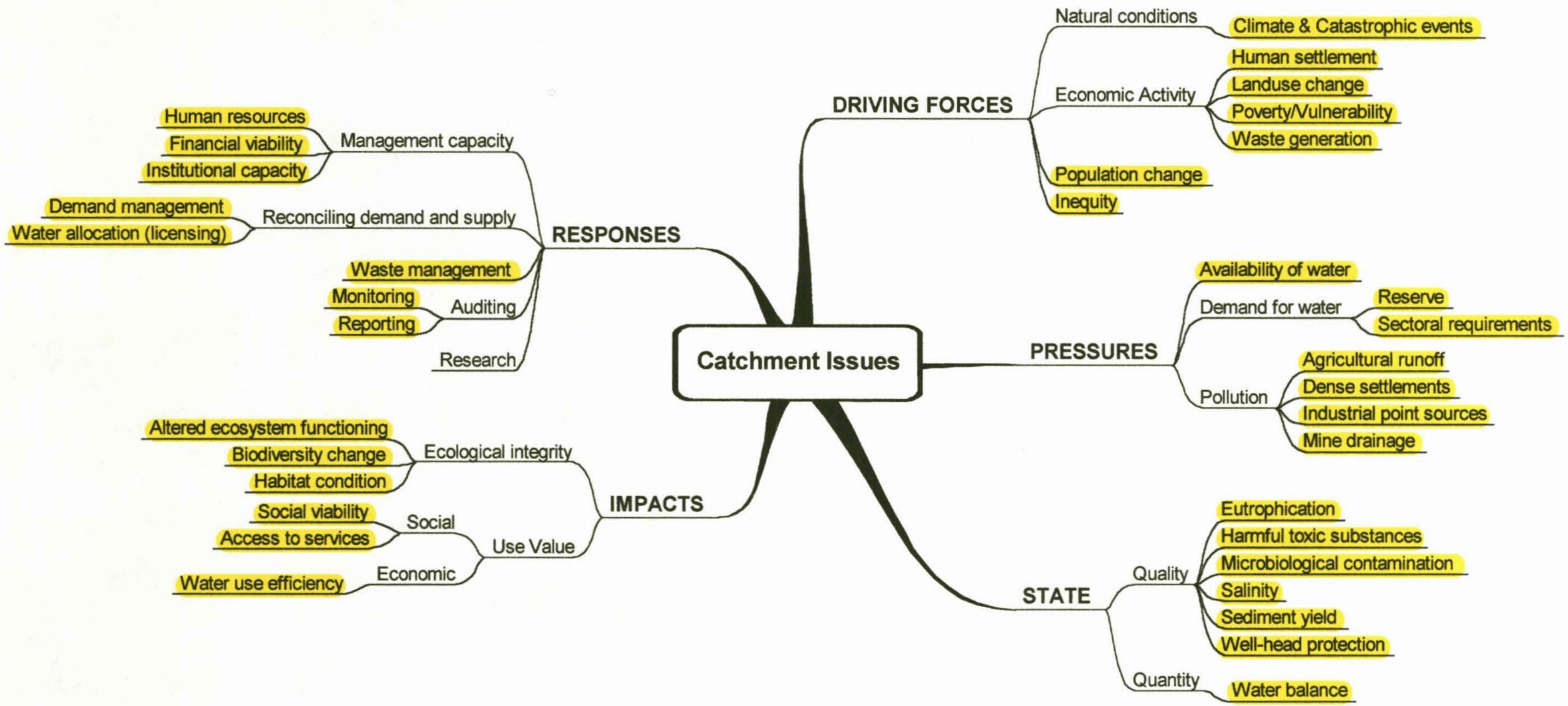


Figure 8.3: Mindmap of the priority issues (highlighted).

It was not envisaged that the final set of indicators would be determined at the workshop, but rather that the workshop would assist in the decision-making process in selecting final set of ideal indicators.

8.4.1 Questionnaire

Prior to the workshop, a list of possible indicators was compiled for each issue from other idicator initiatives (DEAT 2001, 2002a, 2002b; Rand Water 2000; ANZECC 1998). Workshop participants were requested to rate each indicator as one of the following (see Appendix B):

- An *excellent* reflection of the issue;
- A *good* reflection of the issue;
- A *poor* reflection of the issue;
- A *very poor* reflection of the issue.

Issues that had been discarded previously during the workshop (see above), were omitted from the questionnaire. Input from the participants was analysed according to a maximum score that could be obtained for each indicator, reflected as a percentage of the total (see Chapter 3).

Results of the questionnaire are summarised in Table 8.1 for priority issues. Indicators that scored higher than 70% were considered as appropriate indicators for inclusion in the indicator set. Fifty-six of the 88 (63,6%) indicators that were evaluated scored above 70%.

The workshop participants were requested to suggest alternative indicators for each issue in order to provide a wider array of choices in the final indicator selection process. Fifty-nine alternative indicators were suggested. Due to time constraints, the alternative indicators could not be evaluated in the same way as those originally presented to the workshop participants, but they were all considered for inclusion in the final set of indicators.

Table 8.1: Rating for each indicator, as well as suggested alternative indicators from workshop participants (see Appendix B for detailed analysis). Highlighted indicators received scores of ≥70%

ISSUE	INDICATOR	% RATING
DRIVING FORCES		
Climate and catastrophic events	Frequency and extent of flood events	81,0%
	Flood storage availability	55,0%
	Frequency and extent of droughts	73,3%
	Annual temperature deviations within the catchment	52,6%
	Annual rainfall deviations within the catchment	76,2%
	Mean annual precipitation	73,3%
	Mean annual evaporation	70,2%
	Alternatives: • Runoff variability • Mean annual runoff	
Human settlement patterns	Percentage of population in urban areas	70,4%
	Ratio of urban population to rural population	74,1%
	Alternatives: • Percentage of catchment area with planned developments vs. unplanned developments • Change in settlement type/place	
Landuse change	Area (as a percentage) of different land uses (agriculture, mining, industry, forestry, protected areas, human settlements) at 5 year intervals	88,3%
	Ratio of developed land to undeveloped land	85,4%
	Alternatives: • Land use intensity • Irreplacibility of the landscape • Ratio of developed land to land that has the potential to be developed	
Poverty	Proportion of households earning < R 6 000 per annum	58,3%
	Percentage of people living below the poverty line	74,1%
	Gross Geographic Product	54,2%
	Human Development Index	75,0%
	Alternatives: • Vulnerability of the catchment population to change • Water Poverty Index • Percentage of the population employed in the formal and informal sectors	
Waste generation	Amount of waste generated per person	57,4%
	Alternatives: • Effectiveness of waste disposal • Amount of waste generated per sector • Amount of waste removed per person • Amount of waste not disposed of at proper waste disposal sites	
Population change	Population density	75,4%
	Population growth rate	88,3%
	Alternatives: • No suggested alternatives	
Inequity	No suggested indicators provided	
	Alternatives: • No suggested alternatives	
PRESSURES		
Availability of water	Actual runoff per square km	63,2%
	Anthropogenic supply (IBTs and return flows) as a proportion of total available	70,6%
	Total water (surface and ground water) available per capita	83,3%
	Alternatives: • Water availability at different levels of assurance • Yield vs. allocated water supply	

Table 8.1 cont.

ISSUE	INDICATOR	% RATING
Sectoral water requirements	Percentage of water required by each sector	82,5%
	Number of people supported by groundwater	73,7%
	Alternatives: • No suggested alternatives	
Water requirements of strategic industries	Percentage water required by each industry	66,7%
	Alternatives: • Volume of water required by each industry • Volume of water required by each industry in comparison to what is available	
Water requirements for the Reserve	Reserve as a proportion of mean annual runoff	68,8%
	Alternatives: • Volume of water required by each industry • Reserve expressed as a percentage of system yield • Reserve as a percentage of actual flow • Real time flow requirements at selected points in a WMA • Volume of water required	
International requirements	Percentage of MAR required by other countries	85,2%
	Alternatives: • No suggested alternatives	
Agricultural runoff	Agricultural runoff as a percentage of MAR	68,6%
	Agricultural runoff as a percentage of the total water available	70,6%
	Fertiliser used per arable land area	54,8%
	Alternatives: • No suggested alternatives	
Runoff from dense settlements	Runoff from dense settlements as a percentage of MAR	68,8%
	Runoff from dense settlements as a percentage of the total water available	64,7%
	Alternatives: • Runoff from paved areas as a percentage of the total water available	
Industrial point sources (effluents)	Total liquid waste discharged as a proportion of total water available	71,1%
	Wastewater treated as a proportion of water care works' capacity	61,1%
	Proportion of effluents re-used	66,7%
	Pollutant loads discharges above permitted discharge limits	66,7%
	Alternatives: • Percentage compliance with water quality standards/permits	
Mine drainage	Mine drainage as a percentage of MAR	64,4%
	Mine drainage as a percentage of total water available	66,7%
	Alternatives: • Percentage compliance with water quality permits/permits	
	STATE	
Water balance	Demand as a proportion of supply	86,7%
	Proportion of groundwater utilised	70,4%
	Unaccounted for water as a percentage of total available	62,96%
	Groundwater level variations	72,6%
	Alternatives: • Useable water (combined yield from reservoirs) as a percentage of MAR • Demand as a proportion of supply at different levels of assurance	
Eutrophication status (surface)	Chlorophyll a concentration at dam walls of main reservoirs	87,2%
	Total phosphorus concentrations at dam walls of main reservoirs	69,2%
	Phosphate concentrations at dam walls of main reservoirs	72,2%
	Total phosphorus concentrations at the downstream point	66,7%
	Phosphate concentrations at the downstream point	72,2%
	Nitrate concentrations at dam walls of main reservoirs	72,2%
	Nitrate concentrations at the downstream point	69,1%
	Alternatives: • Chlorophyll a concentration at the lowest point in the geographical catchment • Total nitrogen concentration at the lowest point in the geographical catchment • Cost to clean to a certain general standard	

Table 8.1 cont.

ISSUE	INDICATOR	% RATING
Status of harmful toxic substances (surface & ground)	Daphnia toxicity test at dam walls of main reservoirs	74,4%
	Daphnia toxicity test at the downstream point	73,8%
	Alternatives: • No suggested alternatives	
Microbiological contamination (surface & ground)	Faecal coliforms at dam walls of main reservoirs	66,7%
	Faecal coliforms at the downstream point	74,5%
	Faecal coliforms at selected boreholes	72,9%
	E-coli at dam walls of main reservoirs	66,7%
	E-coli at the downstream point	77,1%
	E-coli at selected boreholes	77,8%
	COD at dam walls of main reservoirs	58,3%
	COD at the downstream point	64,7%
	Alternatives: • E.coli at points downstream of specific pollution sources , e.g. dense settlements without sanitation	
Salinity (surface & ground)	TDS at dam walls of main reservoirs	82,1%
	TDS at the downstream point	80,0%
	TDS at selected boreholes	83,0%
	Alternatives: • Conductivity at the lowest geographical point in a catchment • TDS at selected river monitoring points	
Sediment yield (surface)	Percentage of reservoir storage lost to sedimentation	70,4%
	TSS loading at the downstream point as a percentage of catchment sediment yield	68,6%
	Alternatives: • Rate of reservoir sedimentation • Actual catchment erosion per annum • Total sediment load per annum	
IMPACTS		
Altered ecosystem functioning	Change in flow at the downstream point	76,2%
	Reservoir capacity as a percentage of total water available	56,4%
	Alternatives: • Number an extent of impoundments and weirs • Change in flow at the upstream point	
Biodiversity change	SASS at selected sites	81,5%
	Fish Assemblage Integrity Index at selected sites	91,7%
	Percentage of indigenous fish present	72,2%
	Number of aquatic species at risk	77,8%
	Alternatives: • No suggested alternatives	
Habitat condition	Index of Habitat Integrity at selected reaches	79,2%
	Riparian Vegetation Index at selected reaches	79,2%
	Percentage loss of wetland area	89,6%
	Percentage of riparian zone with development	74,5%
	Percentage land area covered by alien invasive plants	76,5%
	Alternatives: • Width of riparian buffer zones along the river • Percentage of land covered by permanent structures • Percentage of species lost in wetland areas	
	Alternatives: • No suggested alternatives	
Access to services	Population without access to piped water on site (%)	81,5%
	Population without access to toilet facilities (%)	76,0%
	Alternative: • Inequality coefficient for water • Population with access to piped water within a distance 200m from the house • Population with access to environmentally-acceptable sanitation systems	

Table 8.1 cont.

ISSUE	INDICATOR	% RATING
	RESPONSES	
Institutional capacity (CMA viability)	No suggested indicators provided	
	Alternatives: • Proportion of the catchment management strategy successfully implemented in a five-year cycle	
Human resources	Number of professional water resource managers	56,9%
	Financial contribution to training for water resource managers	42,7%
	Alternatives: • Percentage of the population aware of water management issues • Level of education of water resource managers • Number of water resource managers per capita/per water distribution or storage facility • Budget available per employee to manage the water resources	
Stakeholder participation	Level of forum establishment	68,8%
	State-of-satisfaction of catchment population	64,3%
	Alternatives: • Success of catchment management strategy • Level of stakeholder representivity at (forum) meetings • Viability of forums	
Demand management	Decrease in use of water in areas where demand management has been introduced	77,8%
	Alternatives: • Efficiency of water use per sector (product per volume)	
Water allocation (licensing)	Number of compulsory licenses issued	64,7%
	Amount of water allocated through compulsory licensing	76,5%
	Alternatives • Amount of water allocated per race group • Amount of water allocated per sector • Percentage compliance to licenses issued • Number of licenses issues in respect of total water that can be allocated	
Waste management	RWQOs set for the catchment	70,6%
	RWQOs met for the catchment	88,9%
	Alternatives: • RWQOs modified during audit	
	Number of research projects in the catchment	60,8%
	Alternatives: • Deliverables and outputs of catchment-based research projects • Type of research undertaken in the catchment	
Monitoring and reporting	Number of active hydrological monitoring stations per 100 km^2	77,1%
	Number of active water quality monitoring stations per 100 km^2	77,1%
	Amount of money spent on monitoring per annum	59,5%
	Alternatives: • Database access and amount it is used • Biomonitoring sites per catchment • Frequency and quality of data per quaternary catchment • Number of catchments monitored in the WMA • Data quality assessment • Resources available for monitoring	

8.4.2 Group excercise and plenary discussion

For the group exercise, the participants were split into five groups according to the five DPSIR categories. Each group was requested to identify a *single* indicator that best described each issue in that category (about 8 issues per group). The aim of this exercise was to encourage group discussion and try to identify the most appropriate indicator for each issue, on the understanding that most issues required more than one indicator, and that some indicators could be included in more than one issue. It provided an indication of the best single indicators. The indicators chosen for each issue by the five groups are shown in Table 8.2.

Table 8.2: Indicator chosen by the group participants to represent each issue

ISSUE	INDICATOR
Driving Forces	
Climate and catastrophic events (floods and droughts)	Frequency and extent of flood and drought events
	Annual rainfall deviations within the catchment
Human settlement patterns	Area under different land uses, including agriculture, mining, industry, forestry, protected areas and urban and rural human settlement
Land use change	
Poverty/Inequity	Human Development Index
Waste generation	Amount of waste generated per person
Population change	Population density
Pressures	
Water requirements (sectoral; strategic, Reserve and international)	Demand and supply at different levels of assurance (100% = Reserve; 95% = strategic; 75% = agriculture etc.)
Water requirements for the Reserve	Instream flow requirements delivered vs. actual runoff
Quality and quantity of waste reaching the water resource	Total waste load reaching the resource
	Cost/benefit to downstream parties for sectoral use
State	
Water balance	Demand as a proportion of supply (over time)
Eutrophication status (surface)	Chlorophyll a concentration at the lowest point of a geographical catchment
Status of harmful toxic substances (surface & ground)	Daphnia toxicity test at the lowest point of a geographical catchment
Microbiological contamination (surface & ground)	Faecal coliforms in a water resource used for domestic & recreational use
Salinity (surface & ground)	Conductivity at the lowest point of a geographical catchment
Sediment yield (surface)	TSS loading at the lowest point of a geographical catchment or the inflow of a reservoir
Well-head protection	Still needs to be defined, but there should be no human and animal activity within a specified area around a well-head
Impacts	
Altered ecosystem functioning	Deviation from Reserve objectives
Biodiversity change	SASS at selected critical sites
	Fish Assemblage Integrity Index
Habitat condition	Index of Habitat Integrity
Access to services/resources	?
Responses	
CMA viability	Proportion of CMS successfully implemented in a 5-year cycle
Human resources capacity	?
Stakeholder participation	State-of-satisfaction of total catchment population
Demand management	Water use efficiency at different scales (Section 27 of NWA)
Water allocation (licensing)	?
Waste management	?
Monitoring	Number of active hydrological monitoring stations per 100 Km^2
	Number of active water quality monitoring stations per 100 km^2
	Amount of money spent on monitoring per annum

8.5 CONCLUSIONS

The workshop provided an opportunity to further acquire the opinion of stakeholders, as well as refine the work that had already been done in terms of issue identification.

The final issues for which indicators need to be developed included:

- Natural conditions - climate and catastrophic events;
- Economic activity - human settlement;
- Economic activity - land-use change;
- Economic activity – poverty/vulnerability;
- Economic activity – waste generation;
- Population change;
- Inequity;
- Availability of water;
- Demand for water – Reserve;
- Demand for water – sectoral requirements;
- Pollution – agricultural runoff;
- Pollution – dense settlement runoff;
- Pollution – industrial point sources;
- Pollution – mine drainage;
- Water quality – eutrophication;
- Water quality – harmful toxic substances;
- Water quality – microbiological contamination;
- Water quality – salinity;
- Water quality – sediment yield;
- Water balance – demand management;
- Water quality – well-head protection & groundwater quality;
- Water balance – water allocation;
- Ecological integrity – altered ecosystem functioning;
- Ecological integrity –biodiversity change;
- Ecological integrity – habitat condition;
- Social use value – social viability;
- Social use value - access to services;
- Economic use value - water use efficiency;
- Management capacity - human resources;

- Management capacity - financial viability;
- Management capacity – institutional capacity;
- Waste management;
- Auditing – monitoring;
- Auditing – reporting

Although it was not possible to finalise the choice of ideal indicators at the workshop, Table 8.1 and Table 8.2 provided input into the final decision-making process (see Chapter 9).

8.6 REFERENCES

AUSTRALIAN AND NEW ZEALAND ENVIRONMENT AND CONSERVATION COUNCIL (ANZECC). 1998. *Core Environmental Indicators for Reporting on the State of the Environment: Discussion paper for public comment.* ANZECC, Canberra. 63 pp.

DEPARTMENT OF ENVIRONMENTAL AFFAIRS AND TOURISM (DEAT). 2001. *National Core Set of Environmental Indicators for State of Environment Reporting in South Africa. Phase 1: Scoping Report. Volumes 1 & 2.* DEAT, Pretoria. 237 pp.

DEPARTMENT OF ENVIRONMENTAL AFFAIRS AND TOURISM (DEAT). 2002a. *Environmental Indicators for National State of the Environment Reporting, South Africa 2002.* DEAT, Pretoria. 37 pp.

DEPARTMENT OF ENVIRONMENTAL AFFAIRS AND TOURISM (DEAT). 2002b. *National Core Set of Environmental Indicators for State of Environment Reporting in South Africa. Phase 3: Selection of Indicators, Inland Waters.* DEAT, Pretoria. 95 pp.

RAND WATER. 2000. *Catchment Diagnostic Framework. Report No. 5: Development of the Catchment Diagnostic Index.* Mzuri Consultants, Pretoria. 91 pp.

SULLIVAN C, MEIGH J & O'REGAN D. 2002. *Evaluating Your Water: A Management Primer for the Water Poverty Index.* DFID and NERC, Wallingford. 95 pp.

CHAPTER 9: INDICATORS FOR ASSESSING SUSTAINABILITY OF CATCHMENTS IN SOUTH AFRICA

9.1 INTRODUCTION

The objective of any indicator development process is a set of indicators that is useful for an intended purpose. In the case of this study, the aim of the indicators chosen is to be able to provide a measure the level of sustainability of catchments in South Africa. It is believed that this has been achieved through the identification of priority issues that impact on the sustainability of South Africa's catchment systems.

This chapter provides information on the indicators chosen. It should be remembered that the indicator set has not been chosen with data availability in mind. In the International Review (Chapter 4) it was pointed out that the efficacy of indicator sets is often limited by data availability, because indicators are often selected for data availability rather than for validity. Thus, the indicator set described in this Chapter should be viewed as a set of indicators that provides "ideal" indicators to describe a series of issues that impact on the sustainability of water resources in South African catchments.

9.2 SET OF IDEAL INDICATORS

Indicators were identified by selecting the most appropriate indicator to represent each priority issue identified at the workshop (see Chapter 8), using the results of the workshop, as well as previous experience (Rand Water 2000; DEAT 2002). In some cases, more than one indicator was chosen to represent an issue, and some indicators covered more than one issue, Criteria for selection of the indicators included:

- All indicators must relate to the final set of priority issues confirmed at the stakeholder workshop;
- All indicators must be current (i.e. indicators not relevant now, e.g. *CMA viability*, were omitted);
- All indicators must be scientifically valid and analytically sound, and
- All indicators must be easily understandable.

The selection process resulted in forty indicators, which were grouped according to traditional water management categories, to facilitate understanding of the indicator set and awareness of linkages between indicators (see Rand Water 2000). The categories included: socio-economic (eight indicators); water balance (five indicators); waste and pollution (twelve indicators); resource condition (six indicators), and management (nine indicators). Fact sheets for each of the indicators were compiled and are provided in Appendix C. A summary table of the indicators, their relevance, their categorisation and the data requirements for each indicator is shown in Table 9.1.

Table 9.1: Summary table of indicators of sustainable development for catchment management in South Africa.

INDICATOR (UNITS)		RELEVANCE	ISSUE & DPSIR CATEGORY		DATA REQUIREMENTS
SOCIO-ECONOMIC					
SE1	Population density (no. km^{-2})	A high or growing population density can threaten the sustainability of water resources by exceeding the carrying capacity of the resource. This is particularly true in catchments where freshwater resources are limited (i.e. most South African catchments). At the same time, population density is considered to be a driving force of technological change in production. A high population density is the main defining feature of urban areas. A high concentration of population also means more local demand for sanitation, services, waste management and general amenities, all of which require water.	Population change	D	Total number of people Catchment area
SE2	Urbanisation (%)	The number of people in urban and rural environments has an impact on the infrastructure and water requirements, as well as waste management and pollution potential. In a highly urbanised environment, the infrastructure requirements will be high, especially with regard to sanitation, water supply and pollution management.	Human settlement	D	Number of people in urban areas Total number of people
SE3	Gross geographic product per capita (R cap^{-1})	Growth in the production of goods and services is a basic determinant of how the economy fares. It indicates the pace per capita of income growth and also the rate at which resources, including water, are used. It does not directly measure sustainable development, but is a very important measure for the economic and developmental aspects of sustainable development, including people's consumption patterns and the use of renewable resources, such as water.	Poverty/ Vulnerability	D	GGP for the catchment Total number of people
SE4	Human Development Index	This indicator is seen as a measure of people's ability to live a long and healthy life, to communicate, to participate in the life of the community and to have sufficient resources to obtain a decent living. If the level of human development is high in a catchment, the lower order needs are being met and high-order needs such as conservation can be dealt with. It also provides an indication of the potential of the population to rationally respond to resource management and sustainable development issues.	Poverty/ Vulnerability	D	Life expectancy at birth % Literacy among 15-year-olds and older Average number of years spent at school for 27-year-olds and older GGP for the catchment Total number of people
SE5	Water Equity Coefficient	One of the cornerstones of the National Water Act (36 of 1998), along with sustainability, is equity. It is stated that water will be allocated in a manner that ensures equity and that past imbalances will be redressed. The domestic sector is particularly prone to imbalance, and is ideal for measuring inequity.	Inequity	I	Total water available for domestic use Total number of people Amount of water received by each decile of the population

Table 9.1 cont.

INDICATOR (UNITS)		RELEVANCE	ISSUE & DPSIR CATEGORY		DATA REQUIREMENTS
SE6	Percentage of households without access to water within 200m (%)	This indicator shows whether the local authorities and water providers are providing adequate water to the population of the catchment. It is assumed that those people that are not linked are required to collect their own water from other sources (rivers and reservoirs). If there are a high proportion of people not serviced, this has implications for the control of water consumption in the catchment. It also indicates how many people still require water in terms of government policy. In general, it tells deals with the lower end of the Lorenz curve discussed in SE5: Water Equity Coefficient.	Inequitable access	P/I	Number of households without access to water within 200m Total number of households
SE7	Percentage of households without access to sanitation (%)	Toilet facilities may include fairly simple communal VIP toilets, septic tank systems or flush toilets. This indicator evaluates whether any of these are available and, as a result, shows whether there are adequate sanitation facilities in the catchment or not. It also assesses the potential for sewage pollution from runoff in areas where there are few toilet facilities provided. It is a key water resource pressure indicator.	Inequitable access	P/I	Number of households without access to toilet facilities Total number of households
SE8	Percentage area under different economic land uses (%)	The land use in a catchment determines the character of the water resource. Certain land uses are beneficial to aquatic ecosystems and thus the water resource (e.g. conservation), others are detrimental (mainly economic uses). The land use will determine the kind of problems apparent in a catchment (e.g. what type of pollution) and the management options available.	Land use change	D	Agricultural area Mining area Industrial area Catchment area
WATER BALANCE					
WB1	Mean volume of precipitation onto the catchment (m^3a^{-1})	South Africa is a country that has a high climatic variability, not only spatially (dry in the West and wet in the East), but also temporally. The country experiences extremes in both floods and droughts. This is exacerbated by the global problem of climate change. With the long-term change in the climate, it is believed that catastrophic events such as floods and droughts are becoming more common and, therefore, of greater concern to water resource managers. Floods and droughts both have severe social and economic implications for the country.	Climate variability/ Catastrophic events	S	Annual rainfall at main meteorological site(s)
WB2	Total water available per capita (m^3 cap^{-1})	This is an internationally-accepted, basic indicator for water availability, and provides a good indication of the level of development that can be sustained in any catchment. The estimated minimum amount of water required for development is 1 000 m^3 a^{-1} per capita (2 700 l per person per day) according to Gliek (1993, cited by http://www.cnie.org/pop/pai/water-12.html). Obviously in catchments in more arid areas where this amount is not available other development strategies need to be developed.	Availability of water	S	Mean annual runoff IBT Volume Total number of people
WB3	Demand as a proportion of total surface water available (%)	This indicator is an excellent core indicator of water balance. The sustainability of a catchment's water resources is dependent on the supply being greater than the demand. If demand is nearing supply, action is required.	Demand/ Availability/ Water balance	P	Total demand Mean annual runoff IBT Volume Return flows

Table 9.1 cont.

INDICATOR (UNITS)		RELEVANCE	ISSUE & DPSIR CATEGORY		DATA REQUIREMENTS
WB4	Proportion of groundwater utilised (%)	Groundwater can be a significant supply of water for domestic and agricultural use. A supply of groundwater where there is little surface water can allow for development where it might not be possible without it. If the demand for ground water is higher than the safe yield (the amount that the aquifer can yield on a sustainable basis), then usage of groundwater in the catchment will not be sustainable.	Demand/ Availability/ Water balance	P	Safe yield Amount of groundwater extracted
WB5	Water requirements per sector as a percentage of total available (%)	The National Water Act recognised four categories of water users in order of preference of water allocation, namely the Reserve (ecological and basic human needs), international water requirements (according to international agreements), strategic industries (such as electricity production) and other user sectors, such as mining, agriculture etc. The type of development in any catchment will determine the water use and availability, as well as influencing the characteristics of the catchment. These all impact on the water resource management approach in a catchment.	Reserve, International, Strategic & Sectoral demands	P	Water required for the Reserve Water required by other countries Water required by Eskom Water required by agriculture Water required by industry Water required by mining Water required by domestic users Mean annual runoff IBT Volume Return flows
WASTE AND POLLUTION					
WP1	Amount of solid waste generated per km^2 (tonnes km^{-2})	Waste is an inevitable consequence of development and must be systematically managed in order to conserve resources and protect the environment. Solid waste production increases annually due to population growth, inadequate services and non-sustainable lifestyles. Waste that is not disposed of properly may have adverse effects on ecosystem functioning and human health, and it is viewed as a major pollution threat to both surface and groundwater resources due to seepage from landfills and other waste disposal sites.	Waste generation	D	Amount of solid waste generated Catchment area
WP2	Proportion of solid waste generated per sector (%)	The type of solid waste generated in a catchment is dependent on the activities in the catchment. Some waste is more benign than others, whilst some requires stricter controls and management (e.g. hazardous waste). A catchment that has high industrial activity is likely to generate more waste, and this indicator should be seen as complementary to the previous indicator (WP1: Amount of waste generated per km^2). It also provides a measure of the need to devote resources and attention to waste management.	Waste generation	D	Amount of domestic solid waste Amount of industrial solid waste Amount of mining solid waste Amount of agricultural solid waste Total amount of solid waste
WP3	Total liquid waste discharged from point sources as a % of total water available	Generation of liquid waste is an indicator of the level of the economic activity in an area as well as domestic usage. The amount of effluent discharged thus depends on industrial processes, as well as population size. Obviously the more waste there is the more cause for concern there is with regard to the carrying capacity of the system. If the amount of effluent generated is equal to a high proportion of the flow, the carrying capacity of the system will be exceeded.	Pollution	P	Mean annual runoff IBT Volume Return flows

Table 9.1 cont.

INDICATOR (UNITS)		RELEVANCE	ISSUE & DPSIR CATEGORY		DATA REQUIREMENTS
WP4	Loading of P, N, POPs & TDS from agricultural runoff (tonnes a^{-1})	Irrigation farming is considered to be of strategic importance to the socio-economic development of South Africa. However, water pollution is a recognised problem. Pollution is mainly in the form of salination and nutrient enrichment of runoff and stored water from irrigated areas, but can also occur in dry-land agriculture where fertilisers are used. Other pollutants in agricultural runoff include pesticides and herbicides that have been used for crop protection.	Pollution	P	P Concentration for all agricultural runoff N Concentration for all agricultural runoff POPs concentration for all agricultural runoff TDS Concentration for all agricultural runoff Runoff volume for each agricultural concern
WP5	Loading of P & N from dense settlements (tonnes a^{-1})	Densely populated human settlements inevitably produce large quantities of waste. This waste, if left unchecked, can pollute rivers, streams and even groundwater resources. These problems are at their worst in the larger more densely populated settlements, many of which are poorly serviced. Unfortunately, many communities in South Africa are still labouring under the burden of an unjust past, and are unable to afford high levels of services, or to maintain those services that have been put in place. In some cases this has lead to severe pollution of nearby surface and groundwater resources, and has impacted on the quality of life in these settlements. This threatens the sustainable use of our water resources (DWAF 1999).	Pollution	P	P Concentration for all settlement runoff N Concentration for all settlement runoff Runoff volume for each settlement
WP6	Loading of TDS and SO_4 from mine drainage (tonnes a^{-1})	The mining industry is vital to the economy of South Africa. However, due to the depth of mineral deposits and, therefore, mining activities, mines are generally forced to dewater underground workings and to discharge the mineralised water to the surface sources. This can cause salinisation of surface waters as well as acidification.	Pollution	P	TDS Concentration for all mine drainage SO_4 Concentration for all mine drainage Runoff volume for all mine drainage
WP7	Conductivity at the lowest point in the geographical catchment (mS m^{-1})	Although dissolved salts occur naturally to varying degrees in aquatic systems, human activities in a catchment may severely increase the levels. Typical effluents, which have an effect on conductivity, are saline industrial effluents, agricultural runoff and acid mine water. Although increases in conductivity may not have a large influence on aquatic fauna, the level of salinity in the water may have other, more significant economic effect for users.	Salinisation	S/I	Conductivity measurement at the lowest point
WP8	P & N concentration s at the lowest point in the geographical catchment (mg ℓ^{-1})	Eutrophication, or enrichment of water systems by plant nutrients, is a world-wide water quality problem. It has far-reaching economic and social costs, and is the single largest problem for South African water resource managers. Anthropogenic activities in a catchment increase phosphate and nitrogen levels in surface waters and the suitability of surface water for various uses is severely affected by eutrophication (with toxic algae, excessive macrophyte growth, odours, taste and blocked filters are common problems). Ecosystems are also severely affected due to anoxic conditions, increased turbidity and toxic algae.	Eutrophication	S/I	P Concentration at the lowest point N Concentration at the lowest point

Table 9.1 cont.

INDICATOR (UNITS)		RELEVANCE	ISSUE & DPSIR CATEGORY		DATA REQUIREMENTS
WP9	Faecal coliforms in the major water resource for domestic and recreational use (no. per 100 mℓ)	Although most sewage is sent to water care works for purification before it enters the water resource, in areas where sanitation facilities are not available raw sewage may present a problem. Occasionally, sewage may overflow from a water care works due to a capacity overload or a breakdown in treatment facilities. A high level of organic enrichment leads to high treatment costs for potable water, as well as potential health risks in a catchment.	Microbiological contamination	S/I	Faecal coliforms in the major water resource for domestic and recreational use
WP10	Daphnia toxicity test at the lowest point in the geographical catchment	One of the major problems caused by industrial pollutants is the introduction of trace metals into freshwater ecosystems. Many of these have toxic effects on the natural fauna (Be, Co, Ni, Cu, Zn, Sn, As, Se, Te, Pd, Ag, Cd, Pt, Au, Hg, Tl, Pb, Sb and Bi) and can be concentrated up the food chain to present a health hazard to humans and higher order animals. They require strict management and a policy of pollution abatement generally applies to these elements. The toxicity effects of water at the downstream point will provide a good indication of whether abatement in the catchment has been effective or not.	Harmful toxic substances	S/I	Daphnia toxicity test at the lowest point
WP11	Turbidity at the lowest point in the geographical catchment or the inflow to the main reservoir (NTU)	Large quantities of sediment are carried downstream in South Africa's rivers each year. In many cases, anthropogenic activities have increased erosion in catchments, with the result that more sediment enters the rivers each year. However, much sediment is also deposited in reservoirs causing a loss in storage capacity. The net effect of all catchment activities on sediment yield will be apparent at the downstream point, measured by turbidity.	Sedimentation	S/I	Turbidity at the lowest point or the inflow to the main reservoir
WP12	Proportion of boreholes contaminated (%)	Groundwater supplies are particularly important in more arid areas of South Africa. In some areas ground water is almost the sole water supply. If these water sources become contaminated future development will be negatively affected. One of the problems facing water resource managers is the protection of well-heads, particularly from the watering of livestock. Other influences on groundwater quality are seepage from landfills, mine water drainage and agricultural seepage.	Well-head protection/ Groundwater quality	S/I	Conductivity of each borehole Total coliforms for each borehole N Concentrations for each borehole Number of boreholes
RESOURCE CONDITION					
RC1	Percentage catchment area covered by natural vegetation and by alien vegetation (%)	The land use in a catchment determines the character of the water resource. Certain land uses are beneficial to aquatic ecosystems and thus the water resource (e.g. natural green areas), others are detrimental (areas dominated by alien vegetation). Resource condition is affected by the level of human activity in the catchment. The higher the proportion of natural green areas, the less impacted the water resource is likely to be. High levels of alien invasion might affect the amount of water available in the catchment, as well as damaging the ecosystem integrity of the catchment.	Land use/ Habitat condition	S	Area covered by natural vegetation Area covered by alien vegetation Catchment area

Table 9.1 cont.

INDICATOR (UNITS)		RELEVANCE	ISSUE & DPSIR CATEGORY		DATA REQUIREMENTS
RC2	South African Scoring System (SASS) scores at selected sites (SASS score)	Aquatic fauna and flora respond in a predictable manner to changes in the physical and chemical nature of the water. If a water body is polluted or severely degraded, certain sensitive species will be unable to live there, whilst less sensitive species may thrive. Changes in the structure of Aquatic invertebrate communities reflect changes in overall river conditions. Invertebrate faunal assemblages, which the SASS system has been designed for, are affected by water quality changes over a relatively short period if compared to fish or vegetation assemblages. They do, however, reflect a longer-term quality than do once-off water samples.	Biodiversity change/ Ecosystem functioning	S/I	SASS scores at selected sites
RC3	Fish Assemblage Integrity Index (FAII) in selected reaches (FAII score)	Fish communities are good indicators of the general condition of a river. They are particularly good medium- to long-term indicators, whilst invertebrates tend to be short-term indicators. If an ecosystem is not functioning properly, changes in fish communities will occur, most often leading to a loss in biotic diversity, ecosystem functioning and rivers health.	Biodiversity change/ Ecosystem functioning	I	FAII scores at selected reaches
RC4	Index of Habitat Integrity in selected reaches (IHI score)	Habitat availability and diversity are major determinants of aquatic community structure and functioning. Loss of habitat is regarded as the single most important factor that has contributed to the extinction of species all over the world. Degradation of aquatic habitats in South Africa includes physical destruction of habitats due to river regulation (e.g. dams and IBTs) and infrastructure development (e.g. bridges), as well as the deterioration in water quality.	Habitat condition/ Ecosystem functioning	I	IHI scores at selected reaches
RC5	Riparian Vegetation Index in selected reaches (RVI score)	The riparian zone is the interface between freshwater and land systems. They maintain channel form and serve as filters for light, nutrients and sediment. If they are damaged, often degradation of the freshwater system occurs, including changing the ecosystem functioning, increased sedimentation, increased water usage etc. In the past, riparian rights of landowners in South Africa have lead to extensive degradation of the riparian zones of rivers, and irreparable damage to river ecosystems.	Habitat condition/ Ecosystem functioning	S/I	RVI at selected reaches
RC6	Percentage wetland area (%)	Wetland systems are some of the most endangered ecosystems in South Africa. Their numerous uses make them invaluable as natural assets and to sustainable development. An estimated 50% of all South Africa's wetlands have been lost, affecting the functioning of the aquatic systems of which they are a part. The extent of wetlands in a catchment gives an indication of the value of wetlands in the catchment, and can be used to track future wetland loss.	Habitat condition	S	Wetland area Catchment area

Table 9.1 cont.

INDICATOR (UNITS)		RELEVANCE	ISSUE & DPSIR CATEGORY		DATA REQUIREMENTS
MANAGEMENT					
MN1	Index of level of CMA establishment in the catchment	The foundation for the National Water Act (No.36 of 1998) is Integrated Water Resources Management (IWRM) at a catchment level. In order to institute this 19 Water Management Areas have been recognised, for which Catchment Management Agencies will be established. The establishment of each CMA is a complex process that includes integration of the current DWAF regional offices, development of the roles of various water management authorities and water boards and extensive stakeholder participation. Forum establishment is one of the first steps towards CMA development, and it is envisaged that forums will be included in the development of CMAs throughout the country. Another key is the development of a catchment management , which must be in harmony with the national water strategy, and should set the principles for allocating water taking into account matters relevant to the protection, use, development, conservation, management and control of water resources.	Institutional capacity/ Financial viability/ Human resources	R	Level of CMA development
MN2	State of satisfaction of catchment population	Public opinion often influences the behaviour of individuals or groups of people. The level of co-operation of the community in water resource management and conservation depends, along with other factors, on their satisfaction with water management in their area. For instance, people unhappy with the present level of service provision, together with other external variables, may be less likely to pay for water provision.	Social viability	R	Opinions of catchment population with regard to water services delivery and water resources management
MN3	Volume of water allocated as a proportion of total water available	The implementation of the National Water Act (No. 36 of 1998) depends largely on the allocation of scarce water resources within every Water Management Area. Water is allocated in a hierarchical fashion, in the following order: Reserve, international requirements, strategic industries and sectoral requirements. The amount of water allocated is a measure of the success of the administrative procedures within the catchment.	Water allocation	R	Volume of water allocated through licensing Mean annual runoff IBT Volume Return flows
MN4	Water use efficiency for different sectors ($R\ m^{-3}$)	In the past, South Africa relied largely on supply-side management to ensure that there was enough water for economic and domestic use in the country. However, most of the water resources in the country have been developed to capacity. The Department is currently encouraging demand management through pricing structures, and education and awareness. A Water Conservation/Demand Management Strategy has been developed as part of the National Water Resource Strategy to ensure the proper implementation of this philosophy. The efficiency of water use is one method to measure its success.	Water use efficiency/ Economic use value	R	Rand value of mining output Volume of water used by mining sector Rand value of agricultural output Volume of water used by agriculture Rand value of industrial output Volume of water used by industrial sector

Table 9.1 cont.

INDICATOR (UNITS)		RELEVANCE	ISSUE & DPSIR CATEGORY		DATA REQUIREMENTS
MN5	Percentage unaccounted for water in the catchment (%)	Water is a precious resource in an arid country such as South Africa and any loss away from a recognised user is important from the point of view of both the resource, and the added cost to supply water.	Water use efficiency/ Management capacity	R	Volume of water unaccounted for Volume of water distributed from bulk suppliers Return flows
MN6	Ratio sub-catchments for which the Ecological Reserve has been set to total number of sub-catchments	The National Water Act (No.36 of 1998) requires that the Reserve (basic human needs and ecological) is set for each catchment in the country. The greatest component of the Reserve, and the one that requires the most effort to determine, is the Ecological Reserve. Once the Ecological Reserve has been determined, RQOs can be set and water resources allocated according to the management class of the resource.	Reserve	R	Number of quaternary catchments for which Ecological Reserve has been set Number of quaternary catchments
MN7	Ratio of sub-catchments for which reliable hydrological data are available to total number of sub-catchments	Continual monitoring of the water resources is important for immediate management. Rainfall in South Africa is irregular over many catchments, and constant surveillance needs to be kept on the amount of water available in the catchment. Both flood control and drought relief are important aspects of water resource management in South Africa.	Monitoring	R	Number of quaternary catchments for which reliable flow data are available Number of quaternary catchments
MN8	Ratio of sub- catchments for which reliable water quality data are available to total number of sub-catchments	Information management is one of the most important aspects of water resource management. Without the correct information, management cannot be effective. Water quality information is important in continual evaluation of pollution in a system. It can also be used as a warning system for spills.	Monitoring	R	Number of quaternary catchments for which reliable water quality data are available Number of quaternary catchments
MN9	Number of official resource condition reports per annum (no. a^{-1})	Information only becomes valuable when it is presented in a way that is understandable to managers. The raw data are obviously essential to the knowledge base, but unless adequate analysis takes place, the data are useless. Reporting is an essential part of information transfer and capacity building within an organisation.	Reporting/ Auditing	R	Number of official reports on water quality Number of official reports on flow Number of official reports on river health

9.3 REPORTING ON SUSTAINABILITY USING THIS SET

Although, the individual indicators are essential in the value that they add to the set, it is important that the set as a whole provide more information than the sum of the individual indicators. The value of indicators is not in their existence, but rather in the way that they are used. During the indicator development process, the stakeholders continually queried how the indicators could be used. Several ways in which this indicator set can be utilised are discussed below.

9.3.1 "Red flagging"

The most obvious use for the set as a whole is as a "red-flagging" system. It is a simple process to provide targets or thresholds for each indicator against which they are measured on a regular basis. The target or threshold provides the value system against which the indicator is judged, thus removing subjective analysis. This also provides a method by which different catchments can be measured against different value systems according to their characteristics.

A good example is the use of water quality guidelines to establish a threshold. The DWAF Water Quality Guidelines (DWAF 1996) have been established for different user groups (industry, agriculture, domestic, aquaculture and recreation). It stands to reason that the user requirements of a catchment system would determine which set of Guidelines would be most appropriate to use as thresholds. Likewise, thresholds or targets can be set taking into account the natural conditions in a system. For instance, the Western Cape has naturally acidic waters, at levels that would be considered unacceptable in other parts of the country (Dallas & Day 1993).

9.3.2 Strategic Reporting

One of the most valuable characteristics of an indicator set is that, once it has been accepted and finalised, it provides a consistent reporting mechanism. This is ideal for the establishment of a strategic reporting system, either at the level of a CMA Board, or at Ministerial level.

Aggregation is an important aspect of strategic reporting, particularly aggregation of indicators into indices. The value of aggregation is that a single figure can summarise an array of information. Water quality parameters are often aggregated into an index, such as the Index of Watershed Indicators used by the US EPA (http://www.epa.gov/iwi 2002). The most obvious form of aggregation of the indicator set developed here is the development of indices based on the traditional categorisation used in

Table 9.1; i.e. Socio-Economic Index, Water Balance Index; Waste and Pollution Index; Resource Condition Index and Management Index.

Unlike a "red-flagging" system, an important component of a strategic reporting system is interpretation of the strategic issues that are brought to the fore by the information provided. It is, thus, a value-added system and requires input from specialists trained to interpret information provided by the indicators.

9.3.3 Thematic reporting

Thematic reporting can form part of strategic reporting, or stand alone as a method of reporting on certain issues that are important to catchment managers or that might relate to objectives set by catchment managers. Thematic reporting uses the linkages between indicators to report on different aspects of a theme or issue. One example of an important issue, which indicators could be used to report on, is poverty. *Alleviation of poverty* was the theme for the 2002 World Summit on Sustainable Development in Johannesburg, and is uppermost on the agenda to ensure a sustainable future for everyone. Water has been recognised as a key resource in alleviation of poverty throughout the world. It is, thus, a current issue that could be reported on using the set of ideal indicators developed here. Figure 9.1 provides an overview of the aspects of poverty that can be reported on using this indicator set.

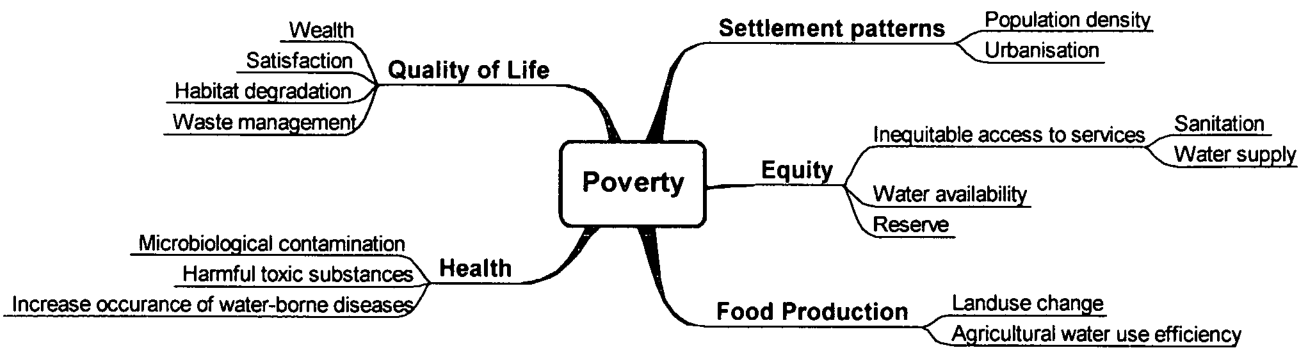


Figure 9.1: Diagram of poverty issues that are included in the indicator set.

Thus, poverty-related indicators included in this set are:

- Population density (no. km^{-2});
- Urbanisation (%);
- Water Equity Coefficient;
- Percentage of Households without access to water within 200m (%);
- Percentage of households without access to sanitation (%);
- Human Development Index;

- GGP per capita (R cap^{-1});
- Percentage area under agricultural use (%);
- Total water available per capita (m^3 cap^{-1});
- Faecal coliforms in the major water resource for domestic and recreational use (no. per 100 mℓ);
- Daphnia toxicity test at the lowest point in the geographical catchment;
- Percentage boreholes contaminated (%);
- Index of Habitat Integrity (IHI Score);
- State of satisfaction of catchment population, and
- Water use efficiency for agriculture.

Because of the complex nature of reporting on themes or issues, a specialist in the field is required for an integrated thematic report to be compiled. In this manner, the indicators can be placed in context and the subtleties of the theme adequately explained. Often thematic reports provide the basis for State-of-the-Environment reporting.

9.4 CONCLUSIONS

The process used to develop the indicators, including stakeholder interaction, ensured that the indicators were representative of all the issues that are currently of concern for sustainable catchments in South Africa. It is believed that the indicator set developed provides an adequate tool to measure the level of sustainability in any catchment in South Africa. The indicator set is flexible, and should change with changing needs (for instance, once Receiving Quality Objectives have been set, or CMAs established), and according to each catchment. In the meantime, this set provides a sound basis on which to test the hypothesis that adequate information is readily available in South Africa to assess sustainability of the country's water resources at a catchment level.

9.5 REFERENCES

DALLAS HF & DAY JA. 1993. *The Effect of Water Quality Variables on Riverine Ecosystems: A Review.* Water Research Commission, Pretoria. 240 pp.

DEPARTMENT OF ENVIRONMENTAL AFFAIRS AND TOURISM (DEAT). 2002. *Environmental Indicators for National State of the Environment Reporting, South Africa 2002.* DEAT, Pretoria. 37 pp.

DEPARTMENT OF WATER AFFAIRS AND FORESTRY (DWAF). 1996. *South African Water Quality Guidelines. Volumes 1-6.* DWAF, Pretoria.

RAND WATER. 2000. *Catchment Diagnostic Framework. Report No. 5: Development of the Catchment Diagnostic Index*. Mzuri Consultants, Pretoria. 91 pp.

PART III
EVALUATING SOUTH AFRICA'S CATCHMENT SUSTAINABILITY INFORMATION

CHAPTER 10: AVAILABILITY OF INFORMATION

10.1 INTRODUCTION

During the compilation of the National State-of-the-Environment Report in 1999, information on the sustainability of South Africa's water resources at a national level was found to be fragmented and often unavailable (Walmsley *et al.* 1999, 2000). For this project, it has been hypothesised that the situation is the same at catchment level.

It is assumed that the indicator set developed (see Part II) adequately reflects sustainability of water resources at a catchment level in South Africa. Therefore, if the water resources are to be managed sustainably at catchment level, the information required to populate the indicators should be available at the level at which management is taking place. Currently the role of catchment management agencies is undertaken by the DWAF regional offices until such time as catchment management agencies are established for the nineteen water management areas of the country. It follows that information for management of catchments within their jurisdiction should be available from each regional office.

An assessment of the availability of information at the regional offices was done, through an evaluation of the data available to populate the indicators for nine pilot catchments, one for each region (see Chapter 3 for methodology). The assessment included:

- Development of an understanding of data requirements and how data availability affects the indicators;
- A regional assessment from the information on the pilot catchments obtained through a survey questionnaire, and
- An integrated assessment of the country's ability to report on the indicators.

10.2 RESULTS

10.2.1 Data requirements

As a preliminary step in the assessment, a list of data requirements to populate the indicator set was compiled from the indicator fact sheets (see Appendix C). Table 10.1 provides a list of the data required (i.e. parameters that make up an indicator), as well as the indicators linked to each parameter.

Table 10.1: Data parameters and corresponding indicators

PARAMETER	INDICATORS REQUIRING PARAMETER
Total number of people in the catchment	Population density Urbanisation GGP per capita Human Development Index Water Equity Coefficient Total water available per capita
Catchment area (km^2)	Population density Percentage area under different economic land uses Amount of waste generated per km^2 Percentage catchment area covered by natural vegetation and by alien vegetation Percentage wetland area
Number of people living in urban areas (formal & informal)	Urbanisation
GGP for the catchment (R/a)	GGP per capita Human Development Index
Life expectancy at birth for people in the catchment	Human Development Index
% Literacy among 15-year-olds and older in	Human Development Index
Average number of years spent at school for 27-year-olds and older	Human development Index
Total water available for domestic use (m^3/a)	Water Equity Coefficient
Amount of water received by each decile of the population for domestic use (from greatest amount to least amount) (m^3/a)	Water Equity Coefficient
Total number of households	Percentage of households without access to water within 200m Percentage of households without access to sanitation
Number of households without access to water within 200m	Percentage of households without access to water within 200m
Number of households without access to any toilet facilities	Percentage of households without access to sanitation
Catchment area used for crops & grazing (km^2)	Percentage area under different economic land uses
Catchment area under mining (km^2)	Percentage area under different economic land uses
Catchment area under industrial use (km^2)	Percentage area under different economic land uses
Catchment area covered by natural vegetation (km^2)	Percentage catchment area covered by natural vegetation and by alien vegetation
Catchment area covered by alien vegetation (km^2)	Percentage catchment area covered by natural vegetation and by alien vegetation
Catchment area covered by wetlands (km^2)	Percentage wetland area
Annual rainfall (at any meteorological site) (mm/a)	Mean volume of precipitation onto the catchment
Mean annual runoff	Total water available per capita Demand as a proportion of total surface water available Water requirements per sector as a percentage of total available Total liquid waste discharged from point sources as a percentage of total available Volume of water allocated as a proportion of water available
IBT Volume – imported water (m^3/a)	Total water available per capita Demand as a proportion of total surface water available Water requirements per sector as a percentage of total available Total liquid waste discharged from point sources as a percentage of total available Volume of water allocated as a proportion of water available
IBT Volume – exported water (m^3/a)	Total water available per capita Demand as a proportion of total surface water available Water requirements per sector as a percentage of total available Total liquid waste discharged from point sources as a percentage of total available Volume of water allocated as a proportion of water available
Total demand for water (m^3/a)	Demand as a proportion of total surface water available

PARAMETER	INDICATORS REQUIRING PARAMETER
Volume of return flows (m^3/a)	Demand as a proportion of total surface water available Water requirements per sector as a percentage of total available Total liquid waste discharged from point sources as a percentage of total available Volume of water allocated as a proportion of water available Percentage unaccounted for water in the catchment
Safe yield for groundwater (m^3/a)	Proportion of groundwater safe yield utilised
Amount of groundwater extracted (m^3/a)	Proportion of groundwater safe yield utilised
Water required for the Reserve (m^3/a)	Water requirements per sector as a percentage of total available
Water required by other countries (m^3/a)	Water requirements per sector as a percentage of total available
Water required by Eskom (m^3/a)	Water requirements per sector as a percentage of total available
Water required by agriculture (m^3/a)	Water requirements per sector as a percentage of total available
Water required by industry (m^3/a)	Water requirements per sector as a percentage of total available
Water required by mining (m^3/a)	Water requirements per sector as a percentage of total available
Water required by domestic users (m^3/a)	Water requirements per sector as a percentage of total available
Total amount of solid waste generated (t/a)	Amount of solid waste generated per km^2 Proportion of solid waste generated per sector
Amount of domestic solid waste generated (t/a)	Proportion of solid waste generated per sector
Amount of industrial solid waste generated (t/a)	Proportion of solid waste generated per sector
Amount of mining solid waste generated (t/a)	Proportion of solid waste generated per sector
Amount of agricultural solid waste generated (t/a)	Proportion of solid waste generated per sector
Runoff volume for each agricultural concern (m^3/a)	Loading of P,N, POPs and TDS from agricultural runoff
Average annual total P concentration for runoff from each agricultural concern (mg/l)	Loading of P,N, POPs and TDS from agricultural runoff
Average annual total N concentration for runoff from each agricultural concern (mg/l)	Loading of P,N, POPs and TDS from agricultural runoff
Average annual POPs concentration for runoff from each agricultural concern (mg/l)	Loading of P,N, POPs and TDS from agricultural runoff
Average annual TDS concentration for runoff from each agricultural concern (mg/l)	Loading of P,N, POPs and TDS from agricultural runoff
Runoff volume for each dense settlement (m^3/a)	Loading of P and N from dense settlements
Average annual total P concentration for runoff from each dense settlement (mg/l)	Loading of P and N from dense settlements
Average annual total N concentration for runoff from each dense settlement (mg/l)	Loading of P and N from dense settlements
Volume for drainage from each mine (m^3/a)	Loading of TDS and SO_4 from mine drainage
Average annual TDS concentration for runoff from each mine (mg/l)	Loading of TDS and SO_4 from mine drainage
Average annual SO^4 concentration for runoff from each mine (mg/l)	Loading of TDS and SO_4 from mine drainage
Average annual conductivity at the lowest geographical point (mS/m)	Conductivity at the lowest point in the geographical catchment
Average annual total P concentration at the lowest geographical point	P concentration at the lowest point in the geographical catchment
Average annual total N concentration at the lowest geographical point	N concentration at the lowest point in the geographical catchment
Average annual faecal coliform counts in the major water resource for domestic and recreational use (number/100ml)	Faecal coliforms in the major water resource for domestic and recreational use
Daphnia toxicity test results at the lowest geographical point	Daphnia toxicity test at the lowest point in the geographical catchment
Turbidity at the lowest geographical point or at the inflow to the main reservoir (NTU)	Turbidity at the lowest point in the geographical catchment or the inflow to the main reservoir
Number of boreholes in the catchment	Percentage of boreholes contaminated
Average annual conductivity of each borehole (mS/m)	Percentage of boreholes contaminated

Table 10.1 cont.

PARAMETER	INDICATORS REQUIRING PARAMETER
Average annual total coliform counts for each borehole (number/100ml)	Percentage of boreholes contaminated
Annual average total N concentrations for each borehole (mg/l)	Percentage of boreholes contaminated
SASS scores	SASS scores at selected sites
Fish Assemblage Integrity Index scores	FAII in selected reaches
Index of Habitat Integrity scores	IHI in selected reaches
Riparian Vegetation Index scores	RVI in selected reaches
Progress with regard to the establishment of a CMA	Index of level of CMA establishment in the catchment
Opinions of the catchment population with regard to water services delivery and WRM	State of satisfaction of catchment population
Volume of water allocated through licensing (m^3/a)	Volume of water allocated as a proportion of water available
Rand value of mining output in the catchment (R/a)	Water use efficiency for different sectors
Volume of water used by mining sector (m^3/a)	Water use efficiency for different sectors
Rand value of agricultural output (R/a)	Water use efficiency for different sectors
Volume of water used by agriculture (m^3/a)	Water use efficiency for different sectors
Rand value of industrial output (R/a)	Water use efficiency for different sectors
Volume of water used by industrial sector (m^3/a)	Water use efficiency for different sectors
Volume of water unaccounted for in the distribution from bulk suppliers to end users (m^3/a)	Percentage unaccounted for water in the catchment
Volume of water distributed from bulk suppliers (m^3/a)	Percentage unaccounted for water in the catchment
Number of quaternary catchments	Ratio of sub-catchments for which Ecological Reserve has been set to total number of sub-catchments Ratio of sub-catchments for which reliable hydrological data are available to total number of sub-catchments Ratio of sub-catchments for which reliable water quality data are available to total number of sub-catchments
Number of quaternary catchments for which Ecological Reserve has been set	Ratio of sub-catchments for which Ecological Reserve has been set to total number of sub-catchments
Number of quaternary catchments for which reliable flow data are available	Ratio of sub-catchments for which reliable hydrological data are available to total number of sub-catchments
Number of quaternary catchments for which reliable water quality data are available	Ratio of sub-catchments for which reliable water quality data are available to total number of sub-catchments
Number of official reports on water quality (2001)	Number of official resource condition reports per annum
Number of official reports on flow (2001)	Number of official resource condition reports per annum
Number of official reports on river health (2001)	Number of official resource condition reports per annum

To populate the 40 indicators, data are required for 81 parameters. The most important parameters are those that are required for several indicators. These include:

- Total number of people in the catchment (6 indicators);
- Volume of return flows (6 indicators);
- Catchment area (5 indicators);
- Mean annual runoff (5 indicators);
- IBT Volume - imported water (5 indicators);
- IBT Volume – exported water (5 indicators), and
- Number of quaternary catchments (3 indicators).

The converse of this is that there are some indicators that require several parameters. This means that they are more vulnerable to failure. A single missing parameter can mean that the indicator becomes redundant, such as for:

- Human Development Index (5 parameters);
- Water Equity Coefficient (3 parameters);
- Total water available per capita (3 parameters);
- Demand as a proportion of total surface water available (4 parameters);
- Total liquid waste discharged from point sources as a percentage of total available (3 parameters);
- Percentage of boreholes contaminated (4 parameters);
- Volume of water allocated as a proportion of water allocated (4 parameters), and
- Number of official resource condition reports (3 parameters).

Other indicators can have parameters missing, but still provide partial information. These include indicators that have more than one figure to represent them, such as:

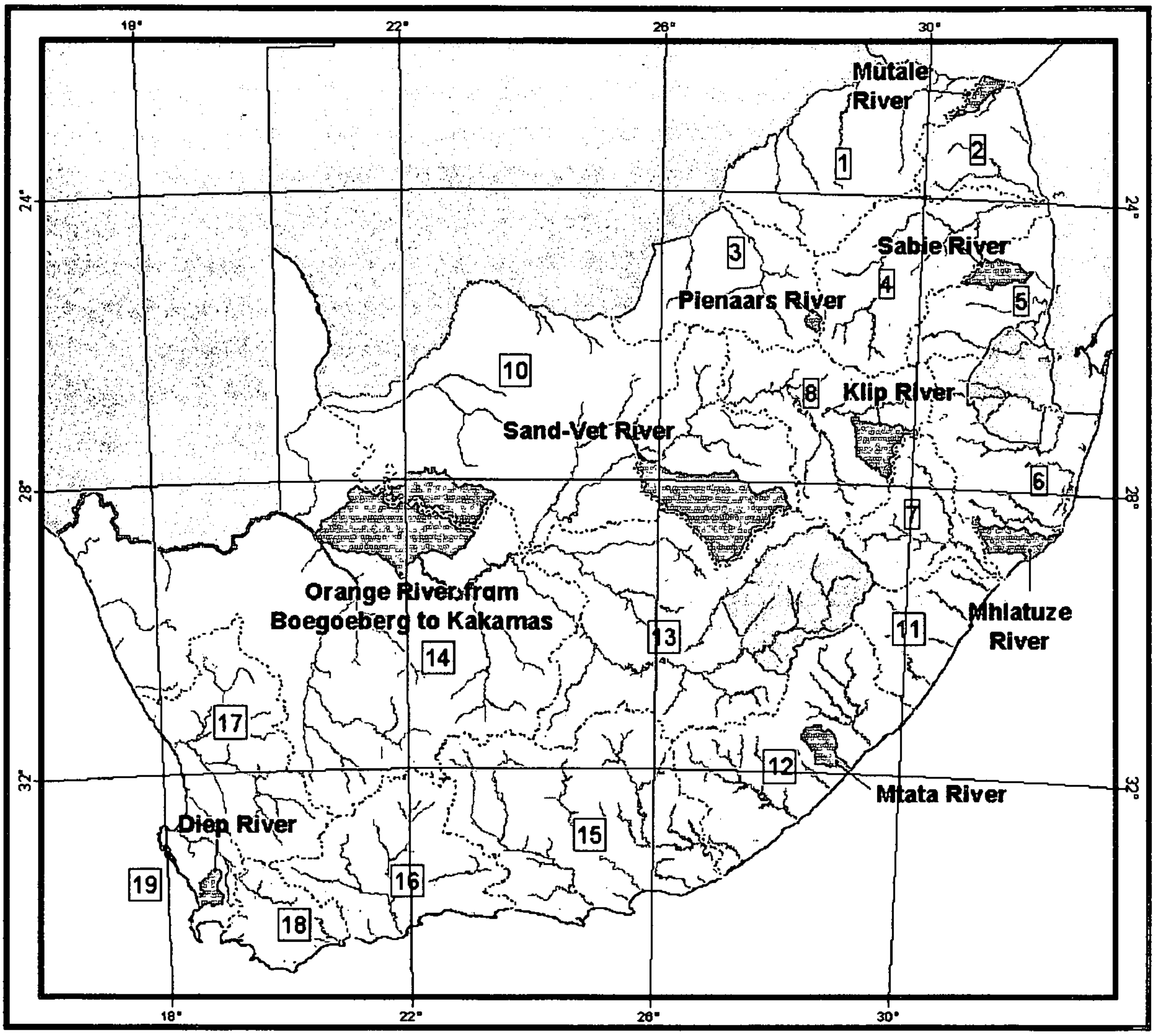
- Percentage area under different economic land uses (1 key parameter; 3 minor parameters);
- Water requirements per sector as a percentage of total available (3 key parameters; 7 minor parameters);
- Proportion of solid waste generated per sector (1 key parameter; 4 minor parameters);
- Loading of P, N, POPs and TDS from agricultural runoff (1 key parameter; 4 minor parameters);
- Loading of P & N from dense settlements (1 key parameter; 2 minor parameters);
- Loading of TDS and SO_4 from mine drainage (1 key parameter; 2 minor parameters);
- Percentage catchment area covered by natural vegetation and by alien vegetation (1 key parameter; 2 minor parameters), and
- Water use efficiency for different sectors (6 minor parameters);

10.2.2 Pilot catchment assessment

Each of the regional offices was requested to select a pilot catchment that fell within its jurisdiction. The size of the catchment chosen was not considered important as long as it represented a management unit that could be managed as an integrated whole, and whose boundaries were readily definable.

The regional catchment managers were required to complete a questionnaire based on the compiled data requirement list (see Table 10.1) for each of the pilot catchments selected (see Appendix D). The questionnaire requested managers to provide information on the availability of data to populate each parameter; the confidence level at which it was available, and possible sources of information if the information was not available at the regional office.

The pilot catchments selected by the DWAF regional offices are shown in Figure 10.1. Their general characteristics (obtained from Acocks 1975; Wells 1992; Midgley *et al.* 1994; Van Riet *et al.* 1997; Steyl *et al.* 2000 and DWAF 2002) are briefly described below, along with the results of the survey.



[1] Limpopo	[8] Upper Vaal	[14] Lower Orange
[2] Luvuvhu & Letaba	[9] Middle Vaal	[15] Fish to Tsitsikama
[3] Crocodile (West) & Marico	[10] Lower Vaal	[16] Gouritz
[4] Olifants	[11] Mvoti to Umzimkulu	[17] Olifants/Doorn
[5] Inkomati	[12] Mzimvubu to Keiskamma	[18] Breede
[6] Usutu to Mhlatuze	[13] Upper Orange	[19] Berg
[7] Thukela		

Figure 10.1: Map of South Africa showing water management areas and pilot catchments (shaded). (Figure supplied by Mr M Silberbauer, Institute for Water Quality Studies, DWAF.)

Mutale River (A92)

The Mutale River falls within the Luvuvhu-Letaba Water Management Area and under the jurisdiction of the Limpopo Regional Office. Rising in the Soutpansberg, it is the largest tributary of the Luvuvhu River and is situated wholly in the Limpopo Province. The catchment experiences rainfall ranging from 800 mm per annum in the Soutpansberg, to 200 mm per annum at the confluence with the Luvuvhu River, and evaporation (Symon's Pan) ranging from1500 mm per annum in the west to 1800 mm per annum in the east. Geologically it is mixed, with the majority of the catchment underlain by the Karoo Complex, and the lithology comprising mainly of intercalated assemblages of compact sedimentary and extrusive rocks. It has an undulating terrain covered with moderate to deep soils (sand, loam and clay). Natural vegetation is mostly mountain bushveld and Mopane shrubveld. The largest water use is irrigation (±97 million m^3 a^{-1}), followed by rural water use (±10 million m^3 a^{-1}) and afforestation (±7 million m^3 a^{-1}).

In general, the amount of data available to populate the indicators was high (Figure 10.2). Data for 81% of the parameters was available, of which 22% was of high confidence and 38 % was of medium confidence. This translated into 70% of the indicators being populated. Of the indicators that could be populated, 71% could be populated with data of medium confidence or higher.

Figure 10.2: Percentage of A) parameters and B) indicators for which information is available (low, medium or high confidence) for the Mutale River (Limpopo Region).

Pienaars River (A23A)

The Pienaars River is a tributary of the Apies-Pienaar River system and falls within in the Crocodile West and Marico Water Management Area (North West Region). The management unit chosen is the catchment of Roodeplaat Dam (A23A), which is at the top of the Pienaars River with the river running through the Eastern suburbs of Pretoria. The Pienaars River is situated in the Highveld, a summer rainfall region, and experiences a rainfall of 600-800 mm per annum and a Symon's Pan evaporation rate of 1 700-1 800 mm per annum. The lithography is mainly porous, unconsolidated and consolidated sedimentary strata, with soils that range from clayey loam to sandy loam (moderate to deep). The natural vegetation is sour grassland and false bushveld. Although values are not available for the Roodeplaat catchment alone, the main water use of the Pienaars River is urban (±268 million m^3 a^{-1}), followed by irrigation (±41 million m^3 a^{-1}) and power generation (±14 million m^3 a^{-1}). Baviaanspoort Water Care Works, which services Pretoria East and Mamelodi, discharges into the Pienaars River.

The amount of information available for this catchment was extremely limited, with 83% of the information (parameters) unavailable or unknown, and 90% of the indicators unable to be populated (Figure 10.3). This is surprising in view of the fact that Roodeplaat Dam is one of the primary recreational sites in the Tshwane area.

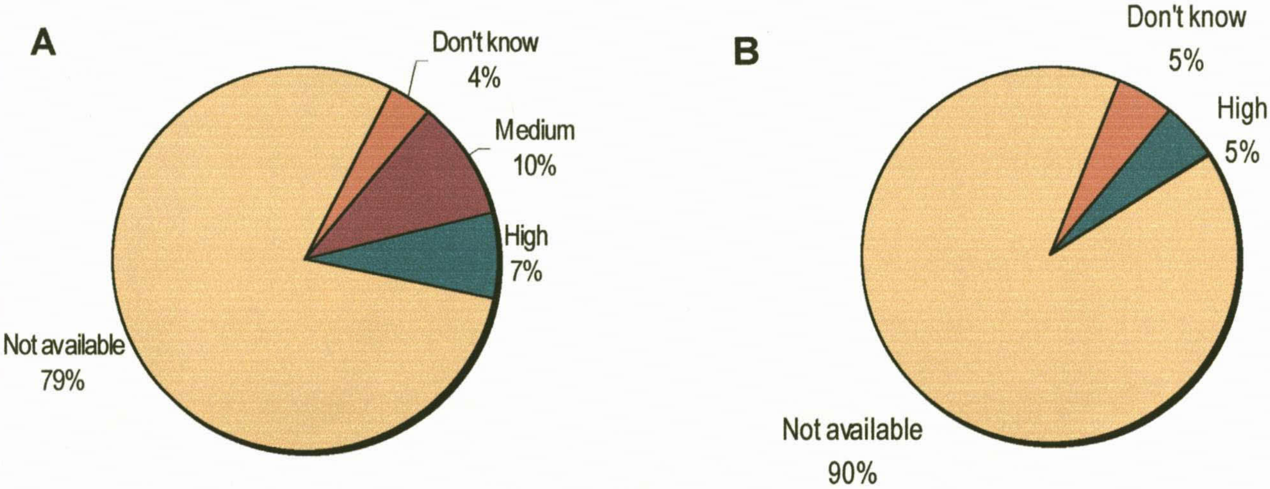


Figure 10.3: Percentage of A) parameters and B) indicators for which information is available (low, medium or high confidence) for the Pienaars River (North West Region).

Klip River (C13)

The Klip River is one of two rivers of the same name in the Upper Vaal Water Management Area (Gauteng Region). It is found in the upper reaches of the Vaal River catchment in the east of the water management area and flows into the Vaal River upstream of Vaal Dam. It experiences similar rainfall patterns to the Pienaars River (about 600-800 mm per annum) and has a Symon's Pan evaporation rate of between 1 300 mm per annum and 1 500 mm per annum. The lithography is predominantly intercalated arenaceous and argillaceous strata, with porous sedimentary strata in the north. It has an undulating terrain covered with moderate to deep sandy loam and clayey soils. The natural vegetation is predominantly Highveld grassland. The catchment is not much developed with no urban areas, mining or industry.

There was little information available for this catchment (Figure 10.4). Although the information that was available was mostly at a high confidence (16% of all parameters), 81% of the information was not available. There was an even higher percentage of indicators that could not be populated (92%). This catchment could be viewed as strategically important as it forms part of the Vaal catchment, which provides water for the industrial heartland of South Africa,

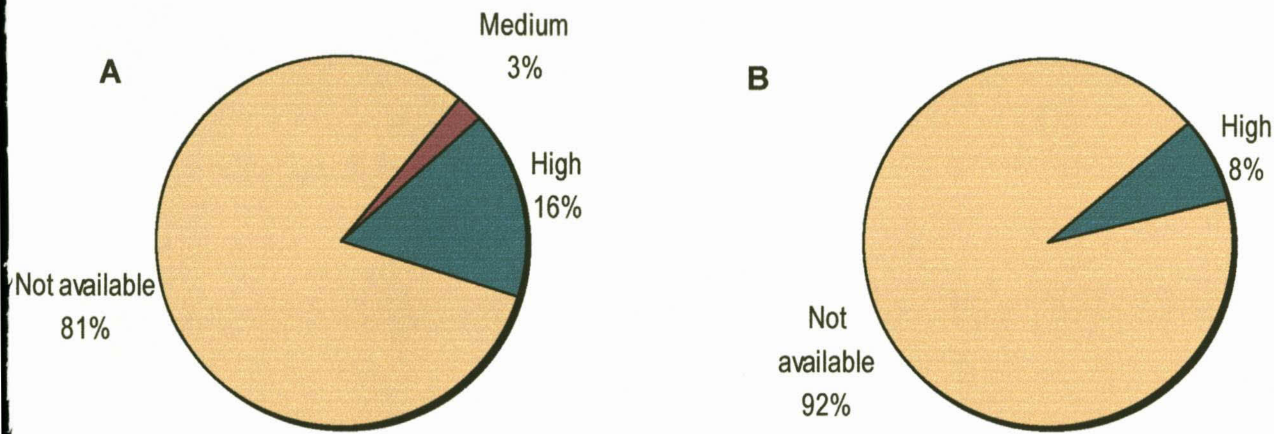


Figure 10.4: Percentage of A) parameters and B) indicators for which information is available (low, medium or high confidence) for the Klip River (Gauteng Region).

Sabie River (X31)

The Sabie River is one of six rivers that run through the Kruger National Park on the Moçambique border, and falls within the Inkomati Water Management Area (Mpumalanga Region). The Sabie River, and its main tributary, the Sand River, fall within the Mpumalanga Lowveld climatic region, with a mean annual precipitation ranging from 600 mm in the east to 2 000 mm in the west. The average annual Symon's Pan evaporation varies from 1 400 mm to 1 700 mm. The Sabie River may be divided into two distinct topographical regions, the Middleveld (mountainous areas in the east to undulating in the west) and the Lowveld (gently sloping pediplain). It is underlain by three major lithostratigraphic units: the Basement Complex, the Transvaal Sequence and the Karoo Sequence. Soils outside the Kruger National Park are lithosols in the upper catchment, changing to ferrallitic clays and arenosols in the lower catchment. Four veld types are recognised in the catchment, including mountain sourveld, sour bushveld, tropical bush and savannah. The main water uses in the catchment are irrigation (±69 million $m^3 a^{-1}$), afforestation (±46 million $m^3 a^{-1}$) and urban use (±21 million $m^3 a^{-1}$).

The Mpumalanga Regional Office had information available for 64% of the parameters, of which 47% (24) were at a high confidence level, 30% (15) were at a medium confidence level and 23% (13) were low confidence parameters (Figure 10.5). The percentage of indicators that could be populated was slightly lower than the parameters available (58%), with most of them at a medium to high confidence (40% of the total).

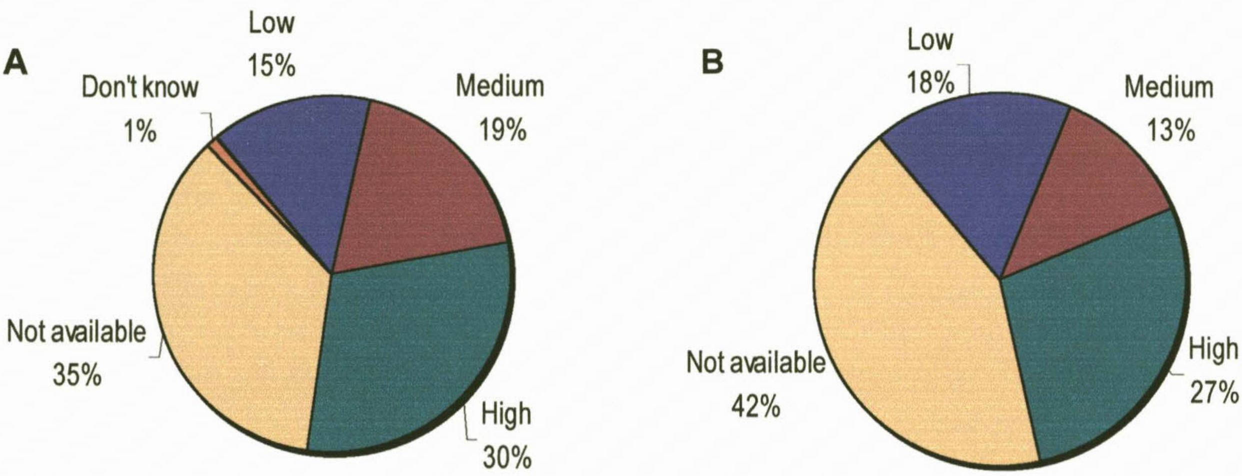


Figure 10.5: Percentage of A) parameters and B) indicators for which information is available (low, medium or high confidence) for the Sabie River (Mpumalanga Region).

Sand-Vet River (C41, 42, 43)

Sand-Vet River is one of the three main drainage areas that make up the Middle Vaal Water Management Area (Free State Region). The river rises in the Drakensberg in the east and flows north-west into Bloemhof Dam on the Vaal River. The rainfall experienced in the catchment ranges from 700 mm per annum in the east to about 400 mm per annum in the east, and mean annual Symon's Pan evaporation ranges from 1 400 mm (east) to 2 000 mm (west). The geology of the catchment falls into two main types, the Ecca Formation and the Adelaide Formation, both of the Karoo Complex. The topography of the catchment is undulating to flat, with moderate to deep loam soils (clayey and sandy). The natural vegetation is Highveld grassland. There are three large reservoirs in the catchment, the Allemanskraal (Sand River), the Erfenis (Vet River) and the Bloemhof at the confluence with the Vaal River. The main water uses in the catchment are irrigation (±100 million $m^3 a^{-1}$), urban (±46 million $m^3 a^{-1}$), mining and industrial (±38 million $m^3 a^{-1}$), and rural (±11 million $m^3 a^{-1}$).

The availability of information to populate the indicators was fair. Data were available for 58% of the parameters, and 48% of the indicators could be populated. Forty-three percent of the data that were available were of high confidence, but most of the indicators translated to medium confidence indicators (28% of the total).

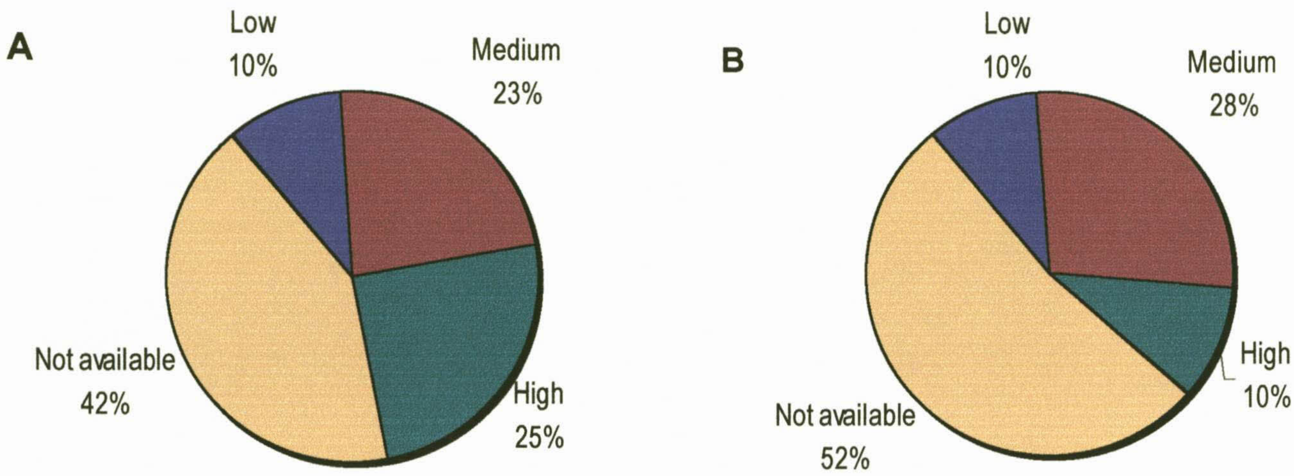


Figure 10.6: Percentage of A) parameters and B) indicators for which information is available (low, medium or high confidence) for the Sand-Vet River (Free State Region).

Mhlatuze River (W12)

The Mhlatuze River is situated in the northern coastal region of the province of KwaZulu-Natal. The catchment is the southernmost basin in the Usutu to Mhlatuze Water Management Area and is under the jurisdiction of the KwaZulu-Natal Region. The Mhlatuze River rises in the west at an altitude of 1 519m and flows east over 100 km to the sea. There are nine quaternary catchments and the coastal area is characterised by several freshwater lakes. It experiences a mean annual rainfall ranging from 800 mm in the west to 1400 mm along the coastal belt, and evaporation (Symon's Pan) of between 1 300 mm per annum and 1 500 mm per annum. It has a mixed geology mainly composed of the Karoo Complex and ancient granites, with the following formations: Dwykka; Meinhardkraal Granite; Beauford; Lebombo and Recent Sands. It has varying topography, steep at the escarpment, but becoming flat in the coastal areas, and has moderate to deep clay, loam and sandy soils. It has one large reservoir, the Goedertrouw Dam with a capacity of 300 million m^3. The Mhlatuze Catchment is recognised as one of the most water-stressed catchments in the country, with the main water uses being irrigation (±94 million $m^3\ a^{-1}$), mining and industrial (±86 million $m^3\ a^{-1}$), urban (±32 million $m^3\ a^{-1}$), afforestation (±19 million $m^3\ a^{-1}$), and rural (±8 million $m^3\ a^{-1}$).

Because the catchment is water-stressed, there have recently been several extensive studies on the Mhlatuze River (Kemper 2000; Steyl *et al.* 2000). Despite this, the availability of information was relatively poor (Figure 10.7). Only 52% of the parameters had data available, and 43% (17) of the indicators could be populated. Although available data for the parameters was relatively high, most of the indicators for which there was information, were at medium confidence (58% of those available).

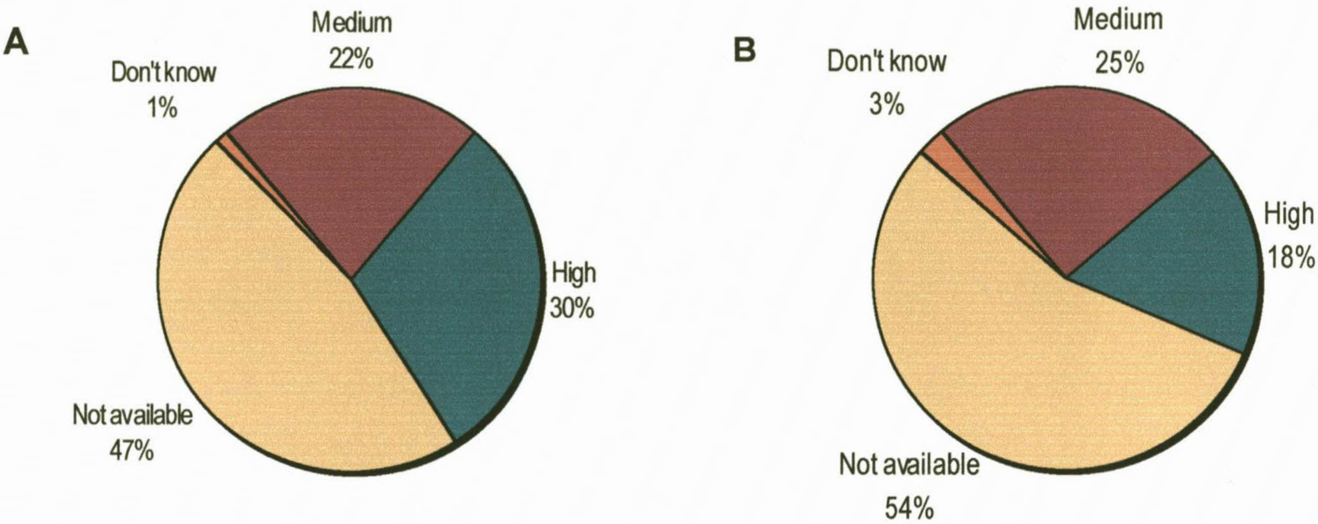


Figure 10.7: Percentage of A) parameters and B) indicators for which information is available (low, medium or high confidence) for the Mhlatuze River (KwaZulu-Natal Region).

Mtata River (T20)

Mtata River (T20) falls within the Mzimvubu to Keiskama Water Management Area in the Eastern Cape, under the jurisdiction of the Eastern Cape Region. Like the Mhlatuze, it is a high rainfall region, with the mean annual rainfall ranging between 700 mm and 1 500 mm, and Symon's Pan evaporation not exceeding 1 400 mm per annum. The catchment is underlain by the Tarkastad, Adelaide and Ecca Formations of the Karoo Complex. The topography is steep (inland) to undulating, and the soils a deep to moderate loams. The natural vegetation consists of moist upland grassland at the head of the catchment, karroid thicket downstream of Umtata and some coastal forest. With the exception of pine plantations in the upland areas and the urban area of Umtata, the catchment is not highly developed, but is regulated by the Mtata Dam. The main water uses are, therefore, afforestation (±28 million m^3 a^{-1}) and urban use (±13 million m^3 a^{-1}).

The amount of information available for the catchment was fair, with 59% of the parameters being available, mostly at a high confidence level (Figure 10.8). However, this translated into poor performance with regard to the number of indicators that could be populated (38%). This was due to single parameters not being available for the more vulnerable indicators (see section 10.2).

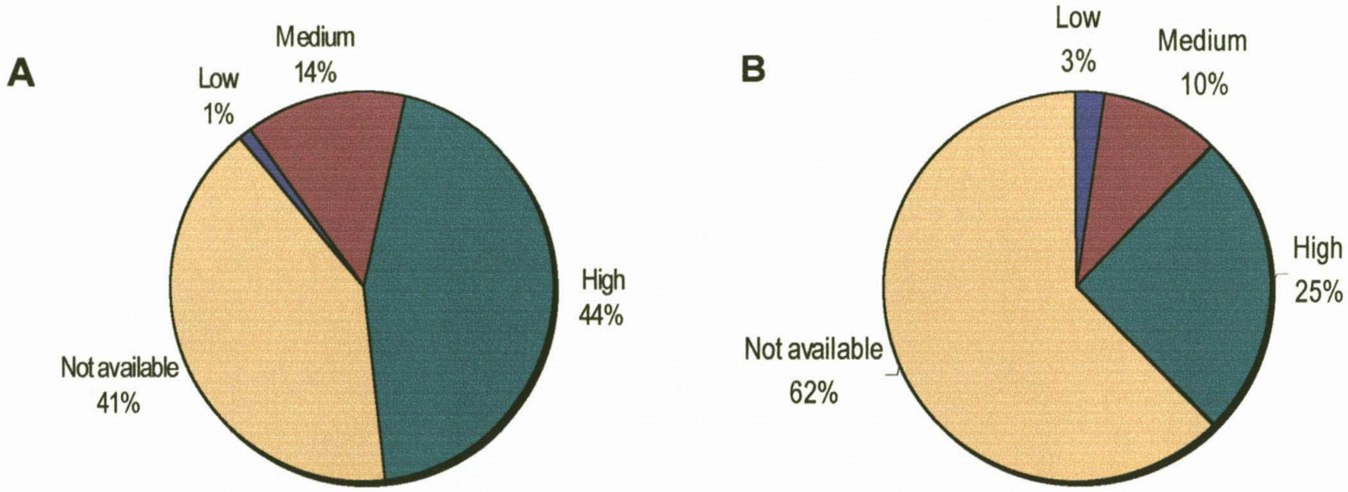


Figure 10.8: Percentage of A) parameters and B) indicators for which information is available (low, medium or high confidence) for the Mtata River (Eastern Cape Region).

Diep River (G21C, D, E, F)

The Diep River is situated in the Lower Berg drainage region within the Berg Water Management Area (Western Cape). The river rises in mountains near Malmesbury and flows south-south-east through Cape Town to the Atlantic Ocean. It is a coastal river, and does not flow into the Berg River at any point. It falls within the winter rainfall region and experiences between 400 mm and 600 mm of rainfall per annum. The mean annual Symon's Pan evaporation ranges between1 400 mm and 1 600 mm per annum in the catchment. The geology of the catchment is mainly of the Malmesbury and Cape Granite Formations. The topography is moderately undulating, except at the headwaters in the mountainous area around Malmesbury. The soils are moderate to deep, with clayey loam inland and sandy soils in the coastal belt. The catchment falls within the Fynbos Biome and the vegetation is dominated by West Coast renosterveld inland and sand plain fynbos in the coastal belt. The main land use in the catchment is crop farming (fruit and wheat), while urban development is predominant in the south towards the river mouth. Water requirements for the Diep River are not readily available, but the main water uses for the Lower Berg River are given by DWAF (2002) as irrigation (±53 million $m^3 a^{-1}$) and urban use (±25 million $m^3 a^{-1}$).

The amount of information available for this catchment was good (Figure 10.9), with 80% of data available, and 67% of the indicators able to be populated. Once again there was a lower percentage of indicators for which all information was available due to indicator vulnerability. In terms of parameters and indicators, the majority of information was at a medium to high confidence level (61% and 53% of the total respectively). Although the Diep River is not a priority catchment for the region, the level of data availability is encouraging.

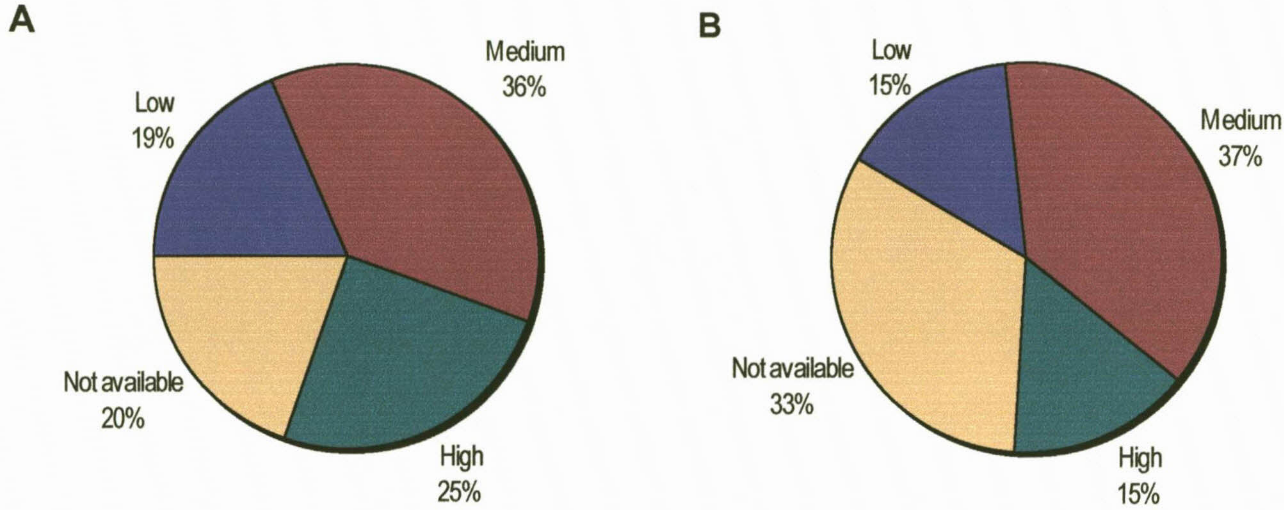


Figure 10.9: Percentage of A) parameters and B) indicators for which information is available (low, medium or high confidence) for the Diep River (Western Cape Region).

Lower Orange River from Boegoeberg to Kakamas (D73)

Lower Orange River is situated in the Northern Cape Province and falls within the Lower Orange Water Management Area (which includes Orange River tributaries and West Coast coastal rivers). The management unit chosen by the Northern Cape Regional Office was the tertiary catchment of the main Orange River from Boegoeberg to Kakamas, which includes the town of Upington. This catchment is arid, experiencing a mean annual rainfall of between 100 mm and 400 mm per annum, and a Symon's Pan evaporation of higher than 2 200 mm per annum. The main geological formations underlying this section of the river are Kalahari Sands to the north and Bushmanland Formation in the south, mostly consisting of hornblende and biotite granite. The topography of the area is dominated lowlands with hills, and dune hills and lowlands, and the soil are dominated by moderate to deep sands. The catchment falls within the Nama Karoo Biome, with the vegetation in the south being Orange River Nama Karoo vegetation and in the north being Kalahari dune bushveld. The main land use in this area is irrigated agriculture, as well as livestock farming. The main water uses for this catchment are not available, but for the Lower Orange River (excluding tributaries and coastal rivers) they are as irrigation (±764 million $m^3\ a^{-1}$) and urban use (±15 million $m^3\ a^{-1}$).

Most of the information required by the indicators was available (Figure 10.10). Only 15% of the parameters were not available, thus allowing 80% of the indicators to be populated. This region is the only one where some of the parameters are not applicable (e.g. water quality from mine drainage). It is also the only region in which the percentage of indicators that could be populated exceeded the percentage of parameters for which data was available. This suggests that the data for those parameters that provided information for several indicators was readily available.

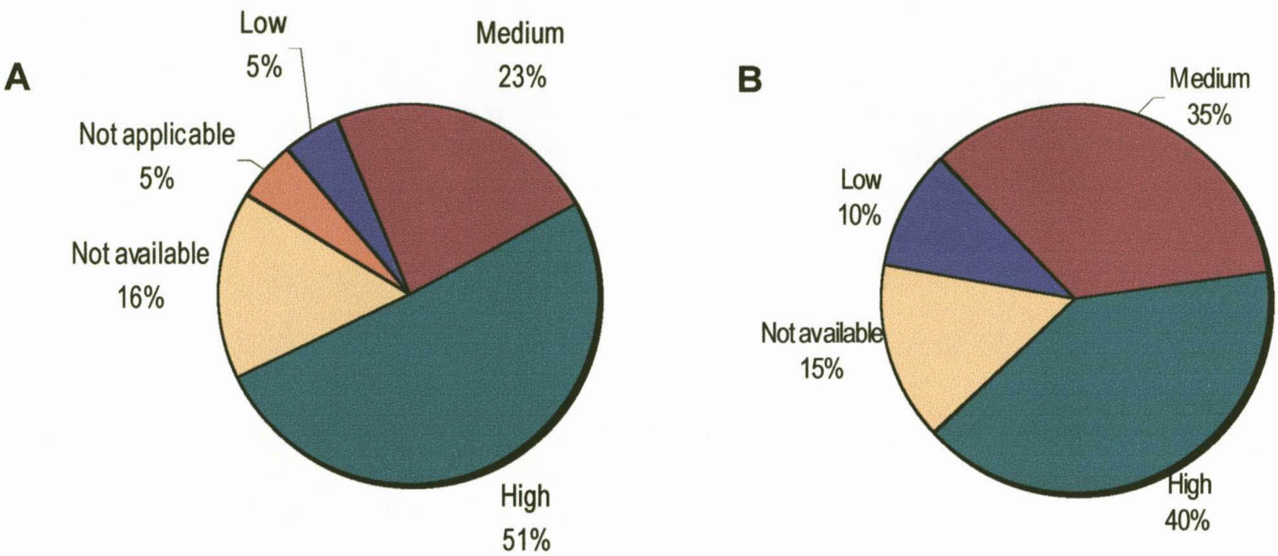


Figure 10.10: Percentage of A) parameters and B) indicators for which information is available (low, medium or high confidence) for the Orange River between Boegoeberg and Kakamas (Northern Cape Region).

10.2.3 Indicator assessment

Each indicator was assessed with respect to how many catchments were able to populate each indicator at any confidence level (Figure 10.11). In general, the overall ability of South Africa to populate the indicators and measure sustainability of the water resources of the country at catchment level was poor. The mean number of catchments for which each indicator could be populated was significantly lower than the ideal of 100% (X^2 test; df = 39; p < 0,01) and also significantly lower than a score of 80% (X^2 test; df = 39; p < 0,05). Only two of the indicators could be populated by all nine regions: *mean volume of precipitation onto the catchment* and *index of level of CMA establishment in the catchment*. Most of the indicators could only be populated in five regions or less. Even indicators that are recognised internationally, such as *total water available per capita* and *water requirements per sector as a percentage of the total available* could only be populated in three regions, and *water use efficiency* could only be populated in one region.

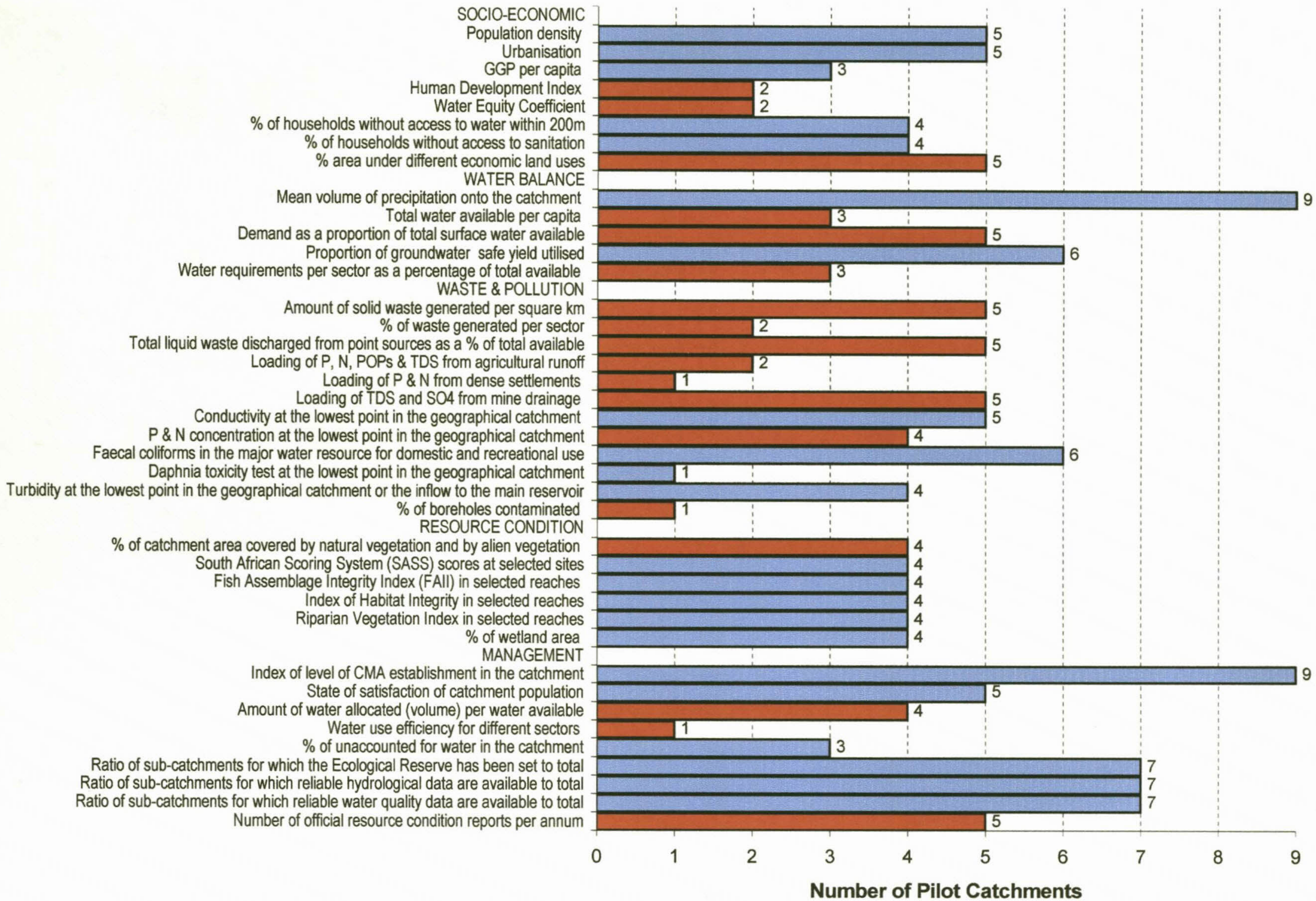


Figure 10.11: Number of pilot catchments for which each indicator can be populated. Indicators with red bars are those that are considered vulnerable.

10.2.4 Alternative data sources

Regional catchment managers were also required to identify possible data sources for parameters for which information was not available at catchment level. The results of this are provided in Appendix D, Analysis 3). The main sources of information included:

- Department Agriculture;
- Department of Education;
- Department of Environmental Affairs & Tourism;
- Department of Local Government & Housing;
- Department of Minerals & Energy;
- District & local municipalities;
- DWAF Directorate of Geohydrology;
- DWAF Directorate of Hydrology;
- DWAF Directorate of Water Quality Management;
- DWAF Directorate of Water Quality Management ;
- DWAF Directorate of Water Resources Planning;
- DWAF Directorate of Water Resources Planning;
- DWAF RDM Office;
- DWAF Head Office (unspecified);
- DWAF Water Resources Development Planning;
- DWAF Working for Water Programme;
- Institute for Water Quality Studies;
- Mining companies;
- Provincial Departments of the Environment;
- Provincial Departments of Agriculture;
- Provincial Integrated Development Plans;
- Universities;
- Statistics South Africa, and
- Water providers.

From this list, it is evident that there is a high reliance by the regions for information provided by DWAF Head Office. The regions are, therefore, not independent with regards to their data collection.

10.3 DISCUSSION AND CONCLUSION

The following statements may be drawn from the results provided above:

- None of the catchments had all the information required to populate the indicators, and the mean number of catchments for which each indicator could be populated was significantly lower than 80%.
- The most data-rich catchments, which had information for the most parameters (low, medium and high confidence), were the Mutale River catchment (81%); Diep River catchment (80%) and Orange River from Boegoeberg to Kakamas (78%).
- The most data-poor catchments, which had information for the least number of parameters, were the Pienaars River catchment (17%) and the Klip River catchment (19%).
- The Orange River from Boegoeberg to Kakamas had mostly data of high confidence (50% of the parameters), and the data available for the Mtata River catchment were also mostly high confidence (44% of the parameters).
- In all cases, except the Orange River, the percentage of indicators that could be populated was less than the percentage of parameters that were available.
- From the data available, the numbers of indicators that could be populated for each catchment were:
  - Orange River from Boegoeberg to Kakamas (Northern Cape): 32 indicators (80%);
  - Mutale River catchment (Limpopo): 28 indicators (70%);
  - Diep River catchment (Western Cape): 27 indicators (67%);
  - Sabie River catchment (Mpumalanga): 23 indicators (58%);
  - Sand-Vet River catchment (Free State): 19 indicators (48%);
  - Mhlatuze River catchment (KwaZulu-Natal): 17 indicators (43%);
  - Mtata River catchment (Eastern Cape): 15 indicators (38%);
  - Klip River catchment (Gauteng): 3 indicators (8%);
  - Pienaars River catchment (North West): 2 indicators (5%).
- Of the possible data sources for the indicators, about 45% of them were DWAF Head Office.

Based on the above, it seems that the ability of South Africa to populate the indicators at a catchment level is poor. There are several reasons for this, including:

- **Indicator vulnerability**

  The possibility of this being due to indicator vulnerability was explored. The indicators that were considered vulnerable (see Figure 10.11; $\bar{x} = 3,07$) were compared statistically using a Student's t-test with those that were not considered vulnerable ($\bar{x} = 4,91$). The mean number of catchments for which data were available for these two types of indicator were found to be significantly different ($df = 38$; $p < 0,05$), with the vulnerable indicators less likely to be populated. However, although vulnerability does play a part in the populating of indicator, the ability to populate the non-vulnerable indicators also varied between one and nine catchments for each.

- **Lack of a cohesive information management system at regional level**

  The indicator analysis (see Appendix D, Analysis 2) showed that there was little conformity between the catchments as to the indicators that could be populated. This suggests that the information available for catchment management in each region varies considerably from region to region, and that information is collected opportunistically and on an *ad hoc* basis, rather than according to a national strategy as part of a cohesive information system. The fact that many of the information systems that are currently used in DWAF (see Chapter 2) are not yet available at the regional offices has implications for information availability throughout South Africa.

- **Lack of understanding with regard to indicators**

  The stakeholder participation process, both the interviews and the workshop, demonstrated that there was little understanding of indicators and their use within DWAF. This is verified by the fact that, despite the strategic value of sustainability indicators, the National Water Resource Strategy does not refer to them at all. The monitoring and information strategy described in the National Water Resource Strategy (DWAF 2002) has been based on the same principles that applied to the old Water Act of 1956, without thought for the how to measure sustainability of water resources. This is not due to a disregard of the principles, but rather a lack of understanding of measuring sustainability.

- **Lack of resources**

  Despite the National Water Act specifying that water resources management authority will be devolved to the lowest possible level, there is little evidence that the regional offices have been given greater authority than previously. This is partly due to financial constraints, and partly due to the lack of human capacity. Much of the authority, the finance and the human resource capacity still rest with DWAF Head Office.

- **Lack of commitment**

  Because much of the information on the water resources of the country is not available at a regional level, commitment is required by the water resource managers to ensure that they have the information that is required to manage the catchments under their jurisdiction. It is apparent that there is little commitment to be well-informed. An example of this is the fact that the Gauteng Regional Office did not have available the size of the Klip River catchment, a figure that is readily available from the WR90 Report of Midgley *et al.* (1994). This problem is exacerbated by the reliance on electronic database systems to provide information, rather than on individual knowledge-bases.

10.4 REFERENCES

ACOCKS JPH. 1975.*Veld Types of South Africa*. Memoirs of the Botanical Survey of South Africa, No. 40. Botanical Research Institute, Pretoria.

DEPARTMENT OF WATER AFFAIRS AND FORESTRY (DWAF). 2002. *Proposed First Edition National Water Resource Strategy: Summary.* DWAF, Pretoria. 37 pp. http://www.dwaf.gov.za.

MIDGLEY DC, PITMAN WV & MIDDLETON BJ. 1994. *Surface Water Resources of South Africa 1990.* Volumes I to VI. WRC, Pretoria.

STEYL I, VERSVELD DB & NELSON PJ. 2000. *Strategic Environmental Assessment for Water use: Mhlatuze Catchment – KZN.* DWAF, Pretoria.

VAN RIET W, CLAASSEN P, VAN RENSBURG J, VAN VIEGEN T & DU PLESSIS L. 1997. Environmental Potential Atlas for South Africa. JL Van Schaik, Pretoria. 60 pp.

WALMSLEY JJ, WALMSLEY RD & SILBERBAUER M. 1999. Chapter 3: Sustainability of Freshwater Systems and Resources. In: Department of Environmental Affairs and Tourism (Ed), *State of the Environment in South Africa*, DEAT Pretoria. http://www.ngo.grida.no/soesa.

WALMSLEY JJ, WALMSLEY RD, PRETORIUS RJ & MARAIS D. 2000. *Information Management and State-of-the-Environment Reporting for Water Resources in South Africa*. Poster Presentation, WISA Conference 2001. Mzuri Consultants, Pretoria.

WELLS JJ. 1992. *A Pre-impoundment Study of the Biological Diversity of the Benthic Macro-Invertebrate Fauna of the Sabie-Sand River System*. MSc Thesis, University of Cape Town, Cape Town. 207 pp.

CHAPTER 11: GENERAL DISCUSSION AND CONCLUSIONS

11.1 INTRODUCTION

Availability of timely, adequate, relevant and valid water resources information is crucial for the sustainable management of South Africa's catchment systems. This is recognised in the National Water Act (No. 36 of 1998), which states that the Minister is required to establish a national monitoring and information system for water resources as soon as possible. The aims of the system are provided in Section 140 of the Act as:

a. *To store and provide data and information for the protection, sustainable use and management of water resources;*
b. *To provide information for the development and implementation of the national water resource strategy;*
c. *To provide information to water management institutions, water users and the public -*
    i. *For research and development;*
    ii. *For planning and environment impact assessments;*
    iii. *For public safety and disaster management; and*
    iv. *On the status of water resources.*

In 1999, when the National State-of-the-Environment Report was compiled (DEAT 1999), there was not adequate information available on all relevant aspects of the water resources of South Africa. Information was considered to be fragmented and there was little evidence of a national information system being achieved in the near future (Walmsley *et al.* 2000). The National Water Resource Strategy, published three years later confirms that spatial coverage was incomplete and problems were experienced with the quality and reliability of information.

The main aim of this thesis was to assess the current availability and quality of information at catchment level in South Africa using sustainability indicators. Within this, the objectives of this study were to:

- Investigate the role of indicators of sustainable development in developing an understanding of the strategic issues in catchment management;
- Determine which core indicators are required to provide information on sustainable water resource management at catchment level in South Africa, and
- Assess the adequacy of the current catchment management information systems for assisting in the sustainable management of South Africa's water resources.

The assumptions that were made were:

- Sustainability indicators are a suitable method of providing information in a format that is usable by managers and decision-makers, and are accepted as basic tools for facilitating public choices and supporting policy implementation.
- The Department of Water Affairs and Forestry, as the custodian of the country's water resources and in accordance with the National Water Act, should have the information required to manage the water resources sustainably, and
- Because the basis of the National Water Act is devolution of authority to the local (catchment) level, the regional offices, which are currently in charge of catchment management in lieu of catchment management agencies, should have the resources, including information, to manage the catchments efficiently and effectively.

The main findings of the investigation are outlined below, as well as recommendations for future action.

11.2 ROLE OF INDICATORS IN UNDERSTANDING STRATEGIC ISSUES IN SUSTAINABLE CATCHMENT MANAGEMENT

11.2.1 General application of indicators in catchments

An indicator is a parameter that provides information about an environmental issue with a significance that extends beyond the parameter itself (OECD 1993). Because of this, indicators have a wide range of strategic applications, including:

- *Monitoring and assessing conditions and trends on a national, regional and global scale* - This provides baseline information for situation analyses, as well as forming the foundation for long-term monitoring.
- *Comparing situations* - This is particularly relevant in South Africa for strategic comparative analyses between water management areas, as well as between catchments in water management areas;
- *Assessing the effectiveness of policy* - South Africa is currently implementing new legislation. A set of indicators will be valuable in assessing the success of the legislation. In particular, performance indicators, which ascertain whether the legislation is being correctly implemented, can be compared to sustainability of catchment systems. If the performance indicators show that the policy is correctly implemented, and yet the sustainability indicators show a deterioration in the water resource, the policy and legislation will have to be re-evaluated.
- *Marking progress against a stated benchmark* - Indicators are ideal to evaluate a system against

known benchmarks or targets. This is especially relevant in South African catchments where resource quality objectives will be established for all catchments as part of the Reserve-determination procedure.

- *Monitoring changes in public attitude and behaviour* - Because of South Africa's past, the Government is particularly aware of including the citizens of the country in decision-making, and all the current policy and legislation has gone through stringent public participation processes. Particularly in water management, the role of the public is becoming more prominent and water users will have more influence in catchment management once catchment management agencies have been established. It is, thus, important to understand public attitudes.
- *Ensuring understanding, participation and transparency in information transfer between interested and affected parties* – This links to the previous point, stakeholders involved in catchment management and the public need to be made aware of the issues in any given catchment or water management area. The social aspect of sustainability is becoming more prominent (WSSD 2002), and policies that require stakeholder and public understanding (e.g. water conservation and demand management) will surely fail without the public being continually informed.
- *Forecasting and projecting trends* – Once trends have been established, future scenarios can be extrapolated and planned for. This is particularly valuable where there is a good understanding of catchment processes.
- *Providing early warning information* – Indicators are excellent at providing an early warning, both in terms of trend analysis and in the meeting of targets. Trend analysis can provide a future warning system, whilst the meeting of targets can provide a "red-flagging" system for immediate concerns.

11.2.2 Indicator development as a strategic tool

The development of indicators is an interactive process that can provide greater understanding of the strategic issues at catchment level. The type of issues identified will depend on the framework chosen to develop the indicators. Thus, it is important to choose the correct framework for indicator development. This study made use of two frameworks:

- DPSIR framework, which provided the foundation to identify key sustainability issues related to catchment functioning in South Africa, and
- An issues-based approach that required a policy review, as well as interaction with stakeholders and water managers in the country.

The process of developing the indicators was valuable from several aspects:

- It provided an understanding of what was occurring elsewhere in the world. In terms of indicator development, few organisations have developed catchment management indicators, and those that have, have done so within their mandates rather than for the purpose of measuring sustainability. Thus, indicators are generally a reflection of the strategic requirements or mandate of an organisation.
- The DPSIR framework provided an objective analysis of the interaction between people and water resources, and the impact of the interaction. It assisted in developing a greater understanding of the origin and results of certain recognised water resource problems, through a cause-effect-response logic, and the linkages between them, as well as providing a framework for use in South Africa.
- The identification of issues through the policy review, provided an understanding of the issues that were catered for in South Africa's policy and legislation. In theory, this should reflect the needs of the people of the country, although there was no way to test this.
- The lack of understanding of indicators and their uses was apparent throughout the interaction with stakeholders. Each interaction required a degree of capacity building, and the overall result was a better understanding by catchment managers of indicators and their value.
- Issue identification through the interviews with stakeholders and the workshop provided a more subjective input, based on the experience of the people managing the resource. In some cases, this highlighted emotive issues (e.g. water for food) as well as providing greater insight into issues that were currently of concern (e.g. HIV/AIDS).

In general, the process of developing the indicators highlighted policy issues and strategic decisions that are required to ensure the sustainability of catchment systems. It also highlighted the need for an indicator system for water resources management in South Africa, and the current lack of capacity and understanding with regard to the strategic value of catchment management indicators.

11.2.3 Indicator reporting

Although, the individual indicators are essential in the value that they add to the set, it is important that the set as a whole provide more information than the sum of the individual indicators. Obviously the strategic value of indicators is not in their existence, but rather in the way that they are used and reported upon.

The most obvious use for the set as a whole is as a "red-flagging" system. It is a simple process to provide targets or thresholds for each indicator against which they are measured on a regular basis. The target or threshold provides the value system against which the indicator is judged, thus removing subjective analysis. This also provides a method by which different catchments can be measured against different value systems according to their characteristics.

One of the most valuable characteristics of an indicator set is that, once it has been accepted and finalised, it provides a consistent reporting mechanism. This is ideal for the establishment of a strategic reporting system, either at the level of a CMA Board, or at Ministerial level. Unlike a "red-flagging" system, an important component of a strategic reporting system is interpretation of the strategic issues that are brought to the fore by the information provided. It is, thus, a value-added system and requires input from specialists trained to interpret information provided by the indicators.

Thematic reporting can form part of strategic reporting, or stand alone as a method of reporting on certain issues that are important to catchment managers or that might relate to objectives set by catchment managers. Thematic reporting uses the linkages between indicators to report on different aspects of a theme or issue (e.g. poverty). Often thematic reports provide the basis for state-of-the-environment reporting.

There is currently no system in place in South Africa that makes use of indicators for reporting on sustainable catchment management. This is mainly due to the fact that the value of indicators is not yet appreciated, and the use of sustainability indicators in water resource management is a relatively new field.

11.3 CORE INDICATORS REQUIRED TO PROVIDE INFORMATION ON SUSTAINABLE WATER RESOURCE MANAGEMENT AT CATCHMENT LEVEL IN SOUTH AFRICA

11.3.1 Core indicator set

Development of indicators can lead to an infinite list of indicators being generated. However, it is necessary to focus on those indicators that, as a set, are representative of the main sustainability issues within a catchment. This was achieved in this study, firstly, through the identification of priority issues and, secondly, through limiting the indicators chosen to represent each issue. The result was a set of 40 indicators that, though possibly not comprehensive, provided a good indication of the level of sustainability in a catchment and represented the 34 priority issues identified by the stakeholders (Table 11.1). The indicators were grouped according to traditional water management categories for ease of understanding by water resource managers. The categories included: socio-economic (eight indicators); water balance (five indicators); waste and pollution (twelve indicators); resource condition (six indicators), and management (nine indicators).

Table 11.1: Sustainability indicators for catchment management in South Africa

SOCIO-ECONOMIC	
SE1	Population density (no. km^{-2})
SE2	Urbanisation (%)
SE3	Gross geographic product per capita (R cap^{-1})
SE4	Human Development Index
SE5	Water Equity Coefficient
SE6	Percentage of households without access to water within 200m (%)
SE7	Percentage of households without access to sanitation (%)
SE8	Percentage area under different economic land uses (%)
WATER BALANCE	
WB1	Mean volume of precipitation onto the catchment (m^3 a^{-1})
WB2	Total water available per capita (m^3 cap^{-1})
WB3	Demand as a proportion of total surface water available (%)
WB4	Proportion of groundwater utilised (%)
WB5	Water requirements per sector as a percentage of total available (%)
WASTE AND POLLUTION	
WP1	Amount of solid waste generated per km^2 (tonnes km^{-2})
WP2	Proportion of solid waste generated per sector (%)
WP3	Total liquid waste discharged from point sources as a % of total water available
WP4	Loading of P, N, POPs & TDS from agricultural runoff (tonnes a^{-1})
WP5	Loading of P & N from dense settlements (tonnes a^{-1})
WP6	Loading of TDS and SO_4 from mine drainage (tonnes a^{-1})
WP7	Conductivity at the lowest point in the geographical catchment (mS m^{-1})
WP8	P & N concentration s at the lowest point in the geographical catchment (mg ℓ^{-1})
WP9	Faecal coliforms in the major water resource for domestic and recreational use (no. per 100 mℓ)
WP10	Daphnia toxicity test at the lowest point in the geographical catchment
WP11	Turbidity at the lowest point in the geographical catchment or the inflow to the main reservoir (NTU)
WP12	Proportion of boreholes contaminated (%)
RESOURCE CONDITION	
RC1	Percentage catchment area covered by natural vegetation and by alien vegetation (%)
RC2	South African Scoring System (SASS) scores at selected sites (SASS score)
RC3	Fish Assemblage Integrity Index (FAII) in selected reaches (FAII score)
RC4	Index of Habitat Integrity in selected reaches (IHI score)
RC5	Riparian Vegetation Index in selected reaches (RVI score)
RC6	Percentage wetland area (%)
MANAGEMENT	
MN1	Index of level of CMA establishment in the catchment
MN2	State of satisfaction of catchment population
MN3	Volume of water allocated as a proportion of total water available
MN4	Water use efficiency for different sectors (R m^{-3})
MN5	Percentage unaccounted for water in the catchment (%)
MN6	Ratio of sub-catchments for which the Ecological Reserve has been set to total number of sub-catchments
MN7	Ratio of sub-catchments for which reliable hydrological data are available to total number of sub-catchments
MN8	Ratio of sub-catchments for which reliable water quality data are available to total number of sub-catchments
MN9	Number of official resource condition reports per annum (no. a^{-1})

Of these indicators, sixteen were considered vulnerable to failure due to the fact that they were made up of several parameters each. They included:

- Human Development Index (5 parameters);
- Water Equity Coefficient (3 parameters);
- Total water available per capita (3 parameters);
- Demand as a proportion of total surface water available (4 parameters);
- Total liquid waste discharged from point sources as a percentage of total available (3 parameters);
- Percentage of boreholes contaminated (4 parameters);
- Volume of water allocated as a proportion of water allocated (4 parameters);
- Number of official resource condition reports (3 parameters);
- Percentage area under different economic land uses (1 key parameter; 3 minor parameters);
- Water requirements per sector as a percentage of total available (3 key parameters; 7 minor parameters);
- Proportion of solid waste generated per sector (1 key parameter; 4 minor parameters);
- Loading of P, N, POPs and TDS from agricultural runoff (1 key parameter; 4 minor parameters);
- Loading of P & N from dense settlements (1 key parameter; 2 minor parameters);
- Loading of TDS and SO_4 from mine drainage (1 key parameter; 2 minor parameters);
- Percentage catchment area covered by natural vegetation and by alien vegetation (1 key parameter; 2 minor parameters), and
- Water use efficiency for different sectors (6 minor parameters).

Although vulnerability affected the number of indicators for which there was data, the assessment of the information availability was primarily at the level of parameters. Thus, the level of vulnerability did not affect the results of the study.

The process used to develop the indicators, including stakeholder interaction, ensured that the indicators were representative of all the issues that are currently of concern for sustainable catchments in South Africa. It is believed that the indicator set developed provides an adequate tool to measure the level of sustainability in any catchment in South Africa. The indicator set is flexible, and should change with changing needs (for instance, once resource quality objectives have been set, or CMAs established). However, it is believed that this set provided a sound basis with which to test the hypothesis that adequate information was readily available in South Africa to assess sustainability of the country's water resources at a catchment level.

11.4 ADEQUACY OF THE CURRENT CATCHMENT MANAGEMENT INFORMATION SYSTEMS

The Department of Water Affairs and Forestry has several information systems that are currently used, all of which are available at Head Office (Table 11.2). It is envisaged that all of these will be available for use by catchment management agencies and regional offices by 2004.

Table 11.1: Summary of information systems envisioned for use in the catchment management agencies (from Carl Bro & CSIR 2002)

	REGIS	WSAM	HYDSYS	WMS	WARMS
Primary Function	Hydrogeology	Water situation assessment	Surface hydrology	Water quality	Authorised water use
Mapping component:	ArcView, using ESRI shape files and coverages	ArcView, using ESRI shape files	Proprietary mapping module	ArcView, using ESRI shape files	None present
Database	Oracle	Access	Proprietary	Informix	Informix (?)
Data exchange	ASCII tables	ASCII tables	ASCII tables	ASCII tables	ASCII tables
Spatial data exchange	Shape files	Shape files	Shape files	Shape files	n/a

However, from the study, it was apparent that, at the moment, information at catchment level is fragmented and not readily available to the people actually managing the catchments. Spatial coverage is incomplete and data quality is mostly within a low to medium confidence range. The results of this study show that:

- None of the catchments had all the data required to populate the indicators, and the mean number of catchments for which each indicator could be populated was significantly lower than 80%.
- The numbers of indicators that could be populated for each catchment were:
  - Orange River from Boegoeberg to Kakamas (Northern Cape): 32 indicators (80%);
  - Mutale River catchment (Limpopo): 28 indicators (70%);
  - Diep River catchment (Western Cape): 27 indicators (67%);
  - Sabie River catchment (Mpumalanga): 23 indicators (58%);
  - Sand-Vet River catchment (Free State): 19 indicators (48%);
  - Mhlatuze River catchment (Kwa-Zulu Natal): 17 indicators (43%);
  - Mtata River catchment (Eastern Cape): 15 indicators (38%);
  - Klip River catchment (Gauteng): 3 indicators (8%);

- ➢ Pienaars River catchment (North West): 2 indicators (5%).

- The most data-rich catchments (Mutale River catchment, Diep River catchment and Orange River from Boegoeberg to Kakamas) had between 78% and 81% of the data required to populate the indicators, whilst data-poor catchments (Pienaars River catchment and Klip River catchment) had less than 20% of the data required.
- In all cases, except the Orange River, the percentage of indicators that could be populated was less than the percentage of parameters that were available.
- Of the possible data sources for the indicators, about 45% of them were DWAF Head Office.

Based on the above, it can be concluded that the ability of South Africa to populate the indicators at a catchment level is poor. There are several reasons for this, including:

- **Lack of an integrated information management strategy**

  There seems to be little appreciation for the strategic value of information particularly with regard to its role in managing the water resources of the country sustainably. The monitoring and information strategy as outlined in the National Water Resource Strategy (DWAF 2002) has been based on the same principles that applied to the old Water Act of 1956, without thought for the how to measure sustainability of water resources, despite this being the cornerstone of the National Water Act. This is not due to a disregard of the principles, but rather a lack of understanding of measuring sustainability.

- **Lack of a cohesive information management system at regional level**

  The information available for catchment management in each region varies considerably from region to region, and it seems that information is collected opportunistically and on an *ad hoc* basis, rather than according to a national strategy as part of a cohesive information system. It is apparent that the needs of regional managers with regards to information are not being met, and it is unclear whether the monitoring and information management strategy of the Department has taken into account the requirements of regional managers.

- **Lack of understanding with regard to indicators**

  The stakeholder participation process, both the interviews and the workshop, demonstrated that there was little understanding of indicators and their use within DWAF. This is verified by the fact that, despite the strategic value of sustainability indicators, the National Water Resource Strategy does not refer to them at all.

- **Lack of resources**

  Despite the National Water Act specifying that water resources management authority will be devolved to the lowest possible level, there is little evidence that the regional offices have been given greater authority than previously. This is partly due to financial constraints, and partly due to the lack of human capacity. Much of the authority, the finance and the human resource capacity still rest with the DWAF Head Office.

- **Lack of commitment**

  Because much of the information on the water resources of the country is not available at a regional level, commitment is required by the water resource managers to ensure that they have the information that is required to manage the catchments under their jurisdiction. It is apparent that there is little commitment to be well-informed. This problem is exacerbated by a reliance on electronic database systems to provide information, rather than on individual knowledge-bases.

11.5 CONCLUSIONS AND RECOMMENDATIONS

It is evident from the above discussion that there is no cohesive information system for the sustainable management of South Africa's water resources on a catchment basis. In general, there seems to be little appreciation for the strategic value of information. The information available for catchment management in each region varied considerably from region to region, and it seems that information is collected opportunistically and on an *ad hoc* basis, rather than according to a national strategy as part of a cohesive information system.

Information at catchment level is fragmented and not readily available to the people actually managing the catchments; spatial coverage is incomplete and data quality is mostly within a low to medium confidence range. It is apparent that the needs of regional managers with regards to information are not being met, and it is unclear whether the monitoring and information management strategy of the Department has taken into account the requirements of regional managers.

Additionally, there is currently no system in place in South Africa that makes use of indicators for reporting on sustainable catchment management. This is mainly due to a lack of capacity and understanding with regard to the strategic value of catchment management indicators. However, the process of developing the indicators highlighted the need for an indicator system for water resources management in South Africa.

The limitations of the current system can be overcome by DWAF through:

- Development of a national information strategy
- Inclusion of sustainability indicators in DWAF information systems.

11.5.1 Development of a national information strategy

The Department of Water Affairs and Forestry requires a national information strategy that is based on the principle of managing for sustainability in an efficient manner. Thus, data in the system should inform the catchment managers, policy-makers and the general public on the level of sustainability attained (including social equity). The current strategy, as outlined in the National Water Resource Strategy (DWAF 2002) is based only on the provision of flow and water quality data, which are only a portion of the overall requirements for measuring sustainability.

As with the development of indicators, the national information strategy should take into account the requirements of stakeholders. Because the National Water Act is reliant upon implementation at a catchment level, the requirements of catchment managers and decision-makers at a local level should be taken into account. The implementation of the strategy should begin at the level of CMAs, i.e. regional offices, rather than at Head Office, and the regional managers should take responsibility for its implementation. A start would be to install the information systems currently available at Head Office in the regional offices as soon as possible. Additionally, human and financial resources will need to be provided to improve catchment management information systems within the regional offices of the Department, and eventually catchment management agencies.

An important aspect of the national information strategy will be capacity building and the encouragement of a knowledge-based culture. A formal capacity-building initiative, which emphasises the value of information, the use of indicators and how to measure sustainability, is required throughout the Department (especially at a regional level). Additionally, water resource managers should be encouraged to interact with the Head Office as well as other water management authorities to access and assimilate information on catchments under their jurisdiction.

Indicators are not mentioned in the National Water Act nor the National Water Resource Strategy (DWAF 2002). It is, however, recommended that indicators form part of the national information strategy and are catered for in the departmental information management systems.

11.5.2 Inclusion of sustainability indicators in DWAF information systems

Although this study was not officially a DWAF study, the indicators that have been developed are viewed by the Department and the Water Research Commission (Dr C Ruiters, DWAF, *pers. comm.*; Dr SA Mitchell, WRC, *pers. comm.*) as the first step in finalising a set of indicators that are used as a matter of course in South Africa. However, DWAF needs to take ownership of the indicators and ensure that they are incorporated into their reporting procedures at catchment level.

The Bellaglio Principles (see section 2.3.1) provide the principles for the measurement of sustainable development, and should form the basis of the development of indicators for use by DWAF for catchment water resources management in South Africa. According to Table 11.3, the development and nature of the indicator set developed in this study adhered to eighteen of the nineteen Bellaglio Principles that were achievable during the study (the other ten being assigned to future implementation of the indicators). Only one principle, that of obtaining broad representation of key grass-roots, professional, technical and social groups, was not strictly adhered to during the development of the indicators.

Table 11.3: Bellaglio Principles that were adhered to during the indicator development process

PRINCIPLE		Adhered to	Partially adhered to	Not adhered to	Future development
1. Guiding vision and goals	Be guided by a clear vision of sustainable development and goals that define that vision		✓		
2. Holistic perspective	Include review of the whole system as well as its parts	✓			
	Consider the well-being of social, ecological, and economic sub-systems, their state as well as the direction and rate of change of the state, of their component parts, and the interaction between parts	✓			
	Consider both positive and negative consequences of human activity, in a way that reflects the costs and benefits for human and ecological systems, both in monetary and non-monetary terms	✓			
3. Essential elements	Consider equity and disparity within the current population and between present and future generations, dealing with such concerns as resource use, over- consumption and poverty, human rights, and access to services, as appropriate		✓		
	Consider the ecological conditions on which life depends	✓			
	Consider economic development and other, non-market activities that contribute to human/social well-being	✓			

Table 11.3 cont.	PRINCIPLE	Adhered to	Partially adhered to	Not adhered to	Future development
4. Adequate scope	Adopt a time horizon long enough to capture both human and ecosystem time scales thus responding to needs of future generations as well as those current to short-term decision making				✓
	Define the space of study large enough to include not only local but also long distance impacts on people and ecosystems	✓			
	Build on historic and current conditions to anticipate future conditions				✓
5. Practical focus	An explicit set of categories or an organizing framework that links vision and goals to indicators and assessment criteria	✓			
	A limited number of key issues for analysis	✓			
	A limited number of indicators or indicator combinations to provide a clearer signal of progress	✓			
	Standardising measurement wherever possible to permit comparison	✓			
	Comparing indicator values to targets,-reference values, ranges, thresholds, or direction of trends, as appropriate				✓
6. Openness	Make the methods and data that are used accessible to all				✓
	Make explicit all judgements, assumptions, and uncertainties in data and interpretations	✓			
7. Effective communication	Be designed to address the needs of the audience and set of users	✓			
	Draw from indicators and other tools that are stimulating and serve to engage decision-makers	✓			
	Aim, from the outset, for simplicity in structure and use of clear and plain language	✓			
8. Broad participation	Obtain broad representation of key grass-roots, professional, technical and social groups, including youth, women, and indigenous people - to ensure recognition of diverse and changing values			✓	
	Ensure the participation of decision-makers to secure a firm link to adopted policies and resulting action	✓			
9. Ongoing assessment	Develop a capacity for repeated measurement to determine trends				✓
	Be iterative, adaptive, and responsive to change and uncertainty because systems are complex and change frequently	✓			
	Adjust goals, frameworks, and indicators as new insights are gained				✓
	Promote development of collective learning and feedback to decision-making				✓
10. Institutional capacity	Clearly assigning responsibility and providing ongoing support in decision-making				✓
	Providing institutional capacity for data collection, maintenance, and documentation				✓
	Supporting development of local assessment capacity				✓

Once the Department has taken ownership of the indicator development process, the Bellaglio Principles that have not yet been fulfilled, need to be considered in the further development of the indicators, including:

- Utilise the indicators set over a time long enough to capture both human and ecosystem time scales, thus responding to needs of future generations as well as those current to short-term decision making;
- Build on historic and current conditions to anticipate future conditions - where we want to go, where we could go;
- Determine targets,-reference values, ranges, thresholds, or direction of trends, as appropriate, for each of the indicators in the set;
- Make the methods and data that are used accessible to all, especially at regional level (i.e. to all CMAs once they have been established;
- Develop a capacity for repeated measurement to determine trends;
- Adjust goals, frameworks, and indicators as new insights are gained or if situations change – this is particularly relevant to the establishment of CMAs.
- Promote development of collective learning and feedback to decision-making within the Department.
- Clearly assign responsibility and providing ongoing support in the decision-making process;
- Provide institutional capacity for data collection, maintenance, and documentation;
- Support development of assessment capacity within the Regional Offices and, later, CMAs.

11.6 REFERENCES

CARL BRO & CSIR. 2002. *Integrated Water Resource Management: Guidelines for Groundwater Management in Water Management Areas, South Africa.* DWAF, Pretoria.

DEPARTMENT OF ENVIRONMENTAL AFFAIRS AND TOURISM. 1999. *State of the Environment South Africa.* DEAT, Pretoria. http://www.ngo.grida.no/soesa.

DEPARTMENT OF WATER AFFAIRS AND FORESTRY (DWAF). 2002. *Proposed First Edition National Water Resource Strategy: Summary.* DWAF, Pretoria. 37 pp. http://www.dwaf.gov.za.

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT (OECD). 1993. *Environmental Indicators: Basic Concepts and Terminology.* Background Paper No.1. OECD, Paris. 150 pp.

WALMSLEY JJ, WALMSLEY RD, PRETORIUS RJ & MARAIS D. 2000. *Information Management and State-of-the-Environment Reporting for Water Resources in South Africa.* Poster Presentation, WISA Conference 2001. Mzuri Consultants, Pretoria.

WORLD SUMMIT ON SUSTAINABLE DEVELOPMENT. 2002. *Plan of Implementation.* WSSD, http://www.earthsummit2002.org.

SUMMARY

Availability of timely, adequate and relevant water resources information is crucial for the sustainable management of South Africa's catchment systems. This is recognised in the National Water Act (No. 36 of 1998), which states that the Minister is required to establish a national monitoring and information system for water resources as soon as possible. The main aim of this thesis was to assess the current availability and quality of water resources management information at catchment level in South Africa using sustainability indicators. Within this, the objectives of this study were to:

- Investigate the role of indicators of sustainable development in developing an understanding of the strategic issues in catchment management;
- Determine which core indicators are required to provide information on sustainable water resource management at catchment level in South Africa, and
- Assess the adequacy of the current catchment management information systems for assisting in the sustainable management of South Africa's water resources.

In order to meet the objectives of this study, a two-phased approach was taken. This included:

1. **Development of a set of sustainability indicators** that described priority issues for the sustainable management of South Africa's water resources at catchment level. This was based on the assumption that sustainability indicators are a suitable method of providing sustainability information in a format that is usable by managers and decision-makers.
2. **Assessment of the information available at catchment level** to populate the indicators, by means of a survey done through the Department of Water Affairs and Forestry (DWAF) regional offices. This was based on the assumptions that DWAF, in accordance with the National Water Act, should have the information required to manage the water resources sustainably, and that this information should be available at the level at which management of catchments is taking place (i.e. DWAF regional offices).

The indicator development process resulted in a set of 40 indicators that provided a good indication of the level of sustainability in a catchment and represented the 34 priority issues identified by the stakeholders. The process used to develop the indicators, including stakeholder interaction, ensured that the indicators were representative of all the issues that were currently of concern for sustainable catchments in South Africa. It is believed that the indicator set developed provided an adequate tool to measure the level of sustainability in any catchment in South Africa.

The assessment of catchment management information revealed that the ability of South Africa to report on sustainability at a catchment level was poor. Information at this level was fragmented and not readily available to the people actually managing the catchments; spatial coverage was incomplete and data quality was mostly within a low to medium confidence range. There were several reasons for this, including: lack of an integrated information management strategy; lack of a cohesive information management system at regional level; lack of understanding with regard to indicators; lack of financial and human resources, and lack of commitment.

Additionally, there was no system in place in South Africa that made use of indicators for reporting on sustainable catchment management. This was mainly due to a lack of capacity and understanding with regard to the strategic value of catchment management indicators. However, the process of developing the indicators highlighted the need for an indicator system for water resources management in South Africa.

It is recommended that a national water resources information strategy, which addresses the shortcomings identified in this study, be developed. The strategy should be based on the principle of managing for sustainability in an efficient manner. Thus, data in the system should inform the catchment managers, policy-makers and the general public on the level of sustainability attained. An important aspect of the national information strategy will be capacity building and the encouragement of a knowledge-based culture. It is also recommended that indicators form part of the national information strategy and are catered for in the departmental information management systems.

OPSOMMING

Beskikbaarheid van tydige, voldoende en toepaslike inligting oor waterhulpbronne is onontbeerlik vir die volhoubare bestuur van Suid-Afrika se opvangsgebiedstelsels. Dit word erken in die Nasionale Waterwet (No. 36 van 1998), waaruit dit blyk dat dit van die Minister vereis word om so gou as moontlik 'n nasionale moniterings- en inligtingstelsel vir waterhulpbronne tot stand te bring. Die hoofdoel van dié tesis was om die huidige beskikbaarheid en gehalte van bestuursinligting oor waterhulpbronne op opvangsgebiedsvlak in Suid-Afrika te bepaal deur indikators van volhoubare ontwikkeling te gebruik. Binne dié verwysingsveld, was die doelstellings van die studie om:

- Die rol van indikators van volhoubare ontwikkeling in die ontwikkeling en begrip van die strategiese aangeleenthede in opvangsgebiedbestuur te ondersoek;
- Te bepaal watter kernindikators benodig word om inligting te voorsien oor die bestuur van volhoubare waterhulpbronne op opvangsgebiedvlak in Suid-Afrika, en
- Die geskiktheid te bepaal van die huidige inligtingstelsels ten opsigte van opvangsgebiedbestuur vir die volhoubare bestuur van Suid-Afrika se waterbronne.

Om te voldoen aan die doelstellings van die studie is dit in twee fases onderneem.

1. **Ontwikkeling van 'n stel van volhoubare indikators** wat prioriteitsaangeleenthede vir volhoubare bestuur van Suid-Afrika se waterbronne op opvangsgebiedvlak omskryf. Dit is gegrond op die aanname dat indikators oor volhoubaarheid 'n geskikte metode is om inligting oor volhoubaarheid te voorsien en wel in 'n formaat wat vir bestuurders en besluitnemers bruikbaar is.
2. **Waardebepaling van die inligting wat op opvangsgebiedvlak beskikbaar is** vir die indikators deur middel van 'n opname wat deur die streekkantore van die Departement van Waterwese en Bosbou (DWB) gedoen is. Die opname is gegrond op die aanname dat DWB ingevolge die Nasionale Waterwet beskik oor die inligting wat benodig word vir die volhoubare bestuur van waterhulpbronne, en dat hierdie inligting beskikbaar behoort te wees op die vlak waar die bestuur van opvangsgebiede plaasvind (d.w.s. DWB streekkantore).

Die indikatorontwikkelingsproses het 'n stel van 40 indikators tot gevolg gehad, wat 'n goeie aanduiding gegee het van die volhoubaarheidsvlak in 'n opvangsgebied en die 34 prioriteitsaangeleenthede behels het wat deur rolspelers geïdentifiseer is. Die proses wat aangewend is om die indikators te ontwikkel, asook die interaksie met rolspelers, het tot gevolg gehad dat die indikators verteenwoordigend was van al die aangeleenthede wat tans toepaslik is vir volhoubare

opvangsgebiede in Suid-Afrika. Daar word geglo dat die stel indikators wat ontwikkel is, 'n geskikte middel verskaf het om die vlak van volhoubaarheid in enige opvangsgebied in Suid-Afrika te meet.

Die waardebepaling van inligting oor opvangsgebiedbestuur het getoon dat die vermoë van Suid-Afrika om verslag te doen oor volhoubaarheid ten opsigte van opvangsgebiede swak was. Inligting op hierdie vlak was gefragmenteer en nie geredelik beskikbaar vir diegene wat die opvangsgebiede bestuur het nie; ruimtelike dekking was onvolledig en die gehalte van die data het meestal gewissel van lae na medium betroubaarheid. Daar was verskeie redes hiervoor, insluitende die gebrek aan 'n geïntegreerde inligtingsbestuurstrategie; gebrek aan 'n samehangende inligtingsbestuurstelsel op streekvlak; gebrek aan begrip van indikators; gebrek aan finansiële en menslike hulpbronne en 'n gebrek aan toewyding.

Daarbenewens was daar geen bestaande stelsel in Suid-Afrika wat gebruik gemaak het van indikators om verslag te doen oor volhoubare bestuur van opvangsgebiede nie. Dit was hoofsaaklik as gevolg van 'n gebrek aan kapasiteit en begrip van die strategiese waarde van indikators vir die bestuur van opvangsgebiede. Die proses ter ontwikkeling van die indikators het egter die behoefte aan 'n indikatorstelsel vir waterhulpbronne in Suid-Afrika beklemtoon.

Daar word aanbeveel dat 'n nasionale strategie vir inligting oor waterhulpbronne ontwikkel word waarin die tekortkominge wat in hierdie studie aangedui word, aangespreek word. Die strategie moet gegrond word op effektiewe volhoubaarheidsbestuur. Data in die stelsel moet beskikbaar wees vir opvangsgebiedbestuurders, beleidmakers en die algemene publiek om hulle in te lig oor die vlak van volhoubaarheid wat bereik is. Die ontwikkeling van kapasiteit en die aanmoediging van 'n kultuur wat op kennis gegrond is, moet 'n belangrike deel uitmaak van die nasionale inligtingstrategie. Daar word ook aanbeveel dat indikators deel uitmaak van die nasionale inligtingstrategie en dat daar voorsiening daarvoor gemaak word in die departementele inligtingsbestuurstelsels.

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I would like to express my sincere thanks to all those people and institutions that contributed to this project. In particular, I would like to thank Mr Maitland Seaman (Centre for Environmental Management, University of the Orange Free State) and Dr Danny Walmsley (Mzuri Consultants, Pretoria) for their supervision, comments and support.

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- Lee Boyd, Water Quality Management, DWAF
- Eberhard Braune, Geohydrology, DWAF
- Chris Dickens, Umgeni Water
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- Bill Rowlston, Strategic Planning, DWAF
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- Ashwin Seetal, KwaZulu-Natal Regional Office, DWAF
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Finally, to my family, thank you for your patience and long-suffering, and my friends for relieving the stress!

APPENDIX A
International Review Results (Chapter 3)

Table 1: List of indicators from the five response organisations, categorised according to five themes and further split into categories under each theme.

	FRASER BASIN COUNCIL (draft indicators)	MURRAY DARLING BASIN COMMISSION (R) = recommended	TENNESSEE VALLEY AUTHORITY	US ENVIRONMENTAL PROTECTION AGENCY	WORLD RESOURCES INSTITUTE
Socio-Economic					
Population	Population outside growth concentration area Mortality rates Legislator's reflection of population			Population change	Urban population growth Population density
Education	Newspaper circulation Connection to internet Levels of education				
Employment	Income rates Employment inside and outside growth concentration area Aboriginal employment rates Jobs by sector				
Community development	Membership in voluntary or community organisations Charitable donations Crime rates				
Economic development	Investment in public assets Economic diversity index Adoption of regional growth strategy Public transit ridership Vehicle ownership per household Total and alternate energy consumption				
Water Balance					
Water availability		Area underlain by shallow water tables, and areas where water tables are rising **(R)**	Flood storage availability Discretionary zone attainment	Hydrologic modification - dams	Primary watersheds Water availability Aridity Existing and proposed major dams

	FRASER BASIN COUNCIL (draft indicators)	MURRAY DARLING BASIN COMMISSION (R) = recommended	TENNESSEE VALLEY AUTHORITY	US ENVIRONMENTAL PROTECTION AGENCY	WORLD RESOURCES INSTITUTE
Water use	Per capita water use	Average water diversion from the Basin **(R)** Ratio of water extracted to water available, including groundwater			
		Waste & Pollution			
Waste production	Waste diverted from landfills Greenhouse gas emissions Rate of non-compliance in mining industry Exceedance of acceptable PM10 levels	Number of waste treatment plants with tertiary treatments and nutrient removal, together with the volume of waste water released to inland waters **(R)** Reduction in phosphorus loads discharged from sewage treatment plants and other point sources		Urban runoff potential Index of agricultural runoff potential Pollutant loads discharged above permitted discharge limits - toxic pollutants Pollutant loads discharged above permitted discharge limits - conventional pollutants	
Water quality	Water quality trends	Salinity and nitrate levels in groundwater **(R)** Salinity levels in surface water **(R)** Estimated concentrations of phosphorus and nitrogen in surface waters **(R)**	Watershed water quality Dissolved oxygen deficit sue to forced outages	Ambient water quality - four conventional pollutants Indicators of source water quality for drinking water systems Ambient water quality data - four toxic pollutants	
Contamination	Contaminants in great blue heron eggs Contaminated and remediated mine sites	Area of land that is reported to have saline soils with top meter, in regions of Australia of >250mm annual rainfall ®		Contaminated sediments	

	FRASER BASIN COUNCIL (draft indicators)	MURRAY DARLING BASIN COMMISSION (R) = recommended	TENNESSEE VALLEY AUTHORITY	US ENVIRONMENTAL PROTECTION AGENCY	WORLD RESOURCES INSTITUTE
		Resource Condition			
Biodiversity & ecosystem integrity	Total run size and spawning escapement of Fraser River sockeye Status of salmonids Percentage of known species at risk	Macro-invertebrate assemblages in rivers assessed by Austrians sampling protocols & computer models **(R)** Conservation status known for species, ecological communities and ecological processes Change in abundance of selected threatened or high profile species or communities Length of stream (or riparian zone) protected, rehabilitated and/or restored through NHT funded projects **(R)** Percentage of total stream length with riparian vegetation per drainage division		Aquatic/wetland species at risk Estuarine Pollution Susceptibility Index Wetland Loss Index	Freshwater fish species and endemism Endemic bird areas Area affected by water erosion Protected areas
Land use change	Composition of forest lands (i.e. age and species distribution) Farm practices (i.e. soil conservation practices and pesticide usage)	Area of remnant vegetation protected and managed by a) areas of formal reserves, b) areas under management or conservation agreements Area of native vegetation by type Difference between regional crop water requirements and water application Area [of cleared agricultural land] renegotiated , in ha/pa, disaggregated into areas renegotiated using local vegetation and other **(R)** Average real Net Farm Income **(R)**			Remaining original forest cover Extent of original forest cover lost Tropical deforestation Cropland irrigation Modified landscape (cropland and developed areas)
Resource use	Outdoor recreation opportunities: area of parkland Number of park user days		Summer reservoir level attainment (recreational use) Days navigable waterway is available from Knoxville to Paducah Shipper savings Minimum flow achievement (for aeration)	Assessed rivers meeting all designated uses established by state or tribal water quality standards Fish and wildlife consumption advisories	

	FRASER BASIN COUNCIL (draft indicators)	MURRAY DARLING BASIN COMMISSION (R) = recommended	TENNESSEE VALLEY AUTHORITY	US ENVIRONMENTAL PROTECTION AGENCY	WORLD RESOURCES INSTITUTE
Policy & Management					
Policy	Number of interim agreements with first nations Number of First Nations in the British Columbia Treaty Consultation process Voter turnout				
Research & training	Reviews regarding access to information	Number of participants in property management plan courses Extent of participation in training and landcare **(R)**			
Management		Percentage adoption of more efficient irrigation techniques (BMPs) **(R)** Number of participants in water trading and volume of water traded **(R)** Number of waterways for which environmental flow provisions have been established, and the number where provisions are being met Removal or modification of structures impeding fish migration and flows for fish movement, and improvement in operating strategies **(R)** Percentage of resource managers using agreed best practice by resource sector and/or catchment if relevant	Completed comprehensive reservoir land plans		

APPENDIX B
Workshop proceedings (Chapter 8)

Water Research Commission

WORKSHOP ON THE DEVELOPMENT OF SUSTAINABILITY INDICATORS FOR CATCHMENT MANAGEMENT

PROCEEDINGS

Compiled by:
Jay Walmsley
Mzuri Consultants
PO Box 72847
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Wednesday 21 January 2002
Water Research Commission, Pretoria

AIMS OF THE WORKSHOP

This workshop forms part of the stakeholder process to develop a set of indicators that can be used for sustainability auditing of catchments in South Africa. The aims of the workshop were threefold:

- Inform water resource managers of the use of sustainability indicators in catchment management;
- Evaluate the priority issues identified during the interview process;
- Identify key indicators for each issue.

TABLE OF CONTENTS

SESSION I: INTRODUCTION

1. WELCOME AND INTRODUCTION
Dr Steve Mitchell, WRC

Dr Mitchell welcomed all the participants to the workshop on behalf of the Water Research Commission. Details of participants are provided in Annex 1.

2. INDICATORS AND THEIR USE IN WATER MANAGEMENT IN SOUTH AFRICA, A DWAF PERSPECTIVE
Dr Cornelius Ruiters, Social and Ecological Services, DWAF

2.1 Introduction

Indicators have various uses, depending on the requirements of water resources managers. This presentation provides an overview of indicators and a vision of their use for water management in South Africa.

2.2 Environmental indicators

An indicator can be defined as:

> *"a parameter, or a value derived from parameters, which points to/provides information about/describes the state of a phenomenon/ environment/ area with a significance extending beyond that directly associated with a parameter value"*

Indicators have two major functions. Firstly, they reduce the number of measurements and parameters that normally would be required to give an "exact" presentation of a situation and, secondly, they simplify the communication process by which the information of results of measurement is provided to the user.

In relation to policy-making, environmental indicators are used for three major purposes:

- Supplying information on environmental problems;
- Supporting policy development and priority setting, by identifying key factors that cause pressure on the environment, and
- Monitoring the effects of policy responses.

2.3 Classification of environmental indicators

Environmental indicators should reflect all elements of the causal chain that link human activities to their ultimate environmental impacts and the societal responses to these impacts. The Driving-forces-Pressure-State-Impact-Response (DPSIR) framework of the European Environment Agency is useful in describing the relationships between the origins and consequences of environmental problems (Figure 1). However, in order to understand the dynamics it is also use to focus on the links between DPSIR elements. This has been done as part of this project (see Section 3 of this report).

Indicators can be classified into 4 types:

- **Descriptive indicators** (Type A) – These answer the question: *What is happening?* They describe the actual situation of the main environmental issues, e.g. toxic contamination, wastes, etc. It is useful to use the DPSIR framework in this context, where:
  - ◊ Driving forces include social, demographic and economic developments in society and the corresponding changes in life styles, overall levels of consumption and production patterns.
  - ◊ Pressures describe developments in release of substances (waste water), physical and biological agents, the use of resources and the use of land.
  - ◊ State indicators provide a description of the quantity and quality of physical phenomena (e.g. temperature), biological phenomena (such as fish populations) and chemical phenomena (water quality).

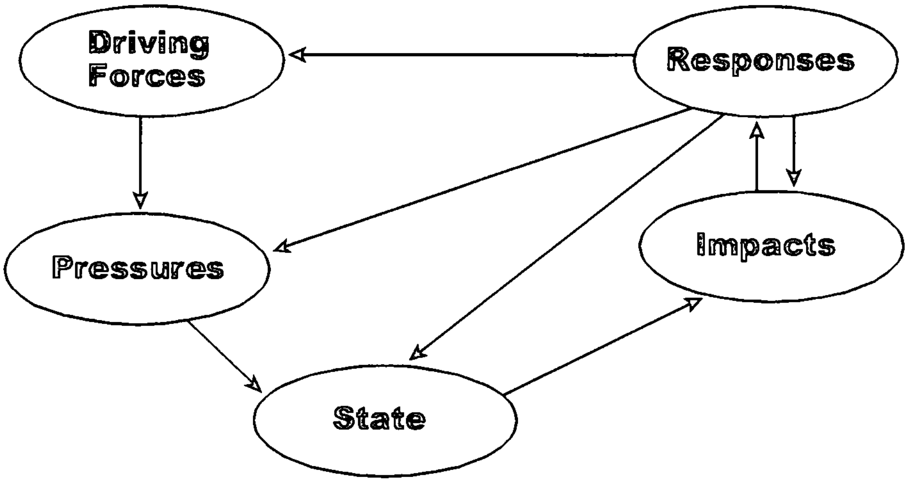

Figure 1: DPSIR framework, showing the linkages between the various sustainability components in an environmental system.

- **Performance indicators** (Type B) - These answer the question: *Does it matter?* They compare actual conditions with a specific set of reference conditions, and measure the 'distance' between the current environmental situation and the desired state or target (i.e. a distance-to-target assessment). These targets might include:
  - ◊ National policy targets (Policy Target Values, PTVs)
  - ◊ International targets, accepted by governments (PTVs)
  - ◊ Tentative approximations of sustainability levels (Sustainable Reference Values, SRVs).
- **Efficiency indicators** (Type C) – These express the relation between separate elements of the causal chain and answer the question: *Are we improving?* They are used mainly in policy development to relate environmental pressures to human activities, and to provide insight in the efficiency of products and processes. They establish the efficiency in terms of the resources used, e.g. water waste generated per unit of desired output, and can be single or aggregated indicators.
- **Total welfare indicators** (Type D) – These indicators answer the question: *Are we on whole better off?* In other words, they provide a measure of total sustainability. In economic terms they are best described by the term "Green GDP". Examples are: Index of Sustainable Economic Welfare (ISEW); Environmental Sustainability Index, Barometer of Sustainablity.

2.4 Application of environmental indicators for water resources management

The different types of indicator have application at different levels within the water resources management structures in South Africa. They should complement the water management policies that have been set up through the legislative structures, in particular the National Water Act (No. 36 of 1998) and the Water Services Act (No. 108 of 1997) (Figure 2). In terms of the National Water Act they could be used to assist in evaluating progress toward the goals and objectives laid out in the National Water Resources Strategy and Catchment Management Strategies, as well as evaluate RDM policies and allocation plans, compulsory licensing, water conservation and demand management strategies, and monitoring, assessment and information.

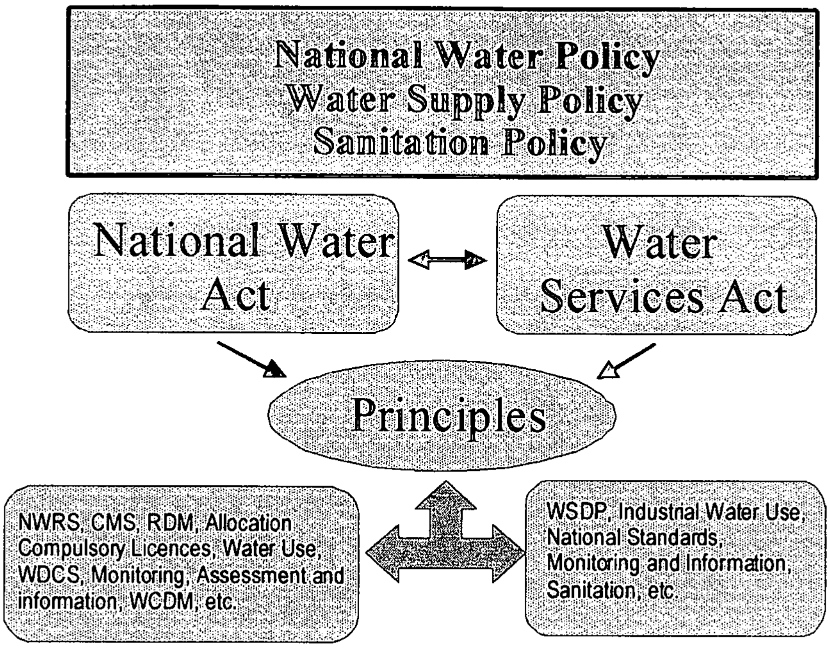

Figure 2: Legislative and policy framework for water resources management in South Africa.

Likewise sustainability indicators should have as their cornerstone the environmental policies that pertain to the country (Figure 3). These indirectly affect water resources management. The National Environmental Management Act (No. 107 of 1998, NEMA) and the Environmental Conservation Act (No. 73 of 1989, ECA) lay the foundation for integrated environmental management (IEM) and co-operative governance for all sectors including water resources.

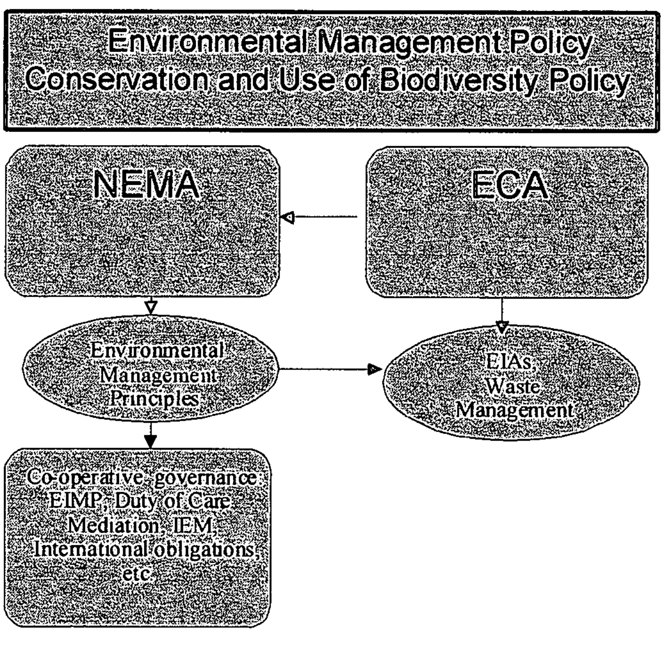

Figure 3: Legislative and policy framework for environmental management in South Africa.

2.5 Discussion

On a question from Mr Francois van der Merwe (Water Utilisation, DWAF), Dr Ruiters said that although the development of indicators was set within the framework of environmental management, the focus was on integrated water resources management at catchment level. Obviously this included social, economic and environmental issues that would impact on water resources.

On a question from Dr Magda Ligthelm (Mpumalanga Regional Office, DWAF), Dr Ruiters said that water resource management indicators had been developed by other agencies internationally, such as the European Environment Agency, the US EPA and the Australian Government, but these were mostly at a national level. Mrs Jay Walmsley (Mzuri Consultants) added that an international review had been done, and that only a few river basin management agencies had developed a full set of sustainability indicators.

3. DEVELOPMENT OF SUSTAINABILITY INDICATORS FOR CATCHMENT MANAGEMENT IN SOUTH AFRICA

Mrs Jay Walmsley, Mzuri Consultants

3.1 Project objectives

Dr Ruiters presented a vision for the use of indicators in water resources management in South Africa. The project that is currently underway is much more limited, with specific aims, including to:

- Develop a set of "ideal" indicators, which together can assess the sustainability of a catchment or water management area, and
- Assess the data availability at a catchment level (tertiary) for the indicators.

3.2 Theoretical background

The theory relating to the development of these indicators has been developed as part of a research project over the past two years. Only now is the project getting to the stage where indicators could be developed and data availability assessed. One of the problems is the concept of sustainable development. Because its measurement is such a new science, there is still some concern that the theory does not fit the practical application. The currently accepted theory states that sustainable development is composed of three components, the economic, social and biophysical components (Figure 4). Sustainablity is achieved when these components are balanced. Thus, any set of sustainability indicators needs to include economic, social and biophysical indicators, although there has been a tendency in the past to concentrate on the biophysical environment.

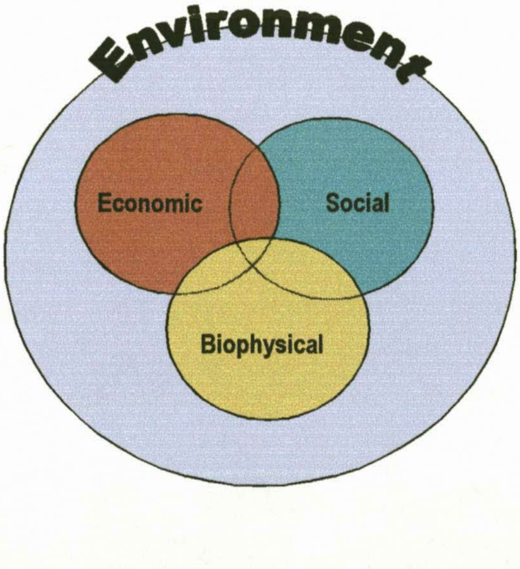

Figure 4: Inter-linkage between the three recognised aspects of sustainability

An international review done as part of this project showed that the use of indicators for catchment management was still in its infancy. Nineteen catchment management and water resource management organisations around the world had been approached about their indicator sets, but only about 25% had catchment management indicator sets. Of those, only one really covered all aspects of sustainability. From the review it was possible to conclude:

- Indicators should reflect the physical characteristics of catchments and the human influences on these;
- Indicators should be relevant in terms of the current catchment management policy;
- The indicator set developed should be useful for major stakeholders involved in catchment management, and
- The selection of indicators should not rely on data availability, but should be guided by what is available.

3.3 Project process

The international review provided the foundation for the process that will take place to completion of the project (Figure 5).

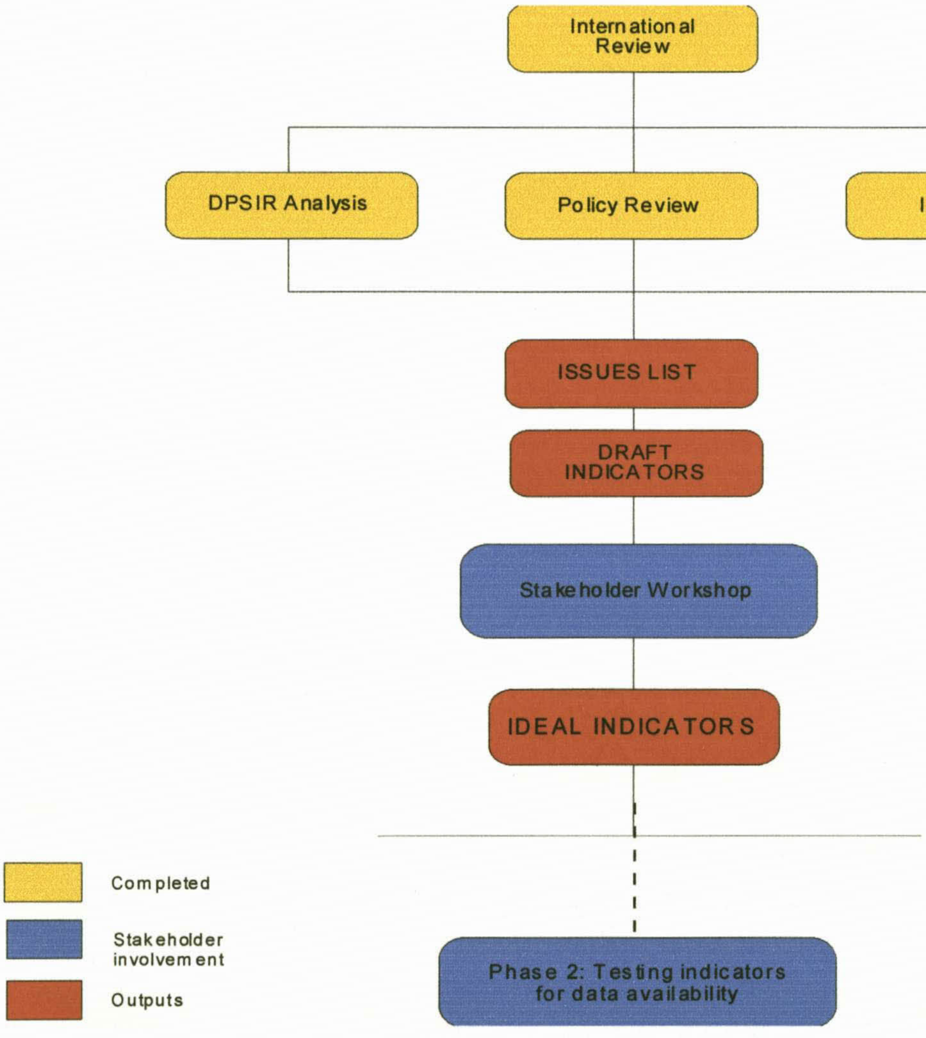

Figure 5: Project process diagram.

The issues were developed through three processes:

- A DPSIR analysis (Figure 6), in which the functional characteristics of a catchment were superimposed upon the DPSIR sustainability framework;
- A policy review of all the legislation and policy for environmental and water resources management in the country (see Figures 2 and 3), and
- Personal interviews of water resource managers in DWAF head office, DWAF regional offices, water providers and local authorities.

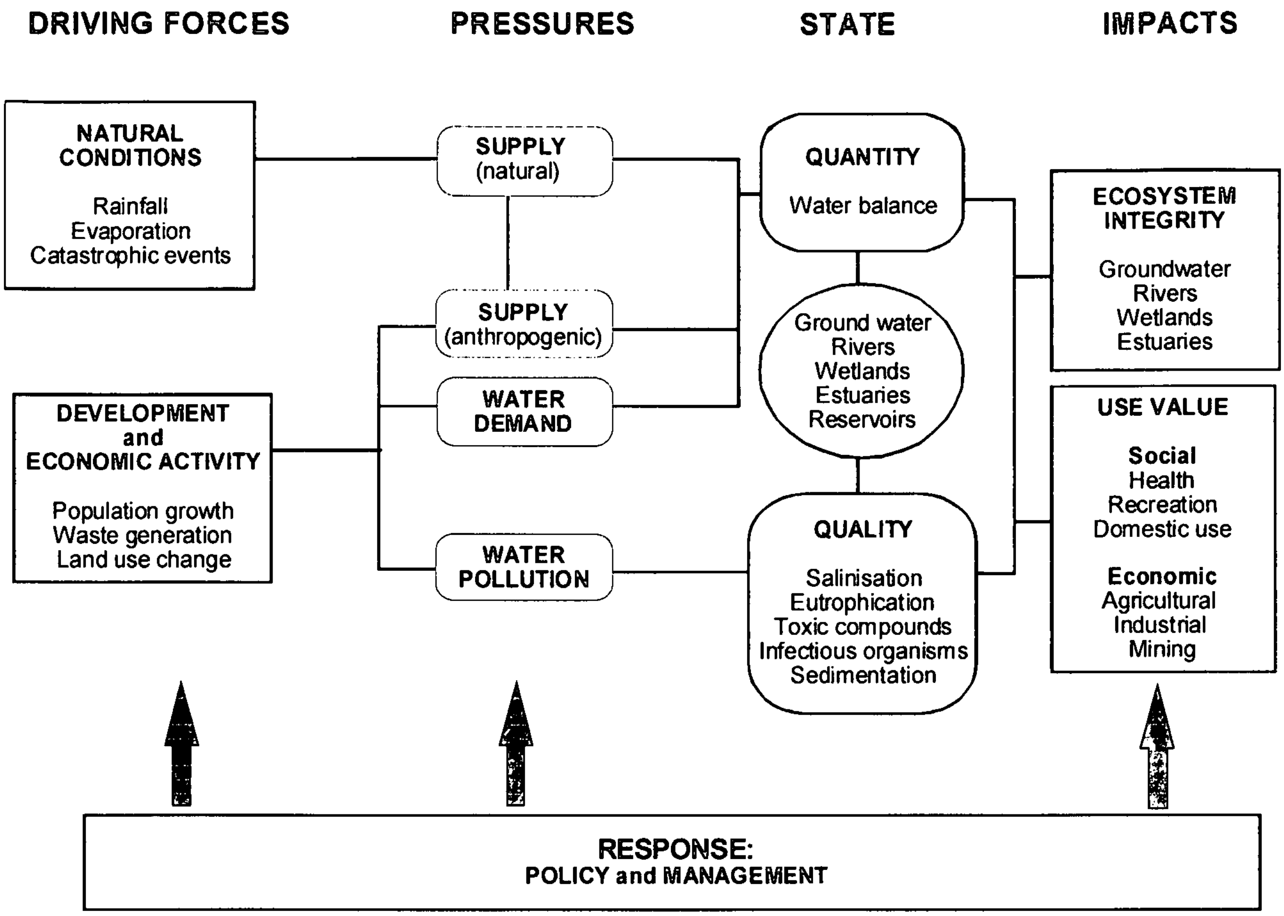

Figure 6: DPSIR analysis for the development of catchment management indicators.

The issues that were identified during this process, were then placed in a mindmap format, within the DPSIR framework (Figure 7). This shows the levels of the issues identified, as well as the complexity of the problem in developing indicators. It is hoped that the workshop will fine-tune this list of issues, which will form the basis of the indicator set. The questionnaires only provide the broader-level issues identified in Figure 7.

3.4 Discussion

Mr Brian Hollingworth (DBSA) questioned the use of indicators as a management tool if the causal link between the impacts and the driving forces was not obvious. Mrs Walmsley said that responses did not need to be at the level of drivers. In fact, more often than not, responses were at the levels of pressures (proactive responses) or state and impacts (reactive responses). Generally linkages between these elements were easy to identify.

Mr Hugo Maaren (Water Research Commission) pointed out that the scale that the indicators were developed and used at was important. The requirements of Water Management Areas might be different from, say, tertiary catchments. Dr Ruiters said that catchment level was a starting point for developing indicators, but that the set produced could be fine-tuned at various levels according to the needs of water resource managers.

Mr Gareth McConkey (Western Cape Regional Office, DWAF) said that each CMA had to develop Catchment Management Plans within their Water Management Area. This required the setting of objectives within the catchment context, according to the activities taking place in the catchment. The indicator set for each CMA should provide an indication of whether these objectives were being met. This could be done once the Catchment Management Plans were in place.

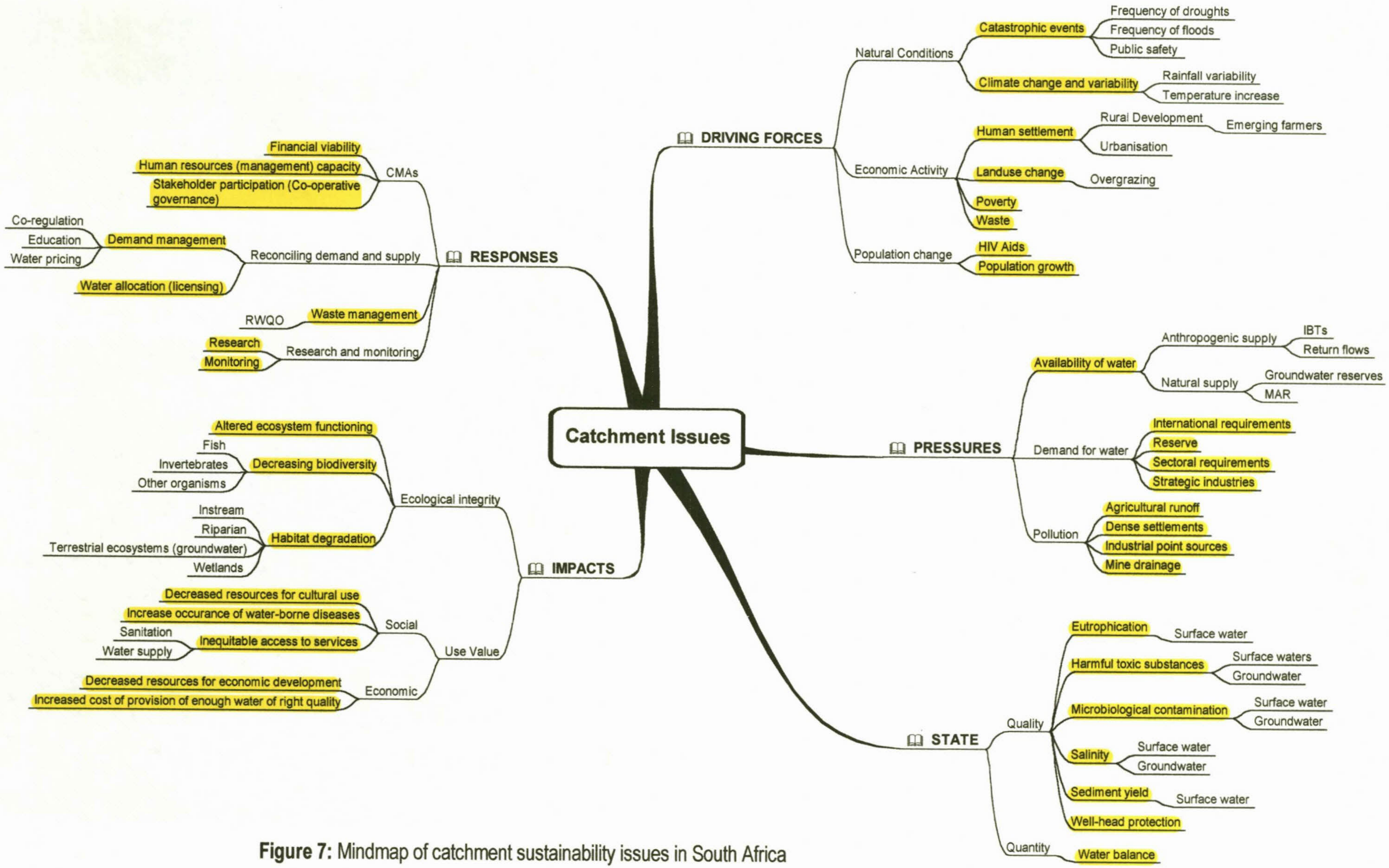

Figure 7: Mindmap of catchment sustainability issues in South Africa

Mr Eberhard Braune (Geohydrology, DWAF) said that we should not lose sight of the fact that the catchment is the producer of the resource. So sustainability of all catchment processes is important in developing indicators.

Ms Eustathia Bofilatos (Catchment Management, DWAF) said that the responses were outlined in the Catchment Management Plans and National Water Resources Management Strategy. Mrs Walmsley said that this had to be taken into consideration, but that these were not yet complete and could not provide the framework for the indicators.

SESSION II: PRIORITY ISSUES

Facilitator: Dr Ralph Heath, Pulles, Howard and De Lange

4. EVALUATION OF ISSUES

Dr Heath explained that the evaluation of the issues, which had been identified during the project, included:

- Completion of a questionnaire (see Annex 2), in order to get an indication of the opinions of individuals, and
- A plenary discussion, which would allow debate on critical or controversial issues.

4.1 Results of the questionnaire

Twenty-one workshop participants completed the questionnaire on issues. Each issue could obtain a high score of three per participant if all three questions were answered positively. The sum of positive answers from all participants provided and "Index of Importance" for each issue (Figure 8).

The issues considered least important were:

- Well-head protection;
- HIV/AIDS;
- International requirements;
- Decreased resources for cultural use;
- Change in climate and variability;
- Increased cost of provision of water
- CMA financial viability;
- Decreased resources for cultural use, and
- Decreased resources for economic use.

Linkages between issues included:

- *HIV/AIDS* could be included in *population change*;
- *Climate change and variability* could form part of *catastrophic events*
- *Availability of water, demand for water, water balance* and *water allocation* were linked;
- *Waste generation, water quality management* and *waste management* were linked;
- *Sectoral water requirements* included *water requirements for strategic industries* and *international requirements*;
- All the water quality issues could be combined into one issue.

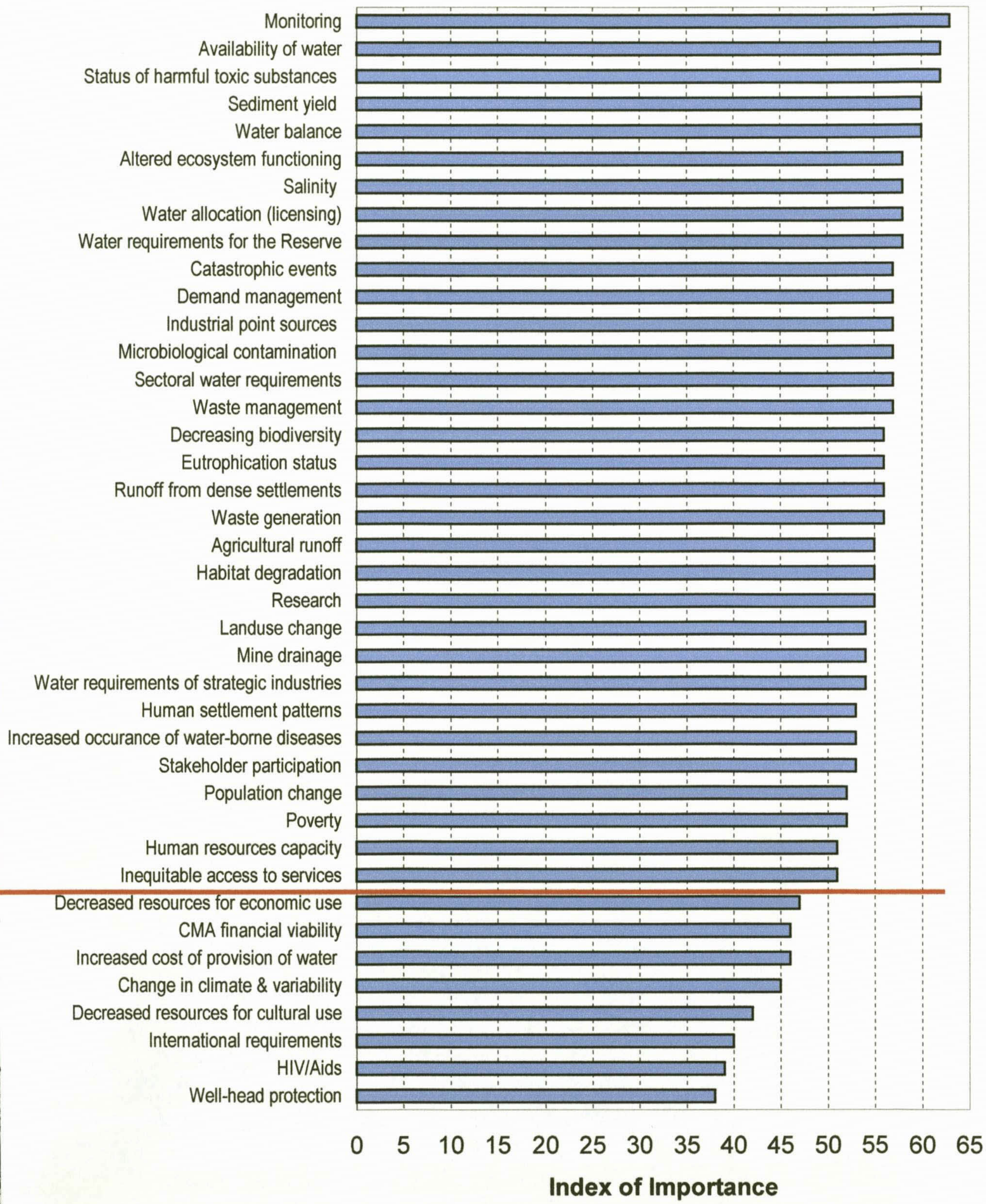

Figure 8: Issues in order of importance (from questionnaire data).

4.2 Plenary discussion

Mr Van der Merwe said that he felt the question on who would manage each issue should have been asked.

The issue of poverty was used as an example of several potential problems. Mr Maaren said that poverty could lead to non-payment, so financial viability was in itself an indicator for poverty and that poverty was not a catchment issue. Dr Dickens said that poverty went hand-in-hand with financial viability, but there was more to poverty than just financial viability. Mr McConkey said that "poverty" as an issue topic might be left out, and that several other issues would provide information on poverty anyway (e.g. access to services; dense settlements etc.).

Mr Hollingworth said that this emphasised the problems with scale and boundaries. Poverty was a national problem and the results were seen at local level, but that catchment boundaries did not, in his opinion, contain the poverty issue. Ms Barbara Weston (Social and Ecological Services, DWAF) added that the effect of poverty on the water resources, and vice versa were at a catchment level, particularly the "water for food" issue that was being investigated for the World Summit on Sustainable Development process.

Dr Ligthelm said that poverty might be a nationally recognised problem, but that it had major implications for the way in which water resources was managed within an area. Mr Jurgo van Wyk (Water Quality Management, DWAF) added that it was also part of the legislative requirement to eradicate past racial and gender discrimination. Mr Dirk Versveld (SEA Consultant, DWAF) added that there was also a need to determine the vulnerability of the people.

There was debate on whether the indicators should only reflect legislated requirements for water, or whether the indicator set should be broader than this. In terms of poverty, this would mean that the topic was not covered as it was not in the National Water Act *per se*, but was rather part of the Government's Poverty Alleviation Policy. Mr McConkey pointed out that the compliance with legislation might not achieve the overall objective of sustainability in the medium-term, because sustainability was broader than just the National Water Act. Ms Bofilatos pointed out that legislation was a merely a management tool, as were indicators. It was agreed that the **indicators should reflect sustainability of catchments and not legislative compliance.**

The question of determining sustainability was brought up. Mrs Walmsley iterated that, unfortunately, the theory of sustainable development did not always fit the practical application. There were no real answers as to what was sustainable and what was not. This project hoped to develop indicators that, if there was a management or policy failure, would highlight unsustainable situations.

On a question from Mr Hollingworth, Mrs Walmsley said that the indicator set developed should be useful to determine sustainability at a catchment or water management area level. Obviously once the CMAs had been established the indicator set developed could be fine-tuned for each CMA.

On a question from Mr Mitchell on the applicability of some indicators at catchment level (e.g. climate change), Mr Jason Hallowes said that some of the issues were linked, although they had been split by using the DPSIR framework. For instance, *catastrophic events* and *climate change and variability* could be one issue. It was agreed that there was the need to identify links and combine the issues (i.e. water balance should also be linked to demand and supply). Mrs Walmsley said that the DPSIR framework had been used as part of the development of indicators. It was recognised that some of the issues were linked and it was likely that the more traditional categories of *socio-economic* issues; *water balance*; *waste and pollution*; *resource condition* and *management* would be used to report on the issues.

Issues that were not critical to sustainability as determined in the questionnaire analysis, would be excluded. No indicators would be developed for them. Where possible, issues should be described in neutral terms (i.e. *biodiversity change*, not *biodiversity loss*).

It was agreed:

- *Water for food* was an issue that should be dealt with under poverty.
- *Eradication of past discrimination* was an issue that should be included.
- *Inequitable access to resources* would be more appropriate as an issue than *inequitable access to services.*
- *HIV/AIDS* would be incorporated in *population change*;
- *International water requirements* would be included under sectoral water requirements;

- *Auditing and reporting* should be included as a response issue;
- *Water resources management capacity* should be included as a response issue;
- *CMA viability* should take the place of *CMA financial viability*;
- *Decreased resources for cultural use* would be excluded;
- *Decreased resources for economic development* would be excluded;
- *Increased cost of provision of enough water of the right quality* would be excluded;
- *Increased occurrence of water-borne diseases* should be excluded, and
- Where possible, issues would be expressed neutrally.

SESSION III: IDENTIFICATION OF INDICATORS

Facilitator: Dr Ralph Heath

5. IDENTIFICATION OF INDICATORS

Dr Heath explained that there were two tasks in the identification of sustainability indicators:

- Completion of a questionnaire (see Annex 2), in order to get an indication of the opinions of individuals, and
- Group discussions, in which the participants would be split into five groups according to DPSIR category. Each group had to decide on one indicator for each issue in that category (about 8 issues per group).

5.1 Results of the questionnaire

Results of the questionnaire are presented in Table 1.

Table 1: Rating for each indicator, as well as comments and suggested alternative indicators from participants. Each rating column is the sum of all participants ratings, where excellent=3 points, good=2 points, poor=1 point. Not all participants rated each issue, so results are presented as the percentage of the highest possible score for the number of people who completed each question.

ISSUE	INDICATOR	Excellent	Good	Poor	Total score	Highest possible score	Percentage
DRIVING FORCES							
1. Catastrophic events (floods and droughts)	Frequency and extent of flood events	36	14	1	51	63	80.95%
	Flood storage availability	15	10	8	33	60	55.00%
	Frequency and extent of droughts	27	16	1	44	60	73.33%
	Comments: ∘ Risk=hazard+vulnerability – the above deal only with hazard ∘ Should form part of hydrological monitoring ∘ The effect of these events on sustainability should be described by an indicator. ∘ The importance of anthropogenic influence needs to be considered (e.g. drought due to bad management) ∘ Looking at variability with vulnerability will capture all of these elements						
2. Change in climate & variability	Annual temperature deviations within the catchment	12	8	10	30	57	52.63%
	Annual rainfall deviations within the catchment	30	14	4	48	63	76.19%
	Mean annual precipitation	18	24	2	44	60	73.33%
	Mean annual evaporation	12	26	2	40	57	70.18%
	Comments: ∘ Seasonal variability needs to be considered ∘ Variability is very different from long-term change ∘ Temperature/evaporation/energy does not need to be at a catchment scale ∘ Climate change takes place on a larger scale than catchment area. ∘ Should form part of hydrological monitoring Alternatives: ∘ Runoff variability ∘ Mean annual runoff						
3. Human settlement patterns	Percentage of population in urban areas	15	20	3	38	54	70.37%
	Ratio of urban population to rural population	21	16	3	40	54	74.07%
	Comments: ∘ The issue is how much people are shifting , where to and why ∘ This should include migration patterns ∘ This issue should include demographics Alternatives: ∘ Percentage of catchment area with planned developments vs. unplanned developments ∘ Change in settlement type/place						

ISSUE	INDICATOR	Excellent	Good	Poor	Total score	Highest possible score	Percentage
4. Landuse change	Area (as a percentage) of different land uses (agriculture, mining, industry, forestry, protected areas, human settlements) at 5 year intervals	45	6	2	53	60	88.33%
	Ratio of developed land to undeveloped land	25	10	6	41	48	85.42%
	Comments: o Five year intervals might provide different information to smaller intervals o Agriculture must be split into cultivation and grazing Alternatives: o Land use intensity o Irreplacibility of the landscape o Ratio of developed land to land that has the potential to be developed						
5. Poverty	Proportion of households earning < R 6 000 per annum	9	14	5	28	48	58.33%
	Percentage of people living below the poverty line	18	20	2	40	54	74.07%
	Gross Geographic Product	15	6	5	26	48	54.17%
	Human Development Index	18	8	1	27	36	75.00%
	Comments: o Poverty should be described in terms of water resources management o HIV/AIDS could be included under this issue o Access to water and sanitation could be included under this issue Alternatives: o Vulnerability of the catchment population to change o Water Poverty Index o Percentage of the population employed in the formal and informal sectors						
6. Waste generation	Amount of waste generated per person	12	10	9	31	54	57.41%
	Comments: o There is a need to distinguish between urban and rural waste or organic and inorganic Alternatives: o Effectiveness of waste disposal o Amount of waste generated per sector o Amount of waste removed per person o Amount of waste not disposed of at proper waste disposal sites						
8. Population change	Population density	24	16	3	43	57	75.44%
	Population growth rate	39	14	0	53	60	88.33%
	Comments: o Population density over time will provide information on the growth rate o This links to settlement patterns and population distribution						

ISSUE	INDICATOR	Excellent	Good	Poor	Total score	Highest possible score	Percentage
	PRESSURES						
9. Availability of water	Actual runoff per square km	18	14	4	36	57	63.16%
	Anthropogenic supply (IBTs and return flows) as a proportion of total available	18	14	4	36	51	70.59%
	Total water (surface and ground water) available per capita	36	12	2	50	60	83.33%
	Comments: ∘ Competition for water resources is an important management issue ∘ Yield from reservoirs and run off in rivers are two separate issues Alternatives: ∘ Water availability at different levels of assurance ∘ Yield vs. allocated water supply						
10. Sectoral water requirements	Percentage of water required by each sector	36	16	0	52	63	82.54%
	Number of people supported by groundwater	21	18	3	42	54	73.68%
	Comments: ∘ Some classification is required in terms of security/risk of supply or demand. A strategic sector would be considered a high security industry (see 11) ∘ It is important to consider the benefit provided by each sector Alternatives: ∘ Efficiency of water use in the irrigation sector ∘ Employment generated per volume of water used ∘ Income generated per volume of water used ∘ Number of people supported by surface water						
11. Water requirements of strategic industries	Percentage water required by each industry	9	20	3	32	48	66.67%
	Comments: ∘ Can be merged with Issue 10 ∘ Should include future requirements, taking into account wet and dry cycles ∘ Quality should also be taken into account ∘ There is insufficient argumemt that the Act allows a preference between users Alternatives: ∘ Volume of water required by each industry ∘ Volume of water required by each industry in comparison to what is available						

ISSUE	INDICATOR	Excellent	Good	Poor	Total score	Highest possible score	Percentage
12. Water requirements for the Reserve	Reserve as a proportion of mean annual runoff	21	8	4	33	48	68.75%
	Comments: • The Reserve has various components. These need to be tested against the time set to reach the various targets • Reserve includes basic human needs • The meeting of the Reserve should encompass all the ecological requirements • Is the setting of the Reserve part of RWQOs? • The low flow or dry-season flow is an important decision criterion • Quality should also be taken into account Alternatives: • Volume of water required by each industry • Reserve expressed as a percentage of system yield • Reserve as a percentage of actual flow • Real time flow requirements at selected points in a WMA • Volume of water required						
13. International requirements	Percentage of MAR required by other countries	15	8	0	23	27	85.19%
	Comments: • This might be important for some catchments, but can be linked to Issue 10 • This should be expressed in terms of wet and dry periods						
14. Agricultural runoff	Agricultural runoff as a percentage of MAR	12	22	1	35	51	68.63%
	Agricultural runoff as a percentage of the total water available	21	12	3	36	51	70.59%
	Fertiliser used per arable land area	3	16	4	23	42	54.76%
	Comments: • This can be grouped with Issue 15 under diffuse sources • This should include runoff from cultivated land only • This could be crop specific; i.e. include forestry • Infiltration to groundwater is important, but difficult to measure • This should be expressed in terms of wet and dry periods • Quality of the runoff is important • This should be at the level of a quaternary catchment						
15. Runoff from dense settlements	Runoff from dense settlements as a percentage of MAR	15	16	2	33	48	68.75%
	Runoff from dense settlements as a percentage of the total water available	16	14	3	33	51	64.71%
	Comments: • This is a quality issue • Can be linked to Issue 14 as a diffuse source of pollution • Obviously links to human settlement patterns • This should be at the level of a quaternary catchment • This should be expressed in terms of wet and dry periods Alternatives: Runoff from paved areas as a percentage of the total water available						

ISSUE	INDICATOR	Excellent	Good	Poor	Total score	Highest possible score	Percentage
16. Industrial point sources (effluents)	Total liquid waste discharged as a proportion of total water available	18	12	2	32	45	71.11%
	Wastewater treated as a proportion of water care works' capacity	9	20	4	33	54	61.11%
	Proportion of effluents re-used	9	24	3	36	54	66.67%
	Pollutant loads discharges above permitted discharge limits	12	24	2	38	57	66.67%
	Comments: ∘ Pollutant load is more important – this links quality and quantity Alternatives: ∘ Percentage compliance with water quality standards/permits						
17. Mine drainage	Mine drainage as a percentage of MAR	12	14	3	29	45	64.44%
	Mine drainage as a percentage of total water available	18	8	4	30	45	66.67%
	Comments: ∘ Pollutant load is more important – this links quality and quantity ∘ This issue is closely related to Issue 16: industrial effluent ∘ Monthly variability should be taken into account ∘ This should include runoff from mine surfaces Alternatives: Percentage compliance with water quality permits/permits						
STATE							
18. Water balance	Demand as a proportion of supply	42	8	2	52	60	86.67%
	Proportion of groundwater utilised	12	24	2	38	54	70.37%
	Unaccounted for water as a percentage of total available	12	18	4	34	54	62.96%
	Groundwater level variations	15	20	2	37	51	72.55%
	Alternatives: ∘ Useable water (combined yield from reservoirs) as a percentage of MAR ∘ Demand as a proportion of supply at different levels of assurance						
19. Eutrophication status (surface)	Chlorophyll a concentration at dam walls of main reservoirs	24	10	0	34	39	87.18%
	Total phosphorus concentrations at dam walls of main reservoirs	9	16	2	27	39	69.23%
	Phosphate concentrations at dam walls of main reservoirs	9	16	1	26	36	72.22%
	Total phosphorus concentrations at the downstream point	12	10	4	26	39	66.67%
	Phosphate concentrations at the downstream point	12	12	2	26	36	72.22%
	Nitrate concentrations at dam walls of main reservoirs	9	16	1	26	36	72.22%
	Nitrate concentrations at the downstream point	12	14	3	29	42	69.05%

ISSUE	INDICATOR	Excellent	Good	Poor	Total score	Highest possible score	Percentage
Eutrophication cont.	Comments: • There is potential here to use information on hyacinth blooms • Obviously linked to other water quality variables • There is a need to include upstream points Alternatives: • Chlorophyll a concentration at the lowest point in the geographical catchment • Total nitrogen concentration at the lowest point in the geographical catchment • Cost to clean to a certain general standard						
20. Status of harmful toxic substances (surface & ground)	Daphnia toxicity test at dam walls of main reservoirs	12	16	1	29	39	74.36%
	Daphnia toxicity test at the downstream point	15	14	2	31	42	73.81%
	Comments: • Rather use this test as near as possible to pollution points • Toxicity testing should include fish and other organisms						
21. Microbiological contamination (surface & ground)	Faecal coliforms at dam walls of main reservoirs	15	12	5	32	48	66.67%
	Faecal coliforms at the downstream point	21	14	3	38	51	74.51%
	Faecal coliforms at selected boreholes	15	18	2	35	48	72.92%
	E-coli at dam walls of main reservoirs	9	18	3	30	45	66.67%
	E-coli at the downstream point	18	18	1	37	48	77.08%
	E-coli at selected boreholes	15	20	0	35	45	77.78%
	COD at dam walls of main reservoirs	6	18	4	28	48	58.33%
	COD at the downstream point	12	18	3	33	51	64.71%
	Comments: • Links to other water quality issues • All these water quality tests are expensive Alternatives: E.coli at points downstream of specific pollution sources , e.g. dense settlements without sanitation						
22. Salinity (surface & ground)	TDS at dam walls of main reservoirs	18	12	2	32	39	82.05%
	TDS at the downstream point	18	18	0	36	45	80.00%
	TDS at selected boreholes	18	16	0	34	42	82.95%
	Comments: • The new quality Reserve has removed TDS and uses actual salts • Where there are large irrigation schemes monitoring should be upstream and downstream of the activity • Include seasonal variability Alternatives: • Conductivity at the lowest geographical point in a catchment • TDS at selected river monitoring points						

ISSUE	INDICATOR	Excellent	Good	Poor	Total score	Highest possible score	Percentage
23. Sediment yield (surface)	Percentage of reservoir storage lost to sedimentation	24	14	0	38	54	70.37%
	TSS loading at the downstream point as a percentage of catchment sediment yield	15	16	4	35	51	68.63%
	Comments: ∘ For riverine ecology there is a need to know the amount of sediment in the rivers Alternatives: ∘ Rate of reservoir sedimentation ∘ Actual catchment erosion per annum ∘ Total sediment load per annum						
IMPACTS							
25. Altered ecosystem functioning	Change in flow at the downstream point	21	10	1	32	42	76.19%
	Reservoir capacity as a percentage of total water available	12	6	4	22	39	56.41%
	Comments: ∘ These indicators may not be relevant to altered ecosystem functioning – check with the RDM office ∘ Evaluation of the success of the Reserve may give some indication of ecosystem functioning ∘ Impact of land use activity should be taken into account Alternatives: ∘ Number an extent of impoundments and weirs ∘ Change in flow at the upstream point						
26. Decreasing biodiversity	SASS at selected sites	27	16	1	44	54	81.48%
	Fish Assemblage Integrity Index at selected sites	36	8	0	44	48	91.67%
	Percentage of indigenous fish present	21	14	4	39	54	72.22%
	Number of aquatic species at risk	27	12	3	42	54	77.78%
	Comments: ∘ Should include streams ∘ These indicators provide a measure of ecosystem health ∘ River Health Programme indicators should be used where possible ∘ What about compliance with the Reserve?						
27. Habitat condition	Index of Habitat Integrity at selected reaches	21	16	1	38	48	79.17%
	Riparian Vegetation Index at selected reaches	18	20	0	38	48	79.17%
	Percentage loss of wetland area	24	18	1	43	54	89.63%
	Percentage of riparian zone with development	15	22	1	38	51	74.51%
	Percentage land area covered by alien invasive plants	18	20	1	39	51	76.47%

ISSUE	INDICATOR	Excellent	Good	Poor	Total score	Highest possible score	Percentage
Habitat condition cont.	Comments: ○ River Health Programme indicators should be used where possible ○ What about compliance with the Reserve? ○ The "biobase" concept of irreplacibility for landscapes is a much better one to use Alternatives: ● Width of riparian buffer zones along the river ○ Percentage of land covered by permanent structures ● Percentage of species lost in wetland areas						
29. Increased occurrence of water-borne diseases	Percentage of catchment residents with classified water-borne diseases	24	16	3	43	60	71.67%
	Comment: ○ The indicator provided is difficult to measure ● This issue is not important for water sustainability ○ This issue is linked to poverty and water quality ○ Differentiate between short- and long-term diseases						
30. Inequitable access to services	Population without access to piped water on site (%)	24	20	0	44	54	81.48%
	Population without access to toilet facilities (%)	21	20	0	41	54	75.93%
	Comments: ○ These indicators should reflect the national standards ● This issue is about equity of access to water (not services). There should be equity in water allocation Alternative: ● Inequality coefficient for water ○ Population with access to piped water within a distance 200m from the house ○ Population with access to environmentally-acceptable sanitation systems						
RESPONSES							
34. Human resources capacity	Number of professional water resource managers	12	14	3	29	51	56.86%
	Financial contribution to training for water resource managers	3	10	5	18	42	42.66%
	Comments: ○ When there is a need, the capacity will appear ○ Need to manage the success of the interaction of professionals to catchment stakeholders ○ This should be linked with organisational viability, financial viability and social viability Alternatives: ● Percentage of the population aware of water management issues ○ Level of education of water resource managers ● Number of water resource managers per capita/per water distribution or storage facility ● Budget available per employee to manage the water resources						

ISSUE	INDICATOR	Excellent	Good	Poor	Total score	Highest possible score	Percentage
35. Stakeholder participation	Level of forum establishment	15	16	2	33	48	68.75%
	State-of-satisfaction of catchment population	9	15	3	27	42	64.29%
	Comments: • The CMA governing board is the most important level at which participation should occur • All people should be considered as stakeholders in the long term • Institutional roles are more important for getting the job done Alternatives: • Success of CMS • Level of stakeholder representivity at (forum) meetings • Viability of forums						
36. Demand management	Decrease in use of water in areas where demand management has been introduced	21	20	1	42	54	77.78%
	Comments: • This is linked to water balance Alternatives: • Efficiency of water use per sector (product per vol)						
37. Water allocation (licensing)	Number of compulsory licenses issued	15	12	6	33	51	64.71%
	Amount of water allocated through compulsory licensing	24	12	3	39	51	76.47%
	Comments: • Compulsory licenses do not only deal with water allocations, but other impacts on water resources • There should be an improvement in the equity of distribution of water Alternatives • Amount of water allocated per race group • Amount of water allocated per sector • Percentage compliance to licenses issued • Number of licenses issues in respect of total water that can be allocated						
38. Waste management	RWQOs set for the catchment	24	10	2	36	51	70.59%
	RWQOs met for the catchment	42	6	0	48	54	88.89%
	Comments: Rather use the broader term "resource quality objectives" A composite indicator could provide additional information for this issue. It must be linked to other indicators This would be covered by the national classification system coupled to the Reserve Alternatives: • RWQOs modified during audit						

ISSUE	INDICATOR	Excellent	Good	Poor	Total score	Highest possible score	Percentage
40. Monitoring	Number of active hydrological monitoring stations per 100 km^2	21	14	2	37	48	77.08%
	Number of active water quality monitoring stations per 100 km^2	21	14	2	37	48	77.08%
	Amount of money spent on monitoring per annum	9	12	4	25	42	59.52%
	Comments: • The monitoring of the catchment depends on the specific needs of the catchment and should be assessed as such • Reporting and auditing are also important • Need to have properly integrated monitoring networks in place (with the correct frequencies, variables etc.). They need to be maintained, and the data captured needs to be used for decision-making. Alternatives: • Database access and amount it is used • Biomonitoring sites per catchment • Frequency and quality of data per quaternary catchment • Number of catchments monitored in the WMA • Data quality assessment • Resources available for monitoring						

5.2 Group report-back and plenary discussion

The indicators chosen for each issue by the groups are shown in Table 2.

Table 2:. Indicator chosen by the group participants to represent each issue.

ISSUE	INDICATOR
Driving Forces	
1. Catastrophic events (floods and droughts)	Frequency and extent of flood and drought events
2. Change in climate & variability	Annual rainfall deviations within the catchment
3. & 4. Human settlement patterns and land use change	Area under different land uses, including agriculture, mining, industry, forestry, protected areas and urban and rural human settlement
5. Poverty	Human Development Index
6. Waste generation	Amount of waste generated per person
8. Population change	Population density
Pressures	
9, 10, 11, 12 & 13. Water requirements (sectoral; strategic, Reserve and international)	Demand and supply at different levels of assurance (100%=Reserve; 95%=strategic;75%=agriculture etc.)
12. Water requirements for the Reserve	Instream flow requirements delivered vs. actual runoff
14, 15, 16 & 17. Quality and quantity of waste reaching the water resource	Total waste load reaching the resource
	Cost/benefit to downstream parties for sectoral use
State	
18. Water balance	Demand as a proportion of supply (over time)
19. Eutrophication status (surface)	Chlorophyll a concentration at the lowest point of a geographical catchment (management unit)
20. Status of harmful toxic substances (surface & ground)	Daphnia toxicity test at the lowest point of a geographical catchment (management unit)
21. Microbiological contamination (surface & ground)	Faecal coliforms in a water resource used for domestic and recreational use
22. Salinity (surface & ground)	Conductivity at the lowest point of a geographical catchment (management unit)
23. Sediment yield (surface)	TSS loading at the lowest point of a geographical catchment (management unit) or the inflow of a reservoir
24. Well-head protection	Still needs to be defined, but there should be no human and animal activity within a specified area around a well-head
Impacts	
25. Altered ecosystem functioning	Deviation from Reserve objectives
26. Biodiversity change	SASS at selected critical sites
	Fish Assemblage Integrity Index
27. Habitat condition	Index of Habitat Integrity
30. Inequitable access to services/resources	?
Responses	
33. CMA viability	Proportion of CMS successfully implemented in a 5-year cycle
34. Human resources capacity	?
35. Stakeholder participation	State-of-satisfaction of total catchment population
36. Demand management	Water use efficiency at different scales (Section 27 of NWA)
37. Water allocation (licensing)	?
38. Waste management	?
40. Monitoring	Number of active hydrological monitoring stations per 100 km^2
	Number of active water quality monitoring stations per 100 km^2
	Amount of money spent on monitoring per annum

Points made regarding the indicators and possible alternatives during the discussion included:

- Poverty should include the problem of the vulnerability of the population to change, but should concentrate on the relationship between poverty and water.
- Waste generation (Issue 6) should include waste generated per sector, and should only deal with solid waste.
- Issues 14 to 17 on pollution sources needed clarification. There was a perceived need to aggregate them, but they represented different types and sources of pollution (e.g. point sources and diffuse sources).
- The indicator for Issue 23: Sediment yield should be *TSS loading at the inflow of a reservoir* to ensure that the rate of sedimentation is taken into account.
- An indicator for Issue 24: Well-head protection needed to be developed. Suggestions included *the length of distribution pipe* (as a reflection on how close animals and people had to come to receive water), the *number of well-heads in the catchment that had a clearance of 25 m or more* (average state of well-heads), and *contamination status in the well* (NO_3, PO_4 and microbial contamination).
- Where possible variability should be minimised by normalising with constants (e.g. per catchment area and not per population).
- The irreplacibility concept should be considered by developing an indicator that shows the *percentage irreplacibility of a landscape.*
- Issue 30: Inequitable access to services is too short-sited and should include other resources. An indicator for this would require careful thought. The work done by the Directorate of Water Services Macro Planning and Information Systems should be taken into consideration.
- The Water Poverty Index that has recently been developed, and should be investigated.
- Water allocation is the Government's tool to achieve equity. It is important to have some indication on the compliance level where compulsory licenses are concerned.
- An alternative indicator to the *number of monitoring stations per 100km2* is *the number of sub-catchments that are monitoried within the CMA*. This ensures that non-functional stations are excluded.

5.3 Written comments

General written comments submitted by participants included:

- The indicators should be translated into manageable entities in order for them to contribute to the management of the catchment (Francois van der Merwe).
- Indicators should be driven by management objectives at water management area, and not by scientific requirements. For example, a water quality index could be useful (Brian Hollingworth).
- A hierarchical system of indicators would also be useful (Brian Hollingworth).
- While acknowledging the role of state-of-the-environment reporting in the development of indicators, the as-many-as-you-can-think-of approach is less useful if the stated purpose is ministerial reporting or management (briefing document). My recollection of the psychology of decision-making is that the human mind is usually able to integrate five concepts (indicators) and that seven is the upper limit (Brian Hollingworth).
- It was not clear whether the outcomes were intended for DWAF or the CMA's when formed. If the latter, capacity is going to be a problem. Also the CMA's will not, under present arrangements, have powers under the Water Services Act so that indicators relevant to these functions will be much less useful. At this level DWAF and CMA needs are probably different (Brian Hollingworth).
- The indicator set should be directly affected by the interventions of a water manager at catchment level. But this is based on the conceptual position that an indicator evidences the outcomes or performance of the catchment management task. Indicators beyond the influence of the manager; i.e. by their using powers under the NWA, are all but irrelevant (Brian Hollingworth).
- There should be a consistency check on methodologies. This extends to:
    - ◊ the accumulation of measurements over spatial areas;
    - ◊ the manipulation of variables (say rainfall) by other variables (say population) or fixed values (say area);
    - ◊ the use of statistical tools such as means, medians standard deviations etc. ;
    - ◊ the distinction of variables (e.g. population) that may have trend but almost no variability from variables with (nearly) true variability (e.g. rainfall);
    - ◊ the use (or avoidance) of ratios or percentages;
    - ◊ the use of loaded words (e.g. "decreasing availability") (Brian Hollingworth).

- On the matter of consistency it would also be preferable to follow international practice where available (for understanding, reporting and comparative purposes) rather than the ideas expressed by an *ad hoc* stakeholder group, which was struggling with some of the concepts. Much of the value of indicators lies in their standardisation (Brian Hollingworth)..

6. THE WAY FORWARD

Mrs Walmsley said, in the immediate future, the proceedings of the meeting would be compiled and sent to all the participants. This would be followed by a report on the development of the indicators (including the interviews and the workshop results), and indicator fact sheets, which would be available by the end of March. The project was due to end in November 2002. Before then the issue of data availability for all the indicators would be investigated.

In the long-term, DWAF had shown an interest in taking the project forward, particularly with regard to developing indicators that could assist with State of the Water Resources Reporting. This was just the first step in the development of indicators for use in the Department. Obviously what was produced during this project would have to be refined to cater more closely with DWAF requirements.

ANNEX 1

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ANNEX 2

QUESTIONNAIRE

NAME:..

POSITION:..

ORGANISATION:..

SESSION II: EVALUATION OF ISSUES

Evaluate the issues listed, by rating them according to the following criteria:

- Is this issue important at a catchment level?
- Do water resources managers need information on this issue?
- Is this issue critical to the sustainability of the water resources?

ISSUE	Is this issue important at a catchment level?	Do water resources managers need information on this issue?	Is this issue critical to the sustainability of the water resources?
Diving Forces			
1. Catastrophic events (floods and droughts)			
2. Change in climate & variability			
3. Human settlement patterns			
4. Landuse change			
5. Poverty			
6. Waste generation			
7. HIV/Aids			
8. Population change			
Pressures			
9. Availability of water			
10. Sectoral water requirements			
11. Water requirements of strategic industries			
12. Water requirements for the Reserve			
13. International requirements			
14. Agricultural runoff			
15. Runoff from dense settlements			
16. Industrial point sources (effluents)			
17. Mine drainage			
State			
18. Water balance			
19. Eutrophication status (surface)			
20. Status of harmful toxic substances (surface & ground)			

21.	Microbiological contamination (surface & ground)			
22.	Salinity (surface & ground)			
23.	Sediment yield (surface)			
24.	Well-head protection			
Impacts				
25.	Altered ecosystem functioning			
26.	Decreasing biodiversity			
27.	Habitat degradation			
28.	Decreased resources for cultural use			
29.	Increased occurrence of water-borne diseases			
30.	Inequitable access to services			
31.	Decreased resources for economic development			
32.	Increased cost of provision of enough water of right quality			
Responses				
33.	CMA financial viability			
34.	Human resources capacity			
35.	Stakeholder participation			
36.	Demand management			
37.	Water allocation (licensing)			
38.	Waste management			
39.	Research			
40.	Monitoring			

SESSION III: IDENTIFICATION OF INDICATORS

The following provides a list of the issues and possible indicators for each issue. Please rate the indicators provided. If you feel that none of the indicators are relevant, please give alternatives in the space provided.

ISSUE	INDICATOR	Excellent	Good	Poor	Very poor
Driving Forces					
1. Catastrophic events (floods and droughts)	Frequency and extent of flood events				
	Flood storage availability				
	Frequency and extent of droughts				
CommentAlternative:...					
2. Change in climate & variability **MERGED WITH ISSUE 1**	Annual temperature deviations within the catchment				
	Annual rainfall deviations within the catchment				
	Mean annual precipitation				
	Mean annual evaporation				
CommentAlternative:...					

ISSUE	INDICATOR	Excellent	Good	Poor	Very poor
3. Human settlement patterns	Percentage of population in urban areas				
	Ratio of urban population to rural population				
CommentAlternative:..					
4. Landuse change	Area (as a percentage) of different land uses (agriculture, mining, industry, forestry, protected areas, human settlements) at 5 year intervals				
	Ratio of developed land to undeveloped land				
CommentAlternative:..					
5. Poverty	Proportion of households earning < R 6 000 per annum				
	Percentage of people living below the poverty line				
	Gross Geographic Product				
	Human Development Index				
CommentAlternative:..					
6. Waste generation	Amount of waste generated per person				
CommentAlternative:..					
7. HIV/Aids	Percentage of population suffering from HIV/AIDS				
CommentAlternative:..					
8. Population change	Population density				
	Population growth rate				
CommentAlternative:..					
Pressures					
9. Availability of water	Actual runoff per square km				
	Anthropogenic supply (IBTs and return flows) as a proportion of total available				
	Total water (surface and ground water) available per capita				
CommentAlternative:..					
10. Sectoral water requirements	Percentage of water required by each sector				
	Number of people supported by groundwater				
CommentAlternative:..					
11. Water requirements of strategic industries	Percentage water required by each industry				
CommentAlternative:..					

ISSUE	INDICATOR	Excellent	Good	Poor	Very poor
12. Water requirements for the Reserve	Reserve as a proportion of mean annual runoff				
CommentAlternative:..					
13. International requirements	Percentage of MAR required by other countries				
CommentAlternative:..					
14. Agricultural runoff	Agricultural runoff as a percentage of MAR				
	Agricultural runoff as a percentage of the total water available				
	Fertiliser used per arable land area				
CommentAlternative:..					
15. Runoff from dense settlements	Runoff from dense settlements as a percentage of MAR				
	Runoff from dense settlements as a percentage of the total water available				
CommentAlternative:..					
16. Industrial point sources (effluents)	Total liquid waste discharged as a proportion of total water available				
	Wastewater treated as a proportion of water care works' capacity				
	Proportion of effluents re-used				
	Pollutant loads discharges above permitted discharge limits				
CommentAlternative:..					
17. Mine drainage	Mine drainage as a percentage of MAR				
	Mine drainage as a percentage of total water available				
CommentAlternative:..					
State					
18. Water balance	Demand as a proportion of supply				
	Proportion of groundwater utilised				
	Unaccounted for water as a percentage of total available				
	Groundwater level variations				
CommentAlternative:..					

ISSUE	INDICATOR	Excellent	Good	Poor	Very poor
19. Eutrophication status (surface)	Chlorophyll a concentration at dam walls of main reservoirs				
	Total phosphorus concentrations at dam walls of main reservoirs				
	Phosphate concentrations at dam walls of main reservoirs				
	Total phosphorus concentrations at the downstream point				
	Phosphate concentrations at the downstream point				
	Nitrate concentrations at dam walls of main reservoirs				
	Nitrate concentrations at the downstream point				
CommentAlternative:..					
20. Status of harmful toxic substances (surface & ground)	Daphnia toxicity test at dam walls of main reservoirs				
	Daphnia toxicity test at the downstream point				
CommentAlternative:..					
21. Microbiological contamination (surface & ground)	Faecal coliforms at dam walls of main reservoirs				
	Faecal coliforms at the downstream point				
	Faecal coliforms at selected boreholes				
	E-coli at dam walls of main reservoirs				
	E-coli at the downstream point				
	E-coli at selected boreholes				
	COD at dam walls of main reservoirs				
	COD at the downstream point				
CommentAlternative:..					
22. Salinity (surface & ground)	TDS at dam walls of main reservoirs				
	TDS at the downstream point				
	TDS at selected boreholes				
CommentAlternative:..					
23. Sediment yield (surface)	Percentage of reservoir storage lost to sedimentation				
	TSS loading at the downstream point as a percentage of catchment sediment yield				
CommentAlternative:..					
24. Well-head protection	?				
CommentAlternative:..					
Impacts					
25. Altered ecosystem functioning	Change in flow at the downstream point				
	Reservoir capacity as a percentage of total water available				
CommentAlternative:..					

ISSUE	INDICATOR	Excellent	Good	Poor	Very poor
26. Biodiversity change	SASS at selected sites				
	Fish Assemblage Integrity Index at selected sites				
	Percentage of indigenous fish present				
	Number of aquatic species at risk				
CommentAlternative:..					
27. Habitat condition	Index of Habitat Integrity at selected sites				
	Riparian Vegetation Index at selected sites				
	Percentage loss of wetland area				
	Percentage of riparian zone with development				
	Percentage land area covered by alien invasive plants				
CommentAlternative:..					
28. Decreased resources for cultural use	Number of days reservoirs are unfit for recreation				
CommentAlternative:..	Excluded				
29. Increased occurrence of water-borne diseases	Percentage of catchment residents with classified water-borne diseases				
CommentAlternative:..	Excluded				
30. Access to services	Population without access to piped water on site (%)				
	Population without access to toilet facilities (%)				
CommentAlternative:..					
31. Decreased resources for economic development	?				
CommentAlternative:..	Excluded				
32. Increased cost of provision of enough water of right quality	Combined municipal and water provider costs to provide water per capita				
CommentAlternative:..	Excluded				
Responses					
33. CMA viability	?				
CommentAlternative:..					
34. Human resources capacity	Number of professional water resource managers				
	Financial contribution to training for water resource managers				
CommentAlternative:..					

ISSUE	INDICATOR	Excellent	Good	Poor	Very poor
35. Stakeholder participation	Level of forum establishment				
	State-of-satisfaction of catchment population				
CommentAlternative:..					
36. Demand management	Decrease in use of water in areas where demand management has been introduced				
CommentAlternative:..					
37. Water allocation (licensing)	Number of compulsory licenses issued				
	Amount of water allocated through compulsory licensing				
CommentAlternative:..					
38. Waste management	RWQOs set for the catchment				
	RWQOs met for the catchment				
CommentAlternative:..					
39. Research	Amount of money spent on research per annum				
	Number of research projects in the catchment				
Excluded *CommentAlternative:*..					
40. Monitoring	Number of active hydrological monitoring stations per 100 km^2				
	Number of active water quality monitoring stations per 100 km^2				
	Amount of money spent on monitoring per annum				
CommentAlternative:..					

APPENDIX C
Indicator Fact Sheets (Chapter 9)

TABLE OF INDICATORS

SOCIO-ECONOMIC INDICATORS

SE1: POPULATION DENSITY		
Social	Population change	Driving force

1. **Definition:** Total population size within the catchment divided by its surface area (no. km^{-2})

2. **Purpose:** To measure the concentration of the human population with reference to space. Population density can be used as a partial indicator of human requirements and activities in an area.

3. **Relevance to sustainable water resource management:** A high or growing population density can threaten the sustainability of water resources by exceeding the carrying capacity of the resource. This is particularly true in catchments where freshwater resources are limited (i.e. most South African catchments). At the same time, population density is considered to be a driving force of technological change in production. A high population density is the main defining feature of urban areas. A high concentration of population also means more local demand for sanitation, services, waste management and general amenities, all of which require water.

4. **Linkages:** This indicator may be linked to the following issues:
   - Human settlement;
   - Poverty/vulnerability;
   - Inequity;
   - Inequitable access to services;
   - Waste generation/waste management;
   - Domestic demand for water;
   - Water allocation/Reserve;
   - Runoff from dense settlements;
   - Microbiological contamination;
   - Demand management;
   - Social viability, and
   - Habitat condition.

5. **Limitations and potential problems:** The significance of the indicator is limited in larger catchments, where population distribution varies significantly. For instance, the Lower Orange River has a low population density and uneven distribution, with the main human impacts arising upstream.

6. **Calculating the indicator:**

$$SE1 = P_T / A_T$$

Where: P_T = Total catchment population (number)
A_T = Total surface area (km^2).

SE2: URBANISATION		
Social	Human settlement	Driving force

1. **Definition:** The percentage of the catchment population living in semi-formal and formal urban areas as defined by the National Census (%).

2. **Purpose:** To measure the number of people living in both formal and informal urban areas. It is useful as an indicator of urban development and, by default, gives an indication of percentage of people living in rural areas.

3. **Relevance to sustainable water resource management:** The number of people in urban and rural environments has an impact on the infrastructure and water requirements, as well as waste management and pollution potential. In a highly urbanised environment, the infrastructure requirements will be high, especially with regard to sanitation, water supply and pollution management.

4. **Linkages:** This indicator may be linked to the following issues:
   - Land-use change;
   - Demand management;
   - Waste generation/pollution management;
   - Inequity;
   - Inequitable access to services;
   - Poverty/vulnerability;
   - Domestic demand for water;
   - Runoff from dense settlements;
   - Microbiological contamination;
   - Social viability, and
   - Habitat condition.

5. **Limitations and potential problems:** This indicator is dependent on Census information and urban classification. Census information is only available in 5-yearly cycles, whilst urban classification still requires clarification.

6. **Calculating the indicator:**

$$SE2 = P_U / P_T \times 100$$

Where: P_U = Semi-formal and formal urban population (number)
P_T = Total catchment population (number).

SE3: GROSS GEOGRAPHIC PRODUCT PER CAPITA		
Economic	Poverty/Vulnerability	Driving force

1. **Definition:** Gross geographic product (GGP) per capita for a catchment is obtained by dividing annual GGP at current market prices by the catchment population (Rands $capita^{-1}$ or US$ $capita^{-1}$ for international comparisons).

2. **Purpose:** To measure the wealth of a catchment area. GGP per capita is a basic economic growth indicator and measures the level and extent of total economic output. It reflects changes in total production of goods and services.

3. **Relevance to sustainable water resource management:** Growth in the production of goods and services is a basic determinant of how the economy fares. It indicates the pace per capita of income growth and also the rate at which resources, including water, are used. It does not directly measure sustainable development, but is a very important measure for the economic and developmental aspects of sustainable development, including people's consumption patterns and the use of renewable resources, such as water.

4. **Linkages:** This indicator may be linked to the following issues:
   - Economic use value;
   - Water allocation;
   - Poverty/vulnerability;
   - Waste generation;
   - Inequity;
   - Sectoral demand for water, and
   - Demand management.

5. **Limitations and potential problems:** At present GGP at catchment level is not calculated as part of the standard South African statistics, although it has been done for planning purposes within DWAF.

6. **Calculating the indicator:**

   GGP is calculated using standard procedures. The current price estimates of GGP are adjusted to GGP at constant prices with the use of price deflators.

   Population estimates enable the conversion of total GGP to per capita levels using the following equation:

   $$SE3 = GGP / P_T$$

   Where: GGP = Annual Gross geographic product for the catchment
   P_T = Total catchment population (number).

SE4: HUMAN DEVELOPMENT INDEX		
Social	Poverty/Vulnerability	Driving force

1. **Definition:** Composite, relative index that quantifies the extent of human development of a community (Index value between 0 and 1).

2. **Purpose:** To evaluate the level of human development based on measures of life expectancy, literacy and income. It is internationally accepted as an index of human vulnerability and standard of living.

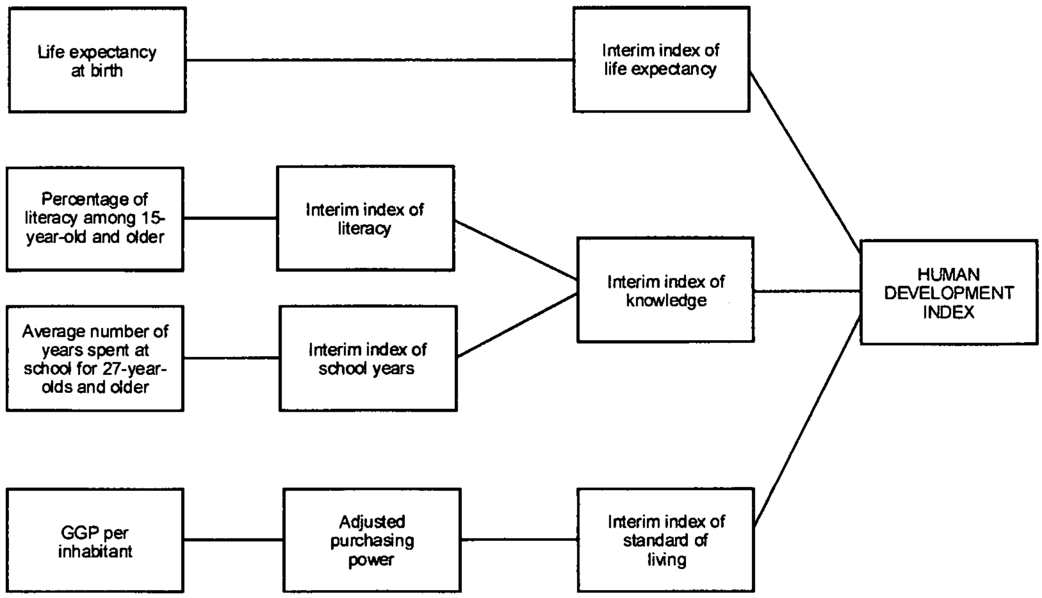
3. **Relevance to sustainable water resource management:** This indicator is seen as a measure of people's ability to live a long and healthy life, to communicate, to participate in the life of the community and to have sufficient resources to obtain a decent living. If the level of human development is high in a catchment, the lower order needs are being met and high-order needs such as conservation can be dealt with. It also provides an indication of the potential of the population to rationally respond to resource management and sustainable development issues.

4. **Linkages:** This indicator may be linked to the following issues:
   - Poverty/vulnerability;
   - Population change;
   - Inequity;
   - Inequitable access to services, and
   - Social viability.

5. **Limitations and potential problems:** The greatest limitation to this index, is that data are often limited and incomplete. It should also be taken into account that other indicators have been used in the index to represent similar aspects of development (e.g. GGP per capita, GGP per employed, services level).

6. **Calculating the indicator:**

The index is calculated as follows:



The initial data are transformed in one or two stages, according to their peculiarities, into interim indices that will be used to calculate the HDI. The following conventional minimum and maximum values for the different indices are used for the calculation of interim indices:

	Min	Max
Life expectancy at birth (a)	25	85
Literacy (%)	0	100
Number of school years	0	15
Purchasing power of GGP (USD)	200	40 000

The interim indices show the relative "distance" covered by a society, somewhere between the respective minimum and maximum figures. Accordingly, a 10-year education would be awarded a score of 0,667; and average life expectancy of 55 years would score 0,5. The interim index of knowledge is derived from a weighted average of literacy and years spent at school, where the weighting is 2 and 1 respectively.

The calculation of the interim index for standard of living assumes that the link between the growth of purchasing power and well-being is not proportional. Thus, the adjusted value of purchasing power is calculated before it is indexed. Income that exceeds the level of the world's average income gradually decreases in the calculation of the adjusted value. If the GGP of the catchment per inhabitant does not exceed the world average (US $5120), the adjusted purchasing power will be the actual one. Thus, the adjusted purchasing power, W(y), will be:

$W(y) = y$ when $0 < y \leq y^*$
$W(y) = y^* + 2(y-y^*)$ when $y^* < y \leq 2y^*$
$W(y) = y^* + 2(y-y^*)/2 + 3/y-2y^*)/3$ when $2y^* < y \leq 3y^*$ etc.

Where: W(y) = Adjusted purchasing power
y = GGP per capita (US$)
y^* = world average purchasing power.

Thus,

$SE4 = (L + K + W(y)) / 3$

Where: HDI = Human Development Index
L = Life expectancy index
K = Knowledge index

SE5: WATER EQUITY COEFFICIENT		
Social	Inequity	Impact

1. **Definition:** Coefficient of equity of water allocation in the domestic sector based on the Lorenz curve of percentage water received against percentage of the population (Index value between 0 and 1)

2. **Purpose:** To evaluate the equitable sharing of resources by the domestic sector.

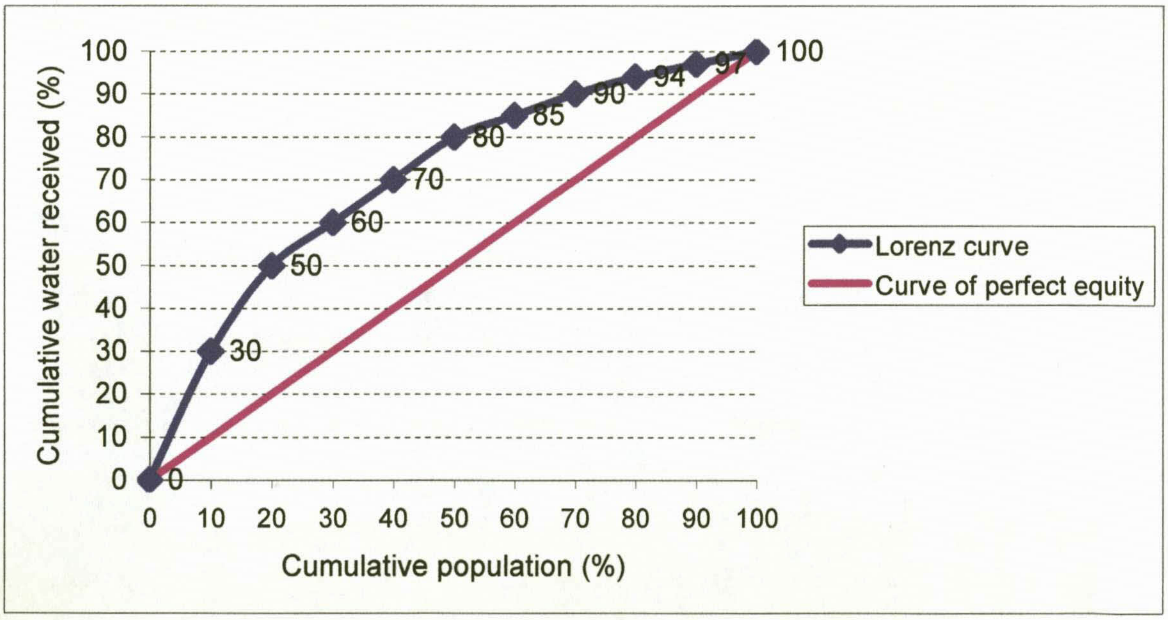
3. **Relevance to sustainable water resource management:** One of the cornerstones of the National Water Act (36 of 1998), along with sustainability, is equity. It is stated that water will be allocated in a manner that ensures equity and that past imbalances will be redressed. The domestic sector is particularly prone to imbalance, and is ideal for measuring inequity.

4. **Linkages:** This indicator may be linked to the following issues:
   - Human settlement;
   - Poverty/vulnerability;
   - Population change
   - Social viability;
   - Availability of water;
   - Water allocation/Reserve, and
   - Inequitable access to resources.

5. **Limitations and potential problems:** This indicator will only be possible to monitor where water services have been implemented and where delivered volumes are measured.

6. **Calculation of the indicator:**

The cumulative proportion of water domestic water received (y) is plotted against the cumulative percentage of the population (x) as shown in the hypothetical example below:



The Water Equity Coefficient is calculated from the above as follows:

$$SE5 = \frac{1}{2} \sum_{i=1}^{k} |x_i - y_i|$$

Where: x_i = relative frequency of x
y_i = relative frequency of y
k = number of classes.

SE6: PERCENTAGE OF HOUSEHOLDS WITHOUT ACCESS TO WATER WITHIN 200m		
Social	Inequitable access	Impact/Pressure

1. **Definition:** Proportion of households without access to water for domestic use within 200m (%).

2. **Purpose:** To assess the infrastructure development in terms of water delivery for domestic purposes, as well as access to water resources, and availability of water for basic use.

3. **Relevance to sustainable water resource management:** This indicator shows whether the local authorities and water providers are providing adequate water to the population of the catchment. It is assumed that those people that are not linked are required to collect their own water from other sources (rivers and reservoirs). If there are a high proportion of people not serviced, this has implications for the control of water consumption in the catchment. It also indicates how many people still require water in terms of government policy. In general, it tells deals with the lower end of the Lorenz curve discussed in SE5: Water Equity Coefficient.

4. Linkages: This indicator may be linked to the following issues:
   - Human settlement;
   - Poverty/Vulnerability;
   - Population change;
   - Availability of water;
   - Water allocation/Reserve;
   - Domestic demand for water
   - Inequity in terms of other services;
   - Social viability, and
   - Economic use value.

5. **Limitations and potential problems:** This indicator is limited by the assumption that piped water within 200m is the minimum requirement for an adequate water supply. This has been obtained from the from the four RDP criteria: 1) at least 25ℓ per day; 2) a distance of less that 200m; 3) adequate quality and 4) a 98% assurance of supply.

6. **Calculating the indicator:**

$$SE6 = P_{NW} / P_T \times 100$$

Where: P_{NW} = Households that do not receive piped water within 200m (number)
P_T = Total catchment population (number).

SE7: PERCENTAGE OF HOUSEHOLDS WITHOUT ACCESS TO SANITATION		
Social	Inequitable access	Pressure/Impact

1. **Definition:** Proportion of population without access to any form of toilet facility (%).

2. **Purpose:** To assess the infrastructure development and need of the people in terms of sanitation. It is also an indicator of potential sewage pollution.

3. **Relevance to sustainable water resource management:** Toilet facilities may include fairly simple communal VIP toilets, septic tank systems or flush toilets. This indicator evaluates whether any of these are available and, as a result, shows whether there are adequate sanitation facilities in the catchment or not. It also assesses the potential for sewage pollution from runoff in areas where there are few toilet facilities provided. It is a key water resource pressure indicator.

4. Linkages: This indicator may be linked to the following issues:
   - Human settlements;
   - Poverty/Vulnerability;
   - Waste generation and management;
   - Runoff from dense settlements;
   - Microbiological contamination, and
   - Social viability.

5. **Limitations and potential problems:** There are few identifiable problems with this indicator. It is similar to the indicator used by the Directorate of Planning, DWAF, to determine the need for sanitation in communities.

6. **Calculation of indicator:**

$$SE7 = P_{NT} / P_T \times 100$$

Where: P_{NT} = Population without any toilet facilities (number)
P_T = Total catchment population (number).

SE8: PERCENTAGE AREA UNDER DIFFERENT ECONOMIC LAND USES		
Economic	Land use change	Driving force

1. **Definition:** Proportion of land in the catchment under different economic land uses (agriculture, mining, and industry).

2. **Purpose:** To provide an indication of the dominant economic land uses, specified as agriculture and forestry, mining and industry, in the catchment.

3. **Relevance to sustainable water resource management:** The land use in a catchment determines the character of the water resource. Certain land uses are beneficial to aquatic ecosystems and thus the water resource (e.g. conservation), others are detrimental (mainly economic land uses). The land use will determine the kind of problems apparent in a catchment (e.g. what type of pollution) and the management options available. The use of this indicator is also important to show changes over time.

4. Linkages: This indicator may be linked to the following issues:
   - Human settlement;
   - Land use change;
   - Waste generation and management;
   - Population change;
   - Pollution (agricultural runoff; industrial point sources; mine drainage);
   - Water quality (all elements);
   - Sectoral demand for water;
   - Water allocation;
   - Altered ecosystem functioning;
   - Habitat condition, and
   - Economic use value.

5. **Limitations and potential problems:** Each catchment is unique. A certain land use should not presuppose a problem, but should act as a guide to the possibilities.

6. **Calculation of indicator:**

   Percentage cover for each land use can be calculated using the following equation:

   $$SE8_{LU} = A_{LU} / A \times 100$$

   Where: $SE8_{LU}$ = Percentage covered by land use
   A_{LU} = Area covered by land use (km^2)
   A = Total surface area (km^2).

WATER BALANCE INDICATORS

WB1: MEAN VOLUME OF PRECIPITATION ONTO THE CATCHMENT		
Water balance	Climate variability/Catastrophic events	State

1. **Definition:** Annual precipitation converted to the volume of water falling on the catchment through precipitation ($m^3\ a^{-1}$).

2. **Purpose:** To determine the amount of water falling on the catchment, and over time, whether there is short-term variability in the climate; the extent and intensity of dry and wet periods, and the long-term change in climate.

3. **Relevance to sustainable water resource management:** South Africa is a country that has a high variability in climate (and thus rainfall), not only spatially (dry in the West and wet in the East), but also temporally. The country experiences extremes in both floods and droughts. This is exacerbated by the global problem of climate change. With the long-term change in the climate, it is believed that catastrophic events such as floods and droughts are becoming more common, and therefore of greater concern to water resource managers. Floods and droughts both have severe social and economic implications for the country.

4. Linkages: This indicator may be linked to the following issues:
   - Poverty/vulnerability;
   - Availability of water;
   - Water quality, particularly sediment yield;
   - Altered ecosystem functioning;
   - Biodiversity change, and
   - Habitat condition.

5. **Limitations and potential problems:** Precipitation is only one aspect of the climate; other aspects include temperature, humidity, evaporation etc. It is, however, the one that has the most influence on the water resource characteristics within a catchment. A single meteorological station may not provide the full picture for the catchment, depending on the size of the catchment.

6. **Calculation of the indicator:**

$$WB1 = \sum_{i=1}^{k} PE$$

Where: PE = Amount of rainfall for each precipitation event ($m^3\ a^{-1}$)
k = Total number of precipitation events per annum.

WB2: TOTAL WATER AVAILABLE PER CAPITA		
Water balance	Availability of water	State

1. **Definition:** Amount of water available per person per year from both ground water and surface water resources (m^3 $capita^{-1}$ a^{-1}).

2. **Purpose:** To determine whether there is enough water in the catchment to ensure development on a sustainable basis.

3. **Relevance to sustainable water resource management:** This is an internationally-accepted, basic indicator for water availability, and provides a good indication of the level of development that can be sustained in any catchment. The estimated minimum amount of water required for development is 1 000 m^3 a^{-1} per capita (2 700 l per person per day) according to Gliek (1993, cited by http://www.cnie.org/pop/pai/water-12.html). Obviously in catchments in more arid areas where this amount is not available other development strategies need to be developed.

4. **Linkages:** This indicator may be linked to the following issues:
   - Human settlement;
   - Poverty/vulnerability;
   - Population change;
   - Inequity;
   - Sectoral water demand;
   - Water allocation;
   - Inequitable access to services;
   - Social viability, and
   - Economic use value.

5. **Limitations and potential problems:** This indicator is method of assessing the richness of the water resource in comparison to the population, rather like GGP per capita is used to assess the "richness" of the economy. It does not take into account the demand for water nor the level of development of the resource.

6. **Calculation of the indicator:**

$$WB2 = (MAR + IBT) / P_T$$

Where:
- MAR = Mean annual runoff (m^3 a^{-1})
- IBT = Inter-basin transfer volume (m^3 a^{-1})
- P_T = Total catchment population (number).

WB3: DEMAND AS A PROPORTION OF TOTAL AVAILABLE		
Water balance	Water balance	Pressure

1. **Definition:** Demand for surface water from all water-use sectors (domestic, mining, agriculture, commercial and industrial) as a proportion of the total available (anthropogenic and natural, %).

2. **Purpose:** To evaluate whether the current demand for water in the catchment exceeds the supply, or to what extent supply exceeds demand.

3. **Relevance to sustainable water resource management:** This indicator is an excellent core indicator of water balance. The sustainability of a catchment's water resources is dependent on the supply being greater than the demand. If demand nearing supply, action is required.

4. **Linkages:** This indicator may be linked to the following issues:
   - Human settlement;
   - Land use change;
   - Population change;
   - Availability of water;
   - Sectoral water demand;
   - Water allocation;
   - Demand management;
   - Altered ecosystem functioning;
   - Habitat condition;
   - Biodiversity change;
   - Social viability;
   - Inequity, and
   - Economic use value.

5. **Limitations and potential problems:** Evaluation of demand for various management units can be time consuming, as all sectors have to be taken into account.

6. **Calculation of the indicator:**

$$WB3 = D / (IBT + RT + MAR) \times 100$$

Where: D = Total demand ($m^3 a^{-1}$)
IBT = Inter-basin transfer volume ($m^3 a^{-1}$)
RT = Return flow volume ($m^3 a^{-1}$)
MAR = Mean annual runoff ($m^3 a^{-1}$).

WB4: PROPORTION OF GROUNDWATER UTILISED		
Water balance	Water balance	Pressure

1. **Definition:** Amount of ground water pumped as a percentage of safe yield (%).

2. **Purpose:** To assess use of water in underground aquifers. It is an assessment of the demand for underground water as a proportion of supply.

3. **Relevance to sustainable water resource management:** Groundwater can be a significant supply of water for domestic and agricultural use. A supply of groundwater where there is little surface water can allow for development where it might not be possible without it. If the demand for ground water is higher than the safe yield (the amount that the aquifer can yield on a sustainable basis), then usage of groundwater in the catchment will not be sustainable.

4. Linkages: This indicator may be linked to the following issues:
   - Human settlement;
   - Land use change;
   - Population change;
   - Availability of water;
   - Sectoral water demand, particularly domestic and agricultural;
   - Water allocation;
   - Demand management;
   - Habitat condition;
   - Social viability;
   - Inequity, and
   - Economic use value.

5. **Limitations and potential problems:** The greatest limiting factor at present is the lack of empirical data. It is assumed, with the registration and licensing of boreholes, that this information will become available in future. Additionally, the indicator will only be applicable in catchments with useable groundwater resources.

6. **Calculation of the indicator:**

$$WB4 = Q_P / Y_S \times 100$$

Where: Q_P = Amount of water pumped ($m^3\ a^{-1}$)
Y_S = Safe yield ($m^3\ a^{-1}$).

WB5: WATER REQUIREMENTS PER SECTOR AS A PERCENTAGE OF TOTAL AVAILABLE		
Water balance	Reserve/ International/Strategic/Sectoral Demand	Pressure

1. **Definition:** Amount of water of water required for the Reserve, to meet international requirements, for strategic industries and to meet sectoral requirements (domestic, agricultural, industrial, mining and commercial) as a percentage of the total available (%).

2. **Purpose:** To assess the sectoral requirements for water, and includes the Reserve, international demands and the requirements of strategic industries (Eskom), as well as other sectors.

3. **Relevance to sustainable water resource management:** The National Water Act recognised four categories of water users in order of preference of water allocation, namely the Reserve (ecological and basic human needs), international water requirements (according to international agreements), strategic industries (such as electricity production) and other user sectors, such as mining, agriculture etc. The type of development in any catchment will determine the water use and availability, as well as influencing the characteristics of the catchment. These all impact on the water resource management approach in a catchment.

4. Linkages: This indicator may be linked to the following issues:
    - Human settlement;
    - Land use change;
    - Population change;
    - Availability of water;
    - Water allocation;
    - Demand management;
    - Inequity, and
    - Economic use value.

5. **Limitations and potential problems:** Water requirements of a sector are catered for by the water allocation process. However, the amount of water used might not be the same as that allocated. The closer the actual use is to the amount allocated the more accurate this indicator will be.

6. **Calculation of the indicator:**

For each sector, the proportion can be calculated using the following equation:

$$WB5 = Q_R / (IBT + RT + MAR) \times 100$$

Where:
- Q_R = Water requirement for the sector ($m^3\ a^{-1}$)
- IBT = Inter-basin transfer volume ($m^3\ a^{-1}$)
- RT = Return flow volume ($m^3\ a^{-1}$)
- MAR = Mean annual runoff ($m^3\ a^{-1}$).

WASTE AND POLLUTION INDICATORS

WP1: AMOUNT OF SOLID WASTE GENERATED PER SQUARE KILOMETER		
Waste and pollution	Waste generation	Driving force

1. **Definition:** Amount of solid waste generated per square kilometre of catchment per year (tonnes km^{-2} a^{-1}).

2. **Purpose:** To assess the pollution potential of the population and to provide an indication of the consumption of resources within the catchment. It also provides an indication of the sustainability of lifestyles within the catchment.

3. **Relevance to sustainable water resource management:** Waste is an inevitable consequence of development and must be systematically managed in order to conserve resources and protect the environment. Solid waste production increases annually due to population growth, inadequate services and non-sustainable lifestyles. Waste that is not disposed of properly may have adverse effects on ecosystem functioning and human health, and it is viewed as a major pollution threat to both surface and groundwater resources due to seepage from landfills and other waste disposal sites.

4. Linkages: This indicator may be linked to the following issues:
   - Human settlement;
   - Population change;
   - Waste management;
   - Pollution (all types);
   - Water quality (eutrophication, salinity, harmful toxic substances and microbiological contamination);
   - Altered ecosystem functioning;
   - Habitat condition;
   - Biodiversity change;
   - Water-borne diseases;
   - Inequity;
   - Water allocation;
   - Demand management;
   - Inequity, and
   - Economic use value.

5. **Limitations and potential problems:** The indicator provides an indication of consumption patterns, waste management requirements and lifestyle patterns, but gives no indication on the amount of waste reaching the water resources. It provides an estimate on the potential to pollute rather than the actual amount of pollution.

6. **Calculation of the indicator:**

$$WP1 = W_G / A$$

Where: W_G = Solid waste generated (tonnes a^{-1}).
A = Total surface area (km^2).

WP2: PROPORTION OF SOLID WASTE GENERATED PER SECTOR		
Waste and pollution	Generation of waste	Driving force

1. **Definition:** Proportion of solid waste generated per sector per year (%).

2. **Purpose:** To determine the contribution of each sector (industry and commercial, agriculture and forestry, mining and domestic) to waste generation in the catchment.

3. **Relevance to sustainable water resource management:** Solid waste has a high potential to contribute to contamination of surface- and groundwater resources. The type of solid waste generated in a catchment is dependent on the activities in the catchment. Some waste is more benign than others, whilst some requires stricter controls and management (e.g. hazardous waste). A catchment that has high industrial activity is likely to generate more waste, and this indicator should be seen as complementary to the previous indicator (WP1: Amount of waste generated per km^2). It also provides a measure of the need to devote resources and attention to waste management.

4. Linkages: This indicator may be linked to the following issues:
   - Human settlement;
   - Land use change;
   - Population change;
   - Waste management;
   - Pollution (all types);
   - Water quality (eutrophication, salinity, harmful toxic substances and microbiological contamination);
   - Altered ecosystem functioning;
   - Habitat condition;
   - Biodiversity change;
   - Water-borne diseases, and
   - Economic use value.

5. **Limitations and potential problems:** The indicator provides and idea of the type of pollution problems that might be experienced in the catchment, but gives no indication on the amount of waste reaching the water resources. It provides an estimate on the potential to pollute rather than the actual amount of pollution.

6. **Calculation of the indicator:**

For each sector, the proportion can be calculated using the following equation:

$$WP2 = W_S / W_T \times 100$$

Where: W_S = Solid waste produced by the sector (tonnes a^{-1})
W_T = Total amount of solid waste produced by the sector (tonnes a^{-1}).

WP3: LIQUID WASTE DISCHARGED FROM POINT SOURCES AS A PROPORTION OF TOTAL WATER AVAILABLE		
Waste and pollution	Pollution	Pressure

1. **Definition:** Amount of water entering the water resource from point sources of pollution as a proportion of total water available (%).

2. **Purpose:** This indicator assesses the contribution of point sources to pollution in the catchment.

3. **Relevance to sustainable water resource management:** Generation of liquid waste is an indicator of the level of the economic and domestic activity in an area. The amount of effluent discharged thus depends on industrial processes, as well as population size. Obviously the more liquid waste there is, the greater the cause for concern with regard to the assimilative capacity of the receiving system. If the amount of effluent generated is equal to a high proportion of the natural flow, there will be negative implications for the assimilative capacity of the receiving system.

4. Linkages: This indicator may be linked to the following issues:
   - Human settlement
   - Population change;
   - Waste management;
   - Pollution (all types);
   - Water quality (eutrophication, salinity, harmful toxic substances and microbiological contamination);
   - Altered ecosystem functioning;
   - Habitat condition;
   - Biodiversity change;
   - Water-borne diseases, and
   - Economic use value.

5. **Limitations and potential problems:** For this indicator, it is assumed that point sources of pollution are synonymous with return flows. Thus return flows that, for instance, are relatively unpolluted are included with those that are not.

   Industrial and domestic effluents differ in character and the way in which they are treated. The effects they have on the natural system also differ in character and impact. This indicator does not differentiate between the two.

6. **Calculating the indicator:**

$$WP3 = RT / (IBT + RT + MAR) \times 100$$

Where:
IBT = Inter-basin transfer volume ($m^3 a^{-1}$)
RT = Return flow volume ($m^3 a^{-1}$)
MAR = Mean annual runoff ($m^3 a^{-1}$).

WP4: LOADING OF P, N, POPS & TDS FROM AGRICULTURAL RUNOFF		
Waste and pollution	Pollution	Pressure

1. **Definition:** Loading of phosphorus, nitrogen, persistent organic pollutants and total dissolved solids entering the water system in the catchment from agricultural concerns (tonnes a^{-1}).

2. **Purpose:** To assess the contribution of agricultural runoff to pollution in the catchment.

3. **Relevance to sustainable water resource management:** Irrigation farming is considered to be of strategic importance to the socio-economic development of South Africa. However, water pollution is a recognised problem. Pollution is mainly in the form of salination and nutrient enrichment of runoff and stored water from irrigated areas, but can also occur in dry-land agriculture where fertilisers are used. Other pollutants in agricultural runoff include pesticides and herbicides that have been used for crop protection.

4. Linkages: This indicator may be linked to the following issues:
    - Land use change;
    - Waste management;
    - Pollution (all types);
    - Water quality (eutrophication, salinity, harmful toxic substances and microbiological contamination);
    - Altered ecosystem functioning;
    - Habitat condition;
    - Biodiversity change;
    - Water-borne diseases, and
    - Economic use value.

5. **Limitations and potential problems:** As with any non-point source of pollution, the amount entering the water resource will have to be estimated, probably using modelling techniques. It is highly unlikely that the exact contribution to return flows will be known. Additionally, quality control during data collection and monitoring needs to be ensured.

6. **Calculating the indicator:**

$$WP4 = V_{AR} \times C_P$$

Where: V_{AR} = Volume of agricultural runoff ($m^3\ a^{-1}$)
C_P = Concentration of the pollutant ($mg\ \ell^{-1}$ or $\mu g\ \ell^{-1}$).

WP5: LOADING OF P & N FROM DENSE SETTLEMENTS		
Waste and pollution	Pollution	Pressure

1. **Definition:** Loading of phosphorus and nitrogen entering the water system in the catchment from dense settlements (tonnes a^{-1}).

2. **Purpose:** To assess the contribution of runoff from dense settlements to pollution in the catchment .

3. **Relevance to sustainable water resource management:** Densely populated human settlements inevitably produce large quantities of waste. This waste, if left unchecked, can pollute rivers, streams and even groundwater resources. These problems are at their worst in the larger more densely populated settlements, many of which are poorly serviced. Unfortunately, many communities in South Africa are still labouring under the burden of an unjust past, and are unable to afford high levels of services, or to maintain those services that have been put in place. In some cases this has lead to severe pollution of nearby surface and groundwater resources, and has impacted on the quality of life in these settlements. This threatens the sustainable use of our water resources (DWAF 1999[1]).

4. Linkages: This indicator may be linked to the following issues:
   - Land use change;
   - Human settlement;
   - Waste management;
   - Pollution (all types);
   - Water quality (eutrophication, salinity, harmful toxic substances and microbiological contamination);
   - Altered ecosystem functioning;
   - Habitat condition;
   - Biodiversity change;
   - Social viability, and
   - Economic use value.

5. **Limitations and potential problems:** As with any non-point source of pollution, the amount entering the water resource will have to be estimated, probably using modelling techniques. It is highly unlikely that the exact contribution to return flows will be known. Additionally, quality control during data collection and monitoring needs to be ensured.

6. **Calculating the indicator:**

$$WP5 = V_{DS} \times C_P$$

Where: V_{DS} = Volume of runoff from dense settlements ($m^3\ a^{-1}$)
C_P = Concentration of the pollutant (mg ℓ^{-1} or µg ℓ^{-1}).

[1] DEPARTMENT OF WATER AFFAIRS AND FORESTRY. 1999. *Managing the Water Quality Effects of Settlements: The National Strategy, First Edition.* DWAF, Pretoria. 65 pp.

WP6: LOADING OF TDS & SO_4 FROM MINE DRAINAGE		
Waste and pollution	Pollution	Pressure

1. **Definition:** Loading of total dissolved solids and sulphate entering the water system in the catchment from mine drainage (tonnes a^{-1}).

2. **Purpose:** To assesses the contribution of mine drainage to pollution in the catchment.

3. **Relevance to sustainable water resource management:** The mining industry is vital to the economy of South Africa. However, due to the depth of mineral deposits and, therefore, mining activities, mines are generally forced to dewater underground workings and to discharge the mineralised water to the surface sources. This can cause salinisation of surface waters as well as acidification.

4. Linkages: This indicator may be linked to the following issues:
   - Land use change;
   - Waste management;
   - Pollution (all types);
   - Water quality (eutrophication, salinity, harmful toxic substances and microbiological contamination);
   - Altered ecosystem functioning;
   - Habitat condition;
   - Biodiversity change, and
   - Economic use value.

5. **Limitations and potential problems:** In some cases, such as closed mines, the amount of mine drainage may not be accurately estimated.

6. **Calculating the indicator:**

$$WP6 = V_{MD} \times C_P$$

Where: V_{MD} = Volume of mine drainage ($m^3\ a^{-1}$)
C_P = Concentration of the pollutant ($mg\ \ell^{-1}$ or $\mu g\ \ell^{-1}$).

WP7: CONDUCTIVITY AT THE LOWEST POINT IN THE GEOGRAPHICAL CATCHMENT		
Waste and pollution	Salinisation	State

1. **Definition:** Mean conductivity of the water exiting the catchment, measured over a year ($mS\ m^{-1}$).

2. **Purpose:** This indicator is a measure of the dissolved inorganic salts in the water. The downstream point has been chosen as an indicator of the sum of all activities in the catchment.

3. **Relevance to sustainable water resource management:** Although dissolved salts occur naturally to varying degrees in aquatic systems, human activities in a catchment may severely increase the levels. Typical effluents, which have an effect on conductivity, are saline industrial effluents, agricultural runoff and acid mine water. Although increases in conductivity may not have a large influence on aquatic fauna, the level of salinity in the water may have other, more significant economic effect for other users (e.g. water treatment and domestic users).

4. Linkages: This indicator may be linked to the following issues:
   - Land use change;
   - Waste generation and management;
   - Pollution (all types);
   - Water quality (eutrophication, salinity, harmful toxic substances and microbiological contamination);
   - Altered ecosystem functioning;
   - Habitat condition;
   - Biodiversity change, and
   - Economic use value.

5. **Limitations and potential problems:** The downstream point has been chosen as a reflection of all the activities in the catchment. This not only includes polluting activities, but also the natural clean-up processes of the ecosystem. It is, therefore, not only an indicator of pollution, but also all activities in the catchment.

6. **Calculation of the indicator:** Conductivity measured at the downstream point over a year can be analysed to provide the mean value, which can be used for comparative purposes.

$$WP7 = \left(\sum_{i=1}^{k} C_0\right) / k$$

Where: C_0 = Conductivity of each sample ($mS\ m^{-1}$)
k = Total number of samples per annum.

WP8: P & N CONCENTRATIONS AT THE LOWEST POINT IN THE GEOGRAPHICAL CATCHMENT		
Waste and Pollution	Eutrophication	Impact

1. **Definition:** Mean phosphorus and nitrogen concentrations at the downstream point, measured over a year (mg ℓ^{-1}).

2. **Purpose:** To provide an indication of eutrophication or nutrient enrichment in the catchment.

3. **Relevance to sustainable water resource management:** Eutrophication, or enrichment of water systems by plant nutrients, is a world-wide water quality problem. It has far-reaching economic and social costs, and is the single largest problem for South African water resource managers. Anthropogenic activities in a catchment increase phosphate and nitrogen levels in surface waters and the suitability of surface water for various uses is severely affected by eutrophication (with toxic algae, excessive macrophyte growth, odours, taste and blocked filters are common problems). Ecosystems are also severely affected due to anoxic conditions, increased turbidity and toxic algae.

4. Linkages: This indicator may be linked to the following issues:
   - Land use change;
   - Waste generation and management;
   - Pollution (all types);
   - Water quality (eutrophication, salinity, harmful toxic substances and microbiological contamination);
   - Altered ecosystem functioning;
   - Habitat condition;
   - Biodiversity change, and
   - Economic use value.

5. **Limitations and potential problems:** Although P & N are indicators of the nutrient enrichment in a catchment, eutrophication is also affected by other factors, such as temperature and light penetration in a water body. P& N alone, therefore, do not reflect the true extent of the water quality problems.

6. **Calculation of the indicator:** Standard methods are used to determine N and P concentrations (mg ℓ^{-1}).

   The mean annual concentration for each parameter is calculated as:

$$WP8 = \left(\sum_{i=1}^{k} C\right) / k$$

Where: C = Concentration of nutrient (mg ℓ^{-1})
k = Total number of samples per annum.

WP9: FAECAL COLIFORMS IN THE MAJOR WATER RESOURCE FOR DOMESTIC AND RECREATIONAL USE		
Waste and pollution	Microbiological contamination	State

1. **Definition:** Mean concentration of faecal coliforms in the major water resource for domestic and recreational use, measured over a year (number per 100mℓ).

2. **Purpose:** To measure the microbiological contamination of the major drinking water and recreational resource in the catchment, particularly due to untreated sewage.

3. **Relevance to sustainable water resource management:** Although most sewage is sent to water care works for purification before it enters the water resource, in areas where sanitation facilities are not available raw sewage may present a problem. Occasionally, sewage may overflow from a water care works due to a capacity overload or a breakdown in treatment facilities. A high level of organic enrichment leads to high treatment costs for potable water, as well as potential health risks in a catchment.

4. Linkages: This indicator may be linked to the following issues:
   - Human settlement;
   - Poverty/vulnerability;
   - Population change;
   - Inequity;
   - Waste generation and management;
   - Pollution (all types);
   - Water quality (eutrophication, salinity, harmful toxic substances and microbiological contamination);
   - Altered ecosystem functioning;
   - Habitat condition;
   - Biodiversity change,
   - Water-borne diseases, and
   - Economic use value.

5. **Limitations and potential problems:** The major water supply reservoir has been chosen as a reflection of the activities in the catchment. In cases where the geographical catchment is not defined as the catchment for the major dam, this might provide problems with comparisons to other water quality indicators.

6. **Calculation of the indicator:**

$$WP9 = \left(\sum_{i=1}^{k} C\right) / k$$

Where: C = Concentration of faecal coliforms (no. per 100 mℓ)
k = Total number of samples per annum.

WP10: DAPHNIA TOXICITY TEST AT THE LOWEST POINT IN THE GEOGRAPHICAL CATCHMENT		
Waste and Pollution	Harmful toxic substances	State

1. **Definition:** Toxicity test for the survival of *Daphnia* sp. at the lowest point in the geographical catchment (% lethality after 48 hours).

2. **Purpose:** To determine whether there are any toxic elements present in the water at the lowest point in the geographical catchment, as an indicator of the sum of all activities in the catchment.

3. **Relevance to sustainable water resource management:** One of the major problems caused by industrial pollutants is the introduction of trace metals into freshwater ecosystems. Many of these have toxic effects on the natural fauna (Be, Co, Ni, Cu, Zn, Sn, As, Se, Te, Pd, Ag, Cd, Pt, Au, Hg, Tl, Pb, Sb and Bi) and can be concentrated up the food chain to present a health hazard to humans and higher order animals. They require strict management and a policy of pollution abatement generally applies to these elements. The toxicity effects of water at the downstream point will provide a good indication of whether abatement in the catchment has been effective or not.

4. Linkages: This indicator may be linked to the following issues:
   - Land use change;
   - Waste generation and management;
   - Pollution (all types);
   - Water quality (eutrophication, salinity, harmful toxic substances and microbiological contamination);
   - Water-borne diseases;
   - Altered ecosystem functioning;
   - Habitat condition;
   - Biodiversity change, and
   - Economic use value.

5. **Limitations and potential problems:** No one test can satisfy a comprehensive coverage of all toxic effects, and the *Daphnia* toxicity test is only an indicator of possible problems.

The downstream point has been chosen as a reflection of all the activities in the catchment. This not only includes polluting activities, but also the natural clean-up processes of the ecosystem. It is, therefore, not only an indicator of pollution, but also all activities in the catchment.

6. **Calculation of the indicator:** The acute 48-hour definitive toxicity test will be used for this indicator. The methodology for this test is documented in detail in EPA (1985[2]). The final results are presented as % lethality after 48 hours.

Mean annual average is calculated as:

$$WP10 = \left(\sum_{i=1}^{k} L_{48}\right) / k$$

Where: L_{48} = Lethality after 48 hours (%)
k = Total number of samples per annum.

[2] ENVIRONMENTAL PROTECTION AGENCY. 1985. Methods for Measuring the Acute Toxicity of Effluents to Freshwater and Marine Organisms. EPA/600/4-85/013, Environmental and Support Laboratory, Office of Research and Development, US EPA, Cincinnati.

WP 11: TURBIDITY AT THE LOWEST POINT IN THE GEOGRAPHICAL CATCHMENT OR THE INFLOW TO THE MAIN RESERVOIR		
Resource condition	Sedimentation	State

1. **Definition:** Turbidity of the water at either the lowest point in the geographical catchment or at the inflow to the main reservoir (NTU).

2. **Purpose: To provide an indication of** sediment yield and change in sediment yield due to land uses in the catchment.

3. **Relevance to sustainable water resource management:** Large quantities of sediment are carried downstream in South Africa's rivers each year. In many cases, anthropogenic activities have increased erosion in the catchment, with the result that more sediment enters the rivers each year. However, much sediment is also deposited in reservoirs causing a loss in storage capacity. The net effect of all catchment activities on sediment yield will be apparent at the downstream point.

4. Linkages: This indicator may be linked to the following issues:
   - Climate and catastrophic events;
   - Human settlement;
   - Population change;
   - Land use change;
   - Pollution (all types);
   - Water quality (eutrophication, salinity, harmful toxic substances and microbiological contamination);
   - Altered ecosystem functioning;
   - Habitat condition;
   - Biodiversity change, and
   - Economic use value.

5. **Limitations and potential problems:** This indicator is not detailed enough to provide the full picture with regards to sedimentation and sediment yield within the catchment. If erosion increases at the top of the catchment, the sedimentation in reservoirs may increase, without a significant change occurring at the downstream point. Turbidity is also affected by other factors, such as the presence of algal blooms.

6. **Calculation of the indicator:**

$$WP11 = \left(\sum_{i=1}^{k} NTU\right) / k$$

Where: NTU = Turbidity (NTU)
k = Total number of samples per annum.

WP12: PROPORTION OF BOREHOLES CONTAMINATED		
Waste and Pollution	Well head protection/ Groundwater quality	State

1. **Definition:** Proportion of boreholes contaminated by water of poor quality to the extent that they are unusable for domestic or agricultural use (%). A well is considered contaminated if one of the following apply (DWAF 1996[3]):
   - EC > 450 mS m^{-1}
   - Total coliforms > 5/100ml
   - N > 10 mg ℓ^{-1}.

2. **Purpose:** To determine the extent of underground water contaminated by pollutants, and the success of well-head protection policies.

3. **Relevance to sustainable water resource management:** Groundwater supplies are particularly important in more arid areas of South Africa. In some areas ground water is almost the sole water supply. If these water sources become contaminated future development will be negatively affected. One of the problems facing water resource managers is the protection of well-heads, particularly from the watering of livestock. Other influences on groundwater quality are seepage from landfills, mine water drainage and agricultural seepage.

4. Linkages: This indicator may be linked to the following issues:
   - Human settlement;
   - Population change;
   - Land use change;
   - Pollution (all types);
   - Water quality (eutrophication, salinity, harmful toxic substances and microbiological contamination);
   - Social viability;
   - Inequitable access to services;
   - Habitat condition, and
   - Economic use value.

5. **Limitations and potential problems:** Currently the definition of "contaminated" is based on the DWAF Water Quality Guidelines for domestic use. These are more stringent than those for agricultural use. The level at which a borehole is contaminated should be determined according to its use.

6. **Calculation of the indicator:**

$$WP12 = W_C / W_T \times 100$$

Where: W_C = Number of boreholes in the catchment that are contaminated
W_T = Total number of boreholes in the catchment.

[3] DEPARTMENT OF WATER AFFAIRS & FORESTRY (DWAF). 1996. *South African Water Quality Guidelines. Volume 1: Domestic Use.* DWAF, Pretoria.

RESOURCE CONDITION INDICATORS

RC1: PERCENTAGE CATCHMENT AREA COVERED BY NATURAL VEGETATION AND BY ALIEN VEGETATION		
Resource condition	Land use/Habitat condition	State

1. **Definition**: Proportion of land in the catchment covered by natural vegetation and proportion of land in the catchment covered by alien vegetation (%).

2. **Purpose:** To provide an indication of the extent of natural habitat in the catchment, as well as the green areas dominated by alien vegetation (including forestry);

3. **Relevance:** The land use in a catchment determines the character of the water resource. Certain land uses are beneficial to aquatic ecosystems and thus the water resource (e.g. natural green areas), others are detrimental (areas dominated by alien vegetation). Resource condition is affected by the level of human activity in the catchment. The higher the proportion of natural green areas, the less impacted the water resource is likely to be. High levels of alien invasion might affect the amount of water available in the catchment, as well as damaging the ecosystem integrity of the catchment.

4. Linkages: This indicator may be linked to the following issues:
   - Human settlement;
   - Land use change;
   - Availability of water;
   - Altered ecosystem functioning;
   - Habitat condition;
   - Biodiversity change, and
   - Economic use value.

5. **Limitations and potential problems:** Much of the land use information available in South Africa is derived from satellite imagery. Unless groundtruthing has been done, it is difficult to accurately differentiate between natural and alien vegetation.

6. **Calculation of the indicator:**

Percentage cover for each land use can be calculated using the following equation:

$$RC1_{VT} = A_{VT} / A \times 100$$

Where: $RC1_{VT}$ = Percentage covered by vegetation type
A_{VT} = Area covered by land use (km^2)
A = Total surface area (km^2)

RC2: SOUTH AFRICAN SCORING SYSTEM (SASS) SCORES AT SELECTED SITES		
Resource condition	Biodiversity change/Ecosystem functioning	State

1. **Definition**: Invertebrate fauna measured using the South African Scoring System (SASS and ASPT, average score per taxon) at selected sites within the river system.

2. **Purpose:** To provide an indicator of the health of the river, and the diversity of invertebrate fauna.

3. **Relevance to sustainable water resource management:** Aquatic fauna and flora respond in a predictable manner to changes in the physical and chemical nature of the water. If a water body is polluted or severely degraded, certain sensitive species will be unable to live there, whilst less sensitive species may thrive. Changes in the structure of aquatic invertebrate communities reflect changes in overall river conditions. Invertebrate faunal assemblages, which the SASS system has been designed for, are affected by water quality changes over a relatively short period if compared to fish or vegetation assemblages. They do, however, reflect a longer-term quality than do once-off water samples.

4. Linkages: This indicator may be linked to the following issues:
   - Climate and catastrophic events;
   - Waste generation and management;
   - Pollution (all types);
   - Water quality (all parameters), and
   - Habitat condition.

5. **Limitations and potential problems:** The SASS system was originally developed as a tool to evaluate water quality. It has since become a tool to determine general rivers health as the faunal assemblages are also dependent on habitat available, distance downstream and catastrophic events (e.g. floods), but the scoring system still reflects sensitivity to water quality.

   In general SASS data should be interpreted in conjunction with other factors that may influence the score (e.g. habitat type). Because of this, the indicator is much more useful as part of a time series for a single site, than a once-off assessment.

6. **Calculation of the indicator:** It is recommended that the standard SASS methodology (currently SASS5) be used to collect the data (see Dickens & Graham 2002[4]). The data collected are presented as the SASS score (as calculated using the standard scoring sheet) and the average score per taxon. Sampling should be during the dry season (e.g. spring and autumn in the summer rainfall areas). The mean value may be used, where two or more samples are taken at a site per annum.

   The boundaries defined by Chutter (1998[5]) can be used as a guide for interpreting SASS scores (see Dickens and Graham 2002),

   - **For non-acidic streams:**
     - SASS > 100, ASTP > 6 water quality natural, habitat diversity high;
     - SASS < 100, ASTP > 6 water quality natural, habitat diversity reduced;

[4] DICKENS CWS & GRAHAM PW. 2002. The South African Scoring System (SASS) Version 5 Rapid Bioassessment Mehod for Rivers. *African Journal of Aquatic Science* **27**: 1-10.

[5] CHUTTER FM . 1998. *Research on the Rapid Biological Assessment of Water Quality Impacts in Streams and Rivers.* WRC Report No. 422/1/98.

o SASS > 100, ASTP < 6	borderline between water quality natural and some deterioration in water quality, interpretation based on extent by which SASS exceeds 100 and ASTP is < 6;
o SASS 50-100, ASTP < 6	some deterioration in water quality;
o SASS < 50, ASTP variable	major deterioration in water quality.

- **For acidic streams**

o SASS > 125, ASTP > 7	water quality natural, habitat diversity high;
o SASS < 125, ASTP > 7	water quality natural, habitat diversity reduced;
o SASS > 125, ASTP < 7	borderline between water quality natural and some deterioration in water quality, interpretation based on extent by which SASS exceeds 125 and ASTP is < 7;
o SASS 60-125, ASTP < 7	some deterioration in water quality;
o SASS < 60, ASTP variable	major deterioration in water quality.

RC2: FISH ASSEMLAGE INTEGRITY INDEX (FAII) IN SELECTED REACHES		
Resource condition	Biodiversity change/Ecosystem functioning	Impact

1. **Definition:** Ratio of observed fish diversity to diversity that would have been expected in the absence of human impacts (FAII score).

2. **Purpose:** To assess the change in biodiversity of the river system in the medium- to long- term.

3. **Relevance to sustainable water resource management:** Fish communities are good indicators of the general condition of a river. They are particularly good medium- to long-term indicators, whilst invertebrates tend to be short-term indicators. If an ecosystem is not functioning properly, changes in fish communities will occur, most often leading to a loss in biotic diversity, ecosystem functioning and rivers health.

4. This indicator may be linked to the following issues:
    - Climate and catastrophic events;
    - Water availability;
    - Waste generation and management;
    - Pollution (all types);
    - Water quality (all parameters);
    - Habitat condition, and
    - Social viability.

5. **Limitations and potential problems:** This indicator becomes less effective in a river with naturally poor diversity.

6. **Calculation of the indicator:** The standard FAII methodology should be used (Kleynhans 1999[6]; http://www.csir.co.za/rhp 2002) at selected reaches in the river at yearly intervals.

    Interpretation of FAII scores is outlined in Kleynhans 1999 as follows:
    - FAII = 90-100 — Unmodified, or approximates natural conditions;
    - FAII = 80-89 — Largely natural with few modifications – a change in community characteristics, but species richness and presence of intolerant species indicate little modification;
    - FAII = 60-79 — Moderately modified – a lower than expected species richness and presence of most intolerant species; some impairment of health at the lower limit of the class;
    - FAII = 40-59 — Largely modified – lower than expected species richness and absence or much lowered presence of intolerant species; impairment of health is more evident at the lower limit of the class;
    - FAII = 20-39 — Seriously modified – a strikingly lower than expected species richness and general absence of intolerant species; impairment of health is evident;
    - FAII = 0-19 — Critically modified – extremely lowered species richness and absence of intolerant and moderately intolerant species; may have complete loss of species at the lower limit of the class; impairment of health very evident.

[6] KLEYNHANS CJ. 1999. Development of a fish index to assess the biological integrity of South African rivers. *Water SA* **25(3):** 265-278.

RC3: INDEX OF HABITAT INTEGRITY (IHI) IN SELECTED REACHES		
Resource condition	Habitat condition/Ecosystem functioning	Impact

1. **Definition:** Condition of the riparian zone and in-stream habitats in rivers (habitat integrity classes)

2. **Purpose:** To assess riparian and instream habitat integrity of the river system.

3. **Relevance to sustainable water resource management:** Habitat availability and diversity are major determinants of aquatic community structure and functioning. Loss of habitat is regarded as the single most important factor that has contributed to the extinction of species all over the world. Degradation of aquatic habitats in South Africa includes physical destruction of habitats due to river regulation (e.g. dams and IBTs) and infrastructure development (e.g. bridges), as well as the deterioration in water quality.

4. **Linkages:** This indicator may be linked to the following issues:
   - Human settlement;
   - Land-use change;
   - Water availability;
   - Waste generation and management;
   - Pollution (all types);
   - Water quality (all parameters), and
   - Biodiversity change.

5. **Limitations and potential problems:** The methodology is time consuming and requires extensive resources.

6. **Calculation of the indicator:** The standard IHI methodology should be used (Kleynhans 1996[7]; http://www.csir.co.za/rhp 2002) at selected reaches at yearly intervals. The final score is determined by scoring criteria that are indicative of habitat integrity that, when modified anthropogenically, are major causes of degradation to the river health. The assessment of the severity of impact is based on six descriptive classes:

SCORE	IMPACT CLASS	DESCRIPTION
0	None	No discernable impact, or the modification is located in such a way that it has no impact on habitat quality, diversity, size and variability.
1-5	Small	The modification is limited to very few localities and the impact on habitat quality, diversity and variability are also very small.
6-10	Moderate	The modifications are present at a small number of localities and the impact on habitat quality, diversity, size and variability are limited.
11-15	Large	The modification is present with clearly detrimental impact on habitat quality, diversity, size and variability.
16-20	Serious	The modification is frequently present and the habitat quality, diversity, size and variability in almost the whole of the defined area are affected. Only small areas are not influenced.
21-25	Critical	The modification is present overall, with a high intensity. The habitat quality, diversity, size and variability in almost the whole of the defined area are influenced detrimentally.

[7] KLEYNHANS CJ. 1996. A qualitative procedure for the assessment of the habitat integrity status of the Luvuvhu River (Limpopo system, South Africa). *Journal of Aquatic Ecosystem Health* **5:** 41-54.

RC 4: RIPARIAN VEGETATION INDEX IN SELECTED REACHES		
Resource condition	Habitat condition/Ecosystem functioning	State or impact

1. **Definition:** Status of riparian vegetation within river reaches based on the qualitative assessment of vegetation removal, cultivation, construction, inundation, erosion, sedimentation and alien vegetation in the riparian zone (% deviation from natural)

2. **Purpose:** To provide a qualitative assessment of the conservation status of riparian vegetation of a water resource

3. **Relevance to sustainable water resource management:** The riparian zone is the interface between freshwater and land systems. They maintain channel form and serve as filters for light, nutrients and sediment. If they are damaged, often degradation of the freshwater system occurs, including changing the ecosystem functioning, increased sedimentation, increased water usage etc. In the past, riparian rights of landowners in South Africa have lead to extensive degradation of the riparian zones of rivers, and irreparable damage to river ecosystems.

4. **Linkages:** This indicator may be linked to the following issues:
   - Human settlement;
   - Land-use change;
   - Water availability;
   - Waste generation and management;
   - Pollution (all types);
   - Water quality (all parameters), and
   - Biodiversity change.

5. **Limitations and potential problems:** The methodology is time consuming and requires extensive resources.

6. **Calculation of the indicator:** The standard RVI methodology, as documented in Kemper (2001[8]), should be used at selected sites on an annual basis.

   The RVI provides a final score out of 20, which may be interpreted as follows (Kemper 2001):
   - RVI = 19-20 Unmodified, natural;
   - RVI = 17-18 Largely natural with few modifications – a small change in natural habitats and biota may have taken place but the ecosystem functions are essentially unchanged;
   - RVI = 13-16 Moderately modified – a loss and change of natural habitat and biota have occurred, but the basic ecosystem functions are predominantly unchanged;
   - RVI = 9-12 Largely modified – a large loss of natural habitat, biota and basic ecosystem functions have occurred;
   - RVI = 5-8 The loss of natural habitat, biota and basic ecosystem functions are extensive;
   - RVI = 0-4 Modifications have reached a critical level and the system has been modified completely, with an almost complete loss of natural habitat and biota; at worst the basic ecosystem functions have been destroyed and the changes are irreversible.

[8] KEMPER NP. 2001. *RVI – Riparian Vegetation Index. Final Report.* WRC Report No. 850/3/01. WRC, Pretoria. 21 pp.

RC5: PERCENTAGE WETLAND AREA		
Resource condition	Habitat condition	Impact

1. **Definition:** Catchment area covered by wetlands divided by the total catchment area (%).

2. **Purpose:** To determine the extent of wetlands in the catchment. Over time this can be converted into the percentage wetlands lost to other land use types.

3. **Relevance to sustainable water resource management:** Wetland systems are some of the most endangered ecosystems in South Africa. Their numerous uses make them invaluable as natural assets and to sustainable development. An estimated 50% of all South Africa's wetlands have been lost, affecting the functioning of the aquatic systems of which they are a part. The extent of wetlands in a catchment gives an indication of the value of wetlands in the catchment, and can be used to track future wetland loss.

4. **Linkages:** This indicator may be linked to the following issues:
   - Human settlement;
   - Land-use change;
   - Poverty/vulnerability;
   - Population change;
   - Availability of water;
   - Sectoral water requirements;
   - Waste generation and management;
   - Water quality (all types);
   - Pollution (all types);
   - Altered ecosystem functioning;
   - Biodiversity change;
   - Social viability;
   - Inequity, and
   - Economic use value.

5. **Limitations and potential problems:** The greatest limitation seems to be the methodology used. Determining wetland area can be extremely time consuming and costly.

6. **Calculation of the indicator:** Wetland area can be estimated using satellite imagery, but requires expert interpretation. The equation to determine the proportion of the total is:

$$RC5 = A_W / A_T \times 100$$

Where: A_W = Area covered by wetlands
A_T = Total catchment area.

MANAGEMENT INDICATORS

MN1: INDEX OF LEVEL OF CMA ESTABLISHMENT IN THE CATCHMENT		
Management	Management capacity	Response

1. **Definition:** Description of CMA establishment in the catchment (rating system).

2. **Purpose:** To determine the level of institutional development for the catchment area. This should be viewed as a temporary indicator until such time as CMAs have been established for all Water Management Areas. Thereafter an indicator of CMA viability can be developed.

3. **Relevance to sustainable water resource management:** The foundation for the National Water Act (No.36 of 1998) is Integrated Water Resources Management (IWRM) at a catchment level. In order to institute this 19 Water Management Areas have been recognised, for which Catchment Management Agencies will be established. The establishment of each CMA is a complex process that includes integration of the current DWAF regional offices, development of the roles of various water management authorities and water boards and extensive stakeholder participation. Forum establishment is one of the first steps towards CMA development, and it is envisaged that forums will be included in the development of CMAs throughout the country. Another key is the development of a catchment management , which must be in harmony with the national water strategy, and should set the principles for allocating water taking into account matters relevant to the protection, use, development, conservation, management and control of water resources.

4. **Linkages:** This indicator may be linked to the following issues:
   - Human resource capacity;
   - Institutional capacity;
   - Financial viability;
   - Social viability, and
   - Monitoring and reporting.

5. **Limitations and potential problems:** The process of CMA establishment will differ depending on the characteristics of each Water Management Area. This Index is based on the key elements for establishment of every CMA, without expanding on the details of each.

6. **Calculation of the indicator:** The indicator is in the form of an Index, based on a set of 10 criteria that have to be met for CMA establishment to be successful (National Water Act 1998; DWAF 1998[9]). The Index is presented as a simple score out of 10. The criteria include:

   1. Has a Catchment Management Forum been established in the catchment?
   2. Has a Catchment Management Committee been established in the catchment?
   3. Has a CMA proposal been submitted to the Minister (Section 77(1))?
   4. Has the Minister published the establishment of the CMA in the Government Gazette?
   5. Has a governing board been established for the CMA?
   6. Has a catchment management strategy been developed?
   7. Have resource quality objectives been established for the catchment?
   8. Has a water allocation plan been established for the catchment?
   9. Has an information management and decision making system been established?
   10. Is the CMA financially independent of DWAF?

[9] DEPARTMENT OF WATER AFFAIRS AND FORESTRY. 1998. *Water Law Implementation Process, A Strategic Plan for the Department of Water Affairs and Forestry to Facilitate the Implementation of Catchment Management in South Africa*. DWAF, Pretoria.

MN2: STATE OF SATISFACTION		
Management/Social	Social viability	Response

1. **Definition:** Composite index that quantifies the level of satisfaction of the catchment population with the management of the water resources and sanitation systems.

2. **Purpose:** To evaluate the level of satisfaction of the catchment population (all socio-economic levels) with regard to the provision of water and sanitation, and water resource quality. It provides and indication of the social success of catchment management strategies.

3. **Relevance to sustainable water resource management:** Public opinion often influences the behaviour of individuals or groups of people. The level of co-operation of the community in water resource management and conservation depends, along with other factors, on their satisfaction with water management in their area. For instance, people unhappy with the present level of service provision, together with other external variables, may be less likely to pay for water provision.

4. **Linkages:** This indicator may be linked to the following issues:
   - Human settlement;
   - Poverty/Vulnerability;
   - Population change;
   - Waste generation and management;
   - Water balance;
   - Domestic demand for water;
   - Inequity;
   - Institutional capacity;
   - Financial viability, and
   - Monitoring and reporting.

5. **Limitations and potential problems:** The greatest limitation would be the manpower and resources required to collect information for each catchment.

6. **Calculation of the indicator:** A structured questionnaire, of about 30 questions, can be used to obtain input on the perceptions of different socio-economic groups of the general population (see questionnaire overleaf, from Rand Water 2000[10]). Information that will need to be gathered includes the availability of water, the reliability of the water, water quality aspects, general water and sewerage service provision as well as general catchment management issues (see attached questionnaire). Based on this questionnaire, a composite index (averaged scores, %) of satisfaction can be calculated (Rand Water 2000).

[10] RAND WATER. 2000. *Catchment Diagnostic Framework: Prototype Catchment Diagnostic Index – User's Manual.* Rand Water, Johannesburg. 53 pp.

QUESTIONNAIRE

1. What is your main source of water (municipal, water service provider, boreholes, river, well, etc)?

2. Group of questions in order to determine LSM levels (socio-economic levels).

3. How satisfied or dissatisfied are you with each of the following aspects in the area where you live?

	Very dissatisfied	Dissatisfied	Just as dissatisfied as satisfied	Satisfied	Very satisfied	Not applicable
Municipal (water service provider) water provision services in general	0	1	2	3	4	*
Municipal sewerage systems	0	1	2	3	4	*
Availability of water	0	1	2	3	4	*
Reliability of water supply	0	1	2	3	4	*
Mineral quality of tap water	0	1	2	3	4	*
Colour of tap water	0	1	2	3	4	*
Taste of tap water	0	1	2	3	4	*
Smell of tap water	0	1	2	3	4	*
Turbidity of tap water	0	1	2	3	4	*
Health aspects of water	0	1	2	3	4	*
Water quality of dams/rivers	0	1	2	3	4	*
Water quality of boreholes/wells, underground water	0	1	2	3	4	*

MN3: VOLUME OF WATER ALLOCATED AS A PROPORTION OF TOTAL WATER AVAILABLE		
Management /Water balance	Human resources/Institutional capacity	Response

1. **Definition:** Amount of water allocated through compulsory and other licensing procedures as a proportion of total water available in the catchment (%).

2. **Purpose:** To determine the success of the allocation policies and administration, and the water quantity management in the catchment.

3. **Relevance:** The implementation of the National Water Act (No. 36 of 1998) depends largely on the allocation of scarce water resources within every Water Management Area. Water is allocated in a hierarchical fashion, in the following order: Reserve, international requirements, strategic industries and sectoral requirements. The amount of water allocated is a measure of the success of the administrative procedures within the catchment. Additionally, the allocation of water in South Africa is not as simple as just issuing licenses. It includes establishment of the Reserve and conformation with RDM procedures. Thus, the indicator has relevance far wider than just the physical process of licensing.

4. **Linkages:** This indicator may be linked to the following issues:
   - Population change;
   - Sectoral demand for water;
   - Institutional capacity;
   - Human resource capacity;
   - Financial viability;
   - Social viability and
   - Monitoring and reporting.

5. **Limitations and potential problems:** The indicator has many aspects to it, when one considers the implementation of allocation policies in South Africa. Interpretation of the indicator is, thus, and important aspect of its use.

6. **Calculation of the indicator:**

$$MN3 = (V_A) / (MAR + IBT + RT) \times 100$$

Where: V_A = Volume of water allocated ($m^3\,a^{-1}$)
MAR = Mean annual runoff ($m^3\,a^{-1}$)
IBT = Inter-basin transfer ($m^3\,a^{-1}$)
RT = Return flows($m^3\,a^{-1}$).

MN4: WATER USE EFFICIENCY FOR DIFFERENT SECTORS		
Management	Water use efficiency	Response

1. **Definition:** Amount of production (Rands) from one cubic meter of water for agricultural, mining and industrial production in the catchment (R m^{-3}).

2. **Purpose:** To determine the level of water use efficiency within different sectors within the catchment (agriculture, industry and mining), as an indication of the efficiency in demand management strategies over time. It also indicates the perceived value of water in the country.

3. **Relevance:** In the past, South Africa relied largely on supply-side management to ensure that there was enough water for economic and domestic use in the country. However, most of the water resources in the country have been developed to capacity. The Department is currently encouraging demand management through pricing structures, and education and awareness. A Water Conservation/Demand Management Strategy has been developed as part of the National Water Resource Strategy to ensure the proper implementation of this philosophy. The efficiency of water use is one method to measure its success.

4. **Linkages:** This indicator may be linked to the following issues:
    - Land-use change;
    - Availability of water;
    - Sectoral demand for water, and
    - Water allocation.

5. **Limitations and potential problems:** Currently this indicator includes agriculture, mining and industry. However, the use of water will depend on the economic use of the water in the catchment. This may include other uses such as forestry or tourism. This will need to be determined for each catchment separately.

6. **Calculation of the indicator:**

For each economic water use, water use efficiency can be calculated as follows

$MN4_{WU} = R_{WU} / V_{WU}$

Where: R_{WU} = Production for each water use (R a^{-1})
V_{WU} = Volume of water used by that economic water use sector (m^3 a^{-1})

MN5: PERCENTAGE OF UNACCOUNTED-FOR WATER IN THE CATCHMENT		
Management /Water balance	Management capacity/Water use efficiency	Response

1. **Definition:** Amount of water lost during distribution from source to the end user (%).

2. **Purpose:** To evaluate the management of distribution systems, by determining loss of water as it is distributed from the source to the end user. It also indicates the perceived value of water in the country.

3. **Relevance to sustainable water resource management:** Water is a precious resource in an arid country such as South Africa and any loss away from a recognised user is important from the point of view of both the resource, and the added cost to supply water. Maintenance of infrastructure is key to efficient water distribution, and lack of maintenance reflects on the management capacity in the catchment.

4. **Linkages:** This indicator may be linked to the following issues:
   - Human settlement;
   - Land-use change;
   - Poverty/vulnerability;
   - Availability of water;
   - Inequity;
   - Human resources;
   - Financial viability;
   - Institutional capacity;
   - Monitoring and reporting.

5. **Limitations and potential problems:** Problems exist in trying to quantify the indicator at a catchment level. The indicator is reliant on information from municipalities, some of which are not restricted by catchment boundaries. The final figure is likely to be an estimate.

6. **Calculation of the indicator:**

$$MN5 = (V_A - V_{EU}) / (MAR + RT + IBT) \times 100$$

Where: V_A = Volume of water abstracted from the resource ($m^3\ a^{-1}$)
V_{EU} = Volume of water provided to end users ($m^3\ a^{-1}$)
MAR = Mean annual runoff ($m^3\ a^{-1}$)
IBT = Inter-basin transfer ($m^3\ a^{-1}$)
RT = Return flows ($m^3\ a^{-1}$).

MN6: RATIO OF SUB-CATCHMENTS FOR WHICH THE ECOLOGICAL RESERVE HAS BEEN SET TO TOTAL NUMBER OF SUB-CATCHMENTS		
Management	Reserve	Response

1. **Definition:** Number of sub-catchments (quaternary) for which the Ecological Reserve has been established in comparison to the total number of sub-catchments.

2. **Purpose:** To establish whether resource directed measures are being implemented in the catchment. (This is an interim indicator until resource quality objectives, against which performance can be measured, have been set).

3. **Relevance:** The National Water Act (No.36 of 1998) requires that the Reserve (basic human needs and ecological) is set for each catchment in the country. The greatest component of the Reserve, and the one that requires the most effort to determine, is the Ecological Reserve. Once the Ecological Reserve has been determined, RQOs can be set and water resources allocated according to the management class of the resource.

4. **Linkages:** This indicator may be linked to the following issues:
   - Poverty/Vulnerability;
   - Population change;
   - Inequity;
   - Availability of water;
   - Water allocation;
   - Human resources;
   - Financial viability;
   - Social viability;
   - Institutional capacity, and
   - Monitoring and reporting.

5. **Limitations and potential problems:** As pointed out above, this is an interim indicator until such time as all catchments have resource quality objectives set. Although implementation of RDM is proceeding, it is uncertain when this indicator will become redundant.

6. **Calculation of the indicator:**

$$MN6 = SC_R : SC_T$$

Where: SC_R = Sub-catchments for which the Ecological Reserve has been set
SC_T = Total number of sub-catchments

MN7: RATIO OF SUB-CATCHMENTS FOR WHICH RELIABLE HYDROLOGICAL MONITORING DATA ARE AVAILABLE TO TOTAL NUMBER OF SUB-CATCHMENTS		
Management	Monitoring	Response

1. **Definition:** Number of sub-catchments (quaternary) for which adequate hydrological monitoring data are available in comparison to the total number of sub-catchments.

2. **Purpose:** To evaluate the extent and success of the hydrological monitoring network, which provides information on water quantity in the catchment.

3. **Relevance to sustainable water resource management:** Continual monitoring of the water resources is important for immediate management. Rainfall in South Africa is irregular over many catchments, and constant surveillance needs to be kept on the amount of water available in the catchment. Both flood control and drought relief are important aspects of water resource management in South Africa.

4. **Linkages:** This indicator may be linked to the following issues:
   - Climate and catastrophic events;
   - Availability of water;
   - Water allocation;
   - Financial viability;
   - Institutional capacity, and
   - Reporting.

5. **Limitations and potential problems:** This indicator does not necessarily give the full picture with regard to hydrological monitoring. For instance, it does not take into account the difference between strip recorders and satellite weirs, nor the level of accuracy of the weirs. Establishing what is reliable and what is not might be subjective.

6. **Calculation of the indicator:**

   $MN7 = SC_H : SC_T$

   Where: SC_H = Sub-catchments for which adequate hydrological monitoring data are available
   SC_T = Total number of sub-catchments

MN8: RATIO OF SUB-CATCHMENTS FOR WHICH RELIABLE WATER QUALITY MONITORING DATA ARE AVAILABLE TO TOTAL NUMBER OF SUB-CATCHMENTS		
Management	Monitoring	Response

1. **Definition:** Number of sub-catchments (quaternary) for which adequate water quality monitoring data are available in comparison to the total number of sub-catchments.

2. **Purpose:** To determine the extent and success of ambient water quality monitoring activities in the catchment (not effluent monitoring).

3. **Relevance to sustainable water resource management:** Information management is one of the most important aspects of water resource management. Without the correct information, management cannot be effective. Water quality information is important in continual evaluation of pollution in a system. It can also be used as a warning system for spills.

4. **Linkages:** This indicator may be linked to the following issues:
   - Waste generation and management;
   - Pollution (all types);
   - Inequity;
   - Water quality (all parameters);
   - Financial viability;
   - Institutional capacity, and
   - Reporting.

5. **Limitations and potential problems:** This indicator may be a reflection of poor water quality in the catchment, rather than the efficiency of the management. It should be evaluated in conjunction with the water quality indicators.

6. **Calculation of the indicator:**

$$MN8 = SC_Q : SC_T$$

Where: SC_Q = Sub-catchments for which adequate water quality monitoring data are available
SC_T = Total number of sub-catchments

MN9: NUMBER OF OFFICIAL RESOURCE CONDITION REPORTS		
Management	Reporting	Response

1. **Definition:** Level of reporting on the condition of the water resources of the catchment (number).

2. **Purpose:** To evaluate the extent to which value is added to the data gathered for the catchment.

3. **Relevance to sustainable water resource management:** Information only becomes valuable when it is presented in a way that is understandable to managers. The raw data are obviously essential to the knowledge base, but unless adequate analysis takes place, the data are useless. Reporting is an essential part of information transfer and capacity building within an organisation.

4. **Linkages:** Reporting should be linked to all aspects of catchment management, and should thus be linked to all other issues. The most important linkages include:
    - Human resources;
    - Institutional capacity, and
    - Monitoring.

5. **Limitations and potential problems:** Reporting can take different forms, and the number of written reports may not reflect the extent of reporting in the catchment. The exact nature of the reporting at catchment level needs to be decided upon. For instance, reporting within a CMA may differ from reporting in DWAF. This indicator should, perhaps, only evaluate reporting at a catchment level to DWAF.

6. **Calculation of the indicator:** Reporting occurs at many levels, local, provincial and national. For the purpose of this project, it is the number of official reports produced by the Regional offices.

APPENDIX D

Survey Questionnaire and Results (Chapter 10)

QUESTIONNAIRE

INFORMATION AVAILABLE TO ASSESS THE SUSTAINABILITY OF CATCHMENTS IN SOUTH AFRICA

Please complete the following questionnaire and return it to:

Jay Walmsley
Sustainability Indicators Project
PO Box 72847
Lynnwood Ridge
0040

Tel: 012-361 2924
Fax: 012-361 9845
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Region: ______________________________

Name ______________________________

Telephone: ______________________________

E-mail: ______________________________

Pilot Catchment: ______________________________

Is the following information available from the regional office for the pilot catchment?

	Yes	Confidence level (low, med, high)	No	If no, where would it be available?
Total number of people in the catchment				
Catchment area (km^2)				
Number of people living in urban areas (formal & informal)				
GGP for the catchment (R/a)				
Life expectancy at birth for people in the catchment				
% Literacy among 15-year-olds and older in				
Average number of years spent at school for 27-year-olds and older				
Total water available for domestic use (m^3/a)				
Amount of water received by each decile of the population for domestic use (from greatest amount to least amount) (m^3/a)				
Total number of households				
Number of households without access to water within 200m				
Number of households without access to any toilet facilities				
Catchment area used for crops & grazing (km^2)				
Catchment area under mining (km^2)				
Catchment area under industrial use (km^2)				
Catchment area covered by natural vegetation (km^2)				

	Yes	Confidence level (low, med, high)	No	If no, where would it be available?
Catchment area covered by alien vegetation (km^2)				
Catchment area covered by wetlands (km^2)				
Annual rainfall (at any meteorological site) (mm/a)				
Mean annual runoff				
IBT Volume – imported water (m^3/a)				
IBT Volume – exported water (m^3/a)				
Total demand for water (m^3/a)				
Volume of return flows (m^3/a)				
Safe yield for groundwater (m^3/a)				
Amount of groundwater extracted (m^3/a)				
Water required for the Reserve (m^3/a)				
Water required by other countries (m^3/a)				
Water required by Eskom (m^3/a)				
Water required by agriculture (m^3/a)				
Water required by industry (m^3/a)				
Water required by mining (m^3/a)				
Water required by domestic users (m^3/a)				
Total amount of solid waste generated (t/a)				
Amount of domestic solid waste generated (t/a)				
Amount of industrial solid waste generated (t/a)				
Amount of mining solid waste generated (t/a)				
Amount of agricultural solid waste generated (t/a)				
Runoff volume for each agricultural concern (m^3/a)				
Average annual total P concentration for runoff from each agricultural concern (mg/l)				
Average annual total N concentration for runoff from each agricultural concern (mg/l)				
Average annual POPs concentration for runoff from each agricultural concern (mg/l)				
Average annual TDS concentration for runoff from each agricultural concern (mg/l)				
Runoff volume for each dense settlement (m^3/a)				
Average annual total P concentration for runoff from each dense settlement (mg/l)				
Average annual total N concentration for runoff from each dense settlement (mg/l)				
Volume for drainage from each mine (m^3/a)				
Average annual TDS concentration for runoff from each mine (mg/l)				
Average annual SO^4 concentration for runoff from each mine (mg/l)				
Average annual conductivity at the lowest geographical point ($mS\ m^{-1}$)				
Average annual total P concentration at the lowest geographical point				
Average annual total N concentration at the lowest geographical point				
Average annual faecal coliform counts in the major water resource for domestic and recreational use (number/100ml)				

	Yes	Confidence level (low, med, high)	No	If no, where would it be available?
Daphnia toxicity test results at the lowest geographical point				
Turbidity at the lowest geographical point or at the inflow to the main reservoir (NTU)				
Number of boreholes in the catchment				
Average annual conductivity of each borehole ($mS\ m^{-1}$)				
Average annual total coliform counts for each borehole (number/100ml)				
Annual average total N concentrations for each borehole (mg/l)				
SASS scores				
Fish Assemblage Integrity Index scores				
Index of Habitat Integrity scores				
Riparian Vegetation Index scores				
Progress with regard to the establishment of a CMA				
Opinions of the catchment population with regard to water services delivery and WRM				
Volume of water allocated through licensing (m^3/a)				
Rand value of mining output in the catchment (R/a)				
Volume of water used by mining sector (m^3/a)				
Rand value of agricultural output (R/a)				
Volume of water used by agriculture (m^3/a)				
Rand value of industrial output (R/a)				
Volume of water used by industrial sector (m^3/a)				
Volume of water unaccounted for in the distribution from bulk suppliers to end users (m^3/a)				
Volume of water distributed from bulk suppliers (m^3/a)				
Number of quaternary catchments				
Number of quaternary catchments for which Ecological Reserve has been set				
Number of quaternary catchments for which reliable flow data are available				
Number of quaternary catchments for which reliable water quality data are available				
Number of official reports on water quality (2001)				
Number of official reports on flow (2001)				
Number of official reports on river health (2001)				

Thank you for the time and effort you have put into completing this survey. The results shall be analysed and distributed to you by end July 2002.

☺

ANALYSIS 1:
INFORMATION AVAILABLE FOR PILOT CATCHMENTS

Key

L = Yes, low confidence
M = Yes, medium confidence
H = Yes, high confidence
? = Do not know whether information is available or not
N = No data
na = Not applicable

	LIM	GAU	NWP	MPU	FS	EC	WC	NC	KZN	TOTAL YES
Total number of people in the catchment	H	N	N	H	N	H	N	M	H	5
Catchment area (km^2)	H	N	H	H	H	H	H	H	H	8
Number of people living in urban areas (formal & informal)	H	N	N	H	N	H	N	M	M	5
GGP for the catchment (R/a)	L	N	N	L	N	N	N	M	N	3
Life expectancy at birth for people in the catchment	L	N	N	M	N	N	N	N	N	2
% Literacy among 15-year-olds and older	L	N	N	M	N	N	N	N	N	2
Average number of years spent at school for 27-yr-olds & older	L	N	N	M	N	N	N	N	N	2
Total water available for domestic use (m^3/a)	M	M	N	N	H	H	M	H	H	7
Amount of water received by each decile of the population for domestic use (from greatest amount to least amount) (m^3/a)	M	M	N	?	M	N	L	H	N	5
Total number of households	H	N	N	H	N	M	N	H	N	4
Number of households without access to water within 200m	H	N	N	M	N	M	H	H	N	5
Number of households without access to any toilet facilities	M	N	N	M	N	M	M	H	N	5
Catchment area used for crops & grazing (km^2)	H	N	N	L	N	N	M	H	M	4
Catchment area under mining (km^2)	H	N	N	L	N	H	M	M	M	6
Catchment area under industrial use (km^2)	H	H	N	L	N	H	M	H	M	7
Catchment area covered by natural vegetation (km^2)	H	N	N	M	N	N	M	M	M	5
Catchment area covered by alien vegetation (km^2)	H	N	N	N	N	M	M	H	H	5
Catchment area covered by wetlands (km^2)	H	N	N	N	N	M	M	H	N	4
Annual rainfall (at any meteorological site) (mm/a)	H	H	H	H	H	H	M	H	H	9
Mean annual runoff	H	N	H	H	H	H	M	H	H	8
IBT Volume – imported water (m^3/a)	M	H	?	N	H	N	H	H	H	6
IBT Volume – exported water (m^3/a)	M	H	?	N	H	N	H	H	H	6
Total demand for water (m^3/a)	M	N	N	N	M	H	M	H	H	6
Volume of return flows (m^3/a)	M	N	N	N	L	M	M	H	M	6
Safe yield for groundwater (m^3/a)	L	N	N	N	L	M	L	H	M	6
Amount of groundwater extracted (m^3/a)	L	N	N	N	L	M	L	M	M	6
Water required for the Reserve (m^3/a)	M	N	N	N	L	N	L	H	M	5
Water required by other countries (m^3/a)	N	H	N	N	H	H	H	H	H	7
Water required by Eskom (m^3/a)	H	H	H	H	H	H	H	H	H	9
Water required by agriculture (m^3/a)	M	N	M	M	M	H	M	H	H	8
Water required by industry (m^3/a)	M	N	M	H	N	H	M	H	H	7
Water required by mining (m^3/a)	M	H	M	H	H	H	M	H	H	9
Water required by domestic users (m^3/a)	M	N	M	H	H	H	H	H	H	8
Total amount of solid waste generated (t/a)	M	N	N	N	M	N	M	M	M	5
Amount of domestic solid waste generated (t/a)	M	N	N	N	M	N	M	M	M	5
Amount of industrial solid waste generated (t/a)	M	N	N	N	M	H	M	M	M	6
Amount of mining solid waste generated (t/a)	M	H	N	N	H	H	M	M	M	7
Amount of agricultural solid waste generated (t/a)	M	N	N	N	N	N	M	N	?	3
Runoff volume for each agricultural concern (m^3/a)	L	N	?	N	H	N	L	N	N	3
Average annual total P concentration for runoff from each agricultural concern (mg/l)	M	N	N	N	N	N	L	N	N	2
Average annual total N concentration for runoff from each agricultural concern (mg/l)	L	N	N	N	N	N	L	N	N	2
Average annual POPs concentration for runoff from each agricultural concern (mg/l)	L	N	N	N	N	N	L	N	N	2
Average annual TDS concentration for runoff from each agricultural concern (mg/l)	L	N	N	N	M	N	L	N	N	3
Runoff volume for each dense settlement (m^3/a)	N	N	N	N	N	N	L	H	N	1

Average annual total P concentration for runoff from each dense settlement (mg/l)	N	N	N	N	N	N	L	na	N	1
Average annual total N concentration for runoff from each dense settlement (mg/l)	L	N	N	N	N	N	L	na	N	2
Volume for drainage from each mine (m^3/a)	L	H	N	H	H	H	M	M	N	7
Average annual TDS concentration for runoff from each mine (mg/l)	M	na	N	M	H	H	H	na	N	5
Average annual SO^4 concentration for runoff from each mine (mg/l)	M	na	N	H	H	H	H	na	N	5
Average annual conductivity at the lowest geographical point (mS m^{-1})	L	N	N	L	H	N	H	H	N	5
Average annual total P concentration at the lowest geographical point	H	N	N	L	N	N	H	H	N	4
Average annual total N concentration at the lowest geographical point	M	N	N	L	N	N	H	H	N	4
Average annual faecal coliform counts in the major water resource for domestic and recreational use (number/100ml)	M	N	N	H	M	L	M	M	N	6
Daphnia toxicity test results at the lowest geographical point	N	N	N	H	N	N	N	N	N	1
Turbidity at the lowest geographical point or at the inflow to the main reservoir (NTU)	N	N	N	M	M	N	H	M	N	4
Number of boreholes in the catchment	L	N	N	L	N	M	L	M	M	6
Average annual conductivity of each borehole (mS/m)	M	N	N	L	N	M	N	M	N	4
Average annual total coliform counts for each borehole (number/100ml)	M	N	N	N	L	N	N	N	N	2
Annual average total N concentrations for each borehole (mg/l)	L	N	N	N	L	N	N	M	N	3
SASS scores	N	N	N	H	M	N	H	L	N	4
Fish Assemblage Integrity Index scores	N	N	N	H	M	N	M	L	N	4
Index of Habitat Integrity scores	N	N	N	H	M	N	H	L	N	4
Riparian Vegetation Index scores	N	N	N	H	M	N	M	L	N	4
Progress with regard to the establishment of a CMA	L	H	H	H	M	H	H	H	H	9
Opinions of the catchment population with regard to water services delivery and WRM	N	N	N	M	L	M	H	N	H	5
Volume of water allocated through licensing (m^3/a)	?	N	M	H	H	H	M	H	M	7
Rand value of mining output in the catchment (R/a)	N	H	N	M	N	H	N	H	N	4
Volume of water used by mining sector (m^3/a)	N	H	M	H	H	H	M	H	H	8
Rand value of agricultural output (R/a)	N	N	N	N	N	N	N	H	N	1
Volume of water used by agriculture (m^3/a)	M	N	M	M	M	H	M	H	H	8
Rand value of industrial output (R/a)	N	N	N	L	N	H	N	H	N	3
Volume of water used by industrial sector (m^3/a)	M	N	M	M	N	H	M	H	H	7
Volume of water unaccounted for in the distribution from bulk suppliers to end users (m^3/a)	M	N	N	N	N	H	N	H	N	3
Volume of water distributed from bulk suppliers (m^3/a)	H	N	N	N	N	H	N	H	N	3
Number of quaternary catchments	H	H	H	H	H	H	H	H	H	9
Number of quaternary catchments for which Ecological Reserve has been set	L	N	N	H	L	H	L	M	H	7
Number of quaternary catchments for which reliable flow data are available	M	N	N	M	M	H	M	M	H	7
Number of quaternary catchments for which reliable water quality data are available	H	N	N	L	M	H	M	M	H	7
Number of official reports on water quality (2001)	M	N	N	L	M	H	H	H	M	7
Number of official reports on flow (2001)	M	N	N	M	M	H	H	H	M	7
Number of official reports on river health (2001)	?	N	N	H	H	H	L	N	M	5
TOTAL LOW	**17**	**0**	**0**	**12**	**8**	**0**	**15**	**4**	**0**	
TOTAL MED	**30**	**2**	**8**	**15**	**19**	**11**	**30**	**19**	**18**	
TOTAL HIGH	**18**	**13**	**6**	**24**	**20**	**37**	**20**	**41**	**24**	
TOTAL ?	**2**	**0**	**3**	**1**	**0**	**7**	**3**	**0**	**9**	
TOTAL N/A	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**4**	**0**	
TOTAL NO	**14**	**64**	**64**	**29**	**34**	**26**	**13**	**13**	**30**	

ANALYSIS 2:

INDICATORS THAT CAN BE POPULATED FOR EACH PILOT CATCHMENT

Shading = available

INDICATOR (UNITS)		LIM	GAU	NWP	MPU	FS	EC	WC	NC	KZN
SE1	Population density (no. km^{-2})	■			■		■		■	■
SE2	Urbanisation (%)	■			■		■		■	■
SE3	GGP per capita (R cap^{-1})	■			■				■	
SE4	Human Development Index	■			■					
SE5	Water Equity Coefficient	■							■	
SE6	Percentage of households without access to water within 200m (%)	■			■		■		■	
SE7	Percentage of households without access to sanitation (%)	■			■		■		■	
SE8	Percentage area under different economic land uses (%)	■			■			■	■	■
WB1	Mean volume of precipitation onto the catchment (mm^3 a^{-1})	■	■	■	■	■	■	■	■	■
WB2	Total water available per capita (m^3 cap^{-1})	■							■	■
WB3	Demand as a proportion of total surface water available (%)	■				■		■	■	■
WB4	Proportion of groundwater utilised (%)	■				■	■	■	■	■
WB5	Water requirements per sector as a percentage of total available (%)							■	■	■
WP1	Amount of solid waste generated per km^2 (tonnes km^{-2})	■				■		■	■	■
WP2	Proportion of solid waste generated per sector (%)	■						■		
WP3	Total liquid waste discharged from point sources as a % of total available	■				■		■	■	■
WP4	Loading of P, N, POPs & TDS from agricultural runoff (tonnes a^{-1})	■						■		
WP5	Loading of P & N from dense settlements (tonnes a^{-1})							■		
WP6	Loading of TDS and SO_4 from mine drainage (tonnes a^{-1})	■			■	■	■	■		
WP7	Conductivity at the lowest point in the geographical catchment (mS m^{-1})	■			■	■		■	■	
WP8	P & N concentration s at the lowest point in the geographical catchment (mg ℓ^{-1})	■			■			■	■	
WP9	Faecal coliforms in the major water resource for domestic and recreational use	■			■	■	■	■	■	
WP10	Daphnia toxicity test at the lowest point in the geographical catchment				■					
WP11	Turbidity at the lowest point or the inflow to the main reservoir (NTU)				■	■		■	■	
WP12	Percentage of boreholes contaminated (%)	■								
RC1	Percentage catchment area covered by natural vegetation & alien vegetation (%)	■						■	■	■
RC2	South African Scoring System (SASS) scores at selected sites (SASS score)				■	■		■	■	
RC3	Fish Assemblage Integrity Index (FAII) in selected reaches (FAII score)				■	■		■	■	
RC4	Index of Habitat Integrity in selected reaches (IHI score)				■	■		■	■	
RC5	Riparian Vegetation Index in selected reaches (RVI score)				■	■		■	■	
RC6	Percentage wetland area (%)	■					■	■	■	
MN1	Index of level of CMA establishment in the catchment	■	■	■	■	■	■	■	■	■
MN2	State of satisfaction of catchment population				■	■	■	■		■
MN3	Volume of water allocated as a proportion of water available					■		■	■	■
MN4	Water use efficiency for different sectors (R m^{-3})								■	
MN5	Percentage unaccounted for water in the catchment (%)	■					■		■	
MN6	**Ratio of sub-catchments for which the Ecological Reserve has been set to total number of sub-catchments**	■			■	■	■	■	■	■
MN7	**Ratio of sub-catchments** for which reliable hydrological data are available **to total number of sub-catchments**	■			■	■	■	■	■	■
MN8	Ratio of **sub-catchments** for which reliable water quality data are available **to total number of sub-catchments**	■			■	■	■	■	■	■
MN9	Number of official resource condition reports per annum (no. a^{-1})				■	■	■	■		■

ANALYSIS 3:
SOURCES OF INFORMATION

PARAMETER	SUGGESTED SOURCES
Total number of people in the catchment	DWAF Directorate of Water Resources Planning Provincial Integrated Development Plans Stats SA
Catchment area (km^2)	Provincial Integrated Development Plans
Number of people living in urban areas (formal & informal)	DWAF Directorate of Water Resources Planning Provincial Integrated Development Plans Stats SA
GGP for the catchment (R/a)	DWAF Directorate of Water Resources Planning Provincial Integrated Development Plans Department of Environmental Affairs & Tourism Stats SA District & local municipalities
Life expectancy at birth for people in the catchment	Stats SA Provincial Integrated Development Plans Department of Health & Welfare DWAF Head Office (unspecified) District & local municipalities
% Literacy among 15-year-olds and older in	Stats SA Provincial Integrated Development Plans Department of Education DWAF Head Office (unspecified) District & local municipalities
Average number of years spent at school for 27-year-olds and older	Stats SA Provincial Integrated Development Plans Department of Education DWAF Head Office (unspecified) District & local municipalities
Total water available for domestic use (m^3/a)	DWAF Directorate of Water Resources Planning
Amount of water received by each decile of the population for domestic use (from greatest amount to least amount) (m^3/a)	Department of Local Government & Housing
Total number of households	Provincial Integrated Development Plans Stats SA DWAF Head Office (unspecified) District & local municipalities
Number of households without access to water within 200m	Stats SA Provincial Integrated Development Plans DWAF Head Office (unspecified) District & local municipalities
Number of households without access to any toilet facilities	Stats SA Water providers Provincial Integrated Development Plans DWAF Head Office (unspecified) District & local municipalities
Catchment area used for crops & grazing (km^2)	DWAF Directorate of Water Resources Planning Department of Agriculture
Catchment area under mining (km^2)	DWAF Directorate of Water Resources Planning Department of Minerals & Energy
Catchment area under industrial use (km^2)	Working for water Provincial Integrated Development Plans Local authorities & individual authorities
Catchment area covered by natural vegetation (km^2)	DWAF Working for Water Department of Agriculture Department of Environmental Affairs & Tourism Provincial Departments of the Environment EMPRs and EIAs South African National Parks Board

PARAMETER	SUGGESTED SOURCES
Catchment area covered by alien vegetation (km^2)	DWAF Working for Water
Catchment area covered by wetlands (km^2)	DWAF Working for Water Rennies Wetlands Project Department of Environmental Affairs & Tourism Provincial Departments of the Environment Arid Zone Ecology Forum Parks Boards
Annual rainfall (at any meteorological site) (mm/a)	Department of Environmental Affairs & Tourism
Mean annual runoff	Department of Environmental Affairs & Tourism
IBT Volume – imported water (m^3/a)	DWAF Directorate of Water Resources Planning
IBT Volume – exported water (m^3/a)	DWAF Directorate of Water Resources Planning
Total demand for water (m^3/a)	DWAF Directorate of Water Resources Planning
Volume of return flows (m^3/a)	DWAF Directorate of Water Resources Planning
Safe yield for groundwater (m^3/a)	DWAF Directorate of Water Resources Planning
Amount of groundwater extracted (m^3/a)	DWAF Directorate of Water Resources Planning
Water required for the Reserve (m^3/a)	DWAF Directorate of Water Resources Planning DWAF RDM Office
Water required by other countries (m^3/a)	DWAF Directorate of Water Resources Planning
Water required by Eskom (m^3/a)	
Water required by agriculture (m^3/a)	DWAF Directorate of Water Resources Planning
Water required by industry (m^3/a)	DWAF Water Resources Development Planning District & local municipalities
Water required by mining (m^3/a)	
Water required by domestic users (m^3/a)	
Total amount of solid waste generated (t/a)	DWAF Directorate of Water Quality Management Local municipalities
Amount of domestic solid waste generated (t/a)	DWAF Directorate of Water Quality Management Local municipalities
Amount of industrial solid waste generated (t/a)	DWAF Directorate of Water Quality Management Individual industries
Amount of mining solid waste generated (t/a)	DWAF Directorate of Water Quality Management Individual mines
Amount of agricultural solid waste generated (t/a)	DWAF Directorate of Water Quality Management Department of Agriculture Individual farmers
Runoff volume for each agricultural concern (m^3/a)	District & local municipalities Department of Agriculture Individual agricultural concerns
Average annual total P concentration for runoff from each agricultural concern (mg/l)	District & local municipalities DWAF Directorate of Water Quality Management Department Agriculture
Average annual total N concentration for runoff from each agricultural concern (mg/l)	DWAF Directorate of Water Quality Management Department of Agriculture
Average annual POPs concentration for runoff from each agricultural concern (mg/l)	DWAF Directorate of Water Quality Management Department of Agriculture
Average annual TDS concentration for runoff from each agricultural concern (mg/l)	DWAF Directorate of Water Quality Management Department of Agriculture
Runoff volume for each dense settlement (m^3/a)	DWAF Directorate of Water Quality Management Department of Local Government & Housing
Average annual total P concentration for runoff from each dense settlement (mg/l)	DWAF Directorate of Water Quality Management Department of Local Government & Housing
Average annual total N concentration for runoff from each dense settlement (mg/l)	DWAF Directorate of Water Quality Management Department of Local Government & Housing
Volume for drainage from each mine (m^3/a)	DWAF Directorate of Water Quality Management Department of Minerals & Energy
Average annual TDS concentration for runoff from each mine (mg/l)	Institute for Water Quality Studies DWAF Directorate of Water Quality Management Department of Minerals & Energy
Average annual SO^4 concentration for runoff from each mine (mg/l)	DWAF Directorate of Water Quality Management Department of Minerals & Energy

PARAMETER	SUGGESTED SOURCES
Average annual conductivity at the lowest geographical point (mS/m)	DWAF Directorate of Water Quality Management
Average annual total P concentration at the lowest geographical point	DWAF Directorate of Water Quality Management
Average annual total N concentration at the lowest geographical point	DWAF Directorate of Water Quality Management
Average annual faecal coliform counts in the major water resource for domestic and recreational use (number/100ml)	DWAF Directorate of Water Quality Management
Daphnia toxicity test results at the lowest geographical point	DWAF Directorate of Water Quality Management CSIR
Turbidity at the lowest geographical point or at the inflow to the main reservoir (NTU)	Institute for Water Quality Studies DWAF Directorate of Water Quality Management
Number of boreholes in the catchment	DWAF Directorate of Geohydrology
Average annual conductivity of each borehole (mS/m)	DWAF Directorate of Geohydrology
Average annual total coliform counts for each borehole (number/100ml)	Department of Local Government and Housing
Annual average total N concentrations for each borehole (mg/l)	Department of Local Government and Housing
SASS scores	Permitted mines Provincial Departments of the Environment Universities
Fish Assemblage Integrity Index scores	Permitted mines Provincial Departments of the Environment Department of Environmental Affairs & Tourism
Index of Habitat Integrity scores	Permitted mines Provincial Departments of the Environment Department of Environmental Affairs & Tourism Universities
Riparian Vegetation Index scores	Permitted mines Provincial Departments of the Environment Department of Environmental Affairs & Tourism University of Zululand
Progress with regard to the establishment of a CMA	
Opinions of the catchment population with regard to water services delivery and WRM	
Volume of water allocated through licensing (m^3/a)	Mining companies
Rand value of mining output in the catchment (R/a)	Mining companies Department of Agriculture Chamber of Mines Department of Minerals & Energy District & local municipalities
Volume of water used by mining sector (m^3/a)	Department of Minerals & Energy
Rand value of agricultural output (R/a)	Department Agriculture Stats SA Department Agriculture Provincial Departments of Agriculture Department of Environmental Affairs & Tourism
Volume of water used by agriculture (m^3/a)	
Rand value of industrial output (R/a)	Stats SA Organized industry Provincial Department of Environmental Affairs & Tourism
Volume of water used by industrial sector (m^3/a)	DWAF Directorate of Water Services Development Planning District & local municipalities
Volume of water unaccounted for in the distribution from bulk suppliers to end users (m^3/a)	Water providers DWAF Directorate of Water Services Development Planning District & local municipalities
Volume of water distributed from bulk suppliers (m^3/a)	Water providers DWAF Directorate of Water Services Development Planning District & local municipalities

PARAMETER	SUGGESTED SOURCES
Number of quaternary catchments	Water providers DWAF Directorate of Water Services Development Planning District & local municipalities
Number of quaternary catchments for which Ecological Reserve has been set	DWAF RDM Office
Number of quaternary catchments for which reliable flow data are available	DWAF Directorate of Hydrology
Number of quaternary catchments for which reliable water quality data are available	DWAF Directorate of Water Quality Management
Number of official reports on water quality (2001)	DWAF Directorate of Water Quality Management
Number of official reports on flow (2001)	DWAF Directorate of Hydrology
Number of official reports on river health (2001)	Provincial Departments of the Environment

APPENDIX E
Published Papers and Report Chapters

The following papers and report chapters were written by myself during the preparation of this thesis, and have been used in part or in full in the thesis:

1. WALMSLEY JJ. 2001. Chapter 3: Frameworks. In: Department of Environmental Affairs and Tourism, *National Core Set of Environmental Indicators for State of Environment Reporting in South Africa. Phase 1: Scoping Report. Volumes 1 & 2.* DEAT, Pretoria. pp. 19-34.

2. WALMSLEY JJ, CARDEN M, REVENGA C, SAGONA F & SMITH M. 2001. Indicators of sustainable development for catchment management in South Africa – Review of indicators from around the world. *Water SA* **27(4):** 539-550.

3. WALMSLEY JJ. 2001. Framework for measuring sustainable development in catchment systems. *Environ. Manage.* **29(2):** 195-206.

Acknowledgement is made of the Department of Environmental Affairs and Tourismn (DEAT). The report chapter on frameworks presented here was written by me as part of the scoping phase of the South African National Environmental Indicator Programme funded by DEAT.

NATIONAL CORE SET OF ENVIRONMENTAL INDICATORS

FOR STATE OF ENVIRONMENT REPORTING IN SOUTH AFRICA

PHASE 1: SCOPING REPORT

VOLUME 1 OF 2

PREPARED FOR:

The Directorate: Environmental Information and Reporting

National Department of Environmental Affairs and Tourism

PREPARED BY:

CSIR, Mzuri Consultants, HSRC

May 2001

CHAPTER 3: FRAMEWORKS

CHAPTER SUMMARY

Sustainability frameworks assist in the development of environmental indicators by providing a logical means to identifying and summarising key issues. There are four main types of frameworks that can be used to develop and report on indicators: physical, issue-based, economic and societal.

Physical frameworks are the most well-known and widely-used frameworks. They are based on the physical interaction between humans and the environment, and the impact of this interaction. They take into account the causal linkages between social, economic and the biophysical elements, and are designed to ensure that the environmental aspects of sustainability are reflected. The most commonly-used of these frameworks are the Pressure-State-Response (PSR) framework and the Driving-Forces-Pressure-State-Impact-Response (DPSIR) framework. The PSR framework is based on a cause-effect-societal-response logic, where human activity causes *pressure* on the environment, whose *state* (quality and quantity) is changed, resulting in a societal *response* to reduce or eliminate the problem. The DPSIR framework has the added aspects of *driving forces*, which are the human activities that underpin environmental change, and *impacts* that result from pressures on the current state of the environment.

Issue-based frameworks are based upon the identification of strategic issues that will influence the sustainability of a system. They are based on the assumption that not all issues are equally important at any given time. Thus, they are dynamic and will change over time as the priority issues are dealt with and other issues emerge. Issues can be identified using a thematic approach (common in most state of the environment reports) or by addressing the risk factor related to an issue (assessment of the probability of occurance and probable impact).

Economic frameworks deal with the linkage between the biophysical environment and the economy. Most of these frameworks are based on the concept of attempting to place a financial value on resources and assets, but the capital-based framework can also be used as a tool to develop environmental indicators. It reflects the three forms of capital including the natural, built and human/social capital, all of which form part of a sustainable system.

Societal frameworks are founded on the premise that the ultimate goal of sustainability is the fulfilment of human needs, which requires the maintenance of the system that can provide this. There are two main societal frameworks, Daly's continuum and the orientor framework. Both frameworks tend to be anthropocentric, although they are based on the premise that the basis of human well-being is the natural system.

South Africa has not yet developed a cohesive sustainable development strategy, although the DEA&T is currently in the process of doing so. Thus, State of the Environment reporting in this country has relied largely on other methods of identifying useful indicators. Indicators for the national and cities State of the Environment reports were developed thematically, using the DPSIR framework to ensure that all elements of each theme were covered. Although this approach was appropriate at the time, and ensured that linkages between the various elements of sustainability were achieved, it is necessary to re-evaluate this methodology. It is recommended that the Bellagio Principles are reflected in the process to develop environmental indicators for South Africa.

3.1 INTRODUCTION

One of the problems in the development of indicator sets is the over-abundance of possible indicators. The use of sustainability frameworks overcomes this by assisting in the development of environmental indicators in a logical fashion so that key issues can be readily identified and summarised, thus making them more understandable to non-experts. They suggest logical groupings of related sets of information and, thus, promote interpretation and integration. They can also help identify data collection needs and data gaps. Finally, indicator frameworks can help to spread reporting burdens, by structuring the information collection, analysis and reporting process across the many issues that pertain to sustainable development (Gouzee *et al.*, 1995; Walmsley & Pretorius, 1996).

There are numerous frameworks or models of sustainability that have been proposed over the last twenty years (see OECD, 1985). However, not all of them are appropriate for the development of environmental indicators. This section briefly outlines only those frameworks that could be used to assist in the identification of environmental indicators. They can be split into four main types: physical, issue-based, economic and societal.

3.2 PHYSICAL FRAMEWORKS

The most well-known and widely-understood frameworks are the physical frameworks, which have been used extensively for development of indicators and as a basis for state of the environment reporting. They are based on the physical interaction between humans and the environment, and the impact of this interaction. They take into account both the static elements of a system, as well as the dynamic elements such as physical flow etc. These physical frameworks are designed to ensure that the environmental aspects of sustainability are reflected, as well as the economic and social aspects. The most commonly-used of these frameworks are the Pressure-State-Response (PSR) framework and the Driving-Forces-Pressure-State-Impact-Response (DPSIR) framework, which is based on the PSR framework.

3.2.1 PSR Framework

The pressure-state-response (PSR) framework (Figure 3.1) was originally developed by the OECD programme on environmental indicators during the late 1980's from earlier work by the Canadian Government (Friend and Rapport, 1979). This framework is based on a cause-effect-societal-response logic, where human activity causes *pressure* on the environment, whose *state* (quality and quantity) is changed, resulting in a societal *response* to reduce or eliminate the problem (Carlsson Reich & Åhman 2000).

Pintér *et al.* (2000) expand upon the three categories of the PSR framework as follows:

- ***Pressures*** are often classified into underlying forces such as population growth, poverty consumption or pollution. The pressures on the environment are often considered from a policy perspective as the starting point for addressing environmental problems. Information on pressures tends to be the most readily available since they are often derived from socio-economic databases. They include primary pressures such as population growth and economic development, and secondary pressures such as consumption patterns and pollution;
- ***State*** refers to the condition of the environment resulting from pressures (e.g. level of air pollution, land degradation or deforestation). The state of the environment will, in turn, affect

human health and well-being as well as the socio-economic fabric of society. Knowing both the state of the environment and its indirect effect is critical for decision-makers and the public.

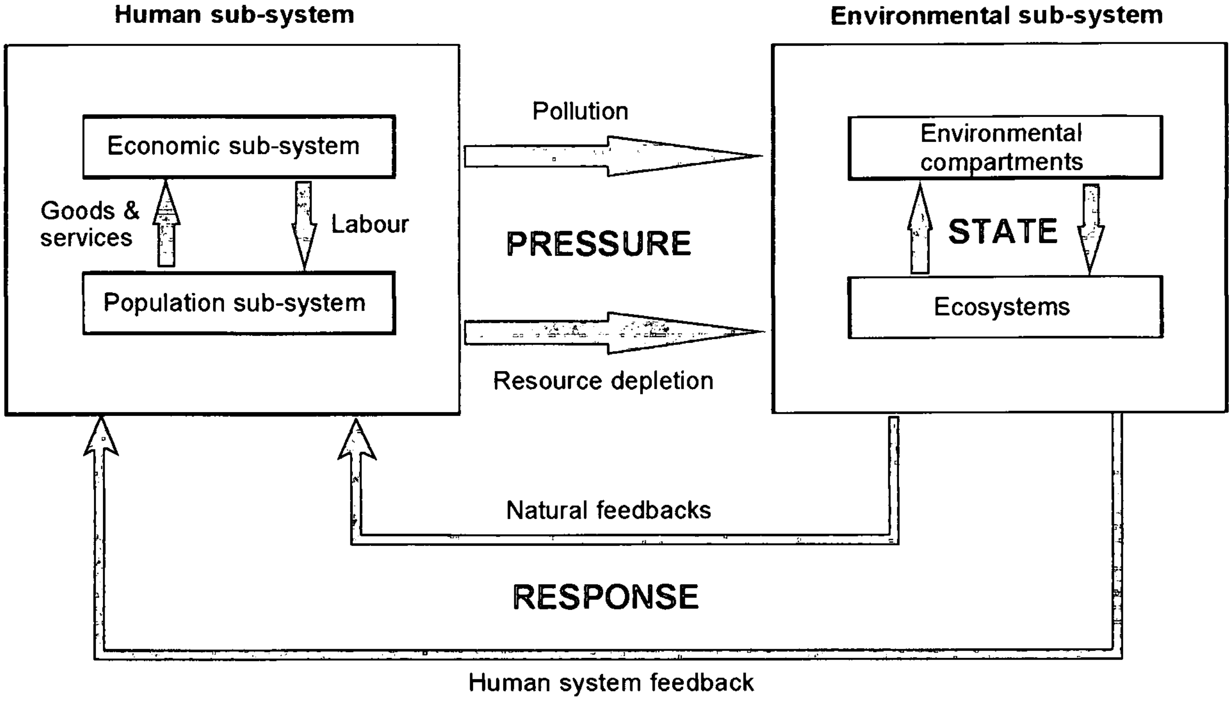

Figure 3.1: Schematic diagram of the Pressure-State-Response framework (Carlsson Reich & Åhman 2000).

- ***Response*** corresponds to societal action taken collectively or individually to ease or prevent negative environmental impacts, correct environmental damage or conserve natural resources. Responses may include regulatory action, environmental or research expenditure, public opinion and consumer preferences, changes in management strategy, and provision of environmental information. Satisfactory indicators of societal response tend to be the most difficult to develop and interpret.

The framework was originally developed as a simple model used for isolated chains of cause and response. However, the framework has been developed to take into account more complex interactions (see Figure 3.1), where societal response is shown to impact on both the pressures and the state of the environment). Some indicators can be placed in more than one category, so the framework should be used for analysis rather than for rigid categorisation of indicators.

This framework has been used as the basis for indicator development for several organisations including the OECD, the UNCSD, the US EPA and the Australian and New Zealand governments (Zinn, 2000; ANZECC, 1998). However, there has been recent concern that the framework limits indicator development because of the strong causal linkages. The UNCSD has recently rejected this approach in the development of its core set of indicators (Division of Sustainable Development, 2001).

3.2.2 DPSIR and PSIR frameworks

The PSR framework was further developed by the United Nations and the European Environment Agency into the Driving-forces-Pressure-State-Impact-Response (DPSIR) framework (Figure 3.2). The DPSIR framework is viewed as providing a systems-analysis view of the relations between the environmental system and the human system (Smeets and Weterings, 1999). According to this view, social and economic developments (*driving forces*) exert *pressure* on the environment and, as a consequence, the *state* of the environment changes (e.g. provision of adequate conditions for health, resources availability and biodiversity). This leads to *impacts* on human health, ecosystems and materials that may elicit a societal *response* that feeds back on all the other elements (Smeets and Weterings, 1999).

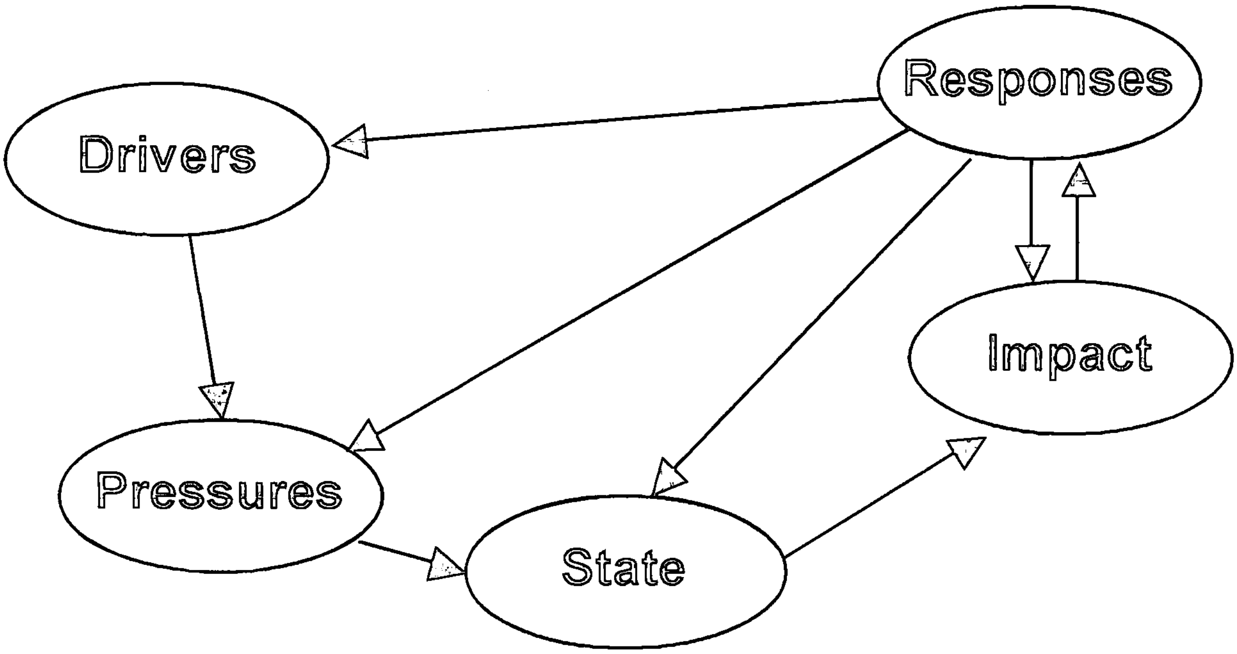

Figure 3.2: Schematic diagram of elements of the DPSIR framework and their interactions (Smeets and Weterings, 1999).

The development of this framework was based on the premise that from a policy point-of-view there was a need for clear and specific information on: *driving forces* and the resulting environmental *pressures*; the *state* of the environment and the *impacts* resulting from changes in environmental quality, and the societal *response* to these and its effectiveness. Thus, two additional categories were added to the original PSR framework:

- ***Driving forces*** are the human influences and activities that, when combined with environmental conditions, underpin environmental change. Indicators for driving forces describe the social, demographic and economic developments in societies and the corresponding changes in lifestyles, overall levels of consumption and production patterns. Primary driving forces are population growth and developments in the needs and activities of individuals. These primary driving forces provoke changes in the overall levels of production and consumption, and thus exert pressure on the environment (Smeets & Weterings, 1999).
- ***Impacts*** are the results of pressures on the current state of the environment, and which occur in a certain sequence. For instance, air pollution may cause global warming (primary effect),

which may in turn cause an increase in temperature (secondary effect), which may provoke a rise of sea level (tertiary impact), which could result in a loss of biodiversity and thus impact on human health and well-being (Smeets & Weterings, 1999).

Driving forces are often seen as those forces that are most difficult to change through the various response mechanisms. For this reason, the DPSIR framework is sometimes modified to include driving force and pressures in one category. This is referred to as the Pressure-State-Impact-Reponse (PSIR) framework (see Pintér *et al.,* 2000).

Although the DPSIR framework was developed as an extended cause-effect-response model, the framework is most useful in describing the origins and consequences of environmental problems. In developing linkages between the various categories the dynamic relationships within a system can be analysed.

The DPSIR framework is currently being used by many countries in the development of their State of the Environment report including South Africa (UNEP/GRID-Arendal, 2001), and is the preferred framework of the European Environmental Agency (EEA, 2000).

3.3 ISSUES-BASED FRAMEWORKS

Issue-based frameworks, as their name suggests, are based upon the identification of strategic issues that will influence the sustainability of a system (country, province, region etc.). They rest upon the premise that not all issues are equally important at any given time. Thus, they are dynamic and will change over time as the priority issues are dealt with and other issues emerge.

3.3.1 Thematic frameworks

Thematic frameworks are the basis for all state of the environment reports (see UNEP/GRID-Arendal, 2001). Indicators are designed and used to describe the status surrounding a specific aspect of the environment. Every society and community will have its own themes and issues that it feels are important. It thus follows that indicators can be aggregated within themes or issues that they describe (Bakkes *et al.*, 1994). It is, thus, essential to define key areas (themes) of concern and identify indicators which can be used to monitor and measure conditions within these priority areas.

Issues represent an item of concern surrounding an environmental problem. They will obviously vary according to the scale of the situation. For example, some investigations have outlined between 100 and 150 indicators, which measure changes in specific issues (Bakkes *et al.*, 1994; OECD, 1993).

In some cases, the themes are chosen in accordance with a specific policy framework, such as a Sustainability Charter. An example of this is the use by the UNCSD using Agenda 21 as their framework to develop themes and issues for which indicators could be chosen.

3.3.2 Impact-Probability framework

The impact-probability framework is based on two strategic considerations. The first is the impact of a particular problem and the second is the probability or risk that the issue *will* cause a problem. This can be represented graphically using a simple business-school model (Figure 3.3).

This framework identifies four types of issue that are of concern when making a strategic sustainability analysis. They are (Walmsley *et al.*, 1999):

- ***Latent issues*** of low impact and low probability. These issues are of concern because they are important as part and parcel of long-term management. However as impact and risk at the present time is relatively low there is only a need for monitoring.
- ***Emerging Issues*** of increasing impact and increasing probability. These are issues that have the potential to emerge as problems or are beginning to emerge as problems. These issues have the potential to cause problems in the near future. There is, therefore, a need to have them monitored as a priority.
- ***Active Issues*** of high impact and high probability. These are issues that should occupy most management time as they require solutions. They not only require monitoring but also the setting of objectives for problem-solving to reduce the risk. These issues require the monitoring of sustainability indicators as well as performance indicators of objective.
- ***Solved Issues*** of high impact and low probability. These are issues where the management problem has been solved through the implementation of an intervention. Monitoring of performance is ongoing to ensure that the intervention has been successfully implemented (performance indicators).

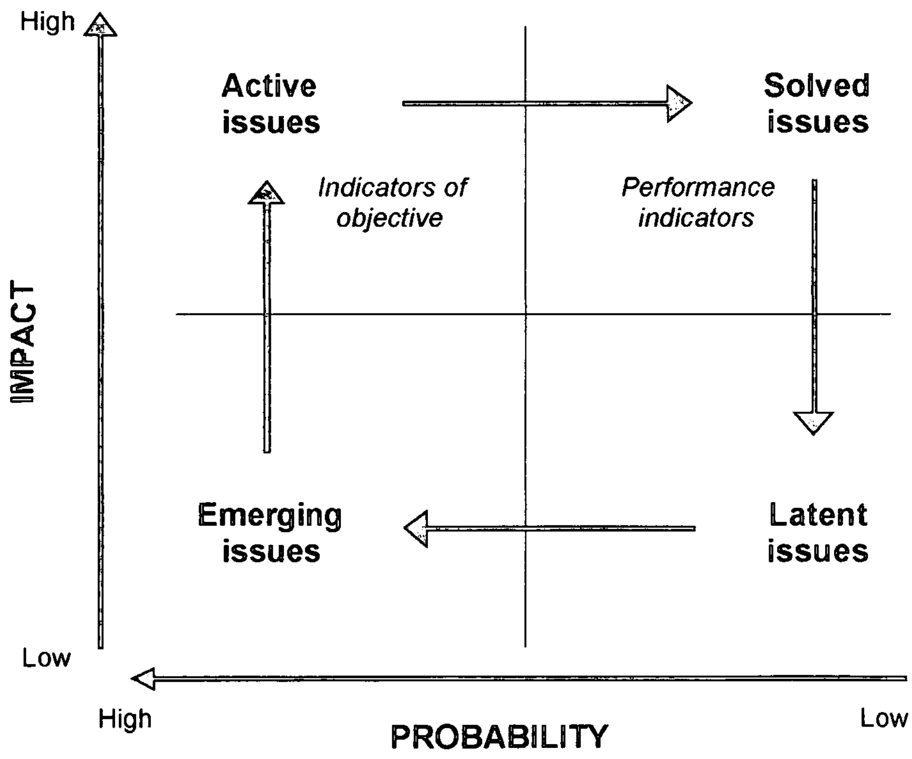

Figure 3.3: Impact-Probability framework (adapted from Walmsley *et al.*, 1999).

3.4 ECONOMIC FRAMEWORKS

Several economic frameworks have been developed, including frameworks such as the System of Integrated Environmental and Economic Accounting (SEEA); measures of wealth; and genuine savings (see OECD, 2000). These economic frameworks are based on the concept of attempting to place a financial value on resources and assets, and deal with the linkage between the biophysical environment and the economy. The basic framework on which all the others rest, is that of the National System of Accounts, which may be extended to include environmental resources and assets, and human and social capital (Obst, 2000). However, although valuable in assessing sustainability, not all these frameworks are appropriate for developing environmental indicators. The only economic framework that lends itself to the development of economic indicators is the capital-based framework.

3.4.1 Capital-based framework

The capital-based framework is founded on the concept of capital conservation, which is based on the idea that sustainability means living off the income *derived* from the stock of wealth or capital rather than living off the capital itself. The capital conservation approach broadens the traditional economic theory to include natural and human/social capital, as well as built capital (OECD, 1995). Thus, the capital-based framework includes three basic capital types, which need to be accounted for when measuring sustainability. They are (OECD, 1995):

- ***Built capital***, which is the human-built physical capacity (factories, tools and technologies) that provide a steady stream of economic output without being directly consumed.
- ***Natural capital***, which consists of the natural resource stocks and energy flows from which the human economy takes its raw material and energy, and the natural sinks into which we throw these materials and energy.
- ***Human or social capital***, which is defined as labour (including unpaid labour such as housework), education, nutrition, health and well-being of a population. Social capital is sometimes distinguished from human capital and reflects the institutional and cultural basis for society to function, which in turn reflects the richness and diversity of civil society.

For a system to be sustainable all these types of capital need to be accounted for. For an economist this would mean including natural and human capital into the System of National Accounts. In terms of the development of environmental indicators, it would reflect the linkages between the biophysical environment and the economy. Manitoba Environment (1997) used this concept to develop its state of the environment report, allowing that the different types of capital were included in the equity of the province (Figure 3.4).

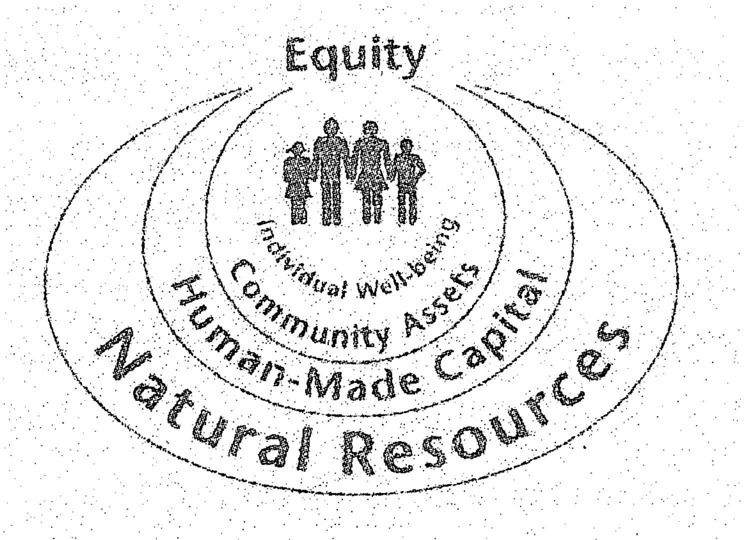

Figure 3.4: Framework of issues used by Manitoba Environment (1997), developed from the capital-based framework (Manitoba Environment, 1997).

3.5 SOCIETAL FRAMEWORKS

Societal frameworks are founded on the premise that the ultimate goal of sustainability is the fulfilment of human needs, which requires the maintenance of the system that can provide this. There are two main societal frameworks, Daly's continuum and the orientor framework. Both of these arose from the Balaton Group, an international network of scholars and activists who work on sustainable development in their own countries and regions.

3.5.1 Daly's Continuum

Daly's Continuum is based on a model outlined by Herman Daly almost thirty years ago (Daly, 1973; Meadows, 1998). It relates natural wealth to ultimate human purpose through technology, economics, politics and ethics, by integrating the four aspects: ultimate means, intermediate means, intermediate ends and ultimate ends (Figure 3.5).

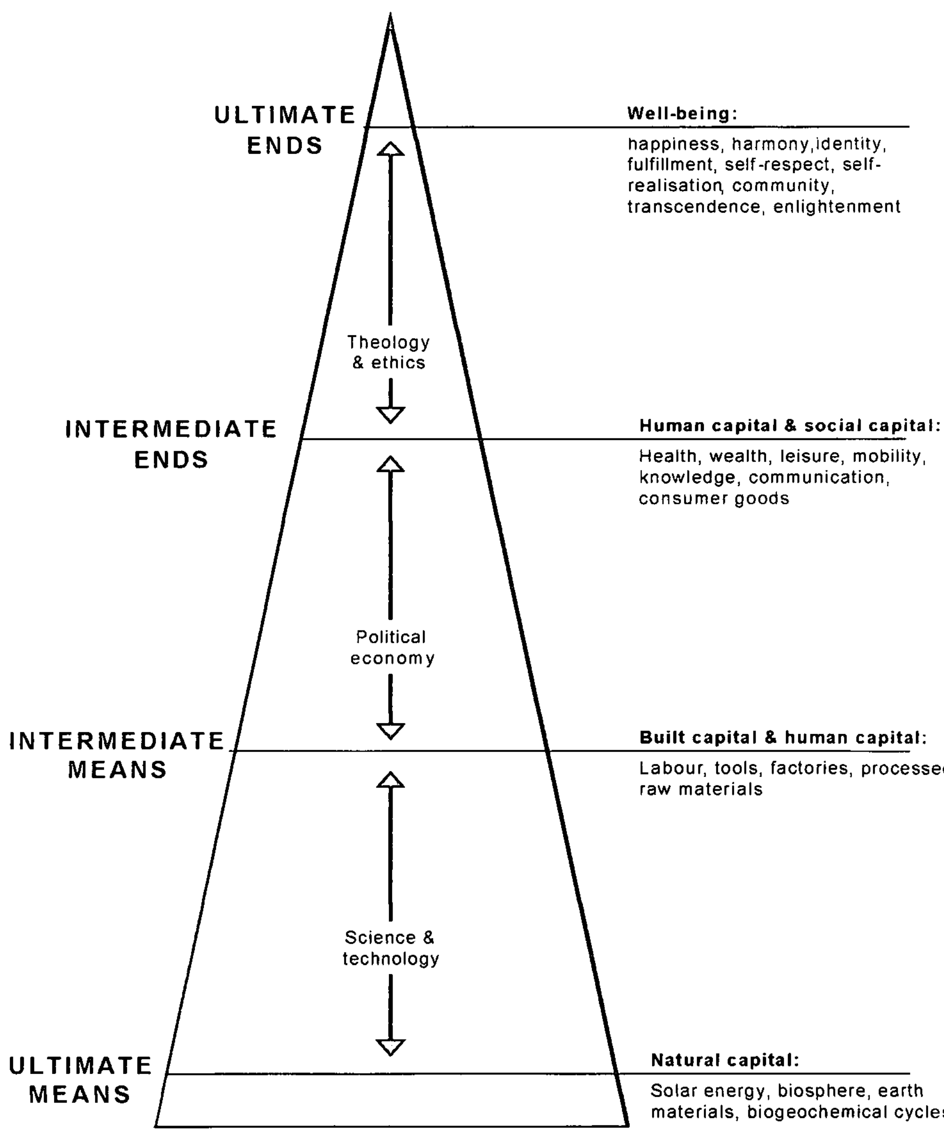

Figure 3.5: Daly's continuum (adapted from Meadows, 1998).

The details of these four aspects are outlined by Meadows (1998) as follows:

- ***Ultimate means*** are the elements upon which all life and economic transactions are built and sustained. This is the natural capital (the matter of the planet, the sun's energy, biochemical cycles, ecosystems and genetic information).
- ***Intermediate means*** are built capital, human capital and raw material (e.g. tools, machines, factories, skilled labour, processed material and energy) that have been developed through science and technology from ultimate means. These intermediate means define the productive capacity of the economy, and are referred to by economists as input.
- ***Intermediate ends*** are the goals that governments promise and economies are expected to deliver (e.g. consumer goods, health, wealth, knowledge, leisure, communication, transportation), and are referred to by economists as output. They are what everyone wants, but do not guarantee satisfaction.
- ***Ultimate ends*** are desired for themselves and are not means to achieving other goals. They are the fulfilment of all needs and include nebulous concepts such as happiness, harmony, fulfilment, self respect etc.

3.5.2 Orientors

The orientation theory on which the orientor framework is based, was developed in the 1970s to understand the divergent interests and visions for the future of various stakeholders in the environmental field, and to define criteria and indicators for sustainable development (Bossel, 1977). Orientors, which form the basis of the framework, are defined by Bossel (1999) as the *'important interests that orient most of our decisions and actions, directly or indirectly'*. If basic orientors can be identified for environmental systems, then all aspects of system viability should be covered.

Bossel (1999) has identified seven basic orientors that can be used to define sustainability indicators, including environmental indicators. They include:

- ***Existence*** – The system must be compatible with and able to exist in the normal environmental state. The information, energy and material inputs necessary to sustain the system must be available.
- ***Effectiveness*** – The system should, over the long term, be effective in its efforts to secure scarce resources (information, matter, energy) and then exert influence on its environment.
- ***Freedom of action*** – The system must have the ability to cope in various ways with the challenges posed by environmental variety.
- ***Security*** – The system must be able to protect itself from the detrimental effects of environmental variability; i.e. variable, fluctuating and unpredictable conditions outside the normal environmental state.
- ***Adaptability*** – the system should be able to evolve, adapt and self-organise to generate more appropriate responses to challenges posed by environmental change.
- ***Co-existence*** – The system must be able to modify its behaviour to account for behaviour and interests of other systems in its environment.
- ***Psychological needs*** – In the case where sentient beings are part of the system, they have psychological needs that should be met.

The method of developing indicators using this framework is not explicit, although Table 3.1 presents the questions that should be asked to develop environmental indicators for each sub-system. The types of indicators that might emerge from using this system are provided (Table 3.1) to give a more clear indication of the framework's effectiveness. There are no records of this framework being used to develop indicators for any specific country or organisation.

Table 3.1: Scheme for identifying indicators of sustainability using orientors (from Bossel, 1999).

BASIC ORIENTOR	VIABILITY OF & CONTRIBUTION TO AFFECTING THE SYSTEM	INDICATOR EXAMPLES
Existence	Is the system compatible with and can it exist in its particular environment? Does the system contribute its part to the existence of the affected system?	Grain surplus factor World fish catch
Effectiveness	Is it effective and efficient? Does it contribute to the efficient and effective operation of the total system?	Gross world product per person Grain yield efficiency
Freedom of action	Does it have the necessary freedom to respond and react as needed? Does it contribute to the freedom of action of the total system?	Energy productivity in industrial nations Water use as a share of total runoff
Security	Is it secure, safe and stable? Does it contribute to the security, safety and stability of the total system?	World grain carryover stock Economic losses from weather disasters
Adaptability	Can it adapt to new challenges? Does it contribute to the flexibility and adaptability of the total system?	Persons per TV set Carbon emissions
Co-existence	Is it compatible with interacting sub-systems? Does it contribute to the compatability of the total system with its partner systems?	Recycled content of US steel
Psychological needs	Is it compatible with psychological needs and culture? Does it contribute to the psychological well-being of people?	Chesapeake oyster catch

3.6 FRAMEWORK COMPARISON

All the frameworks described above have both positive and negative aspects that need to be taken into account when choosing the most appropriate framework for indicator development (Table 3.2). However, the frameworks presented here are not necessarily mutually exclusive. A combination of frameworks can be used to develop a set of indicators that meet the requirements of the organisation or country that is developing them. In essence, a framework is a means to develop indicators that fulfil their purpose, and a tool for reporting on the findings.

Table 3.2: Comparison of reviewed sustainability frameworks, identifying positive and negative characteristics of each framework.

FRAMEWORK	POSITIVE ASPECTS	NEGATIVE ASPECTS
	PHYSICAL FRAMEWORKS	
PSR	Ensures integration of indicators in a specific theme (Walmsley & Pretorius, 1996) Promotes a cause-effect-response logic to policy-setting and environmental management theme (Walmsley & Pretorius, 1996) Provides information on key interactions between nature and society (Pintér *et al.*, 2000) Can be used in conjunction with other frameworks	Neglects the systemic and dynamic nature of environmental processes (Bossel, 1999) Does not necessarily include all aspects of sustainability
DPSIR and PSIR	Describes the relationships between the origins and consequences of environmental problems (Smeets and Wetering, 1999) Provides a systems analysis based on a cause and response logic Identifies dynamic links between elements in an environmental system Includes social and economic elements into the analysis, thus readily analysing all aspects of sustainability Ease of identification of key indicators Can be used in conjunction with other frameworks	Difficult to identify indicators in each category of the DPSIR causal chain Can become highly complex
	ISSUE-BASED FRAMEWORKS	
Thematic frameworks	Identify key areas of concern All aspects of sustainability can be included Can be used in conjunction with other frameworks Ensures stakeholder and expert input	Difficulty in deciding on themes Difficulty in addressing cross-cutting issues
Impact-probability	Has practical application Focuses attention on priority areas Good environmental management tool Stakeholder and expert input is ensured	Excellent for identifying key performance indicators (Walmsley *et al.*, 1999) Does not necessarily ensure sustainability
	ECONOMIC FRAMEWORKS	
Capital-based	Deals with all aspects of sustainability Can be used in conjunction with other frameworks	Tends to favour "weak sustainability" (Zinn, 2000) Not holistic

FRAMEWORK	POSITIVE ASPECTS	NEGATIVE ASPECTS
	SOCIETAL FRAMEWORKS	
Daly's Triangle	Theoretically elegant way of measuring human fulfilment Organises links between aspects of development (Meadows, 1998) Lends itself to dynamic modelling (Meadows, 1998) Can be used in conjunction with other frameworks	Anthropocentric (Meadows, 1998) Based on an economic model that was developed before the concept of sustainability was introduced. Too hierarchical (Meadows, 1998)
Orientors	Systematic and takes into account the dynamic nature of environmental processes	Application is vague

3.7 USE OF FRAMEWORKS IN SOUTH AFRICA

South Africa has not yet developed a cohesive sustainable development strategy, although the DEA&T is currently in the process of doing so. Thus, State of the Environment reporting in this country has relied largely on other methods of identifying useful indicators. Indicators for the National State of the Environment Report were developed thematically, using the DPSIR framework to ensure that all elements of each theme were covered. A similar approach was taken for the cities State of the Environment. Although this approach was appropriate at the time, and ensured that linkages between the various elements of sustainability were achieved, it is necessary to re-evaluate this methodology.

The approach to developing environmental indicators for South Africa is outlined in Chapter 6 of this report. Throughout this process the Bellagio Principles (Box 3.1) should be kept in mind. Although the Bellagio Principles are not a framework as such, they provide guidelines for the implementation of sustainable development. These guidelines are valuable in the determination of environmental indicators and are useful to ensure that the vision of sustainable development is maintained throughout the process of indicator development.

BOX 3.1: BELLAGIO PRINCIPLES (Hardi & Zdan, 1997)

1. GUIDING VISION AND GOALS
   - be guided by a clear vision of sustainable development and goals that define that vision.

2. HOLISTIC PERSPECTIVE
   - include review of the whole system as well as its parts;
   - consider the well-being of social, ecological, and economic sub-systems, their state as well as the direction and rate of change of the state, of their component parts, and the interaction between parts;
   - consider both positive and negative consequences of human activity, in a way that reflects the costs and benefits for human and ecological systems, both in monetary and non-monetary terms.

3. ESSENTIAL ELEMENTS
   - consider equity and disparity within the current population and between present and future generations, dealing with such concerns as resource use, over- consumption and poverty, human rights, and access to services, as appropriate;
   - consider the ecological conditions on which life depends;
   - consider economic development and other, non-market activities that contribute to human/social well-being.

4. ADEQUATE SCOPE
   - adopt a time horizon long enough to capture both human and ecosystem time scales thus responding to needs of future generations as well as those current to short-term decision making;
   - define the space of study large enough to include not only local but also long distance impacts on people and ecosystems;
   - build on historic and current conditions to anticipate future conditions - where we want to go, where we could go;

5. PRACTICAL FOCUS
   - an explicit set of categories or an organizing framework that links vision and goals to indicators and assessment criteria;
   - a limited number of key issues for analysis;
   - a limited number of indicators or indicator combinations to provide a clearer signal of progress;
   - standardizing measurement wherever possible to permit comparison;
   - comparing indicator values to targets,-reference values, ranges, thresholds, or direction of trends, as appropriate;

6. OPENNESS
- make the methods and data that are used accessible to all;
- make explicit all judgements, assumptions, and uncertainties in data and interpretations.

7. EFFECTIVE COMMUNICATION
- be designed to address the needs of the audience and set of users;
- draw from indicators and other tools that are stimulating and serve to engage decision-makers;
- aim, from the outset, for simplicity in structure and use of clear and plain language.

8. BROAD PARTICIPATION
- obtain broad representation of key grass-roots, professional, technical and social groups, including youth, women, and indigenous people - to ensure recognition of diverse and changing values;
- ensure the participation of decision-makers to secure a firm link to adopted policies and resulting action.

9. ONGOING ASSESSMENT
- develop a capacity for repeated measurement to determine trends;
- be iterative, adaptive, and responsive to change and uncertainty because systems are complex and change frequently;
- adjust goals, frameworks, and indicators as new insights are gained;
- promote development of collective learning and feedback to decision-making.

10. INSTITUTIONAL CAPACITY
- clearly assigning responsibility and providing ongoing support in the decision-making process;
- providing institutional capacity for data collection, maintenance, and documentation;
- supporting development of local assessment capacity.

3.8 REFERENCES

Bakkes, J.A., Van den Born, G.J., Helder, J.C., Swart, R.J., Hope, O.W. and Parker, J.D.E., 1994. *An Overview of Environmental Indicators: State of the Art and Perspectives.* UNEP, Nairobi. 73pp.

Bossel, H., 1977. *Concepts and Tools of Computer-Assisted Policy Analysis.* Birkhäuser, Basel.

Bossel, H., 1999. *Indicators for Sustainable Development: Theory, Method and Applications. A Report to the Balaton Group.* IISD, Winnipeg. 123 pp.

Carlsson Reich, M. and Åhman M., 2000. *Survey of Sustainability Indicator Projects. Framkom, Stockholm.* 97 pp.

Daly, H.E., 1973. *Towards a Steady-State Economy.* W. Freeman & Co., San Francisco.

Division for Sustainable Development, 2001. *Indicators of Sustainable Development: Framework and Methodologies. Background Paper No.* 3. UN Department of Economic and Social Affairs.

European Environment Agency, 2000. *Environmental Signals 2000.* EEA, Copenhagen. 109 pp.

Friend, A. and Rapport, D., 1979. *Towards a Comprehensive framework for Environmental Statistics: A Stress-Response Approach.* Statistics Canada, Ottawa.

Gouzee, N., Mazijn, B. and Billharz, S., 1995. *Indicators of Sustainable Development for Decision-Making.* Federal Planning Office of Belgium, Brussels. 34pp.

Hardi, P. and Zdan, T., 1997. *Assessing Sustainable Development: Principles in Practice.* IISD, Winnipeg.

Manitoba Environment, 1997. *State of the Environment Report for Manitoba: Moving towards sustainable development*. Manitoba Environment, Winnipeg.

Meadows, D., 1998. *Indicators and Information Systems for Sustainable Development . A Report to the Balaton Group.* The Sustainability Institute, Hartland Four Corners. 78 pp.

Obst, C., 2000. Report of the September, 1999 OECD expert workshop on the measurement of sustainable development. In: Organisation for Economic Co-operation and Development, 2000.

Frameworks to Measure Sustainable Development. OECD, Paris. pp. 7-17.

Organisation for Economic Co-operation and Development, 1995. *Background Paper to the OECD Workshop: Sustainable Consumption and Production: Clarifying the Concepts, Rosendal, Norway, 2-4 July, 1995.* OECD, Paris.

Organisation for Economic Co-operation and Development, 2000. *Frameworks to Measure Sustainable Development.* OECD, Paris. 164 pp.

Pintér, I., Zahedi, K. and Cressman, D.R., 2000. *Capacity Building for Integrated Environmental Assessment and Reporting. Training Manual.* IISD, Winnipeg and UNEP,Nairobi. 142 pp.

Smeets, E. and Weterings, R., 1999. *Environmental Indicators: Typology and Overview. Technical Report No. 25.* European Environment Agency, Copenhagen., 19 pp.

UNEP/GRID-Arendal, 2001. UNEP/*GRID-Arendal SOE Reports.* http://www.grida.no/soe.

Walmsley R.D. and Pretorius, J.R., 1996. *Environmental Indicators. State of the Environment Series, Document No. 1.* DEA&T, Pretoria. 76 pp.

Walmsley, R.D., Rambalie, K. and Nelson, P., 1999. *A Scan and Discussion Document: Sustainable Development and the Environmental Performance of Eskom.* Eskom, Johannesburg. 59 pp.

Zinn, E., 2000. *Sustainable Development Indicators for Urban Water Systems.* MSc Thesis for Chalmers University of Technology, Götenborg, Sweden. 58 pp.

Indicators of sustainable development for catchment management in South Africa - Review of indicators from around the world

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Abstract

Indicators are the ideal means by which progress towards sustainable development can be measured. However, most indicator initiatives throughout the world have been aimed at state-of-the-environment reporting, with relatively few aimed at developing sectoral indicators. This paper provides the results of a review to establish trends in the development of indicators that assist in integrated water resource management. Twenty-one organisations from around the world were approached with regard to whether they had developed indicators of sustainable development for catchment management. Of these, only five organisations had developed, or were in the process of developing, indicator sets that were available for review. These included the Fraser Basin Council (Canada), the Murray-Darling Basin Commission (Australia), the Tennessee Valley Authority (USA), the United States Environmental Protection Agency and the World Resources Institute. All of these indicator sets were developed using an issues-based approach. Each indicator set was unique, reflecting the policy, both national and organisational, upon which it had been based. An analysis of these five indicator sets revealed that the most important themes that required information for water resource management at a catchment level, were *biodiversity and ecosystem integrity, land-use change, water quality, waste production, water availability* and *resource use*. Common indicators included population growth; community involvement; water availability; water use; water quality trends; soil contamination; non-compliance; species at risk; key species assessment; change in vegetation; agricultural impact; access to recreational opportunities; and ecosystem health. The identification of these themes and common indicators will be useful for the development of indicators for catchment management in South Africa. More importantly, policy frameworks and the physical characteristics of catchment systems in the country need to be taken into account. Additionally, it is recognised that no effective indicator set can be developed without the input of stakeholders.

Introduction

Sound water resource management is one of the key components of sustainable development as advocated by Agenda 21 (Chapter 18). In the last 10 years, governments throughout the world have reviewed their policies so as to achieve sustainability of water resources. In particular, the South African government has introduced the National Water Act (No. 36 of 1998), which will effectively dictate water resource policy and practice for at least the next 10 years. A core feature of this Act is the introduction of catchment management agencies that will be responsible for integrated water resource management of specific catchments. Catchment management strategies are to be developed for each catchment in South Africa to ensure that the water resources are utilised in a sustainable manner. Additionally, the Act (Chapter 14) requires that the Government establish a national monitoring and information system for water resources as soon as possible. This system should provide for the collection of appropriate data to assess the quantity, quality, use and rehabilitation of water resources at catchment and national levels, as well as compliance with resource quality objectives, health of aquatic ecosystems and atmospheric conditions that may impact on water resources.

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Indicators are the ideal means by which progress towards a goal, in this case integrated water resource management, can be monitored. Indicators provide a summary of conditions, rather like temperature and blood pressure are used to measure human health. They have been used for many years by economists to explain economic trends, a typical example being Gross National Product, but have only fairly recently been introduced to determine the sustainability of environmental systems as required by Agenda 21 (e.g. OECD, 1993; MacGillivray, 1994; Gouzee et al., 1995; Hammond et al., 1995; Trzyna, 1995; World Bank, 1995; Bakkes et al., 1994; Moldan and Billharz, 1997).

Most indicator initiatives have been aimed at providing information at a national level for state-of-the-environment reporting (e.g. Ward, 1990; OECD, 1991; ANZECC, 1998; GRID-Arendal, 2000) or for answering specific policy questions at national and international levels (e.g. UNEP and WHO, 1988; FAO, 1992; Eeronheimo et al., 1997). Few initiatives have been aimed at developing sectoral indicators, although some attempt has been made to develop sectoral indicators for agriculture, forestry, transport and energy (Obst, 2000). In South Africa, indicators are currently being developed for national state-of-the-environment reporting (CSIR et al., 2001) and for forestry (NFAC, 2001). It is uncertain to what extent an attempt has been made to develop indicators for catchment or water basin management, either within South Africa or internationally. This paper provides the results of a review to establish what progress has been made towards development of indicators that assist in catchment management. The focus is on the approach taken by various organisations throughout the world; the indicator sets developed by them, and the lessons that can be learnt from these for the development of sustainability indicators for catchments.

Methodology

A literature and internet search was conducted to identify organisations around the world that might be involved in catchment management directly, or which might have addressed the problem of information management at a catchment or watershed level. Four types of organisations were identified:

- **Catchment management agencies** (CMAs), which were directly involved in catchment management and had an official mandate to manage the water resources of the catchment areas for which they were responsible. These were identified through recognition of the catchment areas for which they were responsible (i.e. Tennessee River; Vaal River; Murray-Darling River).
- **Non-governmental organisations and international basin commissions**, which were associated with specific catchment areas, but did not have an official mandate to manage any of the catchment areas. In most cases, they were advisory bodies that were established to provide insight into catchment management issues. As with the CMAs, they were identified through recognition of the catchment areas for which they were responsible (e.g. Rhine River; Fraser River; Danube River).
- **Government agencies and departments**, which were *not* related to specific catchment areas, but which had an interest in catchment management as part of their mandate or complementary to their mandate. For example, the CSIRO had a research responsibility as part of its Sustainable Catchment Management Program, the UK Environment Agency had a responsibility to the environment, including river basins and the South African Department of Water Affairs and Forestry (DWAF) had a legal responsibility to ensure sustainable catchment management.
- **International organisations**, which were involved in the management of the environment and natural resources, including water.

Although it was recognised that these organisations were at different levels of governance, they all had an interest in managing catchments sustainably. Because catchments can be defined by similar characteristics (watersheds defining the boundaries, four-dimensional nature etc.; Wells, 1992), it was accepted that there was a basis for comparison. Additionally, water resource management is not only based on management objectives, but is largely dependent on the condition of the catchment, which can be assessed using sustainability indicators.

In all, 21 organisations were approached with regard to whether they had developed indicators of sustainable development for catchment management (5 CMAs; 6 NGOs and international basin commissions; 7 government agencies and departments, and 3 international organisations). A contact person was identified for each organisation and requested to provide information on any programme or programmes to develop indicators for catchment management, including:

- The policy requirements and mandate of the organisation
- The process followed to develop indicator sets
- Lists of indicators that might depict catchment health; catchment management; condition of water resources in the catchment, and sustainability of catchment systems.

The information provided by the response organisations was reviewed and indicator sets were compared to each other. Common indicators were identified, and the differences between indicator sets were established. The different approaches to the establishment of indicators were noted and commented upon where possible. Lessons to be learnt for development of catchment management indicators in South Africa were extracted and commented upon.

Results

Of the 21 organisations approached, 18 replied. Of these, 12 (67%) had not developed a set of indicators for catchment management, and 6 (33%) had either developed a set or were in the process of developing a set (Table 1). The organisations for which indicators were available for review, included:

- Fraser Basin Council, Canada
- Murray-Darling Basin Commission, Australia
- Tennessee Valley Authority, USA
- US Environmental Protection Agency
- World Resources Institute.

Each of these and their approaches to developing indicators are described briefly below.

Fraser Basin Council

The Fraser River Basin in Canada covers a quarter of British Columbia's land mass, with an area of 240 000 km^2. The river itself is 1 375 km long from the headwaters to the mouth and is the fifth longest in Canada. It supports two-thirds of the province's population and accounts for 80% of its Gross Geographic Product. The economy of the Basin has historically been dependent on the natural resource base with fishing, forestry, mining, and hydro-electric development being important activities. In addition, the Basin supports a diverse agricultural sector.

The Fraser Basin Council is a non-governmental, not-for-profit organisation. It was established in 1997 as the successor to the Fraser Basin Management Program, an intergovernmental co-ordination program that focused on the sustainability of the Fraser River Basin between 1992 and 1997. The Council is guided by a 36-person Board of Directors that represent all four orders of Canadian governance (i.e. federal, provincial, local government and First Nations), as well as non-government and private sector interests. The work of the Council is carried out by co-ordinators in each of the five regions of the Basin.

The mandate of the Council is to enable individuals, organisations and governments of the Fraser Basin to work together to advance the sustainability of the Basin. The Council's work is guided by its Charter for Sustainability, with its vision that states: "*the Basin is a place where social well-being is supported by a vibrant economy and sustained by a healthy environment*" (Fraser Basin Council, 1997). The Charter contains 26 goals related to social, economic, environmental and institutional systems in the Basin. The goals are organised under four directions or themes: understanding sustainability; caring for ecosystems; strengthening communities and improving decision-making.

The constitution of the Council requires that it report to the residents of the Fraser Basin at regular intervals on the progress

TABLE 1
Organisations approached for information and summary of results

Organisation	Catchment or watershed	Reply	Indicators developed
Catchment management agencies			
Colorado River Commission	Colorado River, United States of America	Yes	None
Murray Darling Basin Commission	Murray-Darling River, Australia	Yes	Yes
Rand Water	Vaal Barrage Catchment, South Africa	Yes	Yes, but not publicly available
Ruhrverband	Ruhr River, Germany	Yes	None
Tennessee Valley Authority	Tennessee River, USA	Yes	Yes
NGOs and international commissions			
Advisory Committee for the St Lawrence Vision 2000	St Lawrence River	Yes	None
Fraser Basin Council	Fraser River, Canada	Yes	Draft
Georgia Basin Conservation Authority	Georgia Basin, Canada	Yes	see Fraser Basin Council
Grand River Conservation Authority	Grand River, Canada	Yes	None
International Commission for the Protection of the Danube	Danube River, Europe	Yes	None
International Commission for the Protection of the Rhine	Rhine River, Europe	Yes	None
Government agencies and departments			
Bureau of Reclamation, USA		Yes	None
Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia		No	-
Department of Water Affairs and Forestry, South Africa		Yes	None
Rijksinstituut voor Integraal Zoetwaterbeheer en Afvalwaterbehandeling (RIZA), Netherlands		Yes	None
UK Environment Agency		Yes	None
US Environmental Protection Agency		Yes	Yes
Washington State Water Resources Association		Yes	None
International organisations			
IUCN		No	-
UNEP		No	-
World Resources Institute		Yes	Yes

towards sustainability. The use of sustainability indicators was recognised as an important tool to accomplish this. The Council is currently in the process of identifying a set of sustainability indicators and has, thus far, developed a draft set of 40 indicators using the Council's Charter for Sustainability (Fraser Basin Council, 1997) as a framework.

The indicators chosen are goal-oriented towards the 26 goals of the Charter under the four directions specified by the Charter. A discussion document in the form of a workbook (Fraser Basin Council, 2000) has been developed. This will form the basis of a participatory process (including workshops and an on-line indicators questionnaire) to refine and further develop the indicators presented in the workbook. The indicators available for evaluation at this stage are still a preliminary set, which will be refined by the middle of 2001. For the purpose of the evaluation, the draft indicators will be used.

Murray-Darling Basin Commission

The Murray-Darling River system drains about 14% of the Australian continent, covering a catchment area of 1 061 469 km^2 (Crabb, 1997). It is a highly-utilised basin, with about 81% of the divertible water having been developed (Commonwealth of Australia, 1996). The Murray-Darling Basin Commission (MDBC) was established in 1988 and is responsible for co-ordinating the efforts of the governments (Commonwealth, New South Wales, Victoria, South Australia and Queensland) and communities involved in the management of the Basin.

As part of its mandate to manage the natural resources of the Murray-Darling system, the MDBC has developed the Basin Sustainability Plan (BSP; prior to 2001 this was entitled the Basin Sustainability Program), the aim of which is "*to promote and co-ordinate effective planning and management for the equitable, efficient and sustainable use of the water, land and other environmental resources of the Murray-Darling*" (MDBC, 2000a). The BSP is largely administered through three programmes:

- Riverine Environment Management
- Irrigated Regions Management
- Dryland Regions Management.

The BSP also has four key result areas:

- Water quality
- Sustainable agricultural production
- Nature conservation
- Cultural heritage (introduced in late 1999).

Each programme is required to address specific objectives within each key result area. In addition, the BSP has a set of direction-setting objectives that are shared by all programs. These relate to: government and community capacity development, community empowerment, and development of co-ordinating frameworks.

In 1998, the Commission attempted to develop a set of indicators for assessing progress towards the BSP objectives. Given the multi-jurisdictional nature of the administration of the Murray-Darling Basin, it was essential that data sets in each jurisdiction were sufficiently compatible (or capable of being made so) to generate basin-wide indicators.

An initial set of 130 indicators generated by the Commission, was reduced to 30 (MDBC, 1999). These were tested to evaluate their efficacy, the cost of generating data, and the administrative requirements to align existing data sets in the six jurisdictions. Of the 30, only 16 were recommended for use in the Basin and, of these, only 5 were suitable for rapid implementation due to the general lack of compatible basin-wide data sets. The majority of the 16 indicators recommended dealt with the quality, state and use of aquifers and surface water. The evaluation of indicators in this paper included all 30 indicators tested by the MDBC.

The Commission is now working towards implementing a goal-oriented framework within which indicators will be developed further. In particular, the partners of the MDBC are in the process of agreeing to a new Integrated Catchment Management (ICM) Framework (MDBC, 2000b). When finalised and approved by the partner governments this framework will commit all stakeholders in the Basin to:

- developing a range of basin-wide strategies regarding the management of salinity, water quality, water sharing, riverine ecosystem heath, and terrestrial biodiversity;
- establishing and further developing the capacities of Catchment Management Organisations across the Basin;
- strengthening links between land-use planning legislation and processes and catchment planning and management;
- establishing a range of basin-wide and catchment-level targets, initially these will be for water quality, water sharing, terrestrial biodiversity and river ecosystem health; and
- developing a set of core indicators of catchment health to complement the targets as a means of assessing progress and directing investments and effort to achieve major benefits for the Basin.

In terms of indicators, the development of this ICM Framework represents a shift from previous attempts to utilise only pre-existing data sets and interpretive models such as Pressure-State-Response (PSR) framework. Instead, the ICM Framework will:

- identify the data and indicators needed for catchment management, investment targeting, and accountability purposes, and
- provide the structure for the development of basin-wide and regional-level reporting processes.

Tennessee Valley Authority

The Tennessee River in the Eastern United States is the 5th largest river in the country, and the Tennessee River Valley covers an area of about 103 600 km^2 within seven states. The Tennessee Valley Authority (TVA), created by the US Congress in 1933 to manage the system, has three main goals:

- supplying low-cost, reliable power to the nearly eight million people living in the region;
- stimulating economic growth, and
- supporting a thriving river system.

As part of the environmental stewardship of the river, the TVA has established a citizen advisory council (the Regional Resource Stewardship Council) as well as twelve Watershed Teams whose aim is to improve watershed conditions in the Tennessee Valley.

The TVA has established a set of core performance indicators for each of the three main goals mentioned above, including "supporting a thriving river system", as part of the Strategic Plan for 2000 to 2005 (TVA, 2000). The indicators supporting this goal provide the basis for catchment management within the Tennessee River. The main objectives within the thriving river system goal are to minimise flood damage, maintain navigation, support power production, improve water quality, protect public health, protect the environment and support recreational uses.

Within this Strategic Plan, the TVA has developed a set of indicators that primarily deal with watershed condition in terms of water quality. The approach that they have taken is twofold:

- A Watershed Condition Index is used to assess the overall water quality conditions as an outcome measure. It is based on four physical elements: i.e. reservoir ecological health; stream ecological health; water quality assessments, and reservoir shoreline vegetation condition.
- A planning framework used by the Watershed Teams is aimed at meeting the outcome by focusing on four core stewardship areas of the TVA, i.e. shoreline management, water resource condition, public lands management, and stakeholder or customer interests. This framework allows for development project evaluation based on natural resource conditions (13 measures) and public interests (16 measures), which build toward overall watershed sustainability.

US Environmental Protection Agency

The EPA is a United States federal government organisation, which was established in 1970. Its mission is "the establishment and enforcement of environmental protection standards consistent with national environmental goals...The conduct of research on the adverse effects of pollution and on methods and equipment for controlling it; the gathering of information on pollution; and the use of this information in strengthening environmental protection programmes and recommending policy changes...assisting others, through grants, technical assistance and other means, in arresting pollution of the environment...assisting the Council on Environmental Quality in developing and recommending to the President new policies for the protection of the environment." (EPA, 2001).

The EPA has established a set of 12 national environmental goals, of which two are "safe drinking water" and "clean waters". To check progress towards the national goals, the EPA developed a series of milestones for each goal that set a 10-year target to be reached by 2005. In addition five objectives for meeting the goals have been set. These are: conserve and enhance public health; conserve and enhance ecosystems; support uses designated by the states and tribes in their water quality standards; conserve and improve ambient conditions, and prevent or reduce pollutant loadings and other stressors. In 1996 the EPA, in collaboration with other government organisations, developed a set of indicators to meet the goals, milestones and objectives of the organisation (EPA, 1996). Eighteen indicators were chosen. These were used as a basis for the current Index of Watershed Indicators (EPA, 2001)

Development of the Index of Watershed Indicators was aimed at providing a complete descriptive technique for characterising the condition and vulnerability of water resources at a catchment level; establishing a national baseline on the condition and vulnerability of aquatic resources, and making information readily available (EPA, 2001). The 15 indicators chosen to achieve these aims have been split into "condition indicators" (i.e. state indicators) and "vulnerability indicators" (pressure indicators). There is ongoing development of these indicators, especially with regard to policy and institutional indicators that will eventually be added to the set (EPA, 2001).

World Resources Institute

The World Resources Institute, established in 1982, is an environmental "think-tank" based in Washington DC. Its mission is "to move human society to live in ways that protect Earth's environment and its capacity to provide for the needs and aspirations of current and future generations" (WRI, 2001). Its goals are to reverse the rapid degradation of ecosystems; to halt the changes in the earth's climate; to catalyse the adoption of policies and practices that expand prosperity, while reducing the use of materials and generation of wastes, and to guarantee people's access to information and decisions regarding natural resources and the environment (WRI, 2001).

Within the information programme of the WRI, a set of 15 indicators have been developed that characterise catchments in terms of their ecological value, current condition and vulnerability to potential degradation from human activities. The indicators have been developed as a preliminary set to provide information about major watersheds on a global scale. The set of 15 indicators incorporates 23 data sets that measure catchment characteristics and human activities that potentially affect rivers and lakes. The global data sets include such variables as land use, land cover, aridity, forest extent and loss, erosion, endemic bird species distributions, population density, and protected areas. Additional statistical databases on surface water runoff, location of major dams, and fish species diversity, were included when they could be georeferenced or linked to major rivers or lakes. The WRI has also recently completed additional indicators on the condition of the world's freshwater systems, where condition is defined as the current and future capacity of the systems to continue providing the full range of goods and services needed or valued by humans (Revenga et al., 2000).

Comparison of indicator sets

A direct comparison was made of the catchment indicators developed by each organisation (see Appendix A). Although the governance level of the organisations differs, the level of information required is the same (i.e. catchment level). The authors believe that the differences between the organisations make identification of the common issues for which indicators need to be developed all the more important, whilst the differences are less relevant. Thus, this analysis concentrates on the similarities rather than the differences.

The indicators were split into five water management themes: socio-economic, water balance, waste and pollution, resource condition, and policy and management (Walmsley, 2000). Within each of these categories, the indicators were split into categories, which were felt best reflected their aim. The categories that were represented in the five indicator sets under review included:

Socio-economic

- Population and demographics, which includes population growth and demographic changes within catchments, and can include birth and mortality rates, gender ratios and race ratios.
- Education of the catchment population, which includes levels of education and literacy.
- Employment, including sectoral and regional changes in employment and the job market.
- Community development, which includes issues such as community participation, charitable works, as well as crime rates.
- Economic development, which includes economic growth within the catchment, strategies for development, energy consumption and transportation.

Water balance

- Water availability, which is the amount of water available for use from surface and ground water sources. It includes climate as well as forms of hydrological modification and storage systems;
- Water use, is the sectoral and regional use of water, which includes abstraction of water as well as exporting of water from the basin.

Waste and pollution

- Waste production, which is the amount of waste produced within the catchment area. In this case it includes waste that enters waste treatment plants and landfill sites, as well as polluted runoff. It also includes compliance with pollution and water quality standards.
- Water quality, which is the condition of the water in terms of the possible chemical and physical pollutants that enter it.

Resource condition

- Biodiversity and ecosystem integrity, which includes aquatic ecosystem and species diversity, as well as changes in habitat and aquatic ecosystem health.
- Land use change, which includes changes to the terrestrial ecosystems which may impact on the catchment water resources.

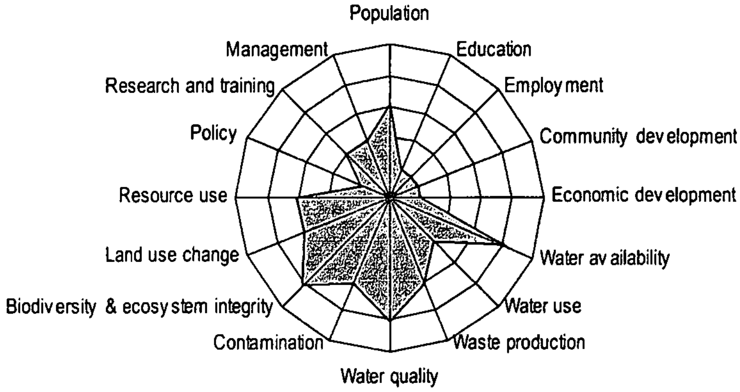

Figure 1
Number of organisations (0-5) that had indicators within each category

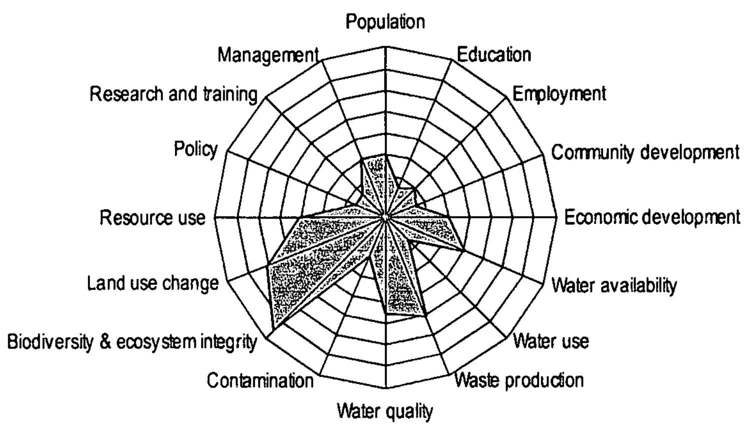

Figure 2
Number of indicators (0-16) within each category

- Resource use, which is the consumptive and non-consumptive use of resources that rely on aquatic systems for their continued existence. Consumptive uses include the harvesting of reeds, fish etc., whilst non-consumptive uses include shipping and recreation.

Policy and management

- Policy, which provides legislated and non-legislated guidelines for management, as well as determining the interaction among various political entities.
- Management, which determines the day-to-day running of the catchment within the policy framework.
- Research and training, which provides the knowledge on which further management steps will be taken.

Using these categories, it was possible to compare the indicator sets at three levels:

- number of organisations that had developed at least one indicator in each category (Fig. 1);
- total number of indicators that had been developed by the five organisations in each category (Fig. 2); and
- identification of common indicators (Table 2).

Figure 1 shows that the most common categories, which were included in the indicator sets of the five organisations, were biodiversity and ecosystem integrity, water quality and water availability. These were followed by population, resource use, land-use change, contamination and waste production, which were included in three of the sets.

A similar pattern was observed with the number of indicators per category (Fig. 2), with biodiversity and ecosystem integrity having the highest number of indicators (15), followed by land-use change (12), waste production (10), water quality (9), resource use (8) and water availability (8). Population, economic development, contamination and management had 6 indicators in each, whilst education, community development, research and training and water use had the fewest indicators (3).

The level of importance of each category can be assessed by summing the scores from the above two analyses to provide an index of importance (Fig. 3). Figure 3 shows that biodiversity and ecosystem integrity, land use change, water quality, waste production, water availability and resource use are common categories, and are valuable at all levels of governance.

Common indicators were also identified (Table 2). In each case, the indicator of one organisation did not have to be identical to a similar one in another organisation. However, if the sense behind the indicator was considered to be similar, it was assumed that there was commonality.

Discussion

From the response to the survey by the 21 organisations approached (see Table 1), it is apparent that not many had developed sets of indicators for catchment management purposes. This is unexpected as the need for integrated catchment and water resource management is recognised throughout the world (DWAF and WRC, 1996), and indicators are the ideal means by tracking changes in catchment conditions, and thus providing information for decision-making. There were a variety of reasons for this, including: the complexity of developing indicator sets for international catchments (e.g. Danube River; Helmut Fleckseder, Danube PCU, pers. comm.); the lack of resources, and the lack of understanding of the use of indicators in catchment water resource management. However, even the five sets of indicators that were available provided an indication of some of the issues that need to be taken cognisance of while developing indicator sets for catchment management, as discussed below.

Frameworks

Indicators need to meet the requirements of the physical system under inspection. For instance, the functional aspects of the Fraser River and Murray Darling differ considerably, and certain key physical characteristics need to be taken into account to ensure that these are represented. In the Fraser River this may mean understanding the ecological requirements of the sockeye salmon and the influence of the natural forests on the system, whilst in the Murray-Darling system salinity is a major problem that requires understanding. These should be reflected in the indicators chosen.

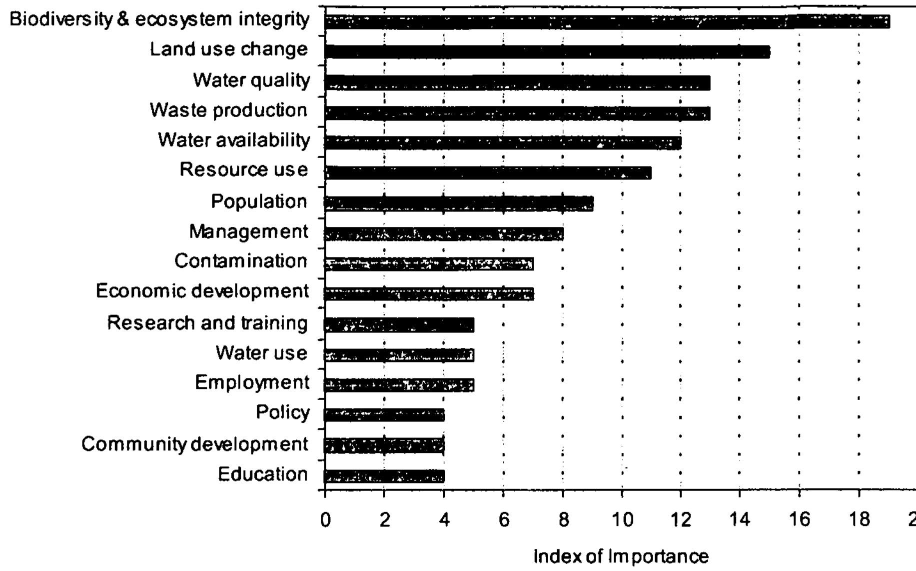

Figure 3
Index of importance for the various indicator categories

TABLE 2
List of indicators found in more than one indicator set

Socio-economic	Water balance	Waste and pollution	Resource condition	Policy and management
Population growth Community involvement	Water availability Water use	Water quality trends Soil contamination Non-compliance	Species at risk Key species assessment Change in vegetation Agricultural impact Access to recreational opportunities Ecosystem health	None

Therefore, a clear understanding of the physical environmental interactions and their socio-economic importance is required to develop a coherent set of indicators.

Walmsley (2002) has shown that one method of doing this is through the use of indicator frameworks such as the Pressure-State-Response (PSR) framework (Hammond et al., 1995; Gouzee et al., 1995) or the Driving-forces-Pressure-State-Impact-Response (DPSIR) framework (Smeets and Weterings, 1999). Both the PSR and DPSIR frameworks have been used extensively in the development of state-of-the-environment reports (DEAT, 1999). These physical frameworks tend to be used most often for identification of environmental indicators, and deal more specifically with natural environmental issues and the influence of humans on the environment.

More recently, issues-based frameworks have been used to identify indicators. These frameworks, as their name suggests, are based on the identification of strategic issues that will influence the sustainability of a system (country, province, region, catchment, etc.). They rest upon the premise that not all issues are equally important at any given time. Thus, they are dynamic and will change over time as the priority issues are dealt with and other issues emerge.

Of the five indicator sets under review, the only one for which there was an obvious framework for development was the Fraser Basin set. These were developed from the Council's Sustainability Charter, which caters for all sustainability issues in the basin. It provides an adequate framework for a set of sustainability indicators. The lack of an obvious framework in the other sets of indicators may stem from the indicators being developed primarily from a needs analysis, leading to issue-based indicators.

The use of one framework, does not preclude the use of another. It is recommended for South Africa that the physical and issues-based frameworks used in conjunction with each other to develop indicators that not only take into account the characteristics of the physical system, but also concentrate on current or emerging issues that will affect the future sustainability of any catchment.

In terms of the physical requirements, Walmsley (2002) has developed a method for selecting indicators for catchment management using the DPSIR framework (see also Walmsley et al., 1999), which can readily be used for developing indicators in South Africa. The framework is useful to identify interactions between various elements of a catchment, and if core (or key) indicators are identified within each of the categories, most major catchment-based management issues will be covered.

The themes identified by Walmsley (2002) include:

- Driving forces
  - Natural conditions
  - Development and economic activity
- Pressures
  - Water supply
  - Water demand
  - Waste and pollution

- State
  - Water quantity
  - Water quality
- Impacts
  - Ecosystem Integrity
  - Use value
- Responses
  - Policy and management, including institutional arrangements.

TABLE 3
Key themes and common indicators within these themes

Theme	Indicator
Biodiversity and ecosystem integrity	Species at risk Key species assessment
Waste production	Amount of waste produced Compliance levels
Water quality	Water quality trends
Water balance	Amount available Water use
Resource use	Access to recreational opportunities
Land-use change	Change in vegetation Agricultural impact
Terrestrial ecosystem condition	Soil contamination Ecosystem health
Social issues	Population change Community involvement

Themes and indicators

The indicator sets evaluated in this paper were different from each other. However, there were several recurring themes and indicators (see Figs. 1 to 3; Table 2). These give an indication of the common problems with regard to sustainability of water resources, and some of the key issues that need to be addressed for adequate catchment management. If the common themes are combined with the common indicators (Table 3), certain key issues emerge that should be considered for inclusion in a catchment sustainability indicator set for South Africa. These include:

- The destruction of ecosystem integrity, which may lead to biodiversity and habitat loss. These can be assessed through monitoring of high-risk species and key species or community assessments.
- Waste production, which is recognised as a major problem in both developing and developed countries. It leads to pollution of the environment and a deterioration in water quality.
- Water quality problems derived from excess pollutants entering freshwater systems. In South Africa these may include eutrophication, salinisation, microbiological deterioration, toxic pollutants and sedimentation.
- Resource use, in particular, access to the resource for recreational purposes, although in South Africa harvesting of the resources may be as important.
- Terrestrial ecosystem condition, which will have an impact on the water resource of the catchment.
- Population growth, which has far-reaching repercussions in terms of development requirements, resource use and sustainability of a system.

All of the themes and indicators presented in Table 3 can be applied to the South African situation, and could provide a basis against which to assess a South African indicator set.

Policy requirements of indicator sets

One of the reasons for the differences in indicator sets in general is that they are a reflection of policy, both national and organisational, upon which they have been based. In this instance:

- The Fraser Basin indicators focus on the need for sustainability, and are the best reflection of Integrated Catchment Management in the true sense of the term.
- The MDBC indicators reflect a policy of integrated water resource management and are based primarily on the management of the water resources, rather than the integration of all resources.
- The TVA indicators reflect mainly the anthropocentric needs.
- The US EPA indicators reflect their mandate to concentrate primarily on pollution control and management, rather than integrated catchment management.

One of the essential requirements of developing catchment indicators for South Africa is to ensure that they reflect the water resources and environment policies of the country. South Africa has recently undergone major transition in terms of both the water and environmental law in the country. The new legislation is underpinned by the concept of sustainability and any indicators based on the legislation could provide information on the progress towards environmental sustainability within the catchment context.

Key environmental legislation in South Africa includes the National Water Act (No 36 of 1998) and the National Environmental Management Act (No 107 of 1998). Other legislation and policy that may influence the choice of indicators will be: the National Forests Act (No 84 of 1998); the Marine Living Resources Act (No 18 of 1998); the White Paper on Integrated Pollution and Waste Management (March 2000); the White Paper on Minerals and Mining Policy (October 1998), and the White Paper on the Conservation and Sustainable Use of South Africa's Biological Diversity Policy (July 1997)

In particular, the National Water Act (No 36 of 1998) highlights certain issues for which indicators would need to be developed, including:

- Scarce and uneven distribution of natural water resources (water use and allocation; provision of water for basic human and ecosystem requirements; supply and demand management; meeting international requirements).
- Deteriorating water quality (pollution prevention; waste management).
- Deteriorating water resource and ecosystem quality (attaining resource quality objectives; atmospheric conditions).
- Increase in natural catastrophic events (floods and droughts).

Stakeholder involvement

A common thread to all the indicator sets was the participation of stakeholders (who influence or will be affected by management of the catchment) in their development. Although expert opinion is required to develop a set of indicators, the core indicators that are finally decided upon, should meet the requirements of stakeholders in the catchment. Obviously indicator sets cannot meet all the needs of all the stakeholders, but an attempt should be made to include the requirements of stakeholders in general. In South Africa, structures have been set up in many catchments for the involvement of stakeholders. Catchment Management Forums have either been set up, or are being set up for most of the highly-developed and sensitive catchments (e.g. Upper Olifants River, Mpumalanga and Palmiet, Western Cape). Likewise, management of the water resources of South Africa at catchment level has been delegated to regional offices of DWAF. Stakeholders who should be approached with regard to the development of indicators for sustainable catchment management include DWAF regional offices; water service providers such as Umgeni Water and Rand Water; local authorities; catchment management agencies and water forums.

Data availability

One of the issues that arose in the development of the indicator sets under review is that the development of indicator sets is often limited by data availability, and indicators are selected for data availability rather than for validity. The WRI indicator set, for instance, was largely based on the amount of data available world-wide, and is limited by some fairly gross-scale indicators. If, however, a core indicator set is developed that takes into account the physical system as well as the policy and management goals, the collection of data should be important enough that monitoring programmes be put in place. The selection of indicators should not rely on data availability, but should be guided by what is available, or what can be collected within reasonable cost, effort and timeframe.

Conclusion

From the review of international initiatives to develop sustainability indicators for catchment management, it is apparent that each situation is unique, and that no two indicator sets will be alike. It is possible to identify some broad criteria for the development of sustainability indicators for catchments in South Africa:

- Indicators should be relevant in terms of the current policy and management issues that affect catchment sustainability.
- Indicators should reflect the physical characteristics of catchments and the human influences on these (i.e. integrated water resource management).
- The selection of indicators should not rely on data availability, but should be guided by what is available, or what can be collected within reasonable cost, effort and timeframe.
- The indicator set developed should be useful for major stakeholders involved in catchment management, such as DWAF, catchment management agencies, local authorities and service providers.

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References

AUSTRALIAN AND NEW ZEALAND ENVIRONMENT AND CONSERVATION COUNCIL (ANZECC) (1998) Core Environmental Indicators for Reporting on the State of the Environment: Discussion Paper for Public Comment. ANZECC, Canberra. 63 pp.

BAKKES JA, VAN DEN BORN GJ, HELDER JC, SWART RJ, HOPE CW and PARKER JDE (1994) *An Overview of Environmental Indicators: State of the Art and Perspectives*. Environmental Assessment Sub-Programme, Nairobi. 73 pp.

COMMONWEALTH OF AUSTRALIA (1996) *Australia State of the Environment.* CSIRO Publishing, Collingwood.

CSIR, HSRC and MZURI CONSULTANTS (2001) *Development of a Core Set of Indicators for the Purpose of Reporting on the State of the Environment at National and State Levels. Scoping Document.* Department of Environmental Affairs and Tourism, Pretoria.

CRABB P (1997) *Murray-Darling Basin Resources: Murray-Darling Basin by Numbers.* MDBC, Canberra.

DEPARTMENT OF ENVIRONMENTAL AFFAIRS AND TOURISM (DEAT) (1999) *State of the Environment South Africa.* DEAT, Pretoria.

DEPARTMENT OF WATER AFFAIRS AND FORESTRY (DWAF) and WATER RESEARCH COMMISSION (WRC) (1996) The Philosophy and Practice of Integrated Catchment Management: Implications for Water Resource Management in South Africa. WRC Report No TT 81/96.

EERONHEIMO O, AHTI A and SAHLBERG S (1997) *Criteria and Indicators for Sustainable Forest Management in Finland.* Ministry of Agriculture and Forestry, Helsinki. 70 pp.

ENVIRONMENTAL PROTECTION AGENCY (EPA) (1996) *Environmental Indicators of Water Quality in the United States.* EPA, Washington DC. 25 pp.

ENVIRONMENTAL PROTECTION AGENCY (EPA) (2001) *United States Environmental Protection Agency* (www.epa.gov.).

FOOD AND AGRICULTURE ORGANISATION (FAO) (1992) *Yearbook Fishery Statistics.* FAO, Rome.

FRASER BASIN COUNCIL (1997) *Fraser Basin Council Charter for Sustainability.* Fraser Basin Council, Vancouver, BC.

FRASER BASIN COUNCIL (2000) *Fraser Basin Council Sustainability Indicators Workbook.* Fraser Basin Council, Vancouver, BC. 45 pp.

GOUZEE N, MAZIJN B and BILLHARZ S (1995) *Indicators of Sustainable Development for Decision-Making.* Federal Planning Office of Belgium, Brussels. 34 pp.

GRID-ARENDAL (2001) GRID-Arendal State of the Environment Reports (www.grida.no/soe.).

HAMMOND A, ADRIAANSE A, RODENBURG E, BRYANT D and WOODWARD R (1995) *Environmental Indicators: A Systematic Approach to Measuring and Reporting on Environmental Policy Performance in the Context of Sustainable Development.* World Resources Institute, Washington. 42 pp.

MACGILLIVRAY A (1994) *Environmental Measures: Indicators for the UK Environment.* Royal Society for the Protection of Birds, Bedfordshire, UK. 107 pp.

MOLDAN B and BILLHARZ S (eds.) (1997) *Sustainability Indicators: A Report on the Project on Indicators of Sustainability.* John Wiley and Sons, New York. 415 pp.

MURRAY-DARLING BASIN COMMISSION (MDBC) (1999) Performance Indicators for the Murray-Darling Basin Sustainability Program: Final Project Report. Murray-Darling Basin Commission, Canberra.

MURRAY-DARLING BASIN COMMISSION (MDBC) (2000a) The Basin sustainability program. In: *Basin Sustainability Program Reporting Guidelines Kit, August 2000.* Murray-Darling Basin Commission, Canberra.

MURRAY-DARLING BASIN COMMISSION (MDBC) (2000b) *Integrated Catchment Management in the Murray-Darling Basin, 2001-2010: Delivering sustainable development.* Murray-Darling Basin Commission, Canberra.

OBST C (2000) Report of the September 1999 OECD Expert Workshop on the measurement of sustainable development. In: Organisation for Economic Co-operation and Develoment: *Framework to Measure Sustainable Development.* OECD, Paris. 7-17.

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT (OECD) (1991) *The State of the Environment.* OECD, Paris.

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT (OECD) (1993) *Environmental Indicators: Basic Concepts and Terminology.* Background Paper No 1 OECD, Paris. 150 pp.

REVENGA C, BRUNNER J, HENNINGER N, KASSEM K and PAYNE R (2000) *Pilot Analysis of Global Ecosystems: Freshwater Systems.* World Resources Institute, Washington, DC. 83 pp.

SMEETS E and WETERINGS R (1999). Environmental Indicators: Typology and Overview. Technical Report No 25. European Environmental Agency, Copenhagen. 19 pp.

TENNESSEE VALLEY AUTHORITY (TVA) (2000) *Government Performance and Results Act (GPRA): Strategic Plan FY 2000-2005.* Tennessee Valley Authority, Chattanooga. 27 pp.

TRZYNA TC (ed.) (1995) *A Sustainable World.* IUCN, The World Conservation Union. 272 pp.

UNITED NATIONS ENVIRONMENT PROGRAMME (UNEP) and WORLD HEALTH ORGANISATION (WHO) (1988) *Assessment of Urban Air Quality Worldwide.* UNEP, Nairobi, Geneva.

WELLS J (1992) Pre-Impoundment Study of the Biological Diversity of the Benthic Macro-Invertebrate Fauna of the Sabie-Sand River System. M.Sc. Thesis, Univ. of Cape Town. 207 pp.

WALMSLEY JJ, WALMSLEY RD and SILBERBAUER M (1999) Chapter 3: Freshwater systems. In: *State of the Environment South Africa.* DEAT, Pretoria.

WALMSLEY JJ (2000) *Catchment Diagnostic Framework. Development of the Catchment Diagnostic Index.* Rand Water, Johannesburg.

WALMSLEY JJ (2002) Framework for measuring sustainable development in catchment systems. *Environ. Manage.* **29.**

WARD CJ (1990) Environment Indicators for State of the Environment Reporting. Information Paper No 21, Centre for Resource Management, Canterbury, New Zealand.

WORLD BANK (1995) *Monitoring Environmental Progress.* The World Bank, Washington DC. 84 pp.

WORLD RESOURCES INSTITUTE (WRI) (2001) *World Resources Institute* (www/wri.org.).

APPENDIX A
List of indicators from the five response organisations, categorised according to five themes and further split into categories under each theme

	Fraser Basin Council (Draft Indicators)	Murray Darling Basin Commission (R) = Recommended	Tennessee Valley Authority	US Environmental Protection Agency	World Resources Institute
Socio-economic					
Population	Population outside growth concentration area Mortality rates Legislator's reflection of population			Population change	Urban population growth Population density
Education	Newspaper circulation Connection to internet Levels of education				
Employment	Income rates Employment inside and outside growth concentration area Aboriginal employment rates Jobs by sector				
Community development	Membership in voluntary or community organisations Charitable donations Crime rates				
Economic development	Investment in public assets Economic diversity index Adoption of regional growth strategy Public transit ridership Vehicle ownership per household Total and alternate energy consumption				

Water balance					
Water availability		Area underlain by shallow water tables, and areas where water tables are rising (R)	Flood storage availability Discretionary zone attainment	Hydrologic modification - dams	Primary watersheds Water availability Aridity Existing and proposed major dams
Water use	Per capita water use	Average water diversion from the Basin (R) Ratio of water extracted to water available, including groundwater			
Waste & pollution					
Waste production	Waste diverted from landfills Greenhouse gas emissions Rate of non-compliance in mining industry Exceedance of acceptable PM10 levels	Number of waste treatment plants with tertiary treatments and nutrient removal, together with the volume of waste-water released to inland waters (R) Reduction in phosphorus loads discharged from sewage treatment plants and other point sources		Urban runoff potential Index of agricultural runoff potential Pollutant loads discharged above permitted discharge limits - toxic pollutants Pollutant loads discharged above permitted discharge limits - conventional pollutants	
Water quality	Water quality trends	Salinity and nitrate levels in groundwater (R) Salinity levels in surface water (R) Estimated concentrations of phosphorus and nitrogen in surface waters (R)	Watershed water quality Dissolved oxygen deficit due to forced outages	Ambient water quality - four conventional pollutants Indicators of source water quality for drinking water systems Ambient water quality data - four toxic pollutants	
Contamination	Contaminants in great blue heron eggs Contaminated and remediated mine sites	Area of land that is reported to have saline soils with top meter, in regions of Australia of >250mm annual rainfall ®		Contaminated sediments	
Resource condition					
Biodiversity & ecosystem integrity	Total run size and spawning escapement of Fraser River sockeye Status of salmonids Percentage of known species at risk	Macroinvertebrate assemblages in rivers assessed by AUSRivAS sampling protocols & computer models (R) Conservation status known for species, ecological communities and ecological processes Change in abundance of selected threatened or high profile species or communities Length of stream (or riparian zone) protected, rehabilitated and/or re stored through NHT funded projects (R) Percentage of total stream length with riparian vegetation per drainage division		Aquatic/wetland species at risk Estuarine Pollution Susceptibility Index Wetland Loss Index	Freshwater fish species and endemism Endemic bird areas Area affected by water erosion Protected areas
Land-use change	Composition of forest lands (i.e. age and species distribution) Farm practices (i.e. soil conservation practices and pesticide usage)	Area of remnant vegetation protected and managed by a) areas of formal reserves, b) areas under management or conservation agreements Area of native vegetation by type Difference between regional crop water requirements and water application			Remaining original forest cover Extent of original forest cover lost Tropical deforestation Cropland irrigation Modified landscape (cropland and developed areas)

		Area [of cleared agricultural land] revegetated, in ha/pa, disaggregated into areas revegetated using local vegetation and other (R) Average real Net Farm Income (R)			
Resource use	Outdoor recreation opportunities: area of parkland Number of park user days		Summer reservoir level attainment (recreational use) Days naviagable waterway is available from Knoxville to Paducah Shipper savings Minimum flow achievement (for aeration)	Assessed rivers meeting all designated uses established by state or tribal water quality standards Fish and wildlife consumption advisories	
Ecosystem condition					
Policy & management					
Policy	Number of interim agreements with first nations Number of First Nations in the British Columbia Treaty Consultation process Voter turnout				
Research & training	Reviews regarding access to information	Number of participants in property management plan courses Extent of participation in training and landcare (R)			
Management		Percentage adoption of more efficient irrigation techniques (BMPs) (R) Number of participants in water trading and volume of water traded (R) Number of waterways for which environmental flow provisions have been established, and the number where provisions are being met Removal or modification of structures impeding fish migration and flows for fish movement, and improvement in operating strategies (R) Percentage of resource managers using agreed best practice by resource sector and/or catchment if relevant.	Completed comprehensive reservoir land plans		

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Framework for Measuring Sustainable Development in Catchment Systems

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ABSTRACT / Integrated catchment management represents an approach to managing the resources of a catchment by integrating environmental, economic, and social issues. It is aimed at deriving sustainable benefits for future generations, while protecting natural resources, particularly water, and minimizing possible adverse social, economic, and environmental consequences. Indicators of sustainable development, which summarize information for use in decision-making, are invaluable when trying to assess the diverse, interacting components of catchment processes and resource management actions. The Driving-Forces–Pressure–State–Impact–Response (DPSIR) indicator framework is useful for identifying and developing indicators of sustainable development for catchment management. Driving forces have been identified as the natural conditions occurring in a catchment and the level of development and economic activity. Pressures include the natural and anthropogenic supply of water, water demand, and water pollution. State indicators can be split into those of quantity and those of quality. Impacts include those that affect the ecosystems directly and those that impact the use value of the resource. It core indicators are identified within each of the categories given in the framework, most major catchment-based management issues can be evaluated. This framework is applied to identify key issues in catchment management in South Africa, and develop a set of indicators for evaluating catchments throughout the country.

The term "sustainable development" has become one of the most widely used expressions in the context of economy, environment, and development. It describes an intended vision for development that provides solutions to current and future social, economic, and environmental problems (e.g., poverty, disease, unemployment, violence, environmental pollution, and loss of biodiversity). In essence it is about "improving the quality of life while living within the carrying capacity of supporting ecosystems" (Monro and Holdgate 1991).

In order to manage natural resources in a sustainable manner, decision- and policy-makers need information. Sustainable development is accepted as a vision for managing the interaction between the environment and economic progress, but experts are still struggling with the practical problem of how to implement and measure it. More often than not, they are faced with an information dilemma. On the one hand, information and information sources are proliferating at an astounding rate. On the other hand, they seldom seem to have the specific information required for good decision-making and effective resource management (Walmsley and Pretorius 1996).

One method of overcoming this dilemma is through the use of sustainability indicators. Indicators provide a means of communicating information about progress towards a goal (such as sustainable resource management) in a significant and simplified manner (Hammond and others 1995). Indicators have been used for many years by economists to explain economic trends, a typical example being gross national product. More recently there have been efforts aimed at developing indicators that are suitable for measuring sustainable development. Those involved include, among others: the World Resources Institute (Hammond and others 1995), the World Conservation Union-IUCN (Trzyna 1995), the Belgian government (Gouzee and others 1995), the OECD (1993) and its member countries, UNEP (Bakkes and others 1994), the UN Commission on Sustainable Development (Moldan and Billharz 1997), the Environmental Challenge Group of the United Kingdom (MacGillivray 1994), the UK Local Government Management Board (1995), and the World Bank (1995).

Most of these indicator initiatives have been aimed at providing information at a national level that would be useful for international comparisons. Few initiatives have been aimed at developing sectoral indicators, although some attempt has been made to develop sectoral indicators for agriculture, transport, and energy (Obst 2000). Most of the sectoral indicators have arisen from state-of-the-environment reporting (e.g., Ward 1990, OECD 1991, ANZECC 1998) or national and international initiatives to answer specific policy ques-

KEY WORDS: Catchment management; Sustainability indicators; Indicator Framework; Water sector; South Africa

tions (e.g., UNEP and WHO 1988, FAO 1992, Eeronheimo and others 1997). In a recent international survey by Walmsley and others 2001), 19 organizations from around the world were approached with regards to whether they had developed indicators of sustainable development for catchment management. Of these, only five organisations had developed indicator sets, of which only one addressed the issue of sustainability comprehensively. There is, thus, a recognized need for an understanding of how indicators can be used and developed in the catchment context.

This paper addresses the usefulness of sustainability indicators in the water sector, particularly with regard to catchment management. It highlights the characteristics of catchments that need to be taken into account when developing a set of indicators and presents a framework for developing a set of core indicators for catchment management information systems. A case study of the situation in South Africa is presented as a guide to using the framework in other countries.

Sustainability Indicators and Frameworks

Indicators of Sustainable Development

Agenda 21 (Chapter 40) states that "indicators of sustainable development need to be developed to provide solid bases for decision-making at all levels and to contribute to the self-regulating sustainability of integrated environmental and development systems". This has led to the acceptance of sustainability indicators as basic tools for facilitating public choices and supporting policy implementation (Von Meyer 2000). They provide information on relevant issues; identify development-potential problems and perspectives; analyze and interpret potential conflicts and synergies, and assist in assessing policy implementation and impacts (Von Meyer 2000). In essence, they allow us to better organize, synthesize, and use information. The main goal of establishing indicators is to measure, monitor, and report on progress towards sustainability.

Indicators have numerous uses and potential for improving environmental management. Some of these include (Hammond and others 1995, Walmsley and Pretorius 1996):

- Monitor and assess conditions and trends on a national, regional and global scale;
- Compare situations;
- Assess the effectiveness of policy-making;
- Mark progress against a stated benchmark;
- Monitor changes in public attitude and behaviour;
- Ensure understanding, participation and transparency in information transfer between interested and affected parties;
- Forecast and project trends;
- Provide early warning information.

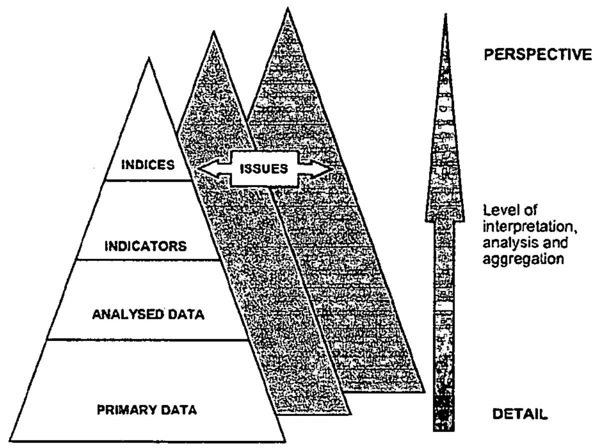

Figure 1. Information pyramid (adapted from Walmsley and Pretorius 1996).

Even though indicators are often presented in statistical or graphical form, they are distinct from statistics or primary data (Hammond and others 1995). Indicators, which may include highly aggregated indices, top an information pyramid, whose base is primary data derived from monitoring and data analysis (Figure 1).

Indicators should have three essential qualities. They should be "simple, quantifiable and communicable" (Walmsley and Pretorius 1996). The following criteria, as proposed by the OECD (1993), provide a useful guide to the selection of appropriate indicators.

With respect to policy relevance and utility for users, an indicator should:

- provide a representative picture of environmental conditions, pressure on the environment or society's response;
- be simple, easy to interpret, and able to show trends over time;
- be responsive to changes in the environment and related human activities;
- provide a basis for comparisons;
- be either national in scope or applicable to issues of national significance (e.g., catchment management); and
- have a target or threshold against which to compare it so that users are able to assess the significance of the values associated with it.

With respect to analytical soundness an indicator should:

- be theoretically well founded in technical and scientific terms;
- be based on international standards and consensus about its validity; and
- lend itself to be linked to economic models, forecasting and information systems.

With respect to measurability, the data required to support the indicators should be:

- readily available or made available at a reasonable cost;
- adequately documented and of known quality; and
- updated at regular intervals in accordance with reliable procedures.

Although the value of indicators to monitor progress towards sustainable development is widely accepted (OECD 1993), development of indicators has proved to be a daunting task. Many countries and international organizations have embarked upon projects involving research and consultation to develop indicators that are suitable for their own situations (Walmsley and Pretorius 1996). They have found that, to address the many issues and areas that pertain to sustainable development, frameworks are required to organise the indicators.

Frameworks for Sustainability Indicators

The use of frameworks is essential as they assist in developing and reporting on indicators in a logical fashion so that key issues can be readily identified and summarized. They suggest logical groupings of related sets of information and, thus, promote interpretation and integration. They can also help identify data collection needs and data gaps. Finally, indicator frameworks can help to spread the reporting burdens, by structuring the information collection, analysis, and reporting process across the many issues that pertain to sustainable development (Gouzee and others 1995, Walmsley and Pretorius 1996).

Two main types of framework are available, economic frameworks and physical environmental frameworks. The economic frameworks tend to favor "weak sustainability" (i.e., where manufactured capital can take the place of natural capital), while the physical environmental frameworks tend towards "strong sustainability," where spent natural capital cannot be replaced (Zinn 2000).

Economic frameworks. Several frameworks, based on the interaction between environmental, social, and economic elements have been developed, including frameworks such as the System of Integrated Environmental and Economic Accounting (SEEA); measures of wealth; and genuine savings (see OECD 2000). These economic frameworks are based on the concept of attempting to place a financial value on resources and assets. The basic framework on which all the others rest is that of the national system of accounts, which may be extended to include environmental resources and assets, and human and social capital (Obst 2000). However, the accuracy of any type of environmental accounting can be questioned, although the concept of including environmental considerations into the national accounting system is sound.

Physical environmental frameworks. Several frameworks have been developed to measure the interaction between humans and the environment. They are referred to here as "physical frameworks" as they tend to be systematic and are useful as a means of organizing and presenting physical data from various subject areas and sources (Alfieri 2000). The most commonly used of these frameworks are the Pressure–State–Response (PSR) framework developed by the OECD in the late 1980s (Walmsley and Pretorius 1996) and the Driving-Forces–Pressure–State–Impact–Response (DPSIR) framework, which is based on the PSR framework.

The PSR framework follows a cause–effect societal-response logic (Figure 2). Within the framework, the indicators are split into three categories:

- pressure indicators that measure the pressures that are exerted on resources and ecosystems from human activities (e.g., emissions, consumption, and utilization);
- state indicators that assess the condition of the resource or ecosystem as a result of the pressures, and
- response indicators that relate to the societal responses via policies, laws, programmes, research etc.

This framework was further developed by the United Nations into the DPSIR framework. There are two additional categories in this framework:

- driving forces, which are the human influences and activities that, when combined with environmental conditions, underpin environmental change; and
- impacts, which are the results of pressures on the current state.

Both the PSR and DPSIR frameworks have been used extensively in the development of state-of-the-en-

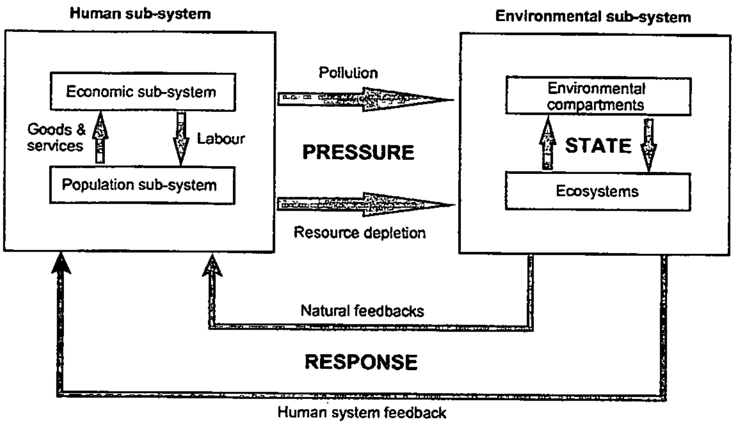

Figure 2. Representation of the pressure–state–response framework. Human activities and processes impact on the environment and exert pressure on it. Pressures can result in changes to the state of the environment. Measures of how society responds to these changes include institutional, legal, or financial measures or changes in management strategies and policy (Walmsley and Pretorius 1996).

vironment reports (DEAT 1999, UNEP 2000). These physical frameworks have tended to be used most often for identification of and reporting on environmental indicators, rather than the full spectrum of sustainability indicators. They deal more specifically with natural environmental issues and the influence of humans on the environment, rather than the economic aspects such as employment, empowerment, local needs, etc. However, if they are used in an innovative fashion, which includes economic aspects, they become valuable tools for assessing all aspect of sustainable development.

River Systems and Catchment Management

It is becoming increasingly apparent that the ability of nations and societies to develop and prosper is linked directly to their ability to develop, utilize, and protect their water resources (DWAF and WRC 1996). Water resources are the cornerstone of industrial development and agricultural production, as well as being useful in the transportation of goods, production of energy, and enhancement of the quality of life through recreational opportunities (DWAF and WRC 1996). Thus most economies rely on their river systems and underground water resources for their development.

A catchment, or drainage basin, is the total land area from which a river system receives its water, and the boundaries are demarcated by the points of highest altitude in the surrounding landscape (Hutchinson 1957, Reid and Wood 1981, DWAF and WRC 1996). A catchment encompasses the entire hydrological cycle, including atmospheric water (quantity, quality, and distribution of precipitation); subsurface water (soil moisture and groundwater reserves), surface water (rivers, lakes, wetlands, impoundments), the estuarine zone, and the coastal marine zone. DWAF and WRC (1996) define a catchment as a "living ecosystem" in which there is a large, interconnected web of land, water, vegetation, structural habitats, biota, and the many physical, chemical, and biological processes that link these. Minshall (1988) states that spatial and temporal dimensions provide the basis of river ecosystem structure. River systems, and thus catchment areas, have a four-dimensional structure, with changes occurring longitudinally, laterally, vertically, and with time (see Ward 1989). Superimposed upon this is the human system, which utilizes the water as an essential resource.

Integrated catchment management (ICM) represents an approach to managing the resources of a catchment by integrating all environmental, economic, and social issues within a catchment into an overall management philosophy, process, and plan (DWAF and WRC 1996). It is aimed at deriving the optimal mix of sustainable benefits for future generations, while protecting the natural resources, particularly water, and minimizing the possible adverse social, economic, and environmental consequences (DWAF and WRC 1996). In essence, it is managing for sustainable development at the catchment level, where water resources are viewed as the limiting factor.

One of the critical success factors for effective water resource and catchment management is the appropriate assessment of the diverse, interacting components of catchment processes, and the resource management actions that impact the water resources in a catchment (DWAF and WRC 1996). A systematic approach to this includes (DWAF and WRC 1996):

- Analysis of aspects of the catchment system that affect use and condition of the water resource;
- Assessment of the prevailing environmental, economic, and social values, together with the values arising from beneficial uses of the water resource

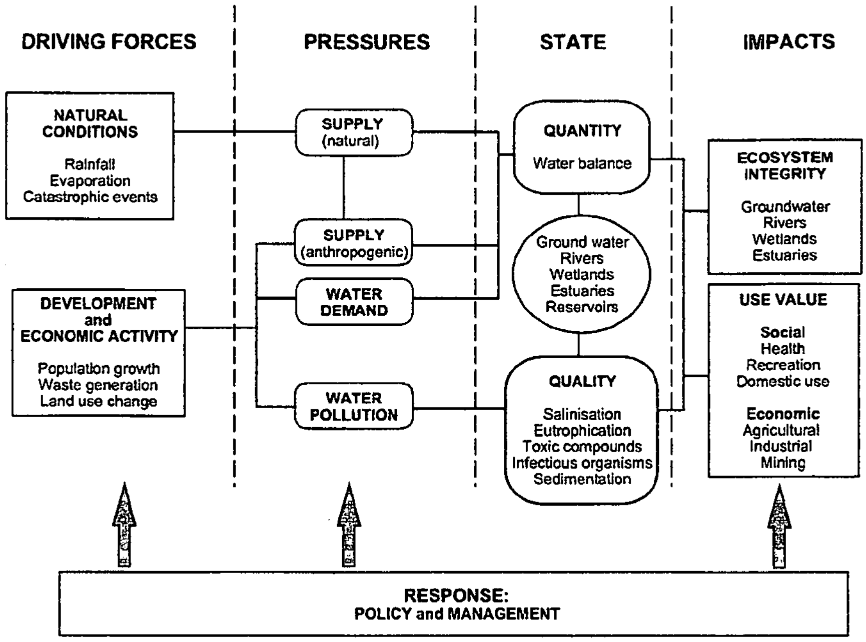

Figure 3. DPSIR linkage diagram showing functional interrelationships of water resource issues at a catchment level.

and the related impacts of management actions; and

- Monitoring of the environmental conditions and related socioeconomic factors.

This provides the basis for a management information system for catchments.

Indicators of sustainable development are invaluable when implementing this systems approach. A physical framework for identifying environmental indicators, such as the PSR or DPSIR frameworks, assists in the analysis of catchment systems; the indicators provide a method for assessing the current situation; and, once developed, the indicator system is ideal for both short- and long-term monitoring. The literature indicates that this approach has not yet been implemented in the catchment context.

Framework for Developing Indicators for Catchment Management

The DPSIR concept has been used here as a basis for a framework to identify and develop indicators for catchment management. The DPSIR framework identifies cause-and-effect relationships, allows for the separation of categories of issues, provides flexibility for usage and analysis, and provides a means by which monitoring can be systematically improved.

For development of catchment indicators, the DPSIR categories are defined as follows:

- Driving force indicators reflect pressures exerted by natural phenomena and anthropogenic activities that are not easily manipulated or managed within the catchment context, but provide essential information to understanding catchment processes;
- Pressure indicators measure the pressures that are exerted on the water resources of a catchment as a result of the driving forces (e.g., increased pollution from domestic waste due to increased population and poor sanitation; increased consumption due to increasing economic activity);
- State indicators assess the current status of the water resource, in terms of quantity and quality for each habitat/ecosystem type;
- Impact indicators assess the effect that a pressure has on the state of the water resource or on water-user groups;
- Response indicators relate to the social response via policies, laws, programes, research etc.

Within this framework a flow diagram was developed showing conceptual links and interrelationships between the DPSIR categories for a catchment-based situation (Figure 3). If core (or key) indicators for catchment management are identified within each of the categories present in the diagram, most major catchment-based management issues will be covered. Each of the elements within this causal diagram are discussed below.

Driving Forces

Natural conditions. The original definition of driving forces excluded natural phenomena, and only included human influence and activities. However, DEAT (1999) in the South African national state-of-the-environment report recommends that natural conditions be included as driving forces. Certainly, in the catchment context, driving forces in the form of climate, geology, and topography, etc., determine the underlying character of a catchment and its water resources. Without knowledge of these aspects, any anthropogenic impacts and changes cannot be monitored and managed. The natural conditions in a catchment can also be viewed as having a generally positive influence or exerting a positive pressure on the resource, while anthropogenic changes tend to be negative in character.

In the catchment context, the most important of these natural conditions is the climate, which directly affects the amount of water in the system. High precipitation and low evaporation ensures an abundance of water, while low precipitation and high evaporation will create arid conditions. Catastrophic events such as droughts and floods also have a major influence on the character of the catchment.

Development and economic activity. Over the last 50 years, the world has experienced an unprecedented growth in economic activity (Walmsley and Pretorius 1996), resulting in humans today using approximately 12,000 times more energy, mainly in the form of fossil fuels, than they did 400 generations ago (Munasinghe and Shearer 1995). For the purposes of developing indicators for catchment management, population growth, waste generation, and land-use change have been identified as the key consequences of development and economic growth within catchments. These, in turn, place pressures on the environment that have direct effects on the water resources.

Some people may argue that population growth is not a consequence of economic development, but a cause. However, most will agree that population growth and economic development are closely interrelated and both have a direct effect on the quantity and waste produced and on the type of land use that the catchment is experiencing.

Pressures

Natural supply. Like the driving forces, pressures on a resource can be either positive or negative. The natural supply of water to a catchment area is considered to be positive, although certain natural phenomena such as droughts and floods may have a negative effect on the quality of life of the human population in a catchment. From a natural environment point of view, the ecosystem is adapted to handle these fluctuations.

The natural supply of water in a catchment is provided by the precipitation on the catchment, which is stored as surface water in rivers lakes, reservoirs, wetlands, and estuaries, and as groundwater in aquifers. The quantity of the surface water available is reflected in the mean annual runoff (MAR), which is the amount of water that reaches the river after evaporation and soil absorption. In arid countries such as Australia and South Africa, this may be as little as about 10% (8.6% for South Africa and 9.8% for Australia) and rises to about 60% in wetter countries (e.g., Italy and Austria) (Allanson and others 1990).

Anthropogenic supply. In many countries in the world, the natural water supply in a catchment needs to be supplemented with water from outside. In most cases this is due to the development in a catchment outstripping the water resource availability. Importation of water takes different forms, the cheapest of which is interbasin transfer (IBT), where water is transferred via pipelines from one catchment to another (even one country to another). This has a negative effect on the water supply in one catchment, while fulfilling a need in another catchment. Other forms of water importation are desalinization of seawater and transportation of icebergs.

In determining indicators of anthropogenic supply, one must be careful of the syntactic difference between "availability" and "supply." The term "supply" is used specifically by hydrologists as the amount of water available for use and includes return flows. Although there is a fixed amount of water available in the catchment (availability = groundwater + MAR + IBTs), there is more available for use due to reuse of water in the form of return flows (supply = groundwater + MAR + IBTs + return flows). This can be confusing to the nonhydrologist and should be taken cognisance of when indicators are being developed.

Water demand. Water demand is the amount of water required by all water use sectors, including the mining, agriculture, industry, domestic, and environmental sectors. Previously the environment was not considered as a legitimate water user, but there is an international trend in recognizing the environment as a legitimate water user. In some countries (e.g., South Africa and Australia), water for the environment and drinking water are both considered basic needs and given priority in terms of water allocation. Sectoral water demand

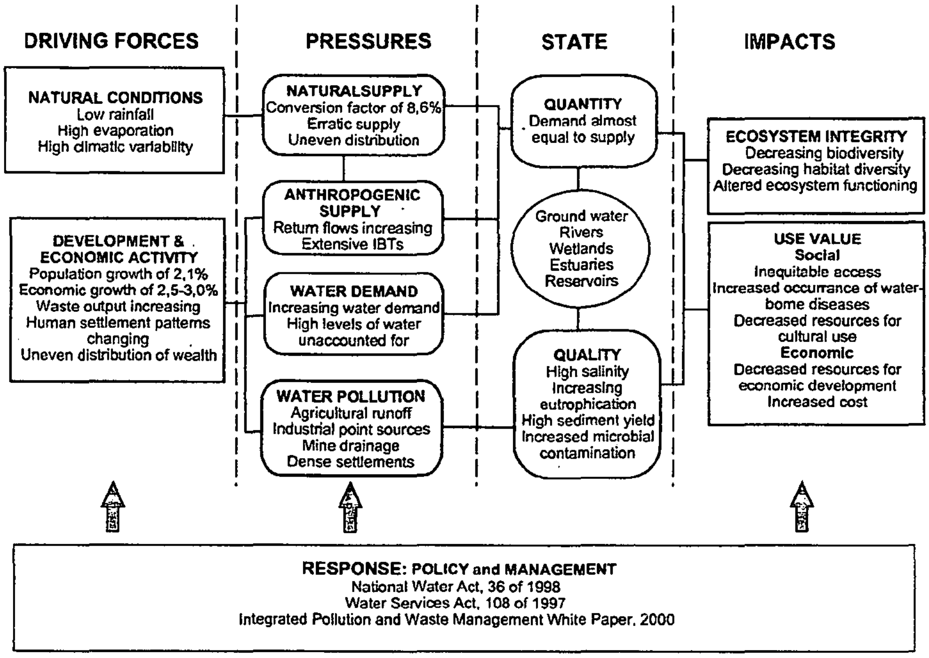

Figure 4. DPSIR linkage diagram for South Africa, showing key characteristics of South Africa's freshwater resources.

may be particularly important when considering policy development or catchment management issues.

As with the supply of water, both surface and groundwater demands should be taken into account. Some countries may rely heavily on their groundwater supplies, while others may rely on surface water resources. In both cases the demand for water needs to be seen in conjunction with supply to have any relevance.

Water pollution. Pollution is one of the greatest threats to water resources throughout the world. It is defined by Dallas and Day (1993) as "the presence of any foreign substance that impairs the usefulness of water." Freshwater pollutants originate mainly from industrial, mining, domestic, and agricultural sources. Those of greatest concern include organic and inorganic chemicals, plant nutrients, oxygen-demanding wastes, radioactive materials, sediment, and microbiological contaminants (DEAT 1996). The type and amount of pollution will vary from catchment to catchment, depending on the land-use and development patterns within each catchment. It is impossible to monitor all forms of pollution, and indicators will have to be chosen keeping in mind the dominant land use of a catchment.

State

The state of water resources in a catchment should be described in terms of both quantity and quality. Both the amount of water in the system and the quality of that water are essential in terms of ecosystem viability, as well as use value. It should be remembered that descriptions of "state" should provide information on the current status of a catchment. The three spatial dimensions of river systems need to be taken into account (longitudinal, vertical, and lateral), as well as short-term variations (i.e., seasonal changes).

Quantity. The state of a catchment's water resources is dependent on the right amount of water being available at the right time. All catchments undergo seasonal and long-term variations in water quantity. The natural system relies on these variations, to which they are adapted (including catastrophic events such as floods and droughts), to maintain ecosystem integrity. For instance, breeding seasons of the fauna are dependent on seasonal changes in the water level, while floods clear the system of weeds such as water hyacinth. On the other hand, humans prefer the system to be constant. To ensure sustainability, there should be a balance between the regulation of rivers and their natural flow regime.

All the ecosystems that make up the freshwater resources of a catchment need to be taken into account when describing water quantity. These include groundwater, rivers, wetlands, lakes, reservoirs and estuaries. Wetlands, estuaries, lakes, and reservoirs all form an important part of the whole river ecosystem, while the

Table 1. Indicators for catchment management in South Africa and their relevance to sustainable management of the country's water resources

Indicator	Importance/relevance
Driving forces	
Population density	A high or growing population can threaten the sustainability of water resources, particularly in South African catchments where freshwater resources are limited.
Urbanization	The number of people living in urban and rural environments has an impact on the infrastructure requirements, as well as waste management and pollution potential.
Proportion of households earning less than US$1000 per annum	Household earnings is an internationally accepted indicator of poverty. If a household in South Africa is earing less than US$1000 per annum, it suggests that the household is barely subsisting and lower order needs are the prime concern.
Gross geographic product per capita	Growth in the production of goods and services is a basic determinant of how the economy fares, as well as the level of development in a catchment. It measures income growth, and is an important indicator of consumption patters and the use of renewable resources.
Pressures	
Catchment population as a proportion of the maximum sustainable population	There is a certain minimum amount of water required for development, which can be expressed on a per capita basis (1000 m^3/yr, (Engelman and LeRoy 1993). If there is not enough water for the size of the population, development will not be possible and subsistence will predominate.
Population without access to piped water on site	Because of past imbalances, not all South Africans have access to water on site. This has implications for the control of water consumption in the catchment, as well as for future infrastructure development.
Population without access to toilet facilities	Not all South Africans have access to adequate sanitation facilities. This has implications for waste disposal and pollution potential in the catchment, as well as future infrastructure development.
Anthropogenic supply as a proportion of total available	In South Africa, there is a reliance in many catchments on importation of water from other catchments, or even downstream in the same catchment. If a catchment is too heavily reliant on water importation, the development of the catchment cannot be considered sustainable.
Reserve as a proportion of mean annual runoff	The National Water Act has legislated that a reserve shall be established for each catchment in South Africa. It consists of social requirements for essential use (minimum of 25 liters/day) and environmental requirements for the maintenance of the ecosystem. The higher the reserve requirement, the less water is available for development.
Total liquid waste discharged as a proportion of supply	Liquid waste generation depends on industrial and agricultural processes as well as the population size. The more liquid waste that is discharged into the system, the more pressure is exerted on the system to maintain itself.
Wastewater treated as a proportion of water care works' capacity	In South Africa, a single wastewater treatment plant will treat all effluents from domestic effluents through to industrial effluents. If the capacity of wastewater treatment plant is inadequate, this could provide a serious pollution threat to the resource.
State	
Total water available per capita	This is an internationally accepted basic indicator for water availability. It can be used at a catchment level and further split sectorally.
Demand as a proportion of supply	This indicator is a the core indicator of water balance. If demand is nearing supply, action with regard to water resource development is required. In many South African catchments, demand has exceeded supply and augmentation is required.
Proportion of groundwater utilized	In certain areas in the country, groundwater is a significant supply of water for domestic and agricultural use. If the demand for groundwater is higher than the safe yield, then groundwater usage will not be sustainable.
Proportion of boreholes contaminated	Groundwater supplies are particularly important in the more arid areas of the country. Good water quality is essential to development in these areas.
Reservoir water quality	Reservoirs are a reflection of what is occurring in the catchment. Particular water quality problems that pertain to South African catchments include salinization, eutrophication, microbiological contamination, toxic compounds and sedimentation. If receiving water quality objectives have been set, these can be compared to the ambient water quality.
Water quality at the downstream point	The downstream point is an indicator of the sum of all activities in the catchment. This indicator will complement water quality in reservoirs to provide an accurate picture of problem areas.
Reservoir capacity as a percentage of total water available	South Africa is a country prone to periodic droughts and floods. River regulation in the form of reservoirs mitigate against these catastrophic events, and this indicator shows the capacity for doing so. It could also be viewed as an indicator of the condition of the natural resource, where a highly regulated system would be viewed negatively.
Riparian zone with development	The riparian zone is the interface between freshwater and land systems. In the past, riparian land rights of landowners in South Africa have led to extensive degradation of the riparian zones of rivers, and irreparable damage to river ecosystems.
Impacts	
Biodiversity of wetland birds	Wetlands are some of the most endangered ecosystems in South Africa, with an estimated 50% of all South Africa's natural wetlands having been lost. The diversity of wetland birds, which require functioning wetland systems for their survival, is a good indication of the quality of wetlands in a catchment.
South African scoring system (SASS) for macroinvertebrate community health	SASS has been tested and is used widely in South Africa as a biological index of water quality. It rests on the basis that the structure of aquatic invertebrate communities is a sign of change in the overall river conditions and is a good indicator of river and habitat health.
Fish assemblage integrity index (FAII)	Fish, being relatively long-lived and mobile, are good indicators of long-term influences on rivers. The number of species, the size classes and health of fish give a good indication of river health.
Riparian vegetation index (RVI)	Healthy riparian zones maintain channel form and serve as filters for light nutrients and sediments. The status of riparian vegetation, including removal, cultivation, construction, inundation, erosion, sedimentation, and alien vegetation, gives an indication of the deviation from the natural, unmodified riparian conditions.
Index of habitat integrity (IHI)	Habitat availability and diversity are major determinants of aquatic community structure. The IHI is useful in assessing the impact of major disturbances on river reaches, including water abstraction, flow regulation, and bed and channel modification.

Table 1. (Continued)

Indicator	Importance/relevance
Recreational index for raw water	Poor water quality in catchments has related health risks. One of the important uses of water is for full- and partial-contact recreation. If water is too polluted for recreation, it will also be unacceptable for domestic use for informal settlements. It also has implications for access.
State of satisfaction of catchment population	Public opinion often influences the behavior of people. The level of cooperation of the community in water resource management and conservation depends, along with other factors, on their satisfaction with water management in their area.
Cost of water treatment	Water treatment costs rise with decreasing water quality. One of the major influences on water management decisions is the economic benefit of an action. If the cost of treating water exceeds the cost of pollution prevention activities, then pollution prevention will become the primary management thrust in a catchment
Responses	
Number of active hydrological monitoring stations per 100 km^2	Continual monitoring of water resources is important for immediate management. Rainfall in South Africa is irregular over many catchments, and constant surveillance is needed on the amount of water available in the catchment.
Number of water quality monitoring points per 100 km^2	Water quality information is important in the continual evaluation of pollution in a system and can be used as a warning system for spills.
Level of forum establishment in the catchment	Water forums have been established, or are being established, in many catchments in South Africa with the objective of allowing participative management in the catchment. They are viewed as essential to the successful establishment of CMAs. One of their primary roles is the establishment of receiving water quality objectives.
Establishment of catchment management agency	The National Water Act requires that CMAs are set up for all the major catchments in South Africa, within a reasonable time. If a CMA has been established, management in that area will be catchment specific.
Completion of catchment management plan	The National Water Act requires that each CMA develop a catchment management strategy for each catchment. The strategies must be in harmony with the national water strategy and should set the principles for allocating water taking into account the protection, use, development, conservation, management, and control of water resources in the catchment.

groundwater is continually replenished by surface waters. The balance between the availability of water and water removed from the system (supply and demand) will be crucial in the viability of these ecosystems. As with all the other categories, there are a large number of indicators that could describe the state of each ecosystem, and the choice will depend on the importance and character of the ecosystems within each catchment.

Water quality. The quality of water in a catchment obviously depends on the level and sources of pollution. The type of water quality problems will vary from catchment to catchment, but several generic problems have been identified (DEAT 1996):

- Salinization reduces crop yields, leads to salinization of irrigated soils, increases scaling and corrosion, and increases the need for pretreatment of water for industrial purposes. Sources include municipal, mining, and industrial effluents; irrigation return water; runoff from urban settlements; and seepage from waste disposal sites.
- Eutrophication causes taste and odor problems, limits recreational use, and can limit stock watering due to the presence of toxic algae. Sources of plant nutrients, which cause eutrophication, include agricultural and urban fertilizers, sewage, and effluent discharges.
- Sedimentation reduces the storage capacity of reservoirs, as well as affecting the ecological functioning of a system. Activities promoting erosion and increasing sedimentation include agriculture, forestry, construction activities, open-cast mining, and other disturbances of vegetation.
- Toxic inorganic compounds include heavy metals (e.g., mercury, lead, tin, cadmium), highly toxic elements (e.g., selenium, arsenic) and inorganic substances, such as acids, nitrates, and chlorine compounds, that become toxic in high concentrations. Sources include industrial processes such as metal finishing, mineral refining, plastics and chemical industries, and household solvents.
- Toxic organic compounds include pesticides, plastics, paints, colorants, pharmaceuticals, and many other products. Many are persistent and bioaccumulative toxins. The largest source of these is improper disposal of household and industrial waste.
- Infectious organisms, such as disease-causing microorganisms and parasites, are a major cause of health problems. Human settlements are the main source of these pollutants, which enter the water in the form of partially treated or untreated sewage, seepage from pit latrines, and runoff from settlements with inadequate sanitation and waste disposal facilities.
- Oxygen-demanding wastes, including sewage, paper and pulp effluent, and food-processing wastes, increase the oxygen consumption of bacteria and reduce the availability for other aquatic life.

Impact

Changes in water quality and quantity have two major impacts, one on the environmental subsystem, in the form of ecosystem integrity, and one on the human subsystem, in the form of use value.

Ecosystem integrity. Any anthropogenic changes to a natural ecosystem may have a negative impact on the balance of that ecosystem, i.e., it will affect the functional integrity of the system. This may take the form of invasion by alien species, increase in the numbers of pest species, decrease in biodiversity, and inability of the system to clean itself etc. In most of these cases, the result will have direct or indirect economic consequences. Once again, the type of environmental impact that is experienced will vary from catchment to catchment, depending on the sensitivity of the catchment and the level of disturbance.

Use value. If the resource is to be maintained for the purpose of human development on a sustainable basis, then the use value of the resource should not decline. Uses that need to be taken into account include social elements, such as health, recreation, and domestic use, and economic elements, such as agricultural, industrial (including power generation), and mining use.

The use value of a system is directly related to ecosystem integrity. If the ecosystem is not functioning properly, this will have a direct effect on use value. For instance, the introduction of plant nutrients will lead to eutrophication, which creates an imbalance in the system, causing algal blooms, which decrease the use value for industrial purposes that require clean water and for domestic use. In both cases, treatment costs will rise, negatively affecting the economic value of the water in the system. It may or may not be possible to pin a financial cost on a drop in use value.

Response

Responses in the context of the DPSIR framework generally apply to more long-term management actions, rather than emergency measures. They may include policy development in the form of international treaties, national and local legislation, and catchment management plans. A more indirect response may be the expansion of the knowledge base, in the form of research and monitoring.

Responses to a catchment problem may be applied anywhere in the causal chain outlined above. Generally, responses aim at adjusting anthropogenic pressures caused by development or by mitigating impacts. They are rarely able to make an impact on the driving forces.

South Africa: A Case Study

South Africa has introduced a new National Water Act (No. 36 of 1998) that will effectively dictate water resource policy and practice for at least the next ten years. A core feature of this act is the introduction of catchment management agencies (CMAs) that will be responsible for integrated water resource management of specific catchments. Catchment management strategies will be developed for each catchment in South Africa to ensure that the water resources are utilized in a sustainable manner. Additionally, the Act requires that the government establish a national monitoring and information system for water resources as soon as possible. This system should provide for the collection of appropriate data to assess the quantity, quality, use, and rehabilitation of water resources at catchment and national levels, as well as compliance with resource quality objectives, health of aquatic ecosystems and atmospheric conditions that may impact on water resources. With this in mind, the identification and use of effective indicators of sustainability for catchment management will be an important information management tool to assist in this aim.

Figure 4 summarizes the main characteristics of the South African water environment using the framework described in this paper. These core characteristics can be applied at any catchment level, from large basin catchments (such as the Orange and Vaal river basins), to quaternary catchments or hydrological units. In other words, it can be applied to any appropriate management unit.

From this, a set of key indicators has been developed by the author for South African catchments (Table 1). The main characteristics of these indicators are:

- They represent essential information that is required for catchment management in South Africa.
- They allow for comparisons to be made between catchments and over time.
- They are relatively simple and easy to understand, while remaining scientifically valid and analytically sound.
- They include all elements of sustainability, including social, economic and bio-physical aspects of catchment systems.
- The data are either readily available (e.g., water quality) or can be made available at a reasonable cost (e.g., state of satisfaction).

Conclusion

If carefully chosen, indicators of sustainable development can provide valuable information for catchment management. One of the main problems is limiting the vast array of indicators to those that are relevant, analytically sound, and measurable. Because the DPSIR framework is based on a cause-and-response logic, it lends itself to be used in identifying core indicators. Initially a comprehensive set of indicators can be identified using the framework described in this paper, and then these can be reduced to a set of core indicators that characterize a catchment using the minimum amount of information. For instance, it is easier collecting information on key water quality elements, than on waste production. Just by using key water quality parameters as part of the state of a catchment, the pollution pressures imposed on the catchment can be inferred.

The core indicators finally chosen will differ slightly depending on the catchment situation. The case study shows that indicators can be developed generically, in this case for catchment management in South Africa, but the framework also has relevance for developing indicators for a single catchment. In all cases, the framework presented here will ensure that the main management issues are covered for integrated water resource management in the catchment context.

Literature Cited

Alfieri, A. 2000. A framework to measure the interaction between the economy and the environment. Pages 29–37 *in* Organisation for Economic Co-operation and Development, Frameworks to Measure Sustainable Development. OECD, Paris.

Allanson, B. R., R. C. Hart, J. H. O'Keeffe, and RD Robarts. 1990. Inland waters of southern Africa: an ecological perspective. Kluwer Academic Publishers, Dordrecht, 457 pp.

ANZECC (Australian and New Zealand Environment and Conservation Council) 1998. Core environmental indicators for reporting on the state of the environment: Discussion paper for public comment. ANZECC, Canberra, 63 pp.

Bakkes, J. A., G. J. van den Born, J. C. Helder, R. J. Swart, C. W. Hope, and J. D. E. Parker. 1994. An overview of environmental indicators: state of the art and perspectives. UNEP, Environmental Assessment Sub-Programme, Nairobi, 73 pp.

Dallas, H. F., and J. A. Day. 1993. The effect of water quality variables on riverine ecosystems: a review. Water Research Commission, Pretoria, 240 pp.

DEAT (Department of Environmental Affairs and Tourism) 1996. Integrated pollution control and waste management: the need for integrated pollution control in South Africa. DEAT, Pretoria, 57 pp.

DEAT (Department of Environmental Affairs and Tourism). 1999. State of the environment South Africa. DEAT, Pretoria.

DWAF and WRC (Department of Water Affairs and Forestry and Water Research Commission). 1996. The philosophy and practice of integrated catchment management: implications for water resource management in South Africa. WRC Report No TT 81/96. WRC, Pretoria, 139 pp.

Eeronheimo, O., A. Ahti, and S. Sahlberg. 1997. Criteria and indicators for sustainable forest management in Finland. Minisury of Agriculture and Forestry, Helsinki, 70 pp.

Engelman, R., and P. LeRoy. 1993. Sustaining water: population and the future of renewable water supplies. Population Action International, Washington, DC, 55 pp.

FAC (Food and Agriculture Organisation). 1992. Yearbook fishery statistics. FAO, Rome.

Gouzee, N., B. Mazijn, and S. Billharz. 1995. Indicators of sustainable development for decision-making. Federal Planning Office of Belgium, Brussels, 34pp.

Hammond, A., A. Adriaanse, E. Rodenburg, D. Bryant, and R. Woodward. 1995. Environmental indicators: a systematic approach to measuring and reporting on environmental policy performance in the context of sustainable development. World Resources Institute, Washington, DC, 42 pp.

Hutchinson, G. E. F. 1957. A treatise on limnology, vol 1: geography, physics and chemistry. John Wiley & Sons, New York, 1015 pp.

Local Government Management Board. 1995. The sustainability indicators research project: consultant's report of the pilot phase. The Local Government Management Board, UK, 164 pp.

MacGillivray, A. 1994. Environment measures: indicators for the UK environment. Royal Society for the Protection of Birds, Bedfordshire, UK, 107 pp.

Minshall, G. W. 1988. Stream ecosystem theory: a global perspective. *Journal of the North American Benthological Society* 7(4):263–288.

Moldan, B., and S. Billharz (eds). 1997. Sustainability indicators: a report on the project on indicators of sustainability. John Wiley & Sons, New York, 415 pp.

Monro, D., and M. Holdgate (eds.). 1991. Caring for the Earth—a strategy for sustainable living. IUCN, UNEP, WWF, Gland, Switzerland.

Munasinghe, M., and W. Shearer (eds.). 1995. Defining and measuring sustainability: the biophysical foundations. World Bank, Washington, DC, 440 pp.

Obst, C. 2000. Report of the September 1999 OECD expert workshop on the measurement of sustainable development. Pages 7–17 *in* Organisation for economic co-operation and development, frameworks to measure sustainable development. OECD, Paris.

OECD (Organisation for Economic Co-operation and Development). 1991. The state of the environment. OECD, Paris.

OECD (Organisation for Economic Co-operation and Development). 1993. Environmental indicators: basic concepts and terminology. Background paper No. 1. OECD, Paris, 150 pp.

OECD (Organisation for Economic Co-operation and Development). 2000. Frameworks to measure sustainable development. OECD, Paris, 164 pp.

Reid, G. K., and R. D. Wood. 1981. Ecology of inland waters and estuaries. Van Nostrand, New York, 485 pp.

Trzyna, T. C. (ed.). 1995. A sustainable world. IUCN, The World Conservation Union, Gland, 272 pp.

UNEP (United Nations Environment Programme). 2000. Grid Arendal Web Site: http:/www.grida.no/soe.

(UNEP and WHO) (United Nations Environment Programme and World Health Organisation). 1988. Assessment of urban air quality worldwide. UNEP, Nairobi.

Von Meyer, H. 2000. Territorial indicators for sustainable development. Why? And how? Pages 150–157 *in* Organisation for Economic Co-operation and Development, frameworks to measure sustainable development. OECD, Paris.

Walmsley, R. D., and J. P. R. Pretorius. 1996. Environmental indicators. Report No. 1. State of the environment series. Department of Environmental Affairs and Tourism, Pretoria, 76 pp.

Walmsley, J., M. Carden, C. Revenga, F. Sagona, and M. Smith. 2001. Indicators of sustainable development for catchment management in South Africa—review of indicators from around the world. *Water SA* (in press).

Ward, C. J. 1990. Environment indicators for state of the environment reporting. Information paper No. 21. Centre for Resource Management, Canterbury, New Zealand.

Ward, J. V. 1989. The four-dimensional nature oflotic ecosystems. *Journal of the North American Benthological Society*. 8(1): 2–8.

World Bank. 1995. Monitoring environmental progress. The World Bank, Washington, DC, 84 pp.

Zinn, E. 2000. Sustainable development indicators for urban water systems: a case study evaluation of King William's Town, South Africa and the applied indicators. MSc thesis. Chalmers University of Technology, Göteborg, Sweden.