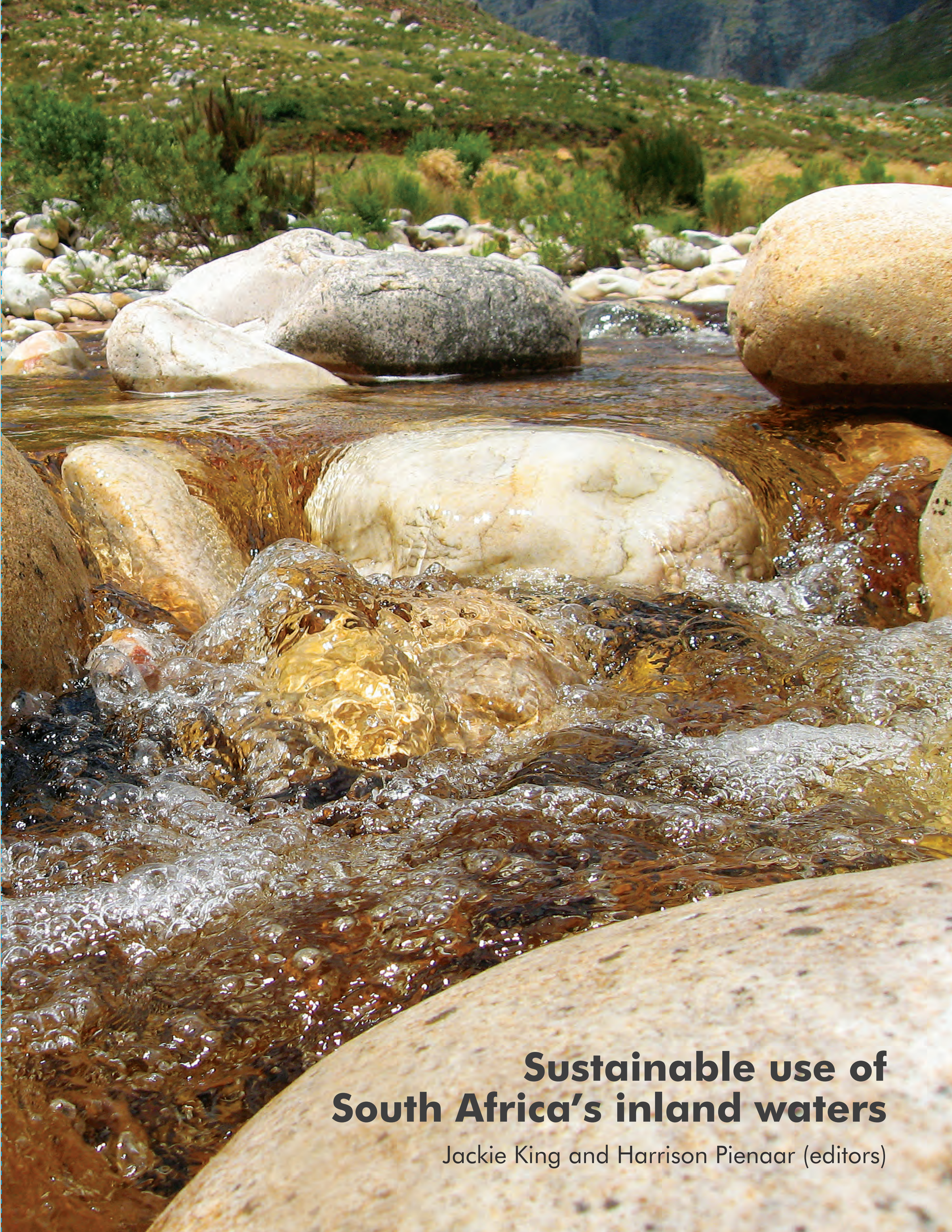

Sustainable use of South Africa's inland waters

Jackie King and Harrison Pienaar (editors)

SUSTAINABLE USE OF SOUTH AFRICA'S INLAND WATERS

A situation assessment of Resource Directed Measures 12 years after the 1998 National Water Act

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FRONT COVER PHOTO

Jackie King - Berg River at Franschhoek

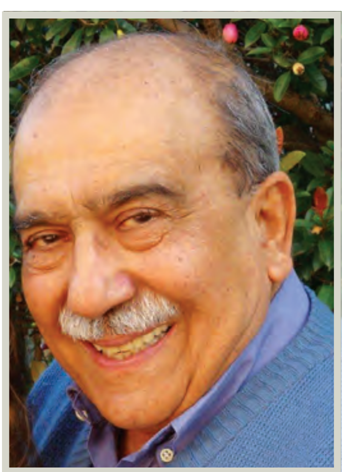
BACK COVER PHOTOS

Top: Bruce Paxton – Clanwilliam yellowfish

Middle Upper: Sharon Pollard – Harvesting reeds from Manalana wetland

Middle Lower: Thomas Peschak – Juvenile sawfin in the Driehoeks River

Bottom: Jackie King – Measuring size of rocks in the Berg River



This book is dedicated to the memory of the late Professor Kader Asmal, principled politician, government minister, lawyer, educator, activist and true champion of human rights, who tirelessly contributed to South Africa's constitutional democracy.

8 October 1934-22 June 2011

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ACRONYMS AND ABBREVIATIONS

1912 Act	The Irrigation and Conservation of Waters Act (1912)
1956 Act	South African Water Act 54 of 1956
1956 Water Act	South African Water Act 54 of 1956
ANC	African National Congress
BBM	Building Block Methodology
BHNR	Basic Human Needs Reserve
C.A.P.E. Project	Cape Action for People and the Environment Project
CD	Chief Director
CD: IWRP	Chief Directorate of Integrated Water Resource Planning Unit
CD: RDM	Chief Directorate of Resource Directed Measures Unit
CE	Chief Engineer
CMA	Catchment management agency
CSIR	Council for Scientific and Industrial Research
CSP	Co-operative Scientific Programmes
D	Directory
DCE	Deputy Chief Engineer
DD	Deputy Director
DEA	Department of Environmental Affairs
DRIFT method	Downstream Response to Imposed Flow Transformations method
DSS	Decision Support System
DWA	Department of Water Affairs
DWAF	Department of Water Affairs and Forestry
EcoSpecs	Ecological Specifications
Ecostatus	Ecological status
EFlows	Environmental Flows
EI	Ecological Importance
EIA	Environmental Impact Assessments
EIS	Ecological Importance and Sensitivity
EWR	Ecological Water Requirements
FBW	Free Basic Water
FETWater	Framework Programme for Research Education and Training in the Water Sector
FFHA	Fish Flow Habitat Assessment
FRAI	Fish Assessment Index
FRD	Foundation for Research and Development
FSR	Flow-Stressor Response
GAI	Geomorphology Assessment Index
GIS	Geographical Information Systems
GRDM	Groundwater Resource Directed Measures
GRYM	Groundwater Yield Model for the Reserve Method
HAI	Hydrology Assessment Index
HFSR	Habitat Flow Stressor Response (previously FSR)
HI	Hydrological Index
IBT	Inter-basin transfer
IDP	Integrated Development Planning
IEWM	Integrated environmental water management
IFIM	Instream Flow Incremental Methodology
IFRs	Instream flow requirements
IGS	Institute of Groundwater Studies
IUA	Integrated Unit of Analysis
IWE	Inland water ecosystems
IWRM	Integrated water resource management
KNP	Kruger National Park
KNPRRP	Kruger National Park Rivers Research Programme
MAR	mean annual runoff (i.e. river flow)

MDG .... Millenium Development Goals
ME .... Managing engineer
MIRAI .... Macroinvertebrate Assessment Index
Mm^3 .... million cubic metres
NAEHMP .... National Aquatic Ecosystems Health Monitoring Programme
NEM .... National Environmental Management
NEM AQA .... National Environmental Management: Air Quality Act (39 of 2004)
NEM BA .... National Environmental Management: Biodiversity Act (10 of 2004)
NEM ICMA .... National Environmental Management: Integrated Coastal Management Act (24 of 2008)
NEM PA .... National Environmental Management: Protected Areas Act (57 of 2003)
NEM WA .... National Environmental Management: Waste Act (59 of 2008)
NEMA .... National Environmental Management Act (107 of 1998)
NGO .... Non-Governmental Organisation
NIWR .... National Institute for Water Research
N-P ratio .... Nitrogen to Phosphorus ratio
NRF .... National Research Foundation
NWA .... National Water Act (36 of 1998)
NWRS .... National water resource strategy
P and R Branch .... Policy and Regulation Branch (DWA)
PAI .... Physico-Chemical Driver (Water Quality) Assessment Index
PES .... Present Ecological Status
RDM .... Resource Directed Measures
RDP .... Reconstruction and Development Programme
REC .... Recommended Ecological Category
RGD .... Research Grants Division
RQOs .... Resource Quality Objectives
SADC .... South African Development Community
SAM .... Strategic adaptive management
SANBI .... South African National Biodiversity Institute
SANPARKS .... South African National Parks
SANSP .... South African National Scientific Programme
SASS5 .... South African Scoring System for Macroinvertebrates, Version 5
SEA .... Strategic Environmental Assessments
SI .... Stress Index
SPATSIM .... Spatial Time Series Information System Framework
spp .... species
SRP-TP ratio .... Soluble Reactive Phosphate to Total Phosphorus ratio
TIN .... Total Inorganic Nitrogen
TPC .... Threshold of Potential Concern
UNESCO .... United Nations Educational Scientific and Cultural Organisation
User specs .... User Specifications
VEGRAI .... Vegetation Assessment Index
Water Research Act .... Water Research Act (34 of 1971)
Water Services Act .... Water Services Act (108 of 1997)
WESSA .... The Wildlife and Environment Society of South Africa
WMAs .... Water management areas
WR .... water resource
WRC .... Water Research Commission
WRCS .... Water Resource Classification System
WS .... water services
WSA .... Water Services Authority
WSAM .... Water Situation Assessment Model
WUA .... Water User Association
WWF SA .... Worldwide Fund for Nature South Africa
WWTW .... waste water treatment works

FOREWORD

Water resources provide important benefits to humankind in the form of commodities such as water and food and by enhancing lives in many other ways. In South Africa, a water-scarce country, we recognise that water resources are under stress as never before, as competition for water increases between potential or actual users from a range of sectors. All these sectors contribute to the welfare of the country, including poverty eradication, through improved economic development and the creation of employment. Water is also fundamental for the long-term sustainability of our water resources as functioning ecosystems but only if they are in good ecological condition can they continue to provide the ecological services we value.

Over the last two decades, the Water Research Commission has helped to stimulate the research-based development of a ground-breaking policy that recognises water resources as living aquatic ecosystems and sets out an approach for South Africa that supports their sustainable use and management. Guided by the Agenda 21 global initiative, this approach is encapsulated in Chapter 3 of the country's National Water Act, Act 36 of 1998 (NWA). The NWA recognises three Resource Directed Measures: the Classification System, the Reserve, and Resource Quality Objectives, which together form the protection measures for the country's water resources. Since the promulgation of the NWA, the move to implement Resource Directed Measures has made considerable progress in South Africa, in parallel with new and visionary technologies that are helping to operationalise these protection measures in harmony with the imperative for water-resource development. There has been constructive engagement between sectors throughout, particularly between water scientists, research institutes and government. Collaboration such as this is possibly unrivalled in the world, even if the road has been rocky at times.

While the NWA, with its measures for protecting water resources is visionary and innovative, its implementation will be neither quick nor easy – worthwhile endeavours such as this seldom are. As a community of water specialists, we have spent the last 20 years developing methods and tools to assess the Reserve – that is, learning how to assess the water needed for basic human needs and for sustaining the ecological health of the aquatic systems. We have created awareness of why this water is necessary for maintaining ecosystem health, done the research, tested the outputs and put the organisational structures in place to make protection measures effective. In the last few years, work on the other two Resource Directed Measures has also begun.

In essence, what comes next is a bigger challenge than all that has gone before – making our new water vision work on the ground and giving effect to all three Resource Directed Measures. This will require greater integration and cooperation than has happened so far, both within the Department of Water Affairs as well as within and between other organisations, stakeholders and society at large. We must also continue to invest in research that allows us to better understand our water resources and predict how human activities can impact them, as this will enhance our ability to make informed and accountable decisions on water use. South Africa is a world leader in this field and aims to continue to claim its space in the global knowledge economy.

Whatever course we follow into the future involves compromise – we may gain benefits with development, but we may incur costs in terms of declining ecosystem health and the loss of ecological services. We need to work together as a country to identify catchment by catchment what these benefits and costs would be and to ascertain the point of acceptable trade-off between water resource development on the one hand and aquatic ecosystem protection on the other. We then need to learn to live within the boundaries we have recognised. That is truly sustainable use of water and the three Resource Directed Measures are designed to help us achieve this.

This situation assessment of Resource Directed Measures is an important publication that summarises what has been achieved in the last 12 years in terms of the protection aspects of the NWA and helps guide our thinking on the next phase. The Water Research Commission, in collaboration with the Department of Water Affairs (DWA) and the World Wide Fund for Nature (WWF), is proud to introduce this summary of the work done over many years by a national body of knowledgeable and hardworking water professionals.

Rivka Kfir
CEO: WATER RESEARCH COMMISSION

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PREFACE

Two hundred and fifty kilometres north of Cape Town, Danie du Toit peered over Clanwilliam Bridge into the fast-flowing waters of the Olifants River. He was looking for fish – not any fish, but beautiful, muscular torpedoes up to a metre long designed to ride the river's floods – the Clanwilliam yellowfish. The fish, endemic to this river, have evolved to migrate upstream through the strong winter flow and then lay their eggs in spring, triggered by small warmer floods. Until the mid-1900s they moved along the river in large numbers, providing food for local people and recreational fishing.

Clanwilliam Dam, built upstream of the bridge in 1935, is now one of several threats to their survival, as it interferes with several vital links in their age-old rhythm of life. The dam stores the floods that would trigger migration and spawning, blocks the fishes' passage to upstream spawning grounds, and changes the temperature of the water downstream of the dam so that to the fish spring still feels like winter. River scientists had shown that small floods released from the dam could trigger the fish to spawn in the one tiny area of suitable cobble riverbed still available to them in the river's sandy middle reaches, but only if the water temperature had risen to spring levels. This year the warm water was late coming and the fish were not yet primed to spawn. And so the scientists went back to their universities leaving Danie, a pensioner from Natal, to watch and wait for the water to warm and the fish to start moving up toward the dam.

Johan Bothma, operator of Clanwilliam Dam, saw his fishing friend on watch at the river, and stopped to check on the situation. "I think the fish are arriving" said Danie, "but it's difficult to see because of the turbulent water". Johan, following arrangements agreed earlier between the Cape Department of Nature Conservation and the Department of Water Affairs, obligingly drove the one kilometre upstream to reduce the flow from the dam, and in the calmer water they saw them. Dozens of great sleek shapes "as big as our legs" were lazily moving into the area and circling around. They watched in fascination as the sun crept toward the horizon, time forgotten, until a downstream farmer phoned to enquire after his irrigation water and Johan raced up to the dam again to increase the water being released from it. Primed by the now-warm waters and triggered by the small artificial flood now pouring down the river, the fish rode the speeding water to hold position on their miniscule spawning ground. Lining up in male and female pairs or trios, they released clouds of fertilized eggs that drifted downstream and settled on the river bed.

The date was 18 December 1995 and Danie and Johan were playing their small part in an extraordinary decade in South Africa's history. It was the decade when the country cast off apartheid and emerged from political isolation to install its first democratic government. It was also the decade when the country's river scientists emerged from scientific isolation to make a major global contribution to a new science aimed at helping resuscitate the world's dying rivers and bring a more caring balance into the management of those still in good condition. As the incoming government prepared its new water law, the scientists were ready with their knowledge and vision for sustainability, and so the two strands of history intertwined again and again in ways not imaginable even a few years earlier. This is a view of those times and what came next from some of those who took part.

Part 1 Background

Each country's water management reflects the natural resources it has at its disposal and how it is has moved to use them. Chapters 1 and 2 provide some of this background for South Africa. Chapter 1 outlines the situation regarding the fresh water available within the country and how it is used. Chapter 2 describes the development of water law in the country, and how this has evolved with the National Water Act (Act 36 of 1998) to embrace the concept of sustainable use.

Peter Chadwick / WWF-SA

1 WATER SUPPLY AND DEMAND

Jackie King, Steve Mitchell and Harrison Pienaar

1.1 South Africa – a dry country

The availability of freshwater is never far from South Africa's collective mind. Lying just outside the tropics at latitudes that are characterised in both the southern and northern hemispheres by low and highly variable rainfall, the country has a mean annual rainfall of 450 mm compared to a world average of 860 mm. Added to the reality of a modest average rainfall are the problems that it is not spread evenly across the country or evenly over time. These large variations in rainfall inevitably translate into a high variability in available water resources. In a comprehensive study of global river flow characteristics, river flow regimes in Australia and South Africa were found to be amongst the most variable on the planet [1,2].

The drier interior of South Africa is separated from the narrow and wetter eastern and southern borders by a line of mountains ranging from the Soutpansberg in the north-east, through the Drakensberg to the Cedarberg in the south-west (Figure 1.1).

The mountains attract annual average rainfalls that exceed 3,000 mm per year in parts of the Drakensberg and the Western Cape, but these high rainfalls drop rapidly with distance. On the Cape Flats of the Western Cape, for instance, rainfall is highest against the Hottentots Holland mountains in the east (1,700 mm per year) but decreases over the 50-60 km to the west coast to about 400 mm per year [3].

Contributing to water scarcity are high temperatures, with an annual mean above 17°C for much of the country, which result in potential evaporation demands that far exceed rainfall in all but a few isolated areas. This causes high water losses from dams and other surface waters, particularly in the west. Much of the country can therefore be seen as arid or semi-arid.

The combined effect of mountains, high levels of solar radiation and evaporation, and different kinds of ocean currents – warm and south-flowing along the east coast, cold and north-flowing along the west coast – is that climatic conditions are highly variable across the country and that locations on the same latitude can experience very different rainfalls in terms of amount and seasonality. Durban, on the east coast, for example, receives an annual average rainfall of 1,070 mm, mainly during the summer months, while Port Nolloth, on the west coast at the same latitude, experiences winter rainfall of about only 58 mm per year [6]. Similarly, potential evaporation ranges from 1,200 mm per year in the south-east of the country to 3,000 mm per year on the Namibian border north of the Orange River 7].

Overall, 65% of the country has an annual rainfall of less than 500 mm and 21% receives less than 200 mm. The former is generally seen as the minimum rainfall needed for successful dry-land farming, and in areas with less than that irrigation plays a vital role in food production. In the remaining 35% of the country with higher rainfall much land is still unsuitable for arable farming due to unsuitable soil formations or excessively steep topography.

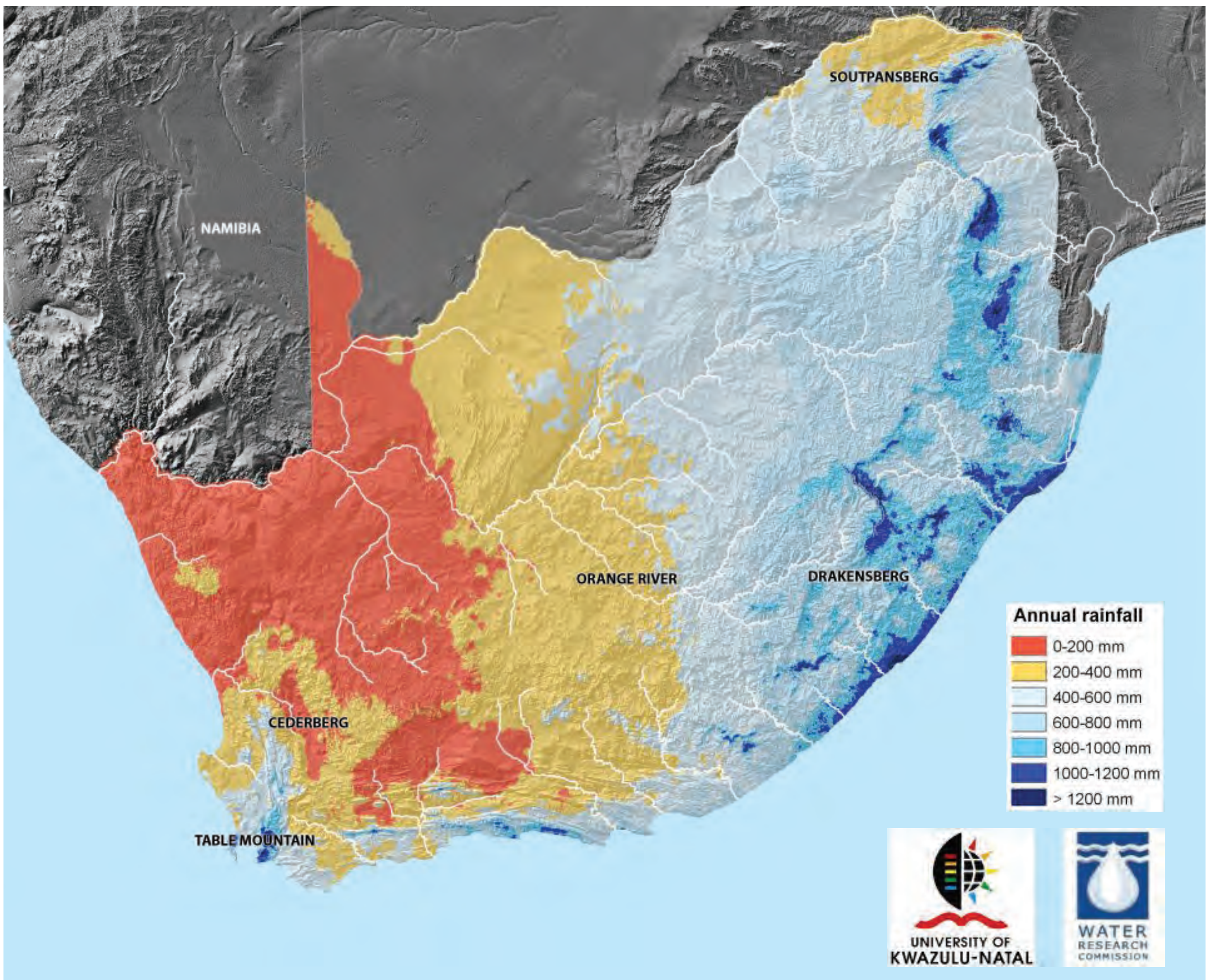


Figure 1.1 Mean annual precipitation of South Africa [4,5]. *Modified by Mike Silberbauer, DWA*


Steve Mitchell

Looking across the Orange River into Namibia, Richtersveld National Park.
Coordinates: S28 08 44 E17 11 30


Steve Mitchell

Nngwangwane River in the Underberg region of the southern Drakensberg.
Coordinates: S29 50 55 E29 13 53.

1.2 How much water does the country have?

The largely perennial rivers in the east and south-east of the country are a highly valuable resource, as they carry approximately 75% of the country's total river flow. By contrast, the west-flowing Orange-Vaal river, occupying about 48% of the total land surface of the country, carries only 22% [6].

Quantifying the available water resources in a country with a highly variable climate is difficult. The most recent estimate of the naturalized mean annual runoff (MAR) of the country's rivers is 49,210 million cubic metres (Mm^3) per year [8], which may sound impressive until compared to the nearest large river to the north, the Zambezi, whose basin produces more than double that amount from an area (1.4 million square kilometres) similar in size to South Africa. The country has yet to fully assess the potential contribution of groundwater systems, but in 2000 the estimated amount of available water was 1,088 Mm^3 per year [7].

Part of the uncertainty about the combined amounts of water available lies in our lack of understanding of the interactions between surface water and groundwater, and specifically how much the estimated groundwater resources contribute to sustaining low flows in the rivers of the country.

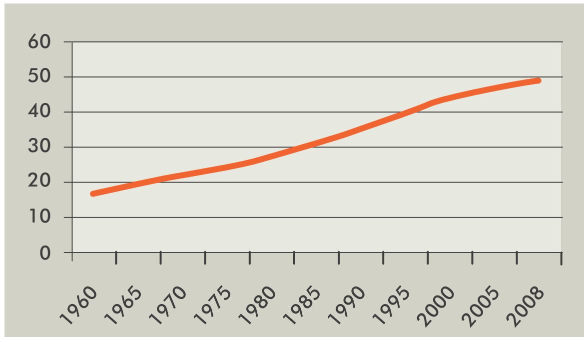
Major impoundments exceeding 1 Mm^3 storage capacity can store approximately 66% of the country's MAR as live[a] storage [7]. The volume of water actually available for offstream use (the 'yield') is less than this live storage for several reasons. Firstly, the level of stored water is dependent upon the variability of the inflow from donor catchments and reservoirs will only be full after high rainfall periods. Good runoff was experienced in some parts of the country during the 13 years preceding the publication of 'Water for Growth and Development', and over this period impoundments stored, on average, 81% of their capacity [9].

Secondly, as a national average, and until more accurate estimates are available, about 20% of the surface water flow is earmarked for maintenance of river ecosystems, as the Ecological Reserve, and is not available for allocation. Thirdly, yield is typically calculated at a 98% assurance of supply (Box 1.1), which means that allocations will be fully met in 98 years out of a 100. The greater the variability in rainfall, and therefore river flow, the lower the percentage of the MAR that will be available at the desired level of assurance. Taking all this into account, a recent estimate of the total yield is 13,227 Mm^3 per year [7].

1.3 Population numbers

In 1904 the total population of South Africa was 5.2 million people. By 1960 it was estimated at 16.4 million and by 2008 had increased to 48.7 million (Figure 1.2) [10,11,12]. South Africa now stands as the second most populous country in the Southern African Development Community, after the Democratic Republic of Congo [13].

Growth has recently slowed, due to a reduced reproduction rate linked to urbanisation and economic growth and also to the impact of HIV/AIDS, but a projected growth to 53 million people is still expected by 2025 [7,14].



Source: World Bank, World Development Indicators [11]

Figure 1.2 Estimate of the South African resident population (millions).

1.4 The growing demand for water

In South Africa, four main trends have dictated how growing population numbers translated into a growth in water demand and these may be broadly categorised as the development of water services, agriculture, mining and urban areas.

[a] *Reservoirs have dead storage at the bottom, which is not included as yield*

1.4.1 Water supply and sanitation

When the post-apartheid government came to power in 1994 it was estimated that there were between 12 and 14 million people in the country without access to safe water [15]. Just ten years later, in the tiny hamlet of Soverby on the banks of the Orange River in the Northern Cape, the Department of Water Affairs (DWA)[b] commemorated its supply of safe clean water to the 10 millionth recipient since 1994.

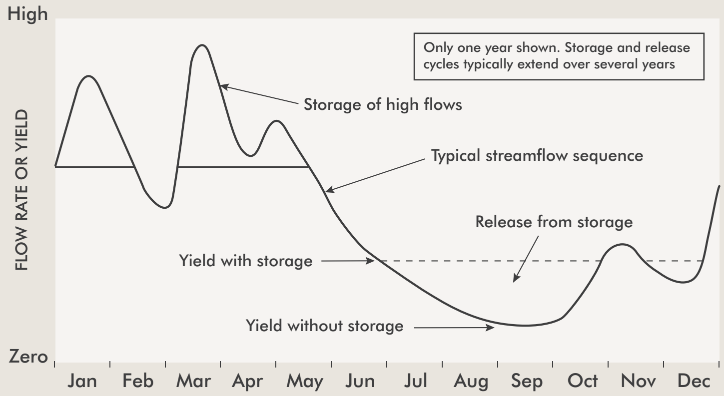
Box 1.1 Yield, reliability, available water and assurance of supply [7]

The yield from a water resource system is the volume of water that can be abstracted at a certain rate over a specified period of time (expressed in Mm^3 for the purposes of the National Water Resource Strategy (NWRS)) [7]. For domestic, industrial and mining use, water is required at a relatively constant rate throughout the year, whereas strong seasonality of use occurs in irrigation. Because of the typically large fluctuations in stream flow in South Africa, as illustrated over a 12-month period in the diagram, the highest yield that can be abstracted at a constant rate from an unregulated river is equal to the lowest flow in the river. By regulating stream flow by means of dams, water can be stored during periods of high flow for release during periods of low flow, as shown by the dotted lines on the diagram. This increases the rate at which water can be abstracted on a constant basis and, consequently, the yield. The greater the storage, the greater the yield that can be abstracted, within certain limits.

Because rainfall, runoff and thus stream flow vary from year to year, low flows (and floods) are not always of the same duration and magnitude. The amount of water that can be abstracted without fail therefore also varies from year to year. The amount of water that can be abstracted reliably for 98 out of 100 years on average is referred to as the yield at a 98% assurance of supply. Implicit in this is the acceptance that some degree of failure with respect to supplying the full yield will, on average, occur two years out of every 100 years. For a specific river and water resource infrastructure, the higher the assurance of supply required (or the smaller the risk of failure that can be tolerated), the smaller the yield that can be abstracted, and *vice versa*. For the purposes of the NWRS all quantities have been adjusted to a 98% assurance, where applicable, to facilitate comparison and processing. This is necessary because yields or water requirements are not directly comparable when at different assurances of supply, but first need to be normalised to a common standard.

Available water refers to all water that could be available for practical application to desired uses. The total yield locally available includes the yield from both local surface water and groundwater resources, as well as contributions to the yield by usable return flows from the non-consumptive component of upstream water use in the area under consideration. Total water available includes the total local yield plus water transferred from elsewhere.

Diagrammatic presentation of stream flow and storage



[b] *The South African government department responsible for water matters has changed its name twice in the last two decades. In the late 1980s it was the Department of Water Affairs (DWA). It then became the Department of Water Affairs and Forestry (DWAF) when the Forestry Branch was added, and reverted to the Department of Water Affairs (DWA) in July 2009 when the Forestry Branch was moved to another department. To avoid using multiple, time-dependent acronyms, the organisation is referred to as DWA throughout this document.*

Its Millennium Development Goals (MDGs) target in respect to the halving of the water-supply backlog was achieved in 2005 [9]. The 'Ten million in ten years' celebration symbolised the end of DWA's direct role in water service delivery as this responsibility has now been transferred to local government [16].

In 1994 there were also estimated to be more than 20 million people in the country without adequate sanitation [15]. Between September 2004 and March 2006 the number of schools without adequate sanitation was reduced from 4300 to 2118, and in the 2005/6 financial year 2185 clinics were provided with sanitation facilities [17]. DWA had aimed for adequate sanitation for everyone by 2010, but this is now set to be achieved by 2014 [18,19]. Its MDG target in respect to halving the sanitation backlog was achieved in 2008 [9].

The drive to supply water and sanitation to all has not been accompanied by an adequate investment in waste-water treatment. The Green Drop Report revealed that only 32 out of the approximately 850 waste-water treatment works (WWTW) in the country achieved the Green Drop Status during the assessment period [20]. Thus inadequately treated sewage is being discharged into the environment by about 96% of the country's WWTWs. This is causing serious eutrophication and pathogen pollution in the rivers and impoundments [21], increasing water treatment costs and reducing the fitness of the water for other uses.

1.4.2 Agriculture

Water has always been important in South African agriculture. About 2000 years ago Khoi herders moved into the comparatively well-watered south-western Cape coastal region. One thousand years ago the Bantu arrived in southern Africa and, being both farmers and pastoralists, settled adjacent to surface water sources on the highveld and the coastal plains as far south as the Fish River. When the Dutch settlers first arrived and moved into the hinterland their settlements also centred on available water sources and so they came into contact, and from time to time conflict, with the people already living there [22].

The development of water resource infrastructure and organisations in South Africa was relatively modest and informal initially, linked to early farms and settlements that were mostly located on or near streams and springs [23]. Responsibility was vested in the hands of private enterprise and local authorities (Box 1.2) and the major focus was water for crops. The formation of irrigation boards was encouraged and irrigation played a major role in both the development of early water policy (Chapter 2) and of infrastructure. The population was largely dependent on subsistence farming and so was mostly rural with less than 30% of people living in urban areas [14].

More people meant a growing food requirement and the gradual commercialisation of food production. As population numbers continued to increase, insufficient food could be produced in areas fed by rainfall and irrigated agriculture became increasingly important. By 2007, the extent of irrigated land was 1,675,882 hectares [24], and this sector had become the greatest user of water (Table 1.1). Irrigation expanded, and was given priority, at a time when the country aimed to provide all its food needs, but this may now be starting to give way to a more broad-based approach where many uses of water are considered before priorities are established (Box 1.3).

Table 1.1 Water-resource allocation per sector for the year 2000 [7].

Water user/Sector	Proportion of allocation (%)
Agriculture	62
Urban	23
Rural	4
Mining and bulk industrial	6
Power generation	2
Afforestation	3

Box 1.2 Early development of infrastructure

The earliest record of water infrastructure development in South Africa by Europeans dates back to 1660, eight years after Jan van Riebeck, the first Governor of the Cape settled in the Cape. He canalised the Varsche River and built a small dam near the jetty on Table Bay as a water supply for passing ships. This proved insufficient during a drought in 1663, and Van Riebeck's successor, Zacharias Wagenaer, mobilised all able-bodied men to hastily dig a large cistern. Remnants of this cistern, which was 55 m long, 5 m wide and 1.5 m deep, are today preserved in the Golden Acre shopping centre in Cape Town [3].

Box 1.3 Food security and self-sufficiency

Food security refers to the assurance of having sufficient food available at all times.

Food self-sufficiency refers to the capability for producing one's own food. Both principles can apply to individuals as well as on a national level.

During the apartheid era, in common with the thinking of the time, national food self-sufficiency was seen as strategically important in South Africa. As a result, irrigated agriculture, which has always been important in South Africa, developed into the largest single user of water and the need for food self-sufficiency has been a motivation for maintaining this water use.

The South African National Water Act (1998) recognises that a strong, diversified and globally well-integrated economy with a high level of employment may better provide for national food security than to strive for self-sufficiency, and so recognises commercial agriculture as an economic use of water. Individual households, however, may not have the financial means to purchase food and their only solution to food security may be through achieving household food self-sufficiency. In these cases, allocation of water for irrigation may be given a much higher priority [7].

1.4.3 Mining

With the discovery of diamonds in 1871, followed by gold on the Witwatersrand in 1886, people began to move to urban areas centred on the mineral resources [14]. South Africa has an extraordinary wealth of minerals, with nearly 90% of the global store of platinum metals, 80% of the manganese, 73% of the chrome, 45% of the vanadium and 41% of the gold. But minerals come at a cost to water resources, and to produce one fine ounce of gold, for instance, requires 5,000 litres of water [25, 26].

Not only is mining water hungry, but the minerals are mostly in areas of inadequate water supply. New platinum mines are being opened in Sekhukhuneland on the border between Mpumalanga and Limpopo Provinces, for instance, and new coal mines in the Lephalale area of Limpopo Province. Sekhukhuneland is a dry area but there is some water in the Olifants catchment that could supply the mines in that area. There is insufficient water in the Lephalale area to support the new mining activities there, however, and water will have to be transferred into the area to fill the need. A possible source of water for this will be the acid water decanting from the disused mines of the West Rand, moving *via* Hartbeespoort Dam and the Crocodile (West) River to the area of mining activity [26].

In summary, the process of mining is placing an ever-increasing set of demands on a finite set of water resources. More water is needed, more effluents are being released back into the ecosystems and acid mine drainage is reaching them. Additionally, the mines are located in areas that require the mass movement of water to them, often from areas with no history of shared water and biotas.

1.4.4 Urbanisation

Over the last century the pattern of settlement and water use has changed from one of people living near water, to one of water being delivered to the people. The National Physical Development Plan, developed in 1975, and the Industrial Decentralisation Programme aimed to achieve the "orderly settlement of an ever increasing population on a finite land area with limited natural resources while avoiding over-concentration of population or economic activity in certain places" [6]. At that time in South Africa's history, control of the nation's water resources was centralised in DWA and rural subsistence livelihoods linked to aquatic ecosystems were not formally recognised.

A number of changes occurred after 1994 that influenced urbanisation. Jacobs *et al*., focusing specifically on rural development, noted that although the agricultural sector continues to play a vital role in the livelihoods of rural households and in local rural economies, forces outside it have had an important influence on it [27]. For instance, commercial farmers responded to the global competitive pressures brought about by the liberalisation of the agricultural trading regime by introducing more capital-intensive methods, which has substantially reduced employment opportunities.

Also, legislation aimed at securing the jobs and livelihoods of farm workers and rural dwellers 'evidently made matters worse'[27]. They concluded that the loss of secure job opportunities in rural areas has been a key driver for migration to urban areas. Thus, for employment and other reasons, urban populations continued to grow and the 2001 census showed a net migration from rural areas into major cities and towns of up to 20%. By 2000 urban areas contained 56% of the country's population (Figure 1.3).

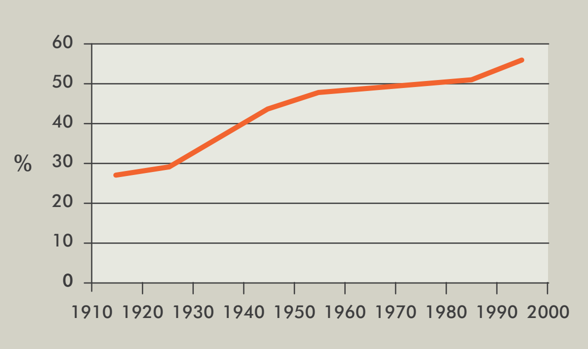


Figure 1.3 The percentage of the South African population living in urban areas between 1910 and 2000 [28].

Urbanisation is usually synonymous with the aspiration for better lifestyles. The country's new government placed great emphasis on providing water and electricity to a previously marginalised majority. The amount of water required to redress past inequities and support poverty alleviation is difficult to estimate and is dependent on the government's development strategies, but as more people move to enhanced life-styles this is bound, on its own, to lead to a continuing growth in the demand for water.

1.5 Meeting the demand

Activities to meet the growing demand for water may go through a series of stages of increasing complexity (Box 1.4). Early increases in the demand for water in South Africa coincided with a major drought in the 1930s that bankrupted many landowners and impacted crop production [29]. Recognising the need for a high assurance of water and food supply, the state began to build storage dams.

Dam building rapidly accelerated after the 1930s, peaking in the decade 1960-69 when 89 large dams were constructed (Figure 1.4). Where the geographic locations of nodes of economic or agricultural activity did not match the occurrence of water, Inter Basin Transfer (IBT) schemes were built to move water to where it was needed (Box 1.5; Figure 1.5; Figure 1.6) [7].

With such massive investments in water delivery, by 2000 the water balances for five of the country's 19 Water Management Areas (WMAs) (Box 1.6) were in 'shortage', four had a 'surplus' and ten were in 'balance' with supply equalling demand (Figure 1.7). All but one of the WMAs have IBTs linking them to another one, in some cases to other countries, and many have IBTs operating within them.

Box 1.4 General trends in approaches to water resource development

When people are few and water is plentiful, sufficient can be obtained simply by tapping into the natural supply, whether that be flowing river water or still water in ponds and lakes. With increasing demand, humans begin to modify the natural availability of water to meet their needs, first perhaps by damming small streams to store some water near their everyday activities. With further increases in demand, for growing urban and industrial areas and for irrigated crops, more formal and costly infrastructure tends to be built, usually by the state or with state support. Large dams may be constructed that can capture most of the flow, even large floods, and store up to the total annual flow of a river or more. These could be as large as 1, 2 or even 3 MAR dams, storing the total volume of several years flow of the river, and the tendency may be to attempt to trap more of the MAR in the drier areas because of the uncertainty of flow. The next steps to meet increasing demand might be to construct inter-basin transfers (IBTs) of water *via* tunnels and pipes, from river basins that may be seen to have an 'excess' of water to others where demand is higher than can be met by local river systems, or to tap into groundwater. Only after all such sources have been exhausted, and the donor ecosystems degraded, has attention tended to turn to managing demand (as opposed to supply), de-salination of sea water and re-cycling of effluent water. These are seen as more expensive options that would drive up the cost of water, but the damming/diversion options are only cheap if one ignores the cost in terms of a degrading environment.

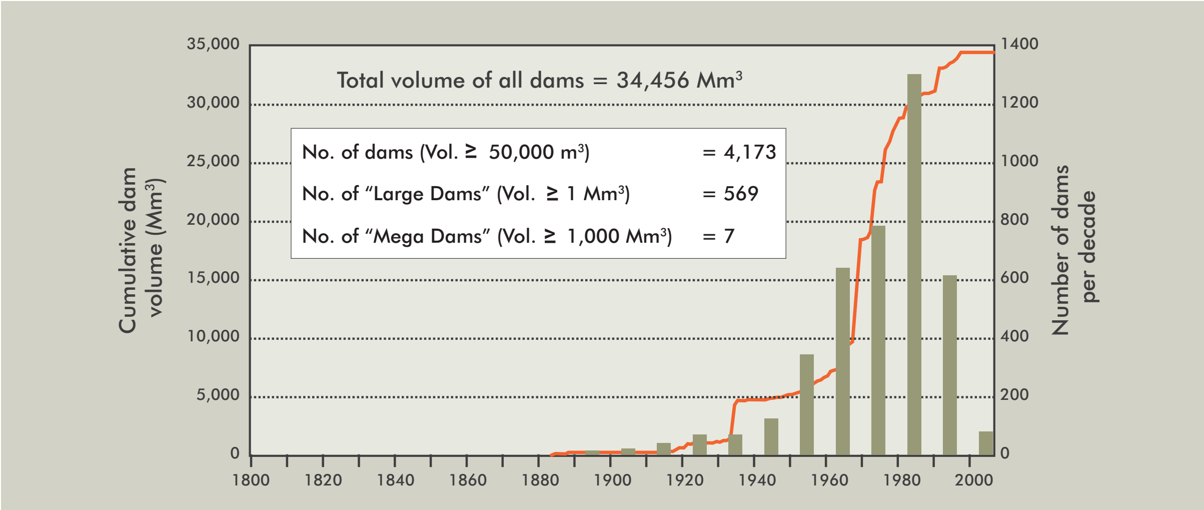


Figure 1.4 Large dams built per decade (histogram) and the cumulative volume of large dams built since 1800 (line) [6].

Figure 1.5 Location of Water Management Areas and major inter-WMA transfers. The figures on each arrow are in Mm³ per year for the scheme [7].

Box 1.5 Mineral discoveries influence water resource planning

The gold deposits discovered on the Witwatersrand in 1886, which led to the early development of what is now Johannesburg, are far from a readily available water supply. Initially, water distribution was in the hands of private companies and the supply of water was both erratic and expensive [22]. The Rand Water Board was established in 1903 through an act of parliament to service the needs of the city from the Vaal River almost 100 km to the south. From these beginnings, Rand Water now delivers 3.65 million litres (0.04 Mm^3) of potable water daily to more than 11 million people in an area stretching over 18 000 square kilometres [30].

Beginning with Kimberley and then Johannesburg, the distribution of South Africa's mineral wealth played, and continues to play, a major role in the development of water infrastructure. The necessary volumes of water do not naturally occur where the minerals or people are, and so it has to be moved from place to place *via* pipes, canals, the river channels themselves, or inter-basin transfer (IBT) schemes.

The large thermal power stations which supply much of the country's present electricity are built over the coalfields of the Mpumalanga Highveld. These are situated on the watershed separating the Olifants and Vaal catchments, and the locally available water resources are inadequate. To cater for the water requirements of the power stations inter-basin transfer schemes have been built from the east-flowing rivers (Figure 1.6).

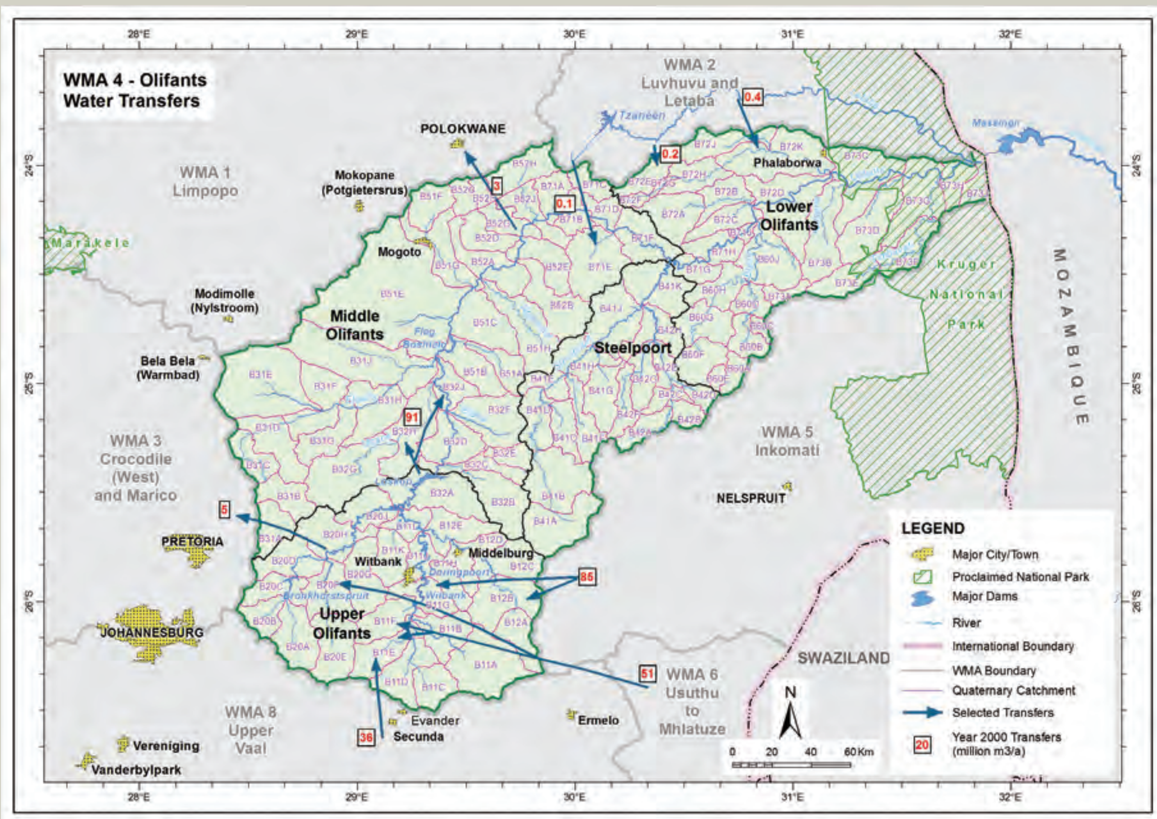


Figure 1.6 Detail of IBTs in the Olifants Water Management Area [31].

Box 1.6 Preliminary estimates of natural mean annual runoff (MAR), and storage in major dams (> 1 million m^3) constructed by 2003, for the 19 Water Management Areas [7]

	Water Management Area	MAR (Mm^3)	Storage (Mm^3)*	% of MAR stored
1	Limpopo	986	319	32.35
2	Luvuvhu/Letaba	1 185	531	44.81
3	Crocodile West and Marico	855	854	99.88
4	Olifants	2 040	1 078	52.84
5	Inkomati**	3 539	768	21.70
6	Usutu to Mhlatuze ***	4 780	3 692	77.24
7	Thukela	3 799	1 125	29.61
8	Upper Vaal	2 423	5 725	236.28
9	Middle Vaal	888	467	52.59
10	Lower Vaal	181	1 375	759.67
11	Mvoti to Umzimkulu	4 798	827	17.24
12	Mzimvubu to Keiskamma	7 241	1 115	15.40
13	Upper Orange ^	6 981	11 711	167.76
14	Lower Orange ^ ^	502	298	59.36
15	Fish to Tsitsikamma	2 154	739	34.31
16	Gouritz	1 679	301	17.93
17	Olifants/Doring	1 108	132	11.91
18	Breede	2 472	1 060	42.88
19	Berg	1 429	295	20.64
	TOTAL FOR SOUTH AFRICA	49 040	32 412	66.09

* takes into account accumulated sediments and dead storage

** includes Komati catchment in Swaziland (MAR = 517 Mm^3 per year)

*** includes the Pongola catchment in Swaziland (MAR = 213 Mm^3 per year)

^ includes Katse and Mohale Dams in Lesotho

^ ^ includes contributions from Senqu and Caledon Rivers in Lesotho (MAR = 4 765 Mm^3 per year)

Further information on WMAs is in Chapter 3.

By this time, the water resource infrastructure was sufficiently comprehensive to be seen by senior aquatic scientists as changing the limnological face of the country, but growth in demand continues. By 2025, if water supplies and demands are not addressed adequately, it could be that six WMAs will be in 'shortage', four in 'surplus' and nine in 'balance'. In general, DWA expects the country to be more likely to be facing future water shortages than surpluses [9].

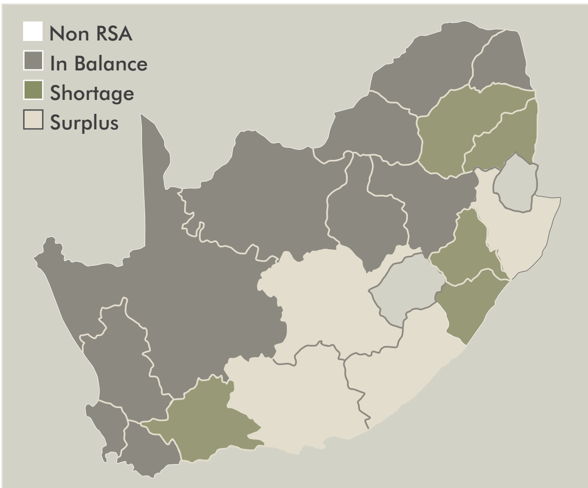


Figure 1.7 Water demand/supply scenarios for 2000 [9].

This situation is set against a background of increasing anthropogenic degradation of the fragile ecosystems supplying the water, through changes in flow regimes that support them, loss of floodplains and other wetlands that store water and more [32]. This reduces their ability to deliver reliable quantities of good quality water as they did in the past.

The situation could be exacerbated by at least two major factors: climate change and water quality. Climate-change scenarios developed for South Africa, Lesotho and Swaziland as part of the Intergovernmental Panel on Climate Change 3rd and 4th Assessment Reports revealed that the east of the country is predicted to receive more rain days and more days with bigger rainfalls, thus increasing surface water availability [33]. The west coast and adjacent interior, however, are expected to receive less rainfall with an increase in inter-annual variability, with both floods and droughts becoming more frequent and more extreme in nature [34]. This means that people in these areas directly reliant on the river ecosystems for livelihoods are expected to face more droughts and floods than at present. Adaptation strategies will need to be put in place to enable people to cope with these increased risks.

Water quality in aquatic systems is becoming poorer, epitomised by higher nutrient levels (eutrophication) and salinities due to agricultural runoff and poorly treated effluents. This will require increasingly expensive treatment before re-use, at a time when such re-use is expected to be an increasingly important component in balancing the water budget.

1.6 Degradation of aquatic ecosystems and the impacts on rural livelihoods

1.6.1 Impacts of development on the river ecosystems

Until the 1980s, water resource management in South Africa was dominated by a philosophy of increasing the supply to meet the demand. The impacts of this on the donor aquatic ecosystems were not understood by management and not voiced effectively by the scientific community, and so they were not factored into water resource planning in any structured way, if at all. DWA was focused on supplying water, and the nation's aquatic ecosystems had no legal right to any of the water.

As a result, through damming and diversion of water, some rivers have changed from perennial to seasonal, some from ephemeral to perennial and most have lost parts of their flow regime essential for maintaining them in good condition. The water that remains in the ecosystems has in many cases been becoming increasingly polluted. Many valued plant and animal species have been reduced in abundance or have disappeared altogether, while some have been transferred through inter-basin transfer schemes to parts of the country where they did not historically occur, perhaps to become pest species in their new locations. Other economic impacts of degrading rivers have become increasingly obvious (Box 1.7).

Responding to growing concern over the state of the rivers, the National River Health Programme, initiated in 1994, represented a new venture for the country. It introduced monitoring of the biological status of rivers to complement the existing chemical and hydrological monitoring network, in a first step toward understanding, and then managing, the overall condition of the nation's rivers [40,41].

At the same time, environmental flow assessments began, to provide input to decision makers on the potential consequences of water resource development options on river ecosystems (the main topic of this document). Although we now have more insight into the state of the nation's rivers and how to manage them more sustainably, much remains to be done. Driver *et al*. reported in a National Spatial Biodiversity Assessment that 82% of the country's river ecosystems (main stems) were threatened, with 44% critically endangered [42]. They compared this to terrestrial ecosystems, where the values were 33% and 5% respectively.

1.6.2 Impacts of water resource development on rural livelihoods

In the early drive to supply water, scant attention was paid to those benefits that rural people received from river ecosystems and which could not be replaced by water being delivered through a pipe (Table 1.2). Following a global trend, it is probable but not well documented that the benefactors of major water resource developments in South Africa have, to a large extent, not been the same as those who bore the costs in terms of failing ecosystem services. These costs were largely carried by the already-poor rural subsistence users living beside development-driven degrading rivers. An early South African investigation of the impacts of such water resource developments on riparian communities revealed that the rivers provided not only water but also food in the form of fish, water plants, water fowl and semi-aquatic mammals; construction material; firewood; and thatches for mats and baskets [44,45]. People who rely on these resources generally have few means of voicing their concern over potential threats to their livelihoods even if they are aware of such threats.

Derick du Toit

A little girl collects water from a communal standpipe in Bushbuckridge.

Table 1.2 Classification of aquatic ecosystem services [43]

Provisioning services	Regulating services	Cultural services
edible plants and animals	groundwater recharge	national symbols & borders
freshwater	dilution of pollutants	religious & spiritual enrichment
raw materials – wood, rocks and sand for construction, firewood	soil stabilisation	aesthetic appeal
genetic resources and medicines	water purification	inspiration for books, music, art and photography
ornamental products for handicrafts and decoration	flood attenuation	advertising
–	climate and disease regulation	recreation
–	refugia/nursery functions	–
Supporting services: nutrient cycling, soil formation, pollination, carbon sequestration, primary production		

Box 1.7 Examples of the ecological impacts of water resource developments

• **Outbreaks of blood-sucking flies along the Orange River** [35,36,37]

The Orange River, South Africa's largest river, is a critical water resource for the country. There are clear economic benefits to building dams to manipulate its flow regime for offstream use, but regulating river flow in this way has resulted in downstream flows in the Orange being less variable than naturally. One of the significant undesirable ecological consequences of this regulation has been regular outbreaks of the pest blackfly species *Simulium chutteri* and *Simulium damnosum* (Diptera: Simuliidae).

These species live as larvae in the water and emerge at maturity as small blood-sucking flies. Their proliferation in the river was part of a flow-regulation driven shift in the composition of the aquatic invertebrate community, with the loss of rarer species and the proliferation of more robust, common species. Outbreaks of blackfly have affected livestock along the river so seriously that they are estimated to have caused losses of up to R25 million per annum to sheep farmers alone in the middle and lower Orange River between Hopetown and Sendelingsdrif. Recovery and maintenance of a healthy aquatic invertebrate fauna in the middle Orange River depends on maintaining, or at least simulating, natural flow fluctuations. This would help to conserve threatened species, such as the blackfly *Simulium gariepense*, which is characteristically found in more variable flows, and reduce population outbreaks of the pest blackfly *S. chutteri*.

• **Crocodile deaths in the Olifants River** [38,39]

The northern Olifants River flows through north-eastern South Africa before joining the Letaba River and flowing into Mozambique. Thirty large dams harness the flow of the river, and its upper reaches drain areas characterised by mining, and industrial and agricultural activities. In May 2008, dying crocodiles were found along the river within Kruger National Park, with 170 carcasses recorded by November 2008. Yellow-orange hardened fat in their tails and fatty tissues pointed to pansteatitis, an inflammation of adipose tissue, which stiffened the animals, making it difficult for them to hunt and maybe causing them to drown.

Tests of soils and crocodile tissue revealed heavy metals, agricultural pesticides, fertilisers, organic waste and persistent organic pollutants, including DDT, PCBs, dioxins and brominated flame retardants, but nothing at levels that would individually cause the condition. Toxic blue-green algae (*Microcystis* spp.) and dinoflagellates (*Ceratium* spp.), which cause red tides in marine environments, were also present. Hundreds of mining operations upstream plus the large-scale regulation of its flow could be concentrating a deadly brew in the river that is killing the crocodiles and possibly also fish, birds, aquatic invertebrates and other river life. SANPARKS views the deaths as a 'clear alarm call that we cannot continue to pollute our water sources as we have done for the past several decades'.

1.7 Conclusion

The trends of population growth, increasing demands for water, resulting water resource development and consequent ecosystem degradation are global. What each country does, or does not do, about these trends is an individual response.

In South Africa, an understanding of what was happening to the rivers was patchy up to and during the 1980s. By the end of that decade, however, moving ahead of the water law existing at that time, water managers, water engineers, research funders, aquatic scientists, resource economists and social specialists started to work together to create a more sustainable approach to water resource development and management.

Against this background, Chapter 2 provides insight into why and how water law in South Africa evolved, and how it eventually included an ecosystem-based, sustainability approach to development designed to pro-actively manage the health of the country's water resources. The remaining chapters describe what is being done to address ecosystem maintenance and basic human needs in the new law.

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Thomas Peschak

2 WATER LAW IN SOUTH AFRICA: FROM 1652 TO 1998 AND BEYOND

Bill Rowlston

2.1 Introduction

This chapter provides a brief overview of the evolution of water law in South Africa from the time of the arrival of the Dutch settlers in the Cape of Good Hope in the mid-17th century to the introduction of the National Water Act (NWA, or the Act) in 1998. The process of reviewing and revising the existing law in the period immediately following the country's first democratic general election in April 1994 is outlined.

The main emphasis of the chapter is on the way in which measures to protect aquatic ecosystems were included in the Fundamental Principles and Objectives for a New Water Law in South Africa (1996 – the Principles), and the White Paper on a National Water Policy (NWP) for South Africa (1997 – the NWP, or the Policy). The provisions to protect aquatic ecosystems that were eventually included in the NWA are then described, together with the relationships between the protection of aquatic ecosystems and the use of water. The chapter concludes with a discussion of the ways in which measures to protect aquatic ecosystems, especially the priority accorded to them in terms of water allocation, are characterised in the NWA, the nature of the Act as framework legislation and how this has influenced its implementation by the Department of Water Affairs (DWA).

Readers who are familiar with the NWA may wonder why the term 'protection of aquatic ecosystems' (and its grammatical variants) is used in this chapter, instead of the more familiar 'protection of water resources'. This latter expression is used throughout the Act – and is in fact the title of Chapter 3 of the NWA – in which the Reserve[a] and other protection-related provisions are addressed. Careful study of the NWA, and the Principles and Policy that laid its foundations – a brief overview analysis is presented in Box 2.1 – reveals that the purpose of one component of the Reserve is to protect aquatic ecosystems. Since this chapter deals primarily with the introduction into policy and law of what has become known as the Ecological Reserve, 'aquatic ecosystems' is considered to be a more appropriate term than 'water resources'. The other component of the Reserve – the Basic Human Needs Reserve – is dealt with in Chapter 5.

Box 2.1: Water, water resources and aquatic ecosystems

Historically 'water use' in South Africa has been taken to mean abstracting (taking, extracting, or diverting) water from surface and groundwater sources for use (on land or in domestic and industrial processes, for instance) away from the source. For most users 'water' and 'water resources' meant – and probably still mean – the same thing: water.

This is not, however, the intended meaning in the NWA, or in the Principles and the Policy that preceded it and upon which it is founded. In all of these, statements can be found that, taken together, indicate that water resources are regarded as more than just water (Table 1.2), that aquatic ecosystems are the resource base on which all other uses depend, and that the purpose of the ecological component of the Reserve is to protect ecosystem functioning (for the Basic Human Needs component of the Reserve see Chapter 5).

- Principle 9 in the final set of the Principles (reproduced in the NWP, and in Appendix 2.1) speaks of reserving water for maintaining 'the ecological functions on which humans depend', so that 'the human use of water does not individually or cumulatively compromise the long-term sustainability of aquatic and associated ecosystems'.
- The NWP describes the purpose of the Environmental Reserve (now known as the Ecological Reserve) as being 'to protect the ecosystems that underpin our water resources'.
- 'Reserve'' is defined as the quantity and quality of water required to (a) provide a basic water supply for all people, and (b) to 'protect aquatic ecosystems in order to secure ecologically sustainable development and use of the relevant water resource'.
- The purpose of the NWA is 'to ensure that the nation's water resources are protected, used, developed, conserved, managed and controlled', and one of the 11 factors that must be taken into account to achieve this purpose is 'protecting aquatic and associated ecosystems and their biological diversity'.
- Other definitions in the NWA – for 'water resource', 'watercourse', and 'resource quality', all of which are discussed in later sections of this chapter – make it clear that a water resource includes the bed and banks, the instream and riparian habitat, and the associated plant and animal communities (from which it will be seen that the definitions are biased towards surface water resources). In other words, a water resource in the NWA means an aquatic ecosystem.

After the Definitions and Purpose (sections 1 and 2) aquatic ecosystems are mentioned only once more in the text of the Act, in the context of monitoring systems, and the NWA refers exclusively to the protection of water resources. The expression is used in all regulatory instruments (regulations, operational policies, strategies and guidelines) that follow, including the First Edition of the National Water Resource Strategy, which was the first attempt at a national-level implementation strategy for the NWA [1].

[a] *Note that Reserve is capitalised throughout the NWA, and this convention has been perpetuated in the many documents that are based on or have arisen from the Act. Capitalisation of 'ecological' seems to be a matter of personal preference.*

2.2 Pre-1998 legislative frameworks

The origins of South African water law can be traced back to the Dutch settlers who established a settlement in the Cape of Good Hope in 1652. Although it was established as a re-supply point for the trading ships of the Dutch East India Company as they travelled between the Netherlands and the East Indies, the support station gradually became a permanent Dutch colony, and was administered by the Company from the Netherlands for the next 150 years or so. During this period all land was held in leasehold from the State, which owned all water and exercised absolute control over its use under the Roman-Dutch law principle of dominus fluminis[b].

During the French revolutionary period and the ensuing Napoleonic Wars, control of the colony changed hands three times (Box 2.2) until, in 1814, the Dutch finally ceded control to the British, who established a Crown Colony. Among many other changes, the British introduced freehold tenure of land. This had a profound influence on the State's control of water resources because, under English law, all natural rights that were attached to land, including water, belonged to the landowner. Accordingly, the riparian principle of English-American law, whereby owners of land alongside rivers have common rights to exclusive and in-perpetuity use of the water in the rivers, was established in the colony's water law.

The State played only a limited role in the development and management of water resources, which was dominated by private agricultural developments. A special Water Court was established to determine water allocations and adjudicate in disputes over water rights, and town and village authorities were fully responsible for the water supply and sanitation needs of local inhabitants.

In 1910, eight years after the end of the Second Anglo-Boer War, the Union of South Africa, a British dominion, was created by the union of the former Boer republics of the Orange Free State and Transvaal, and the former British colonies of the Cape and Natal. The first nationally-applicable water law – the Irrigation and Conservation of Waters Act – was passed into law in 1912, superseding the previous colonial laws.[c] The riparian principle remained a central feature of the new water law, but the water needs of urban and industrial growth, especially in the period after the end of World War II in 1945, required frequent deviations from the strict application of this principle. Two innovative administrative devices – 'normal' and 'surplus' flow (Box 2.3) – were introduced to empower the Water Court to authorise the use of 'surplus' flow on non-riparian land for urban or industrial use. The exclusive rights of riparian owners were restricted to the 'normal' flow, but riparian owners were entitled to as much of the surplus flow as they could use beneficially. Government involvement in water resource management was limited to the development of waterworks for irrigation.

Box 2.2: Control of the Cape Colony

7th April 1652
Dutch Cape Colony established, administered by the Dutch East India Company.

September 1795
Cape Colony occupied by Britain.
Reacting to the occupation of the Netherlands by French revolutionary forces, the British occupied the Cape Colony in order to control the seas and prevent any attempt by the French to reach India.

March 1797
British colony established.

February 1803
Colony of the Batavian Republic established.
Improved relations between Britain and Napoleonic France led the British to hand the Cape Colony to the French-controlled Dutch state.

January 1806
British retake Cape Colony.
Peace between Britain and Napoleonic France turned to open hostility, and the British re-occupied the colony to keep Napoleon out and secure control of the Far East trade routes.

August 1814
Dutch officially cede Cape Colony to Britain.

[b] *Roman law was adopted in the Netherlands between the 14th and 16th centuries.*

[c] *The 1912 law was intended only to control water use by the white colonists. It paid no attention to, and made no provision for, the ways in which the indigenous population developed, used, managed and allocated water, controlled its quality or ensured its productive use. These traditional and mostly informal institutional, socio-economic and cultural arrangements – now commonly referred to as community-based water law – usually existed only in oral form.*

With some amendments, the 1912 Act regulated water resource development in South Africa until 1956. Whilst it was well suited to promoting irrigation development, the 1912 Act's inadequacy to meet the demands of an expanding industrialised economy became increasingly clear in the global industrial recovery following the end of World War II. The resulting high demand for primary raw materials enabled South Africa to enjoy considerable industrial output and extensive raw material exports, but the prevailing water legislation needed adjustments to facilitate the necessary industrial development.

Following the recommendations of the 1952 report of a Commission of Enquiry, the Water Act (54 of 1956) was introduced. This Act perpetuated the riparian principle in terms of 'normal' flow and 'private' water, which granted exclusive rights to use water but not ownership of it. However, the Act also attempted to regulate all 'public' water for all water-user sectors in the national interest, by giving the State control of all water in excess of riparian users' rights, that is, the 'normal' flow as discussed in Box 2.3. The construction of storage and diversion works above a specified capacity also required government approval. The State was thus able to play a much greater role in planning and implementing water resource developments. In addition, a number of surface and groundwater control areas were proclaimed, in which the riparian system did not apply, and where the Water Court, which did not undertake any planning, had no further jurisdiction. The broadened scope of the State's role in managing water resources under the new law was reflected in the change of name of the Irrigation Department to the Department of Water Affairs.

The effect of the administrative compartmentalisation of the water resource into neat (but almost entirely notional) components was that control of low ('normal') flows in rivers, arguably the most important part of the hydrological regime, and also of groundwater, remained in the hands of riparian land owners. There were, however, other developments that further fragmented administrative and legislative control over water resources.

In 1948 the National Party won the general election, and set about introducing its apartheid (racially-segregated 'separate development') policies. Between the late 1960s and the late 1970s the Nationalist Government established ten homelands for the majority black population. These areas, which comprised only about one tenth of the total land area of South African territory, were ultimately intended to be self-governing states, independent in all respects from 'white' South Africa. The homeland scheme was inherently iniquitous and ultimately impractical, and it also militated against integrated water resources management.

Only one of the homelands, Bophuthatswana, developed its own water law – the Water Act (Bophuthatswana) (38 of 1988) – while the others retained the South African Water

Box 2.3: Public and private water; normal and surplus flow

The distinctions between 'public' and 'private' water were made in Roman law, and were a feature of South African water law until the NWA came into force in 1998.

Broadly speaking, in terms of the 1956 Water Act, ***public water*** (in the case of surface water) was a source that had potential for communal use, while ***private water*** was sufficient only to meet individual needs. Only the Water Court was competent to decide whether a source was public or private.

Groundwater, even where the source was able to supply communal needs, was regarded as private water.

The 1912 Act further classified public surface water as ***normal*** or ***surplus flow***. These were administrative devices used to facilitate deviations from strict adherence to the riparian principle, which was proving to be a hindrance to developing South Africa's industrial potential.

Normal flow, approximately equivalent to the perennial part of a river's flow (i.e. its base flow), was sufficiently dependable for irrigation without storage, and this was the component of the flow regime of a river that riparian landowners were entitled to use.

Water exceeding normal flow was ***surplus flow***, the irregularly high flows that occurred after heavy rain. The 1956 Act entitled the State to gain control over some of this component of the flow regime for use in the public interest.

Act of 1956. Fifteen amendments were made to the 1956 Water Act after the establishment of the first homeland, however, some of which may have been effected in the homelands, and some of which may not have been. The result was that, when the country was reunified after the first democratic general election in 1994 there were, to all intents and purposes, 11 variations of the water law in territorial South Africa, administered by 11 different authorities. Traditional systems of water management under community-based water law also continued to operate in many rural areas.

In addition, a very large number of scheme- or area-specific water laws had been promulgated since the 1912 Act was passed, including acts relating to irrigation and town water supply schemes, and large water resource development schemes on the Vaal and Orange Rivers. More than 70 such laws were repealed when the NWA was enacted in 1998.

One positive development that took place during this period concerned the rationalisation of water-related research. During the severe, country-wide drought of 1966, and in view of the rate of industrial expansion at the time and the limited water resources of the country, the State President appointed a Commission of Enquiry into Water Matters, the report of which was accepted by government in 1970. The Commission made recommendations on almost every aspect of water resource management, of which some were implemented and some were not. One that was implemented, and which ultimately became important to the subject of this review, was the establishment, in 1971, of the Water Research Commission (WRC) in terms of the Water Research Act (34 of 1971). The WRC is funded from a levy on bulk sales of water to water boards, local authorities and government irrigation schemes and, in terms of the Act, it is mandated to co-ordinate, promote, encourage or cause to be undertaken research on the occurrence, preservation, conservation, utilisation, control, supply, distribution, purification, pollution or reclamation of water supplies and water as well as the use of water for agricultural, industrial or urban purposes.

Derick du Toit

Female children and young adults often queue for water for many hours a day, with this time lost from income generation, school work and food production.

Jackie King

Luvuvhu River upstream of Kruger National Park in October 1992.

Thus far in this section there has been, apart from a brief mention of the homeland system, no mention of South Africa's infamous racial history. Although it could be imagined that institutionalised racial segregation began with the election of the Nationalist Government in 1948, for the purposes of analysing the origins of institutionalised discrimination in water matters it is necessary to look back at least to 1910.

On May 31st 1910 the Act of Union was signed into law, thereby creating the Union of South Africa. Although this Act united white interests, it stripped black people and people of colour of the franchise (Box 2.4). The discriminatory nature of race relations that was to prevail until near the end of the century was further underpinned by the passage into law of the Natives Land Act in 1913. This was the first major piece of segregation legislation passed by the Union Parliament, and it created a system of land tenure that deprived the majority of South Africa's inhabitants of the right to own or occupy land in 'white' areas. The Act created a number of African reserves for the settlement of black South Africans,

Jackie King

Luvuvhu River within Kruger National Park in October 1992.

Box 2.4 South Africa's racial groups

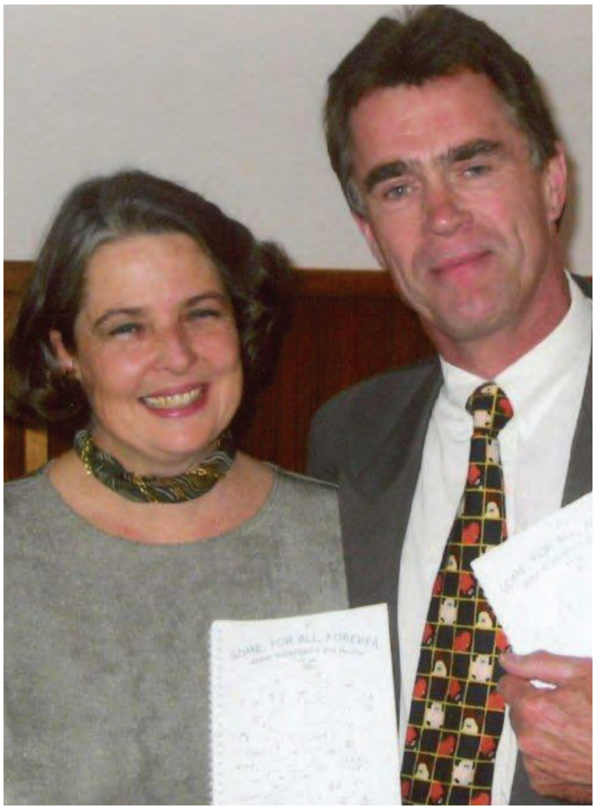
In the South African context the term *Coloured* refers to an ethnic group of mixed-race people who possess some sub-Saharan African ancestry, but not enough to be considered *Black* under imperial and apartheid legislation. Technically they are mixed race, and often possess substantial ancestry from Europe, Indonesia, Madagascar, Malaysia, Mozambique, Mauritius, St Helena and southern Africa. Under the race-focused apartheid system, all such mixed-race people where categorised as *Coloured*, one of the four racial groups identified as Black, White, Coloured and Indian. All of these terms were capitalised in apartheid laws. In post-apartheid South Africa, where it is necessary to use such terms in legislation designed to redress previous racial inequities (such as the Employment Equity Act), the term Black is used as a generic term for African, Coloured and Indian people.

which would serve as pools of migrant labour for white-owned farms and urban-based industry. The total area of the reserves amounted to less than 7% of South Africa's land area. The Act also eliminated independent tenancy by black people in white rural areas, by abolishing sharecropping and rental tenancy arrangements.

Neither the 1912 Irrigation and Conservation of Waters Act nor the 1956 Water Act were intrinsically or overtly discriminatory. However, the combined effect of the riparian system, in which access to water resources was tied to land ownership, and the severe restrictions on land ownership by the majority black population under the Natives Land Act of 1913, which were perpetuated in the policies of racial segregation that lay at the core of apartheid-era social planning, was to skew access to water in favour of the minority white population. The water-related needs of the majority black population, politically voiceless because they had been denied the vote by the Act of Union in 1910, were to all intents and purposes ignored by the government.

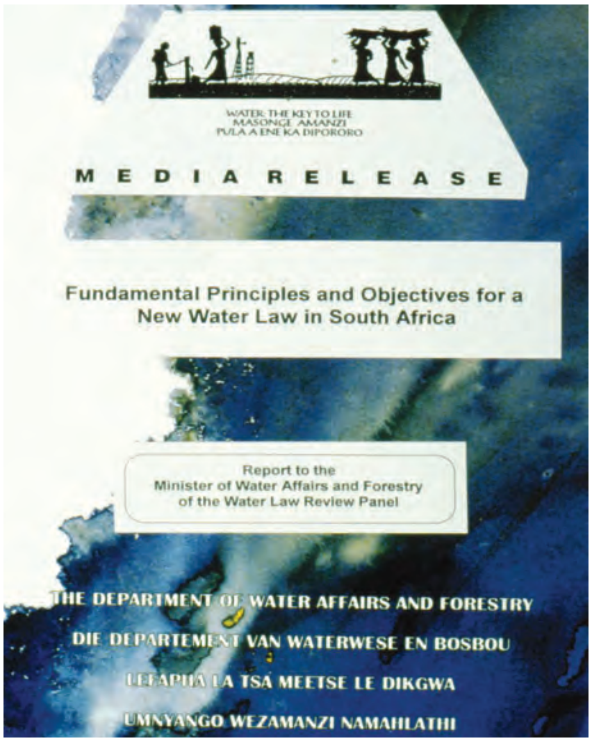
2.3 The development process for the National Water Act

The technical and social deficiencies of the 1956 Water Act had become increasingly evident over a number of years, but it was not until 1994, when the first democratically-elected government came to power in South Africa, that the opportunity presented itself for a thorough review of the existing law. The new government's policies focused strongly on equitable and sustainable social and economic development for the benefit of all South Africans, but many existing laws, including the law relating to water, were found to be not at all appropriate to achieving these objectives. As noted above, the fact that access to water was to a large extent tied to land ownership *via* the riparian system, together with restrictions on land ownership by the majority black population, meant that most people in the country could not claim access to water under the 1956 Water Act. Accordingly, the first post-1994 Minister of Water Affairs and Forestry, Professor Kader Asmal, announced the South African Water Law Review as one of his first initiatives on taking office in May 1994 [2].

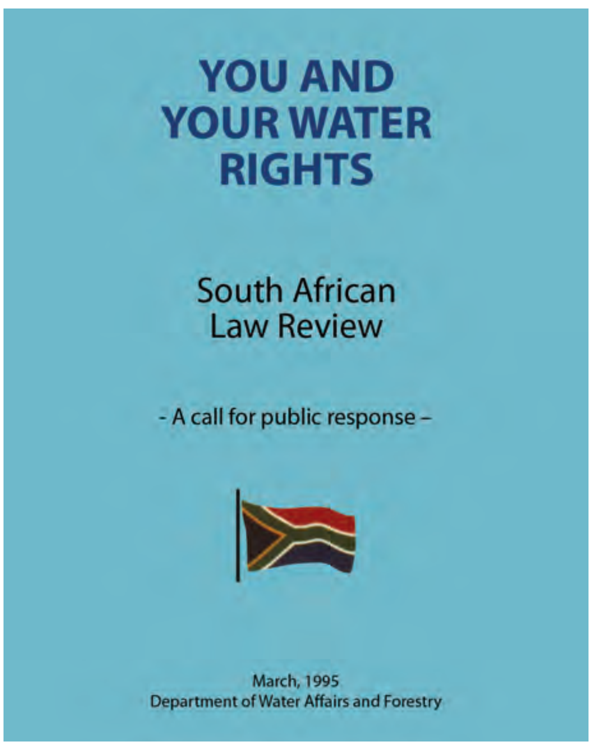


Rhodes University

Caroline Palmer, Vice Chair of the Water Law Review Panel and Bill Rowlston, coordinator of the review process within DWA.



Media release of the initial report from the Water Law Review Panel.



The brochure prepared for public consultations on the proposed principles for a new Water Act.

Few countries have been able to create the environment for peaceful change that existed in South Africa after the political settlement was negotiated in the early 1990s, and few new governments have had the opportunity to scrutinise all the existing laws of the country, and to make dramatic changes to ensure that they are consistent with the new democratic order. There is no doubt that this rare window of opportunity opened as wide for the review of the water law as it did for any other law, and that it facilitated the profound changes that culminated in the passage into law of the National Water Act (Act 36 of 1998). However, Asmal's personal contribution to the water law review process cannot be overstated. A lawyer with a strong sense of social justice (he founded and chaired the Irish Anti-apartheid Movement whilst lecturing in law at Trinity College in Dublin), he provided the necessary legal expertise, intellectual capacity and, importantly, the political will and authority, to ensure that the new law fundamentally transformed the way water was controlled and managed in South Africa.

The decision to write a new law de novo, rather than to make further changes to the already much-amended 1956 Water Act, does not appear to have been formally documented. There are, however, references in the report of the Water Law Review Panel (Section 2.3.1), and in the NWP (Section 2.3.2) to the technical complexities of applying a law based on the riparian system, appropriate to the relatively well-watered northern hemisphere in which most rivers are perennial, to a modern but semi-arid industrial country in which many rivers and streams flow seasonally or episodically. From this perspective it was questionable whether such a law could be amended to successfully reflect the imperatives of managing water resources in the new South Africa. In addition, from the perspective of social equity, it might reasonably be inferred that the 1956 Water Act was judged to be freighted with too much apartheid baggage for an amended act to be acceptable to the majority black population, against whom the 1956 Water Act had de facto discriminated for almost four decades.

2.3.1 Fundamental Principles and Objectives for a New Water Law in South Africa (1996)

The first step in the Water Law Review process was the appointment, in April 1995, of the Water Law Review Panel, a multi-disciplinary team led by Advocate Geoff Budlender, to formulate the principles on which the new law would be founded. The Panel met for the first time in September 1995, with members drawn from a wide range of backgrounds including the different water-user sectors, rural communities, legal experts, departmental officials and an aquatic scientist (Box 2.5). It presented its report *Fundamental Principles and Objectives for a New Water Law in South Africa* to Asmal in January 1996.

After comments received during an extensive programme of public consultation had been considered the final set of 28 Principles, a considerably reworked and refined version of those presented in the Panel's report, was submitted to and approved by the Cabinet at the end of 1996. The final set of 28 Principles is reproduced in Appendix 1 of the NWP and, for ease of reference, it is also included here as Appendix 2.1.

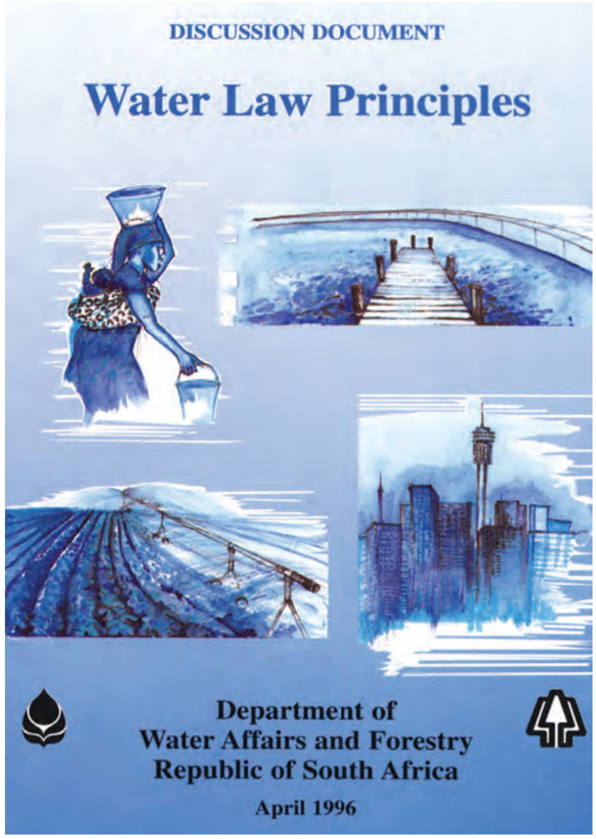
The fragmentation of water-related legislation caused by the variations of the 1956 Water Act in the former homeland areas had been dealt with by the passage of the Water Laws Rationalisation and Amendment Act (32 of 1994) in late 1994. Principles 2 and 4 of the Fundamental Principles and Objectives, under the heading *Legal aspects of water*, addressed the fragmentation of the water resource itself through the administrative devices of 'public' and 'private' water, and 'normal' and 'surplus' flow, by proposing that all water should have a consistent status in law and, importantly, proposed the abolition of the riparian principle that had necessitated them, as follows.

Principle 2: *All water, wherever it occurs in the water cycle, is a resource common to all, the use of which shall be subject to national control. All water shall have a consistent status in law, irrespective of where it occurs.*

Principle 4: *The location of the water resource in relation to land shall not in itself confer preferential rights to usage. The riparian principle shall not apply.*

The proposal in Principle 2, that the use of water should be subject to national control by the National Government, is revisited in Principle 12, in which the National Government is described as the custodian of the nation's water resources, and which refers to water resources as an indivisible national asset.

Principle 3 includes the important principle that water for environmental and basic human needs is a right (highlighted below), whereas other uses were to be the subject of an authorisation for use. This was a critical first step in the eventual introduction into the new policy and law of provisions to protect aquatic ecosystems – provisions that were lacking in the 1956 Water Act – thereby safeguarding the sustained usefulness of water resources to human beings.



The discussion document containing the suggested 28 principles.

Box 2.5 Members of the Water Law Review Panel

Chair: Geoff Budlender – Cape Bar Council

Vice Chair: Caroline Palmer – Rhodes University

Members: Len Abrams; Chris Audie;
Linda Garlipp; Mike Hawke;
Francois Junod; Peter Lazarus;
Grace Nkambule; Hubert Thompson

The Panel was appointed in April 1995 , first met on 7 September 1995 and thereafter on 13 occasions over three months.

Principle 3: *There shall be no ownership of water but only <u>a right (for environmental and basic human needs)</u> or an authorisation for its use. Any authorisation to use water in terms of the water law shall not be in perpetuity.*

Jackie King

Water managers and aquatic scientists contemplate the almost-dry Olifants River upstream of Kruger National Park in 1993, during a workshop to advise on flows for maintaining the river in a healthy condition.

In this respect the appointment of Dr Carolyn Palmer as Vice-Chair of the Panel played a significant role. Central to the debate in the Panel was the question of whether the aquatic environment was to be considered merely as a user of water, in competition with other users, or if it was to be accorded the status of the resource base that supported all other uses. Dr Palmer, an aquatic scientist with the Institute for Water Research at Rhodes University, mobilised the membership of the Southern African Society of Aquatic Scientists to submit information to support the assertion that aquatic ecosystems needed to be protected, by limiting extraction of water from them and discharge of waste water into them, in order for other uses of water to be sustainable in the long term.

Although the concept of aquatic ecosystems as the resource base, on which all other uses depended, was accepted by the Panel, there was scepticism about the ability of aquatic scientists to make credible estimates of how much water should be left in water resources such as rivers and streams to maintain their health. Dr Palmer was able to present to the Panel the results of about 20 exercises [3], undertaken during the previous five years or so as part of DWA's environmental impact assessments for proposed dam developments, to quantify the flow requirements for river maintenance (further details below and in Chapter 4). The Panel found these results to be sufficiently compelling to include, as Principle 4.2 in its report to Prof. Asmal – 'Water required for basic human needs and for the ecological reserve shall be termed the 'Reserve' (author's emphasis).

In early 1996, between the submission of the Panel report and the adoption of the final set of Principles by the Cabinet, Francois Junod (a Senior Advocate of the Pretoria Bar with many years of experience in administering the 1956 Water Act) attended a workshop where the environmental flow requirements (or instream flow requirements (IFRs) as they were then known) for the Sabie-Sand River System were being addressed.

It is probable that the Advocate's positive opinion of the scientific credibility of the approach used at the workshop, and the legal defensibility of the results, also played a role in the inclusion of 'water to meet the needs of the environment' in the final Principles. In this, Principles 7 to 10 were established as part of the section on *Water resource management priorities*.

The Sabie River in Kruger National Park was the focus of much of the early research on the nature and functioning of river ecosystems (details in Chapters 4 and 6).

Principle 7: *The objective of managing the quantity, quality and reliability of the Nation's water resources is to achieve optimum, long term, environmentally sustainable social and economic benefit for society from their use.*

Principle 8: *The water required to ensure that all people have access to sufficient water[d] shall be reserved.*

Principle 9: *The quantity, quality and reliability of water required to maintain the ecological functions on which humans depend shall be reserved so that the human use of water does not individually or cumulatively compromise the long term sustainability of aquatic and associated ecosystems.*

Principle 10: *The water required to meet the basic human needs referred to in Principle 8 and the needs of the environment shall be identified as "The Reserve" and shall enjoy priority of use by right. The use of water for all other purposes shall be subject to authorisation.*

There is no doubt that the establishment of the new democratic government in South Africa presented the opportunity for aquatic scientists and water resource managers to propose measures for the protection of aquatic ecosystems that would, as will be seen in the following sections, eventually be included in national policy and legislation. However, the roles of DWA and the WRC, in laying the scientific and technical groundwork, should not go unmentioned.

It is reasonable to say that, for most of its existence, one of DWA's principal preoccupations was the creation of storage for surface water runoff by building dams. It was not until the late 1970s[e], midway through a period of intensive dam construction (Box 2.6), that DWA began to give serious consideration to the environmental impacts of its activities. In the early 1980s the focus in this respect was on issues such as the restoration of dam sites after construction or on decommissioning, and reducing visual impacts by, for instance, grassing the downstream faces of embankment dams[f].

In the latter years of the decade the focus of impact assessments broadened considerably to include the aspects of the biophysical environment that are habitually included in an environmental impact assessment (EIA) today. What was remarkable about this period – and for which DWA deserves considerable credit – was that EIAs for proposed dams were being carried out before there was any legislative requirement to do so, and before regulations were made prescribing the processes and procedures by which the assessments were to be undertaken. Instead, DWA, in collaboration with the WRC and the national body of aquatic scientists, began to develop appropriate procedures, and implemented them with some success until the regulations were eventually published (Box 2.7).

Among the many environmental impacts of dams, those linked to damming a river and altering, usually profoundly, the flow regime of the watercourse downstream of the dam wall, were among the most severe, a fact that aquatic scientists had been pointing out to DWA for many years. In order to mitigate these impacts it was necessary to know what the downstream flow regime should be – the quantity, pattern and timing of releases from the dam – to maintain the ecological functioning of the river at some acceptable level. Accordingly, in the early 1990s, DWA embarked on a series of studies to determine Instream Flow Requirements (IFRs), the precursor to the Ecological Reserve, for all rivers on which dams were mooted for construction. The first of these studies, which are still a routine part of DWA's work for Reserve determinations, was carried out in February 1992 for the Lephalala River, a tributary of the Limpopo River in the north west of the country.

[d] *Note that 'the water required to ensure that all people have access to sufficient water ... ' in Principle 8 becomes 'basic human needs' in Principle 10. This was defined, in the Water Supply and Sanitation Policy White Paper, November 1994, as being a minimum of 25 litres of potable water per person per day, at a maximum cartage distance of 200 metres, delivered at a minimum flow rate of 10 litres a minute, and at an assurance of supply of 98 per cent. This quantification was confirmed, with only minor refinements, in the Strategic Framework for Water Services, September 2003. Achievement of this level of service was government's 'most important policy priority' (Preface), but the daily volumetric allowance is to be reviewed with a view to increasing it from 25 to 50 litres per person.*

[e] *In 1980, environmental impact statements were included in two departmental proposals to construct dams, which were tabled in parliament as White Papers, as required by the 1956 Water Act.*

[f] *Instead of the less visually appealing rock facing. The unit established in DWA to undertake this work initially comprised landscape architects, and a person described as a horticultural technician.*

The studies ultimately led to the development of a distinctly South African approach – the Building Block Methodology – for assessing the ecological water requirements for rivers (details in Chapter 4) [4].

They also provided the results that Dr Palmer was able to present to the Water Law Review Panel to convince them that the Ecological Reserve could be quantified in practice.

Box 2.6 Dams in South Africa

'Dam' is the South African term for more or less any artificially-created collection of water; in this document it refers to both the dam wall and the reservoir impounded behind it. Dams have long been a necessary feature of water resources management in South Africa, intended to increase security of supply in the face of a generally dry and highly variable climate. DWA's records* include details of 23 dams built in the latter part of the 19th century, but building accelerated to a peak between 1969 and 1989 when more than 1800 dams – large and small – were constructed (Figure 1.4).

By 1989, the capacity of all dams was sufficient to store a little less than 60% of the total mean annual runoff (MAR) from all surface water sources in the country. Although the rate of dam construction has declined significantly since the end of the 1980s, by the end of 2009 the total storage capacity had grown to around 65% of MAR.

*Dam safety legislation was incorporated into the 1956 Water Act in the mid-1980s, and incorporated, with some amendments and refinements, into the NWA. DWA's List of Dams Registered in Terms of Dam Safety Legislation is arguably the most comprehensive record of South Africa's dams. In September 2009 it contained details of more than 4000 dams with a storage capacity equal to or exceeding 50 000 cubic metres, from individual farm dams to South Africa's largest impoundment, the Gariep Dam, which has a storage capacity of 5674 million cubic metres.

Box 2.7 Environmental Impact Assessments in South Africa

EIAs became mandatory in South Africa in 1989 with the enactment of the Environmental Conservation Act (73 of 1989). Regulations prescribing the activities for which EIAs were required, and the procedure to be followed in conducting EIAs, were published by the Department of Environmental Affairs and Tourism in 1997.

The publication in April 2006 of listed activities in terms of the National Environmental Management Act (NEMA – Act 107 of 1998) brought water and environmental law much closer together. Some of the listed activities refer specifically to the requirements of the NWA, and national and provincial environmental authorities should not grant authorisation for water-using activities unless DWA has indicated that the NWA's requirements have been complied with.

The relationship between environmental and water law is made clear in NEMA's definition, in s1, of the environment, ... "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 interrelationships among and between them; and
iv. the physical, chemical, aesthetic and cultural properties and conditions of the foregoing that influence human health and wellbeing."

In some respects the NWA can therefore legitimately be regarded as part of the overarching environmental legislation.

Jackie King

Water managers, water engineers and aquatic scientists meet for the first IFR workshop at Lapalala Game Ranch in February 1992.

Jackie King

Participants of the Lephalala River IFR workshop visit a river site at Molope. Damming of the river was under consideration.

One of the most outstanding features of the decade between the mid-1980s and the mid-1990s was the level of cooperation and collaboration, unprecedented within South Africa and probably also in most other countries, between DWA's water managers and engineers, and aquatic scientists, and this is where the contribution of the WRC must be acknowledged. Although the IFR studies were organised and partially funded by DWA, the participation of most of the aquatic scientists in the studies, as well as their research projects that provided so much of the essential data and information that enabled credible estimates of water requirements to be made, was funded by the WRC. Chapter 6 details what was to become an outpouring of scientific literature, and teaching and training activities, emanating and growing from this modest beginning.

At the close of this first phase of the Water Law Review, Cabinet had accepted the recommendations of the Panel that water to meet basic human needs and water to maintain ecological functioning – jointly, the Reserve – should "*enjoy priority of use by right*". The use of water for all other purposes was to be authorised by processes that were not defined in the Principles document.

2.3.2 The White Paper on a National Water Policy for South Africa (1997)

Although the Principles had been approved by Cabinet, they could not be regarded as formal government policy until Cabinet adopted the White Paper on a National Water Policy for South Africa (NWP, or the Policy) – in April 1997. The NWP was based on the Fundamental Principles and Objectives, with the overall objective of ensuring equitable and sustainable access to a limited resource. This was encapsulated in DWA's pithy slogan *Some (water), for all, for ever.*

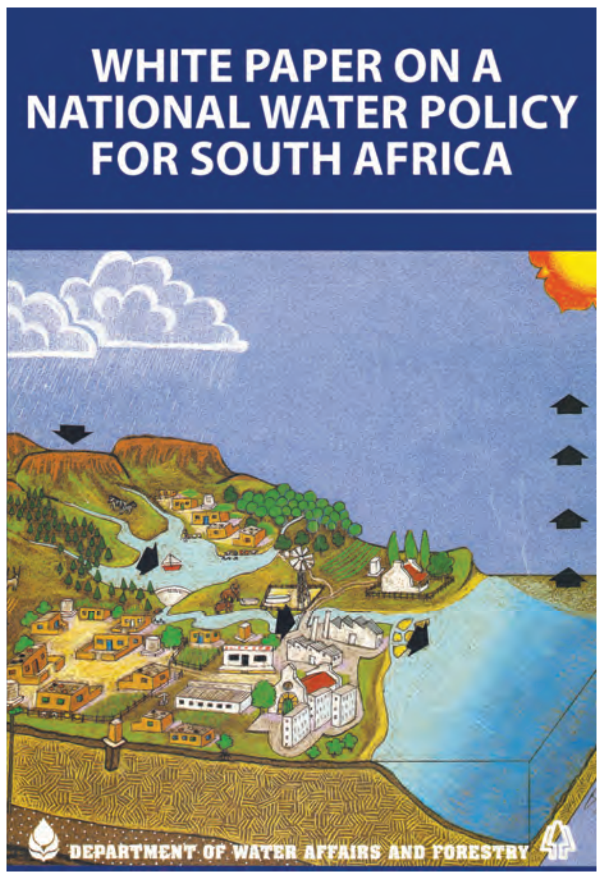
The framework for managing water resources, as outlined in the Principles, was considerably expanded and explained in the Policy, but the main thrusts were summarised in *Key Proposals* at the beginning. The key proposals that enabled the introduction into legislation of provisions that required water to be set aside for ecosystem maintenance – the Ecological Reserve – and others directly relating to them are reproduced below together, where appropriate, with references to the sections of the NWP in which they are discussed in detail.

First of all the Policy confirmed the National Government's authority over all water, wherever it occurs in the hydrological (water) cycle.

- *The status of the nation's water resources as an indivisible national asset will be confirmed and formalised.*

- *National Government will act as the custodian of the nation's water resources and its powers in this regard will be exercised as a public trust.*
  (See section 5.1.2 of the NWP – Public trust)

- *All water in the water cycle whether on land, underground or in surface channels, falling on, flowing through or infiltrating between such systems, will be treated as part of the common resource and to the extent required to meet the broad objectives of water resource management, will be subject to common approaches.*



The information brochure on the National Water Policy for South Africa, 1997.

Next the Policy established an order of priorities by which water would be allocated, in which water for environmental requirements is second only to water for basic human needs.

- *Only that water required to meet basic human needs and maintain environmental sustainability will be guaranteed as a right. This will be known as the Reserve.* (See sections 5.2.1 of the NWP – Basic needs and 5.2.2 – Environmental requirements, and section 6.3 – Protection of water resources)

  Water for basic human needs as the first priority, before environmental requirements, is explicit in the wording of s5.2.2 – "*After providing for the basic needs of citizens* ... ". This order of priorities is also affirmed in s5 of the Water Services Act (108 of 1997)[g].

- *In (internationally) shared river basins, Government will be empowered to give priority over other uses to ensure that the legitimate requirements of neighbouring countries can be met.* (See section 5.2.3 – International Obligations)

- *All other water uses will be recognised only if they are beneficial in the public interest.*

- *These other water uses will be subject to a system of allocation that promotes use which is optimal for the achievement of equitable and sustainable economic and social development.* (See section 6.2 – Water use authorisations)

These provisions explicitly established the order of priorities for allocating water as:

1. Basic human needs and ecosystem requirements.[h]
2. International obligations.[i]
3. All other uses of water.

In section 6.3 – Protection of water resources – the Policy discussed the ecosystem services – referred to at that time as 'silent services' – offered by healthy, functioning aquatic ecosystems (Table 1.2), and introduced the concept of resource quality. This term includes ' ... the health of all of the parts of a water resource that together make up an ecosystem, including plant and animal communities and their habitats', and not merely the physical and chemical characteristics of the water.

The Policy also proposed the introduction of a national Water Resource Classification System. Using this, and through a process of consensus-seeking among water users and other stakeholders, the level of use and protection of any one water resource (or the different geographical parts of larger water resources) would be decided by first identifying its agreed class from minimally modified to highly modified and then by setting Resource Quality Objectives (the quantity, quality and assurance of the water, as well as the nature of communities of living organisms and their habitats), in accordance with this class. It was intended that the objectives would show the degree of ecosystem change or impact considered acceptable for the expected benefits that would emanate from using the resource, and also provide target numbers that could be used in monitoring programmes (see below and also Chapters 4 and 7).

A distinction was made between *resource-directed measures*, by which objectives would be set for the desired level of protection for the aquatic ecosystems of each water resource, and the more traditional *source-directed controls*, by which the uses of a water resource (abstraction of water, discharge of waste water, for instance) that impact on its quality would be controlled to achieve the agreed level of ecosystem health, and so ensure its sustainable use.

The links between the protection of aquatic ecosystems and their use were thus firmly established in the Policy. It was explicitly recognised that because achieving objectives for protecting aquatic ecosystems would involve controlling water use (in particular, in many cases, curtailing existing use), it would be necessary to involve water users and other interested and affected parties in making recommendations and decisions about the level of protection to be afforded to them.

[g] *Water Services Act, s5 Provision of basic water supply and basic sanitation to have preference – If the water services provided by a water services institution are unable to meet the requirements of all its existing consumers, it must give preference to the provision of basic water supply and basic sanitation to them.*

[h] *See sections 27 and 24 of the Bill of Rights in the Constitution of the Republic of South Africa (No 108 of 1996) that speak of people's right of access to sufficient food and water, and their right to an environment that is not harmful to their health or well-being, and to have the environment protected for the benefit of present and future generations, respectively.*

[i] *This is based on the African National Congress's post-1994 election Reconstruction and Development Programme, which emphasised, among other things, the importance of integrated social and economic development between South Africa and its southern African neighbours.*

2.3.3 National Water Act (1998)

The third and final stage of the Water Law Review process was completed when the State President assented to the NWA on 20th August 1998j, thereby giving legal effect to Government's intentions for managing water resources as they were expressed in the NWP.

Measures to protect water resources are described in Chapter 3 of the Act – Protection of water resources – where protection in relation to a water resource means *"the maintenance of the quality of the water resource to the extent that the water resource may be used in an ecologically sustainable way, the prevention of the degradation of the water resource, and the rehabilitation of the water resource"* (s1(1) (xvii)).

The first three parts of Chapter 3 deal with (in the order they appear in the Act) a classification system for water resources, classification of water resources and Resource Quality Objectives using this system, and the Reserve, all as previously discussed in the NWP.

2.3.3.1 Definitions

A number of definitions in the NWA (s1(1)) indicate the intention to provide comprehensive protection to all water resources. A water resource (xxvii) includes a watercourse, surface water, estuary, or an aquifer, while a watercourse (xxiv) includes a river or spring, a natural channel, a wetland, a lake or dam. Estuary and wetland are defined in (ix) and (xxix) respectively. Instream and riparian habitat are defined in (xi) and (xxi) respectively. The definition of pollution (xv) includes any alteration to a water resource that could be harmful to, among others, any aquatic or non-aquatic organisms or to the resource quality. Arguably the most important definitions are for the Reserve and Resource Quality Objectives.

The definition of the Reserve in the Act (s1(1) (xviii)) confirmed the proposals in the Principles and the NWP that the water requirements for basic human needs and ecosystem functioning should be combined:

> (xviii) ***"Reserve"*** *means the quantity and quality of water required:*
> (a) *to satisfy basic human needs by securing a basic water supply, as prescribed under the Water Services Act, 1997 (Act No. 108 of 1997), for people who are now or who will, in the reasonably near future, be –*
> (i) *relying upon*
> (ii) *taking water from; or*
> (iii) *being supplied from,the relevant water resource;*
> (b) *to protect aquatic ecosystems in order to secure ecologically sustainable development and use of the relevant water resource;*

The definition of Resource Quality Objectives (xix) implicitly acknowledges that water resources are more than just the water in them, and that their condition depends not only on the quantity and quality of the water, but also on the condition of the animals, plants and micro-organisms that inhabit the bed, water column and banks, and the interactions that take place among the various biotic and abiotic components that comprise the ecosystem as a whole.

> (xix) *"**resource quality**" means the quality of all the aspects of a water resource including:*
> (a) *the quantity, pattern, timing, water level and assurance of instream flow;*
> (b) *the water quality, including the physical, chemical and biological characteristics of the water;*
> (c) *the character and condition of the instream and riparian habitat; and*
> (d) *the characteristics, condition and distribution of the aquatic biota.*

It is clear from these two definitions that there is a close inter-relationship between the Reserve and Resource Quality Objectives, since both include the quantity and quality of water. It could reasonably be inferred that the Reserve is a component, albeit a special one, of the Resource Quality Objectives.

2.3.3.2 System for classifying water resources

The classification system is central to the suite of provisions in the NWA for protecting water resources, because the class determined for a water resource sets the level of protection that is to be afforded to the resource. However, the NWA also makes it clear that the class of a water resource is not determined only by ecological considerations, since the needs of water users must also be taken into account.[k]

[j] *The Act 'commenced' – came into effect – progressively via three Government Notices in September and December 1998 and October 1999.*

[k] *At least, that is, in respect of users' water-quality requirements (s12(2)(b)(ii)). The reasons for including water quality in the definition, and excluding users' quantity requirements, are not clear.*

Prescription of classification system

12. *(1) As soon as is reasonably practicable, the Minister must prescribe a system for classifying water resources.*
    (2) *The system for classifying water resources may:*
    (a) *establish guidelines and procedures for determining different classes of water resources;*
    (b) *in respect of each class of water resource*
    (i) *establish procedures for determining the Reserve;*
    (ii) *establish procedures which are designed to satisfy the water-quality requirements of water users as far as is reasonably possible, without significantly altering the natural water-quality characteristics of the resource;*
    (iii) *set out water uses for instream or land-based activities, which activities must be regulated or prohibited in order to protect the water resource; and*
    (c) *provide for such other matters relating to the protection, use, development, conservation, management and control of water resources, as the Minister considers necessary.*

The class of a water resource arising from application of the classification system can, therefore, legitimately be regarded as a *management class*, in that it includes consideration of the water needs for the aquatic ecosystems as well as the needs of the users of the water resource. This understanding is reinforced by the proposed definitions of the classes (see below), which relate to the extent to which the resource is or may be used.

"Prescribe" in the NWA means prescribe by regulations (subsidiary legislation).[l] Draft regulations on the classification system were prepared in 2007 and published for public comment, as required by NWA s69, in September 2008. After a considerable delay, during which the draft regulations were amended after considering the comments, DWA published the regulations in September 2010.[m] The regulations define three classes of water resources, as follows.

- A *Class I water resource* is one which is minimally used; and in which the configuration of the ecological categories of the water resources within a catchment results in an overall condition of that water resource that is minimally altered from its pre-development condition.

- A *Class II water resource* is one which is moderately used; and in which the configuration of ecological categories of the water resources within a catchment results in an overall condition of that water resource that is moderately altered from its pre-development condition.

- A *Class III water resource* is one which is heavily used; and in which the configuration of ecological categories of the water resources within a catchment results in an overall condition of that water resource that is significantly altered from its pre-development condition.

The regulations also set out, in broad terms, a 7-step procedure for determining different classes of water resources, and stepwise procedures for determining Resource Quality Objectives and the Reserve, which are linked to the procedure for determining the class (see also Chapter 4). Comprehensive guidelines for all aspects of the process are available on DWA's website [5].

The proposal for different classes of water resources (compared with, for instance, the single objective of "Good (ecological and chemical) Status" in all surface and ground waters required by the European Union Water Framework Directive) implies that, after all water resources in the country have been classified, there will be some resources in each class – a mosaic of different classes across the country – rather than all resources being in the heavily used class in order to maximise use.

This is not specifically stated in the Act, but was subsequently addressed in a proposal to establish a quantitative operational objective of conserving a proportion of all resources in a near-natural state[n], and is described as an objective in the National Water Resource Strategy, First Edition (NWRS) [6].

[l] *The process of making regulations, and the impact of this on the implementation of the Act, is briefly discussed in section 2.5. of the NWA*
[m] *Regulations to Establish a Water Resource Classification System, Government Notice No R.810, Government Gazette 33541*
[n] *Cross-Sector Policy Objectives for Conserving South Africa's Inland Water Biodiversity – see Bibliography.*

2.3.3.3 Classification of water resources and Resource Quality Objectives

S13 of the NWA requires both that water resources be classified using the classification system, and that Resource Quality Objectives be determined for each in accordance with the agreed class, 'as soon as reasonably practicable' after the classification system has been prescribed.

Determination of class of water resources and resource quality objectives

13. *(1) As soon as reasonably practicable after the Minister has prescribed a system for classifying water resources the Minister must, subject to subsection (4), by notice in the Gazette, determine for all or part of every significant water resource:*°

(a) *a class in accordance with the prescribed classification system; and*

(b) *resource quality objectives based on the class determined in terms of paragraph (a).*

(2) *A notice in terms of subsection (1) must state the geographical area in respect of which the resource quality objectives will apply, the requirements for achieving the objectives, and the dates from which the objectives will apply.*

(3) *The objectives determined in terms of subsection (1) may relate to:*

(a) *the Reserve;*

(b) *the instream flow;*

(c) *the water level;*

(d) *the presence and concentration of particular substances in the water;*

(e) *the characteristics and quality of the water resource and the instream and riparian habitat;*

(f) *the characteristics and distribution of aquatic biota;*

(g) *the regulation or prohibition of instream or land-based activities which may affect the quantity of water in or quality of the water resource; and*

(h) *any other characteristic of the water resource in question.*

Karl Reinecke

A minimally-used water resource, the Amandel River in the Western Cape with an intact bank vegetation community.

° *A "significant water resource" is not defined in the Act.*

The difference between the Reserve (in 3(a)) and the instream flow (in 3(b)) is that the former relates to the water requirements of the aquatic ecosystem, while the latter refers to the flow regime required for uses such as domestic, agriculture and industry. Releases from a dam for downstream off-channel purposes may, for instance, exceed the Reserve requirements. In such cases, particularly where Reserve requirements during normal seasonal low-flow periods are significantly exceeded, it will be necessary to investigate the implications of the impacts on the aquatic ecosystem of flows higher than those required for the environment.

It was acknowledged that it would take some time to establish the classification system, and so the NWA provided (in s14) for 'preliminary determinations' of the class of and Resource Quality Objectives for a water resource. Preliminary determinations are discussed in the next section.

2.3.3.4 The Reserve

The Reserve is to be determined in accordance with s16 of the Act.

Determination of Reserve

16. *(1) As soon as reasonably practicable after the class of all or part of a water resource has been determined, the Minister must, by notice in the Gazette, determine the Reserve for all or part of that water resource.*

(2) *A determination of the Reserve must:*

(a) *be in accordance with the class of the water resource as determined in terms of section 13; and*

(b) *ensure that adequate allowance is made for each component of the Reserve.*

Susan Taljaard

The Goukou estuary near Mossel Bay: the NWA requires that the Management Class and Resource Quality Objectives be set for all significant estuaries.

Roger Parsons

Groundwater abstraction may affect wetlands and springs; research is required to compare the impacts of different kinds of development. The NWA requires that a Management Class and Resource Quality Objectives be set for all significant groundwater resources.

The implication is that the determination of the Management Class of a water resource, the Resource Quality Objectives and the Reserve should ideally be undertaken as an integrated exercise for the whole or part of a water resource. This could not be done initially, as the classification system was not promulgated until September 2010. Before that, many Reserve assessments had to be completed in response to water use licence applications, with only informal consideration, if any, of the basin-wide picture. In these cases s17 provides for 'preliminary determinations' of the Reserve, and all Reserve determinations undertaken since the NWA took effect in 1998 up to the end of 2010 have in fact been 'preliminary'.

It is important to note that 'preliminary determination' does not relate to the method used for the determination, nor does it say anything about the level of resolution of, or confidence in, the determination.[p] It simply refers to an assessment undertaken before a class has been finalised using the prescribed classification system. (Similar remarks apply for preliminary determinations of the Management Class of and Resource Quality Objectives for a water resource.) Preliminary determinations will be superseded by 'determinations' as the classification system comes into effect. Provided that all relevant factors have been taken into account during the preliminary determination, and provided that the preliminary determination was undertaken at a resolution appropriate to the water resource, there seems to be no reason that a preliminary determination should not become a determination without the need for the exercise to be entirely revisited.

The NWA does not explicitly require a process of public consultation for preliminary determinations (of Management Class, Resource Quality Objectives or the Reserve), nor does it require preliminary determinations to be published in the Government Gazette.[q] Consultation and publication are required, however, for determinations. This requirement will also apply if a preliminary determination is later converted to a determination. At the successful conclusion of these processes a determination can be regarded as being 'agreed' among all stakeholders.

[p] *See also Box 3.1.1 in the National Water Resource Strategy, Chapter 3.1, P60.*

[q] *DWA has, however, consulted with water users, stakeholders and other interested and affected persons during preliminary determinations of the Reserve for major catchments such as the Thukela.*

2.4 Protection of aquatic ecosystems and use of water

The Management Class, Resource Quality Objectives and Reserve are, jointly, an expression of the agreed condition or state of a water resource for a desired level of protection – often referred to as the desired future state of the resource. These objectives can only be achieved if the use of the water resource – the volume of water taken from it, the volumes and nature of the waste water discharged into it, the extent to which the physical structure of the resource is modified, for instance – is regulated. The two sides of the protection and use balance are referred to as *resource directed measures* (RDM) and *source directed controls* respectively, expressions that are not used in the NWA, but which do appear in the NWP (Section 2.3.2).

The essential link between the protection of aquatic ecosystems and the use of the water resource (as defined in s21 of the NWA) is in the conditions attached to an authorisation to use water (a general authorisation or a licence[r]), because the specifications from a Reserve determination contribute to the conditions in the authorisation, and therefore also contribute to controlling the extent to which the resource can be used. This link is given effect by s29:

> ***Conditions for issue of general authorisations and licences***
>
> 29. *(1) A responsible authority may attach conditions to every general authorisation or licence*
>   (a) *relating to the protection of:*
>   *(i) the water resource in question;*
>   *(ii) the stream flow regime; and*
>   *(iii) other existing and potential water users;*

In terms of s27 a Reserve must be determined before a general authorisation or a water use licence can be issued. The two (of 11) factors that relate explicitly to the protection of aquatic ecosystems are sub-sections (1)(g) and (1)(j), as follows:

> ***Considerations for issue of general authorisations and licences***
>
> 27. *(1) In issuing a general authorisation or licence a responsible authority must take into account all relevant factors, including ...*
>   (g) *the class and the resource quality objectives of the water resource; ...*
>   (j) *the quality of water in the water resource which may be required for the Reserve ...*

[r] *See Section 3.3.3 for definitions*

Most water resources in South Africa are already heavily used, and achieving the resource protection objectives will require new uses to be limited by 'taking into account' the Management Class of the resource and its implications. In addition, some or all existing uses might have to be curtailed [7]. Individual new licences are the subject of Part 7 of the NWA Chapter 3 – *Individual applications for licences*.

In theory it should be relatively simple to ensure that the conditions attached to such licences reflect the resource protection objectives, but much depends on the extent to which knowledge and information exists – and is used – on the present use and condition of the resource.

General adjustments of existing uses are dealt with in Part 8 of NWA Chapter 3 – *Compulsory licences for water use in respect of specific resource.* This is an altogether more complex process – technically and administratively – than individual licensing, and involves calling for licence applications from existing users (who should previously have registered their existing uses) and prospective new users, followed by the preparation of and consultation on a series of allocation schedules, culminating in the issue of licences. The process is illustrated in outline in Figure 2.1 and its application is discussed in Chapter 7.

At the conclusion of the Water Law Review process South Africa had a new water law which, after almost two centuries of one based on riparian rights, returned the control of all water resources in the country to the State. The National Government, acting through the Minister and DWA, was declared to be the public trustee of the nation's water resources, and all water, wherever it occurs in the water cycle, now enjoys a consistent legal status. The new law provides the means to protect the integrity of aquatic ecosystems, which are acknowledged to be the resource base on which the sustainable use of water resources depends, by means of an integrated system of water resource protection that includes a Water Resource Classification System, the Ecological Reserve, and Resource Quality Objectives. The Ecological Reserve and Resource Quality Objectives depend on the Management Class of a water resource, and the class in turn reflects the outcome of stakeholder consultations in terms of the needs of the users of the water resource and the agreed water requirement for the aquatic ecosystems (see Chapter 7 on operationalisation).

Two Olifants Rivers with high levels of water abstraction: (a) in the Western Cape in November 1990 (b) in Mpumalanga in 1993.

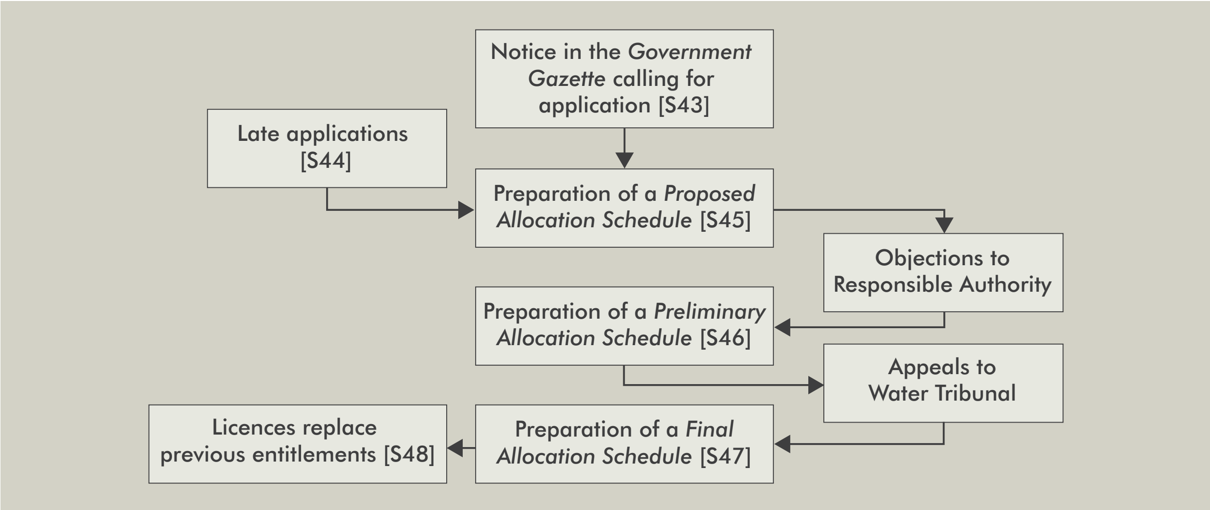


Figure 2.1 The compulsory licensing process.

As a transitional measure, 'preliminary determinations' of the Reserve and Resource Quality Objectives were undertaken before the classification system was established, but now that this has happened the preliminary determinations must be replaced by 'determinations', which require stakeholder consultation. Rights to use water under the riparian system are replaced by a system of administrative authorisations to use water, and conditions in these authorisations must reflect the agreed class of the water resource and the associated Ecological Reserve and Resource Quality Objectives.

Professor Kader Asmal, Minister of Water Affairs and Forestry, receiving the Stockholm Water Prize in 2000.

2.5 Conclusion

The measures to protect aquatic ecosystems in the NWA are a significant improvement on those in the previous legislation, in which there were, to all intents and purposes, none, and the Act is acknowledged to be one of the most progressive in the world in this respect. The intention to implement the protection measures described previously is clear in sections 15 and 18 of the Act, which require the Minister, the Director-General of DWA, an organ of state or a water management institution to give effect to any determination of the Management Class of a water resource and the Resource Quality Objectives (s15), and the Reserve (s18), when exercising a power or performing any duty in terms of the NWA. 'Give effect to' means 'to make operative, put into force[s]'. The direct implication is that it is not enough merely to *determine* the Management Class, Resource Quality Objectives and Reserve for a water resource, but steps must be taken to ensure that the quantity and quality of water and the character and condition of habitat and biota are as they are described by the Resource Quality Objectives and the Reserve. The NWA's provisions for protecting aquatic ecosystems may not be ignored by any person or organisation, irrespective of their position. As observed previously, in many cases giving effect to these provisions will mean that existing uses will have to be curtailed.

There are some aspects where the Act does not appear to explicitly reflect the intentions of the Policy, however,

[s] *Shorter Oxford English Dictionary*

inasmuch as it contains no unequivocal statement to the effect that the Ecological Reserve enjoys "priority of use by right", as stated in the Policy[t] and, especially, in the Principles[u] that preceded the NWA. There is a general understanding among water resource managers and environmental practitioners that the NWA is quite explicit in this regard (and the author of this chapter has written as much on a number of occasions), but careful scrutiny of the NWA will fail to find such a clear statement and it has been suggested that there is not a common understanding of the purpose of the Ecological Reserve [8].

The misperception probably arises from the present generation of managers and practitioners having either been involved in or closely following the process of developing the Principles and the Policy, and assuming that the Act says the same things with equal clarity.

Anyone reading the NWA in the absence of an understanding of the documents upon which it was founded could legitimately conclude that the Reserve was an important consideration in allocating water for use, but not that it enjoyed any degree of special priority.

Box 2.7 in Chapter 2 of the NWRS, which was established in 2005 as an implementation strategy for the NWA, provides 'a general guide on priorities for water use', and puts 'Provision for the Reserve' at the head of a list of priorities in descending order of importance. It goes on to say, however, that the order may vary under particular circumstances, without making an exception of the Reserve.

There is, then, a possibility that the Reserve will progressively lose its special status in the minds of those who administer the NWA, as the institutional memories of the Principles and the NWP fade with time, and the First Edition of the NWRS is replaced by successive editions[v]. When this happens, reliance will be solely on the wording of the NWA, and this is far from explicit on the subject of the Reserve enjoying priority by right.

There are several examples in the NWA where consideration of the Reserve in making allocation decisions is only one of a number of considerations, and where there is no clear indication that the Reserve is a priority in such decisions. For instance:

Jackie King

The Letaba River inside Kruger National Park in October 1992.

[v] *The NWRS must be reviewed at least every five years*

[t] *Section 5.2.2*

[u] *Principle 10*

Jackie King

A healthy functioning river providing many ecosystem services that benefit people – the Thamalakane River in Botswana.

Purpose of Act

2. *The purpose of this Act is to ensure that the nation's water resources are protected, used, developed, conserved, managed and controlled in ways which take into account amongst other factors:*

   (a) *meeting the basic human needs of present and future generations;*
   (b) *promoting equitable access to water;*
   (c) *redressing the results of past racial and gender discrimination;*
   (d) *promoting the efficient, sustainable and beneficial use of water in the public interest;*
   (e) *facilitating social and economic development;*
   (f) *providing for growing demand for water use;*
   (g) *protecting aquatic and associated ecosystems and their biological diversity;*
   (h) *reducing and preventing pollution and degradation of water resources;*
   (i) *meeting international obligations;*
   (j) *promoting dam safety;*
   (k) *managing floods and droughts;*

   - and for achieving this purpose, to establish suitable institutions and to ensure that they have appropriate community, racial and gender representation.

Note that, although basic human needs (underlined) is first in this list, the ecological part of the Reserve (underlined) appears in seventh place – the Reserve is separated into its component parts for no apparent reason. Note also the first appearance of the expression *protected, used, developed, conserved, managed and controlled,* which is repeated (often with the words in noun form) 12 more times in the Act. The order of the words was carefully chosen when the NWA was edited prior to its submission to the parliamentary process (in early 1998) to indicate that protection of water resources was a necessary requisite for all the others. The priority of protection can, however, only be inferred from the order of the words, and is not explicit.

Other examples where the status of the Reserve is not clearly reflected in the NWA's wording are s27 and s29[w]. S27 deals with the considerations for issue of general authorisations and licences, in which two of the factors to be taken into account are the Management Class and Resource Quality Objectives of the water resource (27(1)(g)), and the quality (but not the quantity) of water required for the Reserve (27(1)(j)). These are two factors in a list in 11, with no indication of the relative importance of, or weight to be attached to, each. Although s29, which lists the conditions for issue of general authorisations and licences, puts conditions relating to the protection of water resources at the head of the list, they are just two conditions of around 30 types of conditions that may be attached to permission to use water, and they appear in the same sub-section (and could legitimately be assumed to have the same standing) as conditions designed to protect existing or potential water users.

A more conceptual difficulty may arise because the NWA, like the Constitution on which it is founded, is human-centred. S3 – *Public trusteeship of nation's water resources* – establishes the National Government as public trustee of the nation's water resources, with the responsibility to ensure that they are protected, used, developed, conserved, managed and controlled for the benefit of all persons. Although this section requires the Minister to promote environmental values, and although the suite of environmental legislation provides for the protection of natural systems, aquatic ecosystems have status in the NWA only insofar as they are useful to humankind. In an age where it is easy to believe that technology has freed us from dependence on natural systems, the message that aquatic ecosystems provide valuable services that are difficult and costly, if not impossible, to replicate using technology, needs to be continuously emphasised, particularly among high-level government legislators, and policy and decision makers.

In this respect the NWA's many requirements for the public to be consulted before any regulatory instrument is established or activity is commenced (which include establishing the classification system, the Management Class of, and Resource Quality Objectives and the Reserve for, a water resource) are, although expensive and time consuming, an important way of informing the public of the value of functioning ecosystems and enlisting support for the necessary measures to achieve the NWA's objectives.

This section has painted a rather gloomy picture of the Act and implicitly poses the question: does the NWA make sufficient provision for protecting aquatic ecosystems? Despite the reservations, expressed above, about the priority status of the Reserve in the Act compared to its status in the Principles and Policy, it is quite evident that

[w] *See section 2.4 for the relevant text of these sections of the Act.*

the NWA's intention is to reserve water for sustaining the ecological functioning of water resources. The provisions for protecting aquatic ecosystems (the classification system, Resource Quality Objectives and the Reserve) are intimately interrelated, and they are also closely linked to the ways in which water use is authorised in the Act (*via* the conditions attached to general authorisations and licences). Discovering the exact nature of these interrelationships and linkages requires careful analysis of the Act, which is not everyone's idea of a good time, and some judicious, and relatively minor, amendments to the text of the Act, including an explicit statement of the Reserve's priority, would make them much clearer.

The profound changes to water policy and law in South Africa were as a result of, and were enabled by, the equally profound changes in the political dispensation, and it is possible that similar opportunities for mega change are unlikely to arise again in the foreseeable future [2]. Some relatively minor changes have been made to the Act since it was enacted, in response to difficulties experienced with interpretation and, as a result, implementation, and it is probable that further *ad hoc* amendments will continue to be made into the future. However, there is no meta-policy in place – that is, an agenda for regular and systematic reviews of policy and legislation – and neither is there a set of indicators or criteria against which the achievement of policy objectives can be monitored, and which would inform the need for changes [2].

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Part 2 Implementation

Chapters 3 to 8 cover implementation of the resource protection aspects of the NWA. Many judge successful implementation as seeing the right amount of flow moving along a river, but it is far more complex. Key aspects of successful implementation in South Africa could be seen to include:

1. Development of the appropriate policy, legislation and transboundary basin agreements
2. Re-organisation of water management institutions to meet the requirements of the new Act
3. Structured and continual engagement with stakeholders
4. Development of holistic flow-assessment methods
5. Design of new kinds of infrastructure and operating rules to deliver and monitor environmental flows
6. Management of water quality, and of the quality of the ecosystems that form the water resource base of the country
7. Development of catchment management strategies and regional regulatory mechanisms for the authorisation of water resource use
8. Creation of awareness among government and other stakeholders
9. Continual investment in research and capacity building
10. Delivery of the environmental water allocation
11. Monitoring, enforcement and adaptive management.

This section summarises progress to date with this wide-ranging interpretation of implementation.

Jackie King

3 INSTITUTIONAL ARRANGEMENTS FOR THE PROTECTION OF AQUATIC ECOSYSTEMS

Bill Rowlston and Barbara Schreiner

3.1 Introduction

The importance of effective water management institutions cannot be overemphasised. In 1989 the American water resource practitioner Jerome Delli Priscoli[a] wrote 'Institutions are the embodiment of values in regularised patterns of behaviour. The institutions and organisations that supply and distribute water resources reflect society's values towards equity, freedom and justice' [1]. Quoting Priscoli in his book *Land, Water and Development*, English geographer Malcolm Newson added that, 'of all the aspects of water resources management – legal, institutional, financial, environmental and technical – the institutional framework is the most important because it determines and channels the effectiveness of legal structures and financial processes' [2]. Newson went on to highlight the increasing realisation among water resource managers of the necessity to consult with the affected population in developing and implementing water-related policies, and pointed out the central role of institutions in facilitating such interactions.

The purpose of this chapter is to examine the restructuring of the South African State and of its water-related institutions to meet the requirements of the 1998 National Water Act. The main focus is on the roles and

[a] *Senior Advisor for the US Army Corps of Engineers' Institute for Water Resources*

responsibilities of water management institutions such as DWA and catchment management agencies, especially those relating to protection of aquatic ecosystems. The legislative mandates of the various organisations responsible for administering South Africa's suite of environmental legislation are also addressed, since the effectiveness of DWA's measures depends to a large degree on supportive and cooperative relationships with these other water- and environment-related organisations, under the general heading of cooperative governance (Box 3.1).

3.2 Restructuring of the South African State

The review and revision of South Africa's water law comprised the development of the Fundamental Principles and Objectives for a New Water Law in South Africa (the Principles), the White Paper on a National Water Policy for South Africa (the NWP or the Policy) and the National Water Act (NWA). This review took place between 1995 and 1998 (Chapter 2) and coincided with, indeed was an integral part of, a major programme of State restructuring. The restructuring was aimed at moving from a predominantly white, male, rule-bound, centralised and authoritarian State to a representative, participatory, and service-delivery oriented State, and was based on and guided by the Reconstruction and Development Programme (RDP) (Box 3.2).

The RDP set out a vision for a restructured State and a restructured economy, including recognising the importance of involving ordinary people in the business of government: 'The way to real development is through democracy which allows everyone the opportunity to shape their own lives and to make a contribution to development'. At the same time the RDP proposed better and fairer control of natural resources, and a process of democratisation. This would mean that all South Africans could participate in the process of reconstructing the country, through participating in decision making *via* 'people's forums, negotiating forums, workplace committees, local development committees and referendums'.

Drafting of the RDP started shortly after the United Nations Conference on the Environment and Development, held in Rio de Janeiro in June 1992. The RDP mirrors the democratisation calls of Agenda 21[b] in relation to natural resource management, calling for such management to take place at the lowest appropriate level, and for people to be involved in decisions regarding the management of natural resources that affect their lives[c].

Subsequent to the general election in 1994 the South African Government published the White Paper on the Transformation of the Public Service, which set out the vision of a transformed State as follows – 'The Government of National Unity is committed to continually improve the lives of the people of South Africa through a transformed public service which is representative, coherent, transparent, efficient, effective, accountable and responsive to the needs of all'. To give effect to this vision the government envisaged a public service that was integrated, coordinated and decentralised, consultative and democratic, and open to popular participation.

One of the central goals outlined in the White Paper was 'to assist in creating an integrated yet adequately decentralised public service capable of undertaking both the conventional and developmental tasks of government, as well as responding flexibly, creatively and responsively to the challenges of the

Box 3.1 Government and governance

The terms cooperative government and cooperative governance are often used interchangeably, although they are not exactly the same. The former refers to cooperation among organs of state (government departments and agencies), and is mandated in Chapter 3 of the Constitution of the Republic of South Africa (Act 108 of 1996). The latter broadens the cooperative concept to include the involvement, in all aspects of policy, from development to implementation, of non-governmental organisations, consumer groups, stakeholder forums, research and academic institutions, and society at large.

[b] *The full text of Agenda 21 was revealed at the United Nations Conference on Environment and Development – the Earth Summit – held in Rio de Janeiro in June 1992* [3]. *One hundred and seventy eight governments voted to adopt the programme. The number 21 refers to an agenda for the 21st century.*

[c] *Preamble to Section III of Agenda 21 – Strengthening the role of major groups, Chapter 23: 23.1. Critical to the effective implementation of the objectives, policies and mechanisms agreed to by Governments in all programme areas of Agenda 21 will be the commitment and genuine involvement of all social groups.*

Box 3.2 The Reconstruction and Development Programme

The RDP was developed by the African National Congress (ANC) in consultation with its political partners and a range of organisations in civil society [4,5]. The development of the RDP began before the 1994 general election brought the ANC to power, and continued after the election. It is described as an integrated, coherent socio-economic policy framework, and it laid the foundation for the development of a detailed policy and legislative programme necessary to implement its provisions.

change process'. The vision of the new State was premised on a partnership between the government, the public service and civil society, with structured opportunities for civil society to be involved in 'the formulation, implementation and monitoring of government policies and programmes at all levels'.

3.3 Restructuring the Department of Water Affairs

Restructuring of the State was mirrored by re-structuring in many parts of government, not least within the national department responsible for managing the nation's water. The NWA identifies the Minister of Water Affairs and Forestry (now the Minister of Water and Environmental Affairs) as the public trustee of the nation's water resources on behalf of the national government, and the Minister may delegate most of her or his powers and duties to the Department of Water Affairs (DWA). DWA is therefore responsible for administering all aspects of the NWA on behalf of the Minister, including the development and implementation of strategies and internal policies, plans and procedures, and regulatory instruments relating to the Act. DWA is also responsible for planning, developing, operating and maintaining State-owned water resource management infrastructure, and for overseeing the activities of all water management institutions (Box 3.3).

South Africa's Constitution created nine Provinces in the country, and DWA established Regions that were, and still are, defined in terms of the Provinces' geographic boundaries, and are named after them (Table 3 1). Each Region has a Regional Office, and during the restructuring these were grouped into four geographically-defined Clusters, each with a Chief Director as Cluster Manager based at one of the Regional Offices in the Cluster. Later, DWA discarded the Cluster concept and established Chief Directors in each of the nine Regions. Nineteen Water Management Areas (WMAs), established by Government Notice in October 1999, are distributed through the nine Regions, although they are not all aligned to Provincial boundaries (Figure 1.5; Box 1.6).

By 2004 restructuring within DWA had progressed to the stage where two new Branches[d] had been established: the Policy and Regulation (P&R) Branch and the Regions Branch. The P&R Branch was to be responsible for the development of operational policies relating to the management of water resources and the Regions Branch was, in broad terms, to be responsible for implementing across the country the policies developed by the P&R Branch. The line separating the responsibilities of the two Branches was, deliberately, neither fine nor bright. The P&R Branch was expected to make use of the operational expertise in the Regional Offices in developing operational policies, and subsequently to involve DWA regional staff in piloting the implementation of the policies in the Regions. Once the policies were proven and stable the responsibility for full-scale implementation was to be transferred to the Regions Branch.

Caroline Palmer

Mike Muller, then Director General of DWA, studying the aquatic life of the Sabie River.

[d] *The hierarchy of organisational units within DWA (headed by the Director-General), comprises Branches (Deputy Director-General), Chief Directorates (Chief Director), Directorates (Director), and Sub-directorates (Deputy Director).*

Box 3.3 Part of the National Water Resource Strategy [6]

DWA's organisational structure will change in accordance with its new role and functions under the NWA, in order to facilitate the development of well-defined relationships with other water-related institutions. The following principles and approaches are guiding the transformation process.

- DWA will progressively adjust its role in water resource management to concentrate on policy and strategy issues, overall regulatory oversight, and institutional support, co-ordination and auditing. Its Regional Offices are currently responsible for direct service provision and their transformation will be particularly profound.
- DWA may progressively withdraw from direct involvement in the development, financing, operation and maintenance of water resource infrastructure as this is at odds with the regulatory role. Alternatively, if DWA retains the development function, this role will be clearly separated from its policy and regulatory functions. The question of which institution(s) should be responsible for infrastructure development and operation is still under discussion.
- The establishment, capacitation and empowerment of regional catchment management agencies (CMAs) for all Water Management Areas (WMAs) should proceed as rapidly as possible. The transitional period during which a CMA and the relevant Regional Office are jointly responsible for water resource management must be carefully managed to reduce uncertainties around the division of functional responsibilities and accountability.
- DWA will transfer the responsibility for operating and maintaining some infrastructure to water management institutions and water services institutions, but CMAs may take on these responsibilities only if their regulatory role is not prejudiced.

Slightly adapted from: NWRS, First Edition, 2004, Chapter 3, Part 5, section 3.5.2.2

The Principles[e], the NWP[f] and the NWA[g] instigated by the then Minister of Water Affairs and Forestry Professor Kader Asmal reflected this re-structuring, with provisions for the progressive decentralisation of some of DWA's responsibilities to appropriate regional and local institutions. Eventually, DWA's role would mainly 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 activities and performance of these institutions. It would also continue to manage South Africa's international water affairs, although some aspects of these may eventually also be dealt with through institutions established with neighbouring countries (Section 7.11).

The newly-planned regional institutions would be known as catchment management agencies (CMAs) (Box 3.4). Each CMA was to have jurisdiction over a defined Water Management Area (WMA), in order, among other things, to enable water users and other stakeholders to participate more effectively in the management of water resources. It was recognised that it would take some time to establish the CMAs and subsequently to build sufficient capacity in them to perform all the functions that could be delegated or assigned[h] to them. Accordingly the Act specifies that DWA will act as the CMA in a Water Management Area until such time as an agency is established. Furthermore, the CMA and DWA will initially share the responsibility

[e] *Principles: Water Institutions: Principle 23 – Responsibility for the development, apportionment and management of available water resources shall, where possible and appropriate, be delegated to a catchment or regional level in such a manner as to enable interested parties to participate.*

[f] *NWP: Key Proposals: Provision will be made for the phased establishment of catchment management agencies, subject to national authority, to undertake water resource management in these water management areas. More details elsewhere in the NWP.*

[g] *NWA: Preamble: Recognising the need for the integrated management of all aspects of water resources and, where appropriate, the delegation of management functions to a regional or catchment level so as to enable everyone to participate. Chapter 7 of the NWA – Catchment Management Agencies, and Chapter 8 – Water User Associations, provide for the establishment of the decentralised institutional framework for water resource management.*

[h] *When powers and duties are delegated the delegator remains accountable for the consequences of actions carried out under the delegated authority. When powers and duties are assigned to institutions or individuals, the assignee becomes accountable.*

for managing the water resources in the CMA's area of jurisdiction, with additional responsibilities being delegated or assigned to the agency as it progressively builds its capacity.

Provision was also made in the NWA for a third tier of water management institutions, Water User Associations, which the Act describes as 'cooperative associations of individual water users who wish to undertake water-related activities for their mutual benefit[i]. The main intention of the Act was to transform the existing irrigation boards, subterranean-water control boards and stock-watering water boards that were established under the 1956 Water Act, into Water User Associations in order to achieve broader participation in their activities, particularly by resource-poor black farmers, but also by farm workers. It was anticipated that the majority of Water User Associations would continue to focus on managing irrigation water, but they can, at least in theory, be established for any purpose, including using the water surface of dams (impounding reservoirs) for recreation, managing groundwater, or multi-sector uses of water within a defined management boundary.

The vision, therefore, was one of decentralised management of water resources, with DWA as the overall custodian[i] of the nation's water resources, decentralised CMAs as catchment-based water management institutions, and Water User Associations as locally-based organisations managing shared water resources on behalf of their members (Figure 3 1).

The National Water Resource Strategy (DWAF 2004 – section 3.5.2.8) also discusses forums, seen as voluntary bodies with an interest in some aspect of water-resource management. Although these are not explicitly provided for in the NWA, the NWRS acknowledges their usefulness in, among other things, helping with the creation of the CMAs and providing them with assistance when they have been established.

Table 3.1 Initial division of responsibilities for water management areas among DWA Regional Offices, and membership of Regional Clusters.

	DWA Regions	Water Management Areas	Regional Cluster
1	Limpopo	• Limpopo • Luvuvhu/Letaba	Northern
2	North West	• Upper Vaal • Crocodile West and Marico	Central
3	Gauteng		
4	Free State	• Upper Orange • Middle Vaal	
5	Northern Cape	• Lower Vaal • Lower Orange	
6	Mpumalanga	• Inkomati • Olifants	Eastern
7	KwaZulu-Natal	• Usutu to Mhlatuze • Thukela • Mvoti to Umzimkulu	
8	Eastern Cape	• Mzimvubu to Keiskamma • Fish to Tsitsikamma	Southern
9	Western Cape	• Olifants/Doring • Berg • Breede • Gouritz	

[i] *NWA, Chapter 8, Explanatory Note. Explanatory Notes are not to be used in interpreting the law.*

[i] *The NWA, in s3, uses the term 'public trustee' for the Department's role of custodian.*

3.3.1 Division of functions between DWA Head Office, Regional Offices and CMAs

It was envisaged that each of the 19 geographical WMAs would fall under the authority of a CMA and, until the CMAs are established, management of them would be the responsibility of the relevant Regional Office (Table 3 1). To facilitate this, organisation within the Regional Offices was separated after 1998 into:

1) on-going functions relating to the management of water resources

2) functions that would eventually be delegated or assigned to CMAs

3) functions concerned with managing water resource (raw water) infrastructure such as dams and inter-basin water transfer schemes.

This was designed to allow those management functions that would be performed by DWA to be separated from those to be performed by the CMAs, and also planned for an eventual National Water Resources Infrastructure Agency that would be established in the near future to be responsible for the third set of functions[k].

The units in the Regional Offices dealing with the second set of functions became known as proto-CMAs, to indicate that they preceded – and were an impermanent early stage in – the development of the actual CMAs. They dealt with four of the five functions identified for CMAs (Box 3.4), namely institutional cooperation, stakeholder participation, investigation and advice, but excluded the fifth – development of catchment management strategies[l], which would later be addressed by the fully-fledged CMAs. In the interim, DWA prepared Internal Strategic Perspectives (ISP) to guide the management of water resources in the WMA.

When the First Edition of the National Water Resource Strategy was approved by the Cabinet in September 2004, the transition from no CMAs to 19 CMAs was planned to take place in four phases:

Phase 1: the P&R Branch would immediately take responsibility for authorising water use (the responsible authority function – Box 3.3), and a variety of other responsibilities including those linked to Resource Directed Measures (RDM) (Sections 2.3.3 and 3.4). At the same time, the activities undertaken by the proto-CMAs within the Regional Offices would be ring-fenced from the Regions' other responsibilities, to facilitate a smooth transfer of these functions to the CMAs as they were established.

Phase 2: Responsibilities for implementation and decision-making, including those related to RDM, would be decentralised to the regions.

Phase 3: CMAs would be established and governing boards appointed. The proto-CMA functions – including the departmental staff who performed them – would be transferred to the CMAs within two years of their establishment, with transfers negotiated because of their labour-related implications. The Regional Offices would continue to perform water resource management functions that had not yet been delegated or assigned to the CMA.

Phase 4: With a governing board in place, ideally no more than 4-5 years would elapse until a CMA was able to take on the duties of a responsible authority, with all remaining water-resource management functions transferred to it (Table 3.2). The relevant Regional Office would then adopt a regulatory and oversight role. The pace of this transfer would take account of the limitations of financial and human resources, the necessity for a process in which all interested parties may participate and the time needed to build the capabilities of the agencies.

Subsequently the Department reconsidered the proposed number of CMAs, with a view to grouping some WMAs under the control of a single CMA. No final conclusion has been reached, but the indications are that the eventual number of CMAs could be between seven and nine.

[k] *Provisions for such an agency (then provisionally called the National Water Utility) were included in the Draft of the National Water Bill that was submitted to the Parliamentary Portfolio Committee on Water Affairs and Forestry at the beginning of 1998. When it became clear that the proposal to establish another parastatal body, viewed at the time with some scepticism by the ANC Government, was likely to delay the progress of the Bill through the parliamentary process, the provisions for the Utility were excised from the Bill, to be revisited at a later stage.*

[l] *See NWA s80. A catchment management strategy is the equivalent of the National Water Resources Strategy at the level of a Water Management Area.*

In reality, by March 2009, only two CMAs had been formally established (Inkomati and Breede/Overberg) and begun to develop their catchment management strategies, although progress has been made with proto-CMAs [7] (next section). The issue of slow progress in establishing CMAs is re-visited in Chapter 7.

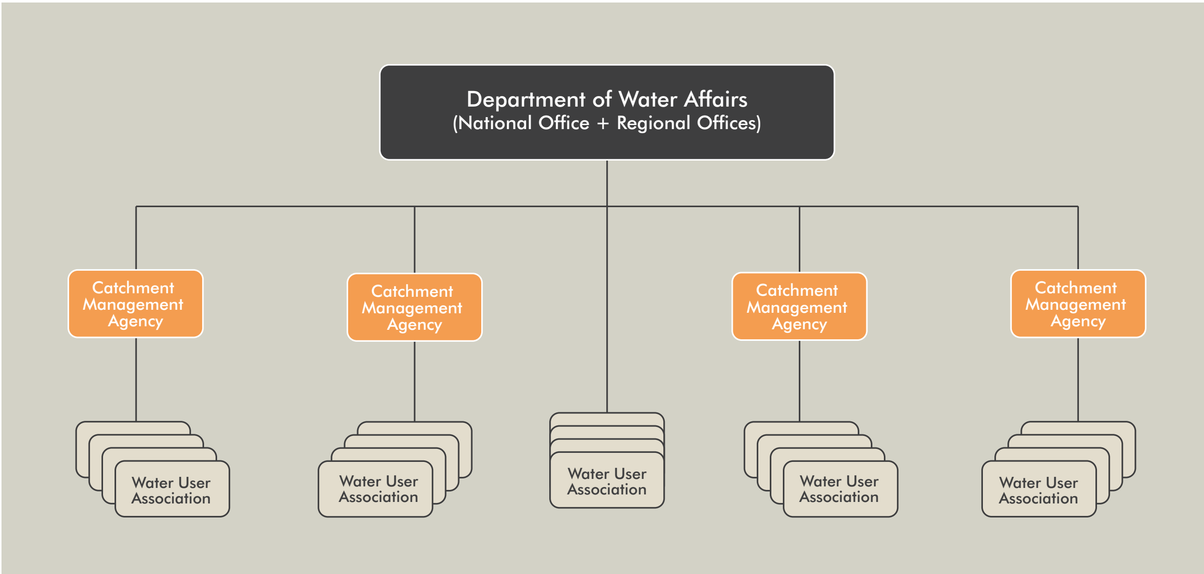


Figure 3.1 Cascading water management institutions envisaged under the National Water Act.
The WUAs can also report directly to DWA.

Box 3.4 Catchment management agencies

CMAs are statutory bodies, established in terms of the NWA, with jurisdiction in defined Water Management Areas to manage water resources and co-ordinate the water-related activities of water users and other water management institutions. An agency begins to be functional once a representative governing board has been appointed by the Minister, and it is then responsible for the initial functions described in section 80 of the Act, as well as any other functions that are subsequently delegated or assigned to it.

The initial functions of CMAs are to: (a) investigate and advise interested persons on the protection, use, development, conservation, management and control of the water resources in its Water Management Area; (b) develop a catchment management strategy; (c) co-ordinate the related activities of water users and of the water management institutions within its Water Management Area; (d) promote the co-ordination of its implementation with the implementation of any applicable development plan established in terms of the Water Services Act, 1997 (Act No. 108 of 1997); and (e) promote community participation in the protection, use, development, conservation, management and control of the water resources in its Water Management Area.

CMAs are not the only water management institution defined in the Act. Also defined are Water User Associations, as well as bodies responsible for international water management, and any person who fulfils the functions of a water management institution in this category (s1(xxvi)).

However, a CMA is the only institution other than DWA that may, when the function has been assigned to it by the Minister, authorise the use of water by issuing a general authorisation or a water use licence. This authorisation function is the exclusive domain of a 'responsible authority', as defined in s1(xx) of the NWA.

Adapted from Chapter 3, Part 5 of the National Water Resource Strategy, First Edition, 2004

Table 3.2 Original anticipated dates of establishment of the catchment management agencies for each Water Management Area (DWAF 2004).

WMA no.	WMA name	Anticipated date of establishment	Full functionality
1	Limpopo	2007	2012
2	Luvuvhu/Letaba	2007	2012
3	Crocodile West and Marico	2005	2010
4	Olifants	2006	2011
5	Inkomati	2005	2010
6	Usutu to Mhlatuze	2006	2011
7	Thukela	2006	2011
8	Upper Vaal	2007	2012
9	Middle Vaal	2009	2014
10	Lower Vaal	2010	2015
11	Mvoti to Umzimkulu	2006	2011
12	Mzimvubu to Keiskamma	2010	2015
13	Upper Orange	2010	2015
14	Lower Orange	2010	2015
15	Fish to Tsitsikamma	2009	2014
16	Gouritz	2006	2011
17	Olifants/Doring	2007	2012
18	Breede	2006	2011
19	Berg	2009	2014

3.3.2 Proto-CMAs

Activities within the Gauteng and North West Regions provide an example of regional adaptations that are taking place since the NWA. In 2005, they began restructuring to prepare for their new role under the NWA. The Upper Vaal WMA is arguably one of the most complex in the country from a water resource management perspective, as it covers parts of four provinces, and includes the industrial and mining complex in and south of the Johannesburg conurbation (Figure 1.5). Nevertheless, during restructuring, functions were identified for the Upper Vaal Proto-CMA through a process that can reasonably be taken as a model for all of the other proto-CMAs. These proposed functions are summarised in Box 3.5.

As and when the proto-CMA becomes a fully-fledged CMA, these functions should be transferred, with the budget and staff, to the CMA.

3.3.3 Water use and authorisation

Virtually all management of a nation's water resources condenses down to a need to manage how much water is available for people, how they use it and what impact all this might have on the aquatic ecosystems providing the water. The NWA's definition of water use (NWA s21) is very broad, and relates to the quantitative use of water, as well as to uses that affect water quality and the quality of the relevant aquatic ecosystems. All require some form of administrative authorisation, of which there are three types in the Act.

Schedule 1 permits the use of relatively small quantities of water, mainly for domestic purposes, but also for non-commercial gardening, livestock watering not exceeding the carrying capacity of the land, use in emergency situations, and for certain recreational purposes. Users must have lawful access to the resource in order to exercise the Schedule 1 entitlement. The Act does not specify any numerical limits for Schedule 1 use.

A general authorisation allows limited, but conditional, water use without a licence. Numerical limits are placed on water use depending on the nature of the use and the capacity of the resource to accommodate this without significant degradation. For some of these situations the extent of use differs in different parts of the country.

Schedule 1 and general authorisations are primarily intended to reduce the administrative effort of authorising every use in the country individually. Their underlying assumption is that the cumulative impacts of a number of small uses will not cause significant harm to the functioning of aquatic ecosystems. Any water use that exceeds a Schedule 1 use, or that exceeds the limits imposed under general authorisations, must be authorised by a licence[m].

A water use licence is required for uses that have the potential to cause resource degradation and damage to the integrity of aquatic ecosystems. Water use licences may be acquired *via* individual applications, or by the process of general, catchment-wide, compulsory licensing (see below and Section 2.4).

Existing lawful use: A fourth type of authorisation is water use that was lawful under the previous water law, or any other relevant and applicable law. Recognition of existing lawful use is a transitional measure under the NWA, intended to preserve the legality of present water uses until the new compulsory licensing process is complete (see below). Such use may continue until DWA requires it to be licensed. Users are required to register their uses with DWA in terms of Government Notice No.R.1352 published on 12th November 1999. The formal time period for the registration of water use closed at the end of June 2001, but provisions were made for late registration.

Box 3.5 Detail of the functions recognised for the Upper Vaal proto-CMA [8]*

- Coordination of the process of developing a catchment management strategy for the WMA.
- Review of and inputs to the Water Services Development Plans and the Integrated Development Plans prepared by local authorities, and the Growth and Development Strategies prepared by the provincial authorities, from the water resource management perspective. This is with a view to ensuring consistency among these plans, the National Water Resource Strategy and the catchment management strategies and their forerunners the Internal Strategic Perspectives prepared by DWA and the CMAs.
- Coordination of RDM and other integrated initiatives, including classification of water resources, determination of Reserves and RQOs, compulsory licensing and water allocation planning.
- Strategic water resource planning for the Upper Vaal WMA, in conjunction with the Infrastructure and P&R branches, including inputs to the operation of the Vaal water supply system, and the management of water quality in the most heavily industrialised part of the country.
- Planning technical responses to water-related disasters such as floods, droughts and emergency incidents such as spills of hazardous materials.
- Ensuring the integration of water quantity and quality issues in planning processes.
- Managing hydrological and geohydrological assessments for planning, strategy development and protection of water resources.
- Providing specialist inputs to water use authorisation processes.
- Interpretation and assessment of hydrological and geohydrological data and information derived from water resource monitoring.

**with some minor amendments*

[m] *Adapted and abbreviated from National Water Resource Strategy, First Edition, 2004, Chapter 3, Part 2 – Water use*

Compulsory licensing, a requirement of the NWA, is a new and fundamental step in long-term, co-ordinated, catchment-level water management (Box 3.6). It is essentially a once-off exercise to regularise all water use in the Act's framework of administrative authorisations. Compulsory licensing is part of DWA's Water Allocation Reform programme, and by the end of March 2009 DWA reported that a water allocation plan had been developed for the Mhlathuze Water Management Area, as well as a water allocation framework for the catchment of the Jan Dissels River (a sub-catchment of the Olifants-Doorn Water Management Area) and a draft water allocation framework for the Inkomati Water Management Area [7]. The principal result of compulsory licensing will be, after a thorough review of all water use in a catchment, the conversion of existing lawful uses of water resources to licences, but the process will also deal with any new applications for water use licences that exist at the time the general licensing exercise is undertaken. Compulsory licencing will require careful catchment-wide balancing of all existing and potential uses of water with each other and with the need to reserve water for maintenance of the aquatic ecosystems.

There are provisions in the NWA for general reviews of licences at five-yearly intervals[n], during which the conditions attached to them may be amended, but these reviews differ from the original licensing exercises. As noted above, the main aim of compulsory licensing is to ensure that all water use is the subject of a water use licence: that is, to bring all water use under administrative control. The 5-yearly reviews provide the means to amend the conditions attached to licences if such changes are necessary to maintain the integrity of aquatic ecosystems, to restore a sustainable balance between the availability of and requirements for water, or to accommodate changes in water use priorities. This important provision provides the flexibility to adjust water use to respond, for instance, to changes in hydrological regimes arising from climate change.

3.4 DWA's restructuring to address its environmental responsibilities

During the mid to late 1900s the noticeable decline in condition of the country's aquatic ecosystems was causing growing concern. At that time there were no provisions in the 1956 Water Act to set aside water to sustain ecosystems, and water-resource protection within DWA was focused largely on water-quality issues[o]. Realisation by the country that the massive dam-building programme and other relevant infrastructure development of the 1900s (Chapter 1) was seriously degrading rivers led to the recognition that water had to be reserved for maintenance of the donor aquatic systems. Working ahead of any requirement in environmental legislation (Chapter 2), DWA then set about developing the institutional capacity to do this.

The early stages are difficult to determine from departmental records, but by the 1980s the Special Tasks Division had been created and, among other things, produced an assessment of the water requirements for South Africa's estuaries [9]. Subsequently the sub-directorate Environment Studies was established within the Civil Design Directorate. Initially it was responsible for work related to rehabilitating dam sites and mitigating the visual impacts of dams, but later progressed to consider

Box 3.6 Compulsory licensing

Compulsory licensing is the principle vehicle provided by the NWA to make adjustments to existing uses of water, by converting what are essentially in-perpetuity and unalterable entitlements to use water in terms of the riparian system of the 1956 Water Act, into the reviewable and adjustable administrative authorisations of the NWA. Compulsory licensing therefore provides for a more equitable distribution of water than at present, and can help to redress past water allocation disparities as part of the process of transformation. It is also the means whereby water can be retained in rivers, streams and wetlands through the reduction of existing abstractions, and can ensure that new abstractions are limited to levels that allow an appropriate quantity and quality of water to be maintained for ecosystem maintenance.

[n] *Review of licences: see NWA s49.*

[o] *The objective of managing water quality was to maintain "fitness for use", where use implicitly meant off-channel use. There was no explicit intention to safeguard ecosystem functioning.*

Drinie van Rensburg

Crocodile River downstream of Hartbeespoort Dam, near Brits, infested with algae and water hyacinth.

the environmental impacts of water resource development projects in general, and the need for environmental flows to sustain rivers in particular (at that stage called 'instream flow requirements') (Section 4.1). By the early to mid-1990s social aspects, such as people's direct dependence on functioning aquatic ecosystems, were added to the unit's responsibilities, and its name was changed to Social and Ecological Services. The advent of the NWA resulted in the legislative requirement to address protection of the aquatic ecosystems formally through Resource Directed Measures.

The following sections recap what the Resource Directed Measures are and outline the establishment and growth of the unit designed to address them.

3.4.1 Recap on Resource Directed Measures

The suite of Resource Directed Measures comprises three main elements: classification, the Reserve and Resource Quality Objectives (Chapter 2). The central feature is the catchment-based classification system for water resources, the application of which results in a Management Class for each part of the catchment's water resources. This is derived through stakeholder consultation and with consideration of the water requirements for sustaining the catchment's aquatic ecosystems. At present three Management Classes are envisaged – minimally used, moderately used, and heavily used (Classes I, II and III respectively) – these describing, in turn, water resources whose ecological condition will be minimally, moderately or significantly altered from their pre-development states. Any water resource that falls below the specification for heavily used, however that may eventually be defined, should be the subject of management interventions to improve its class at least to 'heavily used' status.

The other two components of the RDM suite are the Reserve (water quantity and quality) and the Resource Quality Objectives (RQOs). RQOs are quantitative and qualitative descriptions of the hydrological, chemical, physico-chemical, geomorphological and biological attributes adopted for use in the classification system, and the Reserve is, in effect, one of the RQOs. All relevant RQOs must be determined for each water resource in accordance with its agreed Management Class. In broad terms the water-quantity component of the Reserve will indicate, for instance, that a Class 1 resource will require a larger proportion of its natural amount of water than will a Classes II or Class III resource, and its water-quality standards will be more demanding.

The aim is to use the Water Resource Classification System (WRCS) to reach a negotiated agreement on the future Management Class for each and every significant water body within every catchment within the country. These agreed Management Classes will provide the target values for the Reserve, water quality and any other RQOs, for use in monitoring programmes. They will thus also provide information that can be used to assess the quantity of water available for offstream use and the degree to which effluents can be released without jeopardising the RQOs, which will inform the compulsory licensing process for all water uses.

Until such a classification is in place for a catchment, *ad hoc* Reserve determinations have been done since 1998 whenever a water use licence is applied for within the relevant area.

3.4.2 Setting up the RDM functions within DWA

Through its Environmental Studies/Social and Ecological Services sub-directorate DWA had been promoting and supporting studies to determine the environmental water requirements for aquatic ecosystems, sporadically in the 1980s and more consistently since the early 1990s (Chapter 2), as part of its environmental impact assessment (EIA) procedures during the planning phases of water resource development projects. This work had been carried out largely by aquatic scientists who were not departmental officials but who were participating as part of research programmes funded at least partially by the Water Research Commission. With the advent of the NWA, RDM-related work – essentially Reserve determinations only (Chapters 4 and 7) – continued to be undertaken, primarily by external specialist consultant scientists contracted to DWA because of the very limited specialist capacity in the aquatic sciences within DWA.

To address the requirements of the NWA, DWA therefore needed, to all intents and purposes, to start *ab initio* the development of a dedicated in-house organisational unit with appropriate technical capacity to address RDM. This was done as part of the restructuring process, led by the Restructuring Core Committee. One of its tasks was to use Equate, the computer software package used in the South African public service to grade posts, to assess the level at which all posts should lie. The RDM unit was one of those that fell under the spotlight, its institutional arrangements complicated by this being a new legislative mandate for DWA.

Jackie King

Drying pan with dying fish, Nylsvley. January 1991.

The overarching objective of the RDM unit was defined by the Restructuring Core Committee in 2002 as to ensure the protection of water resources in order to contribute to the achievement of equity between present and future generations when allocating water. The unit was intended to provide a framework for the sustainable use of water resources to meet ecological, social and economic objectives, and also to monitor the state of South Africa's water resources against these objectives. Its responsibilities were to:

- develop operational policies, strategies, guidelines, systems, processes, tools and mechanisms for RDM
- determine (and update as required) Reserves for significant[p] water resources
- prioritise, pilot and coordinate RDM operationalisation in the Regions
- build capacity and provide technical support for RDM operationalisation
- develop indicators and assess the state of the nation's water resources
- monitor the effectiveness of operationalisation of RDM.

The RDM unit was placed in the newly-created Policy and Regulation (P&R) Branch (Section 3.3) at the level of a Directorate, headed by a Director, while the other seven units within P&R were headed by Chief Directors and each comprised a number of Directorates (Figure 3 2). This organisational structure was endorsed by DWA in 2003, despite the recommendation by the Restructuring Core Committee that the RDM unit should be a Chief Directorate because of its importance in protecting the integrity and sustainability of the country's water resources.

Nevertheless, the growing understanding in DWA of its importance resulted in the RDM unit rapidly gaining such status (Figure 3 3). Overall, within six years, it transformed from an original Sub-Directorate in the Directorate responsible for civil design, with reporting lines through three tiers of management to the Director-General, through a Directorate with two tiers of reporting, and finally to a Chief Directorate reporting directly to a Deputy Director-General[q]. This direct reporting line reflected the increasing importance of the inputs from the unit, and was perceived as necessary to preserve its independence from other units in DWA that were responsible for the development and utilisation of water resources.

Within the RDM unit, three directorates have been created as outlined below (Figure 3.4).

Jackie King

Elephant in Kruger National Park drinking from a water tank during the 1992 drought.

[p] *A "significant water resource" is not defined in the NWA.*

[q] *For a while this post was known as Strategic Executive Manager: Policy & Regulation*

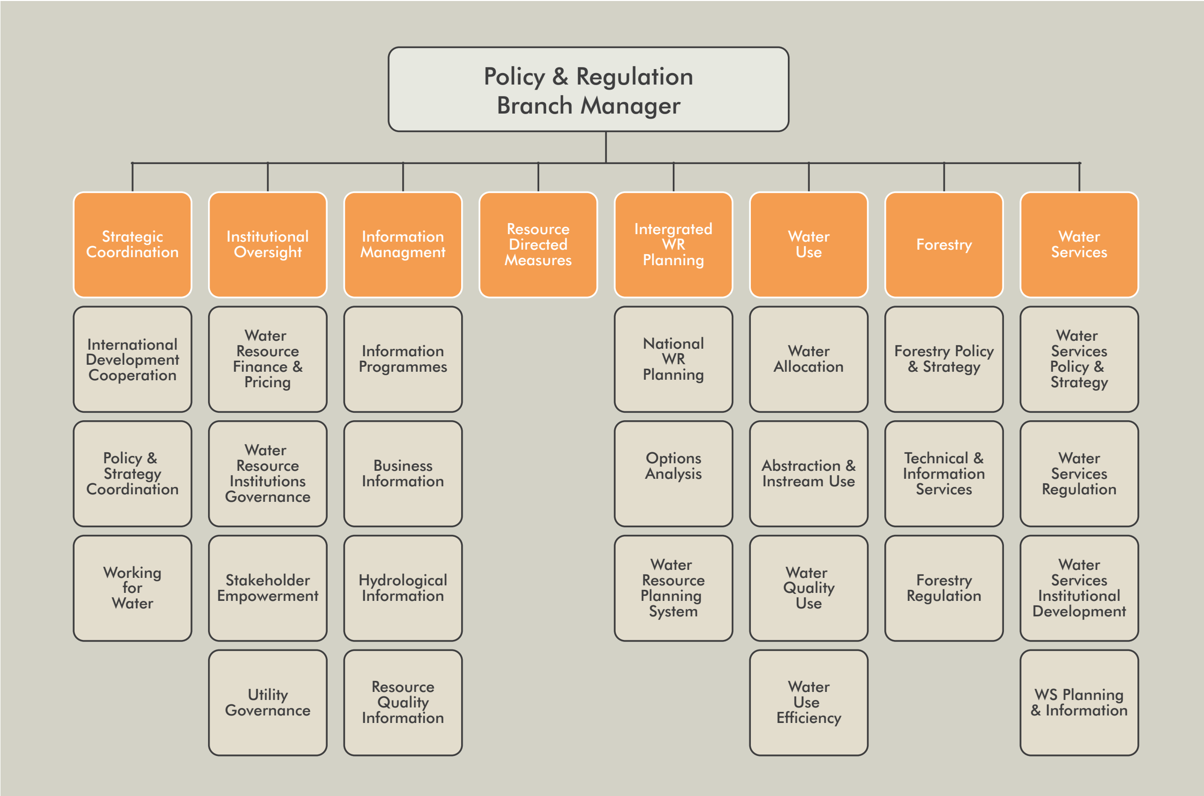
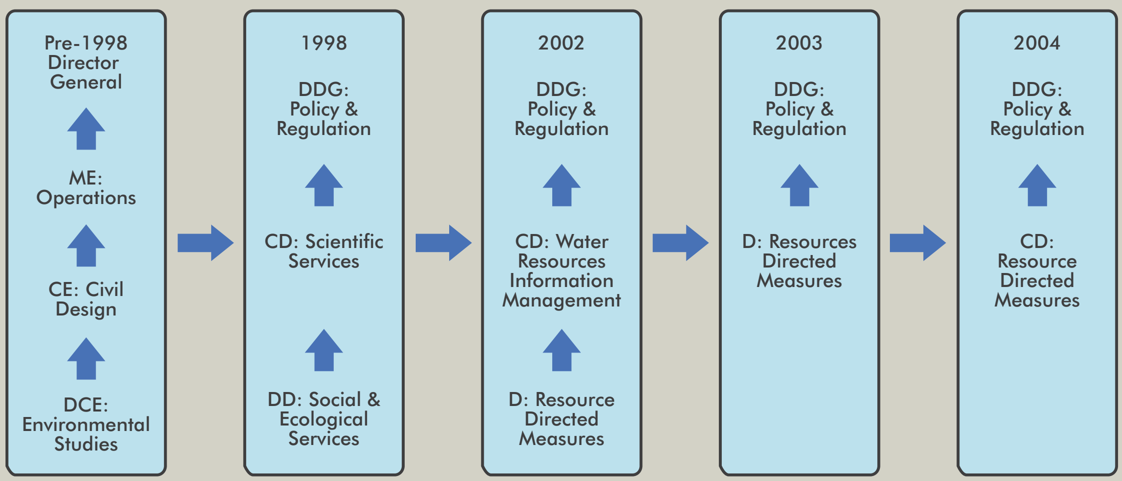


Figure 3.2 High level organogram for the Policy and Regulation Branch in 2004.



ME: Managing Engineer, the pre-1998 equivalent of a Chief Director (CD)

CE: Chief Engineer, the pre-1998 equivalent of a Director (D)

DCE: Deputy Chief Engineer, the pre-1998 equivalent of a Deputy Director (DD)

To all intents and purposes Director-General and Deputy Director-General can be regarded as first-tier management. Prior to 1998 there were no Deputy Directors-General in DWA.

Figure 3.3 Evolution of the RDM function and reporting lines in DWA.

Blyde River: all parts of inland aquatic ecosystems will be the subject of RDM assessments, including riparian zones.

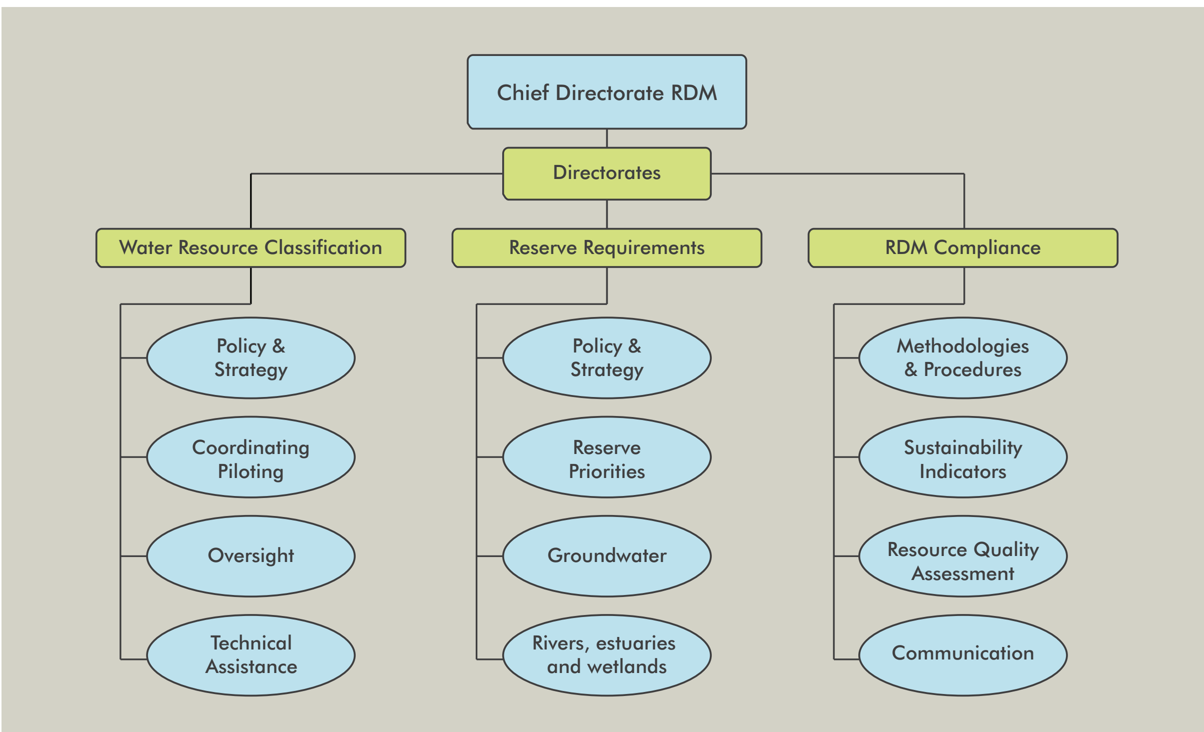


Figure 3.4 Organisational structure for RDM Head Office (2010).

3.4.2.1 Directorate: Water Resource Classification

The directorate is responsible for developing the classification system for water resources and for overseeing its application, including piloting of the system during the initial stages. Specific focus areas for the directorate are as follows.

- Developing the operational policies and strategies for the Water Resource Classification System (WRCS).
- Prioritising, piloting and coordinating the application of the classification system. These duties would eventually be transferred to Regions Branch.
- Monitoring and auditing the application of the classification system once it is transferred.
- Providing technical assistance and capacity building to the groups in the Regional Operations Branch who are responsible for WRCS and compulsory licensing.

3.4.2.2 Directorate: Reserve Requirements

This directorate will initiate, manage, and in some cases carry out, determinations of the Reserve. This will include the development of procedures, methodologies and guidelines for estimating the ecological requirements of all aspects of water resources (rivers, groundwater, wetlands and estuaries).

Janine Adams

Estuarine research, such as that for the East Kleinmonde estuary, Eastern Cape, has been a leading part of RDM work from the outset.

The focus areas of the directorate are as follows.

- Developing operational policies and strategies for Reserve determinations.
- Developing a country-wide prioritised strategy for Reserve determinations at all levels, in consultation with all other units involved in or contributing to the process.
- Completing and, where necessary, updating Reserve determinations for significant water resources in partnership with the Regions.
- Liaising with the Regions and CMAs to respond to their challenges.

3.4.2.3 Directorate: RDM Compliance

This directorate has an essentially monitoring function. It assesses the state of the nation's water resources when judged against RQOs and reports on the implications of deviation from these objectives. The focus areas of the directorate are as follows.

- Developing procedures and methodologies for the setting of RQOs and the Reserve.
- Developing sustainability indicators against which to assess the implications of not meeting RQOs, particularly in terms of public health, ecological, social and economic impacts.
- Assessing the state of the nation's water resources and the resource quality of significant resources against the RQOs and the Reserve to ensure that water resources are being managed sustainably in the public interest.
- In catchments where RQOs are not being met, undertaking a preliminary evaluation of the ways in which water resources are being managed to determine the reasons for failure to meet RQOs.
- Communicating the results of these assessments, including the requirement for strategic or other interventions to rectify deficiencies.
- Providing technical assistance and capacity building in RDM-related functions to DWA Head Office and the regions.

Mark Rountree

A Reserve determination was completed for the Bedford wetland in 2010.

3.4.3 In summary

The RDM Chief Directorate (CD:RDM) in the P&R Branch has been set up to be responsible for leading all RDM work.

It is intended that it will work with other relevant units within DWA, such as the Chief Directorate of Integrated Water Resource Planning (CD:IWRP), to complete a classification and set the Reserve and RQOs for all significant water resources, audit the monitoring of the outcomes (by region) and supply this information to aid the process of compulsory licensing of all water uses.

Internal links within DWA, such as with CD:IWRP and others listed below, are areas of potential weakness, because a failure on the part of one or more of the units on which CD:RDM depends for information or action could prejudice the achievement of the NWA's objectives for the protection of aquatic ecosystems. The links are to:

- Water Resources Information Management, which provides hydrological data and other relevant information
- Water Use, which is responsible for the allocation of water use licences and needs to take cognisance of how the Reserve is being implemented
- Regional Offices, which will ultimately be responsible for ensuring that the Reserve is implemented and for both hydrological and ecological monitoring
- Systems Operations (part of the Infrastructure Branch), which will have to address the implications of the Reserve on dam operation.

3.4.4 Interim implementation of RDM functions

DWA requires an assessment of the Reserve requirements for every water use licence application. This will inform the eventual decision on whether and with what conditions the licence will be granted. The requirement has meant that the newly-formed RDM unit has had to hit the ground running, not only creating itself and appointing and training staff, but also managing the development of methods for all Resource Directed Measures, including the Reserve, and playing an integral part in the nation's water licensing activities. All of this has happened up to 2010 without the WRCS being in place, which has meant that Reserves were being estimated for short sections of river and licences then possibly being awarded without much (if any) understanding of the catchment-wide implications of either.

Chapter 4 explains the WRCS and the methods currently being used to assess the Reserve. These range from rapid desktop approaches to comprehensive, research and field-based approaches (Table 3 3). The minimum requirement for DWA to issue a water use licence is a Rapid Reserve assessment, which should only be used in the relatively rare cases of 'small impacts in unstressed catchments of low importance and sensitivity.' The WRCS will require a detailed assessment for every significant water resource, some of which have already been done as Preliminary Comprehensive Reserve determinations and will need to be retro-fitted. Once these have been done – and this an urgent countrywide need – then catchment plans will essentially have been created that clearly lay out how much water should remain in the aquatic ecosystems across the catchment, how much is available for offstream use and how much effluent the system can assimilate. Such a framework will facilitate a more efficient processing of individual licence applications. At present, licence applications can be held up for considerable periods of time in CD:RDM awaiting a Reserve assessment.

In 2004 it was anticipated that compulsory licensing for high priority catchments, with Comprehensive Reserve determinations to inform the exercise, would have been completed within about 13 years of the NWRS's publication: that is, by about 2017. At this time it was also anticipated that compulsory licensing would also have been undertaken for more than half of the lower priority catchments. Staff members of the RDM unit have been overwhelmed by the avalanche of Reserve determinations they have to undertake for individual licence applications, however, and have had little time to do the necessary groundwork that would lead to water resource classification and compulsory licensing. This issue is re-visited in Chapter 7.

Table 3.3 Levels of Ecological Reserve determinations.

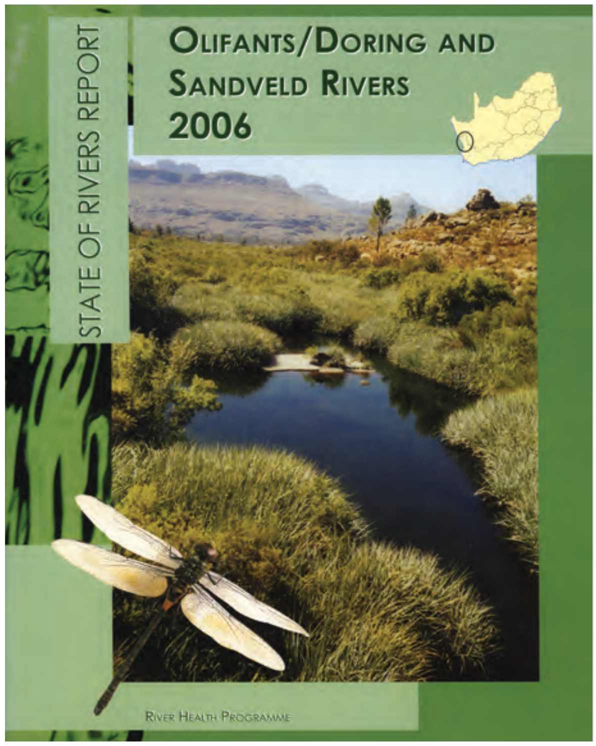
Method	Ecosystem context	Use
Desktop	Abundant unallocated water resources and no immediate plans for further development	Planning guide used in the National Water Balance Model
Rapid	Minor water allocations and developments planned	Individual licensing for small impacts in unstressed catchments of low importance and sensitivity
Intermediate	Possibility of conflict between the Reserve requirements and those of water users	Individual licensing in relatively unstressed catchments
Comprehensive	Major developments or for very important and sensitive ecosystems	All compulsory licensing; in individual licensing, for large impacts in any catchment; small or large impacts in very important and/or sensitive catchments

Monitoring and subsequent adaptive management are essential parts of successful Integrated Water Resource Management.

Such management should include monitoring of hydrological, chemical, biological[r], economic and social variables as well as water use and compliance with licence conditions.

While monitoring of the hydrological and water quality networks are routine DWA activities, and a River Health Programme already undertakes country-wide biological and environmental monitoring, formal monitoring systems for RDM and to determine the social and economic impacts of RDM do not yet exist, and compliance monitoring is weak.

The division of responsibilities for monitoring between DWA and the CMAs has yet to be determined in detail, but, given the multi-facetted nature of monitoring and the purposes for which the information is used, it is probable that the CMAs will monitor compliance with licence conditions within their WMAs whilst some other aspects such as the national monitoring networks[s] could remain the responsibility of DWA.



The State of the Rivers Report for the Olifants/Doring and Sandveld Rivers 2006.


Jackie King

A flow monitoring site on the Swart Doring River in Namaqualand.

[r] *Biological monitoring has the advantage over traditional water quality monitoring, which essentially provides a snapshot in time of the physico-chemical characteristics of the river, in that the condition of the biota that inhabit river ecosystems reflects the long-term historic effects of the quantity and quality of the water in the system.*

[s] *The distinction between national and operational monitoring networks is discussed in Chapter 3, Part 6 of the National Water Resource Strategy, First Edition, 2004.*

3.4.5 The potential transfer of RDM responsibilities to the Regions

Motivated by the NWA's requirement for subsidiarityt DWA intends to progressively decentralise its responsibilities to the Regions, thereby paving the way for the eventual full empowerment of the CMAs via delegation and assignment. Although DWA yet has to decide if managing RDM can be regarded as 'routine' water resource management that can legitimately be delegated or assigned to a CMA, it is currently expected that the RDM functions will be performed by DWA in the short to medium term, with the possibility of transferring the responsibility to CMAs in the longer term (Figure 3 5). Two major factors that constrain this move are the lack of sufficient numbers of appropriately skilled people to undertake RDM work in the regions, and the lack of regional funding to pay for the full suite of RDM activities.

In the interim, each CMA will develop a catchment management strategy for its Water Management Area(s) (Box 3.7). This will include, among other things [10], making plans about how water will be allocated for various purposes, including maintenance of the environment. Such plans set out the principles of how and with what priorities water will be allocated in a CMA's area of jurisdiction, and so they require that the CMAs work with their stakeholders to achieve a fair balance between protection of the natural aquatic resources and their use. This balance will be negotiated through a public consultation process, and can reasonably be regarded as 'agreed' when the consultation process is completed and a decision made by DWA. Its output will include identification of a Management Class (Chapter 2 Section 2.3.3) for each of the various water resources, and therefore the Reserve and other RQOs for them.

Development of the catchment management strategies and the process of transferring responsibilities to the CMAs will require strong co-ordination between DWA and the CMAs because RDM-related decisions made by DWA with input from stakeholders (and perhaps later by the CMAs) on the class, RQOs and the Reserve of an aquatic ecosystem will directly influence the volume of water available from it for allocation by the CMA to users. This in turn will influence the revenue that can be derived from water use charges, on which the CMA depends to meet its operating costs.

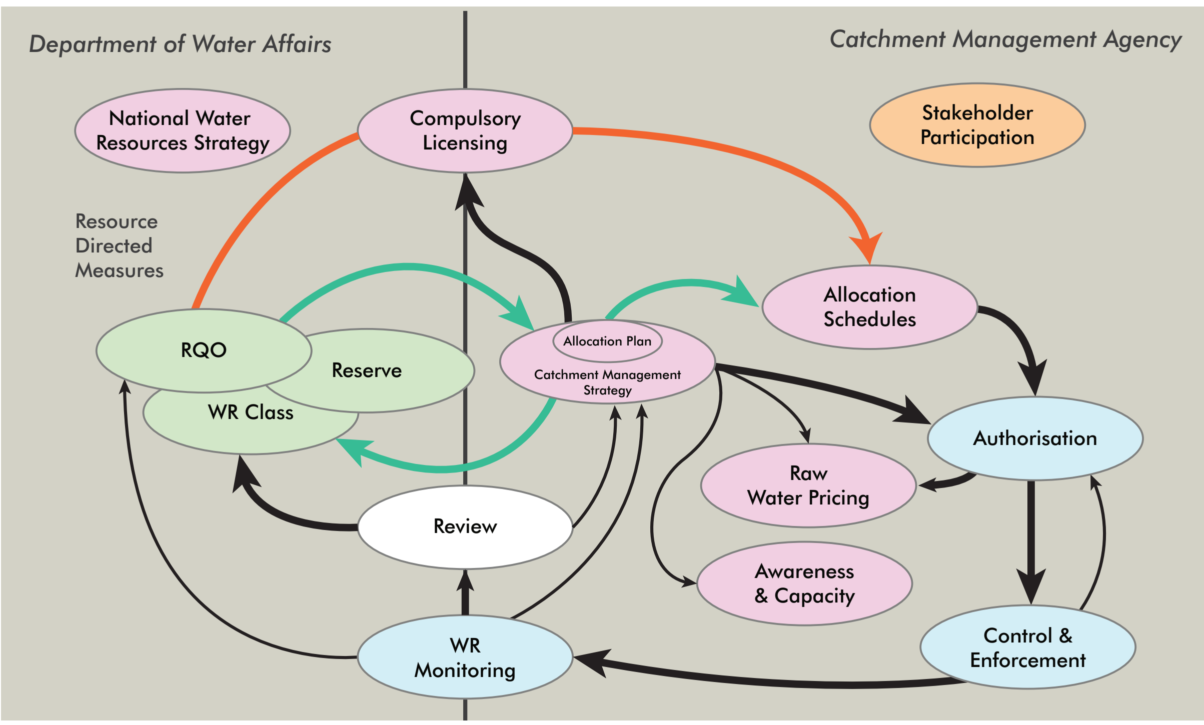


Figure 3.5 Catchment-level water resource management cycle. WR=Water Resource

[t] *NWA chapters 7 (Catchment Management Agencies) and 8 (Water User Associations).*

3.5 Links with other government departments

Although DWA has the overall responsibility for RDM, there are, in addition to the CMAs, a number other organs of state, in all three spheres of government, that have a role, or at the very least a keen interest, in RDM, the latter shared by many private sector organisations that require a licence for their activities.

Section 2 of the NWA describes the purposes of the Act, one of which (s2(d)) is "promoting the efficient, sustainable and beneficial use of water in the public interest". Since the purpose of the Ecological Reserve is to maintain the ecological functioning of aquatic ecosystems, thereby maintaining their ability to provide humankind with ecosystem services – one of which is the provision of water – the Reserve is clearly important to the sustainable part of the NWA's purposes. The NWA can therefore legitimately be regarded as a component of South Africa's suite of environmental legislation, concerned as much with conserving aquatic ecosystems as with using the water they provide. DWA's mandate therefore links with a number of other organisations that also have mandates relating to natural resources. Some of these are briefly discussed below and the process to establish cross-sectoral links outlined in Box 3.8.

3.5.1 The Department of Environmental Affairs

The mission of the national government Department of Environmental Affairs (DEA) is "to lead the sustainable development of (South Africa's) environment for a better life for all". This is to be achieved by, inter alia, promoting the conservation and sustainable utilisation of natural resources – including all aspects of water resources – to enhance economic growth, and protecting and improving the quality and safety of the environment. DEA is responsible for developing policies and strategies for all aspects of its mission, and is custodian of the suite of national environmental management (NEM) legislation[v], of which the overarching National Environmental Management Act (NEMA) and the NEM Biodiversity and Waste Acts are of particular relevance to the RDM. Regulations dealing with environmental impact assessments, made under NEMA, the NEM: Waste Act, and the EIA Regulations promulgated in terms of NEMA are also relevant to RDM's work and are discussed further in section 3.5.3 following. The NEM: Integrated Coastal Management Act is a further important link between environmental and water legislation, since it requires the development of an estuarine management protocol at national level, and an estuarine management plan for each individual estuary. The responsibility for administering this act will eventually lie with coastal local authorities.

The DEA is also responsible for the implementation of a number of international protocols, of which the Ramsar agreement [11] and the Biodiversity Convention are of particular relevance to the RDM.

Box 3.7 Catchment management strategies

A catchment management strategy will be established for each Water Management Area to guide the protection, use, development, conservation, management and control of water resources in the area. A catchment management strategy differs from classification of the catchment, as it must (NWA s9(e)) contain water allocation plans that are subject to section 23, and that must set out principles for allocating water, taking into account the factors mentioned in section 27(1). These plans are not intended to specify, among other things, the quantities allocated to individual users. This is the job of the water allocation schedules of NWA ss 45, 46 and 47, and which are the result of compulsory licensing. Preparation of these schedules requires the water resource(s) to be classified, and Reserves and RQOs determined, in order to determine the amount of water that can be allocated for offstream use, and to inform the conditions that should be attached to the water use licences.

[u] *South Africa's Constitution – the Constitution of the Republic of South Africa (No 108 of 1996) – defines three distinct spheres of government: National, Provincial and Local.*

[v] *At present (May 2010) the NEM suite of legislation comprises*
- *National Environmental Management Act (Act 107 of 1998) (NEMA)*
- *National Environmental Management: Protected Areas Act (Act 57 of 2003) (NEM: PA)*
- *National Environmental Management: Biodiversity Act (Act 10 of 2004) (NEM: BA)*
- *National Environmental Management: Air Quality Act (Act 39 of 2004) (NEM: AQA)*
- *National Environmental Management: Integrated Coastal Management Act (Act 24 of 2008) (NEM: ICMA)*
- *National Environmental Management: Waste Act (Act 59 of 2008) (NEM: WA)*

3.5.2 The South African National Biodiversity Institute

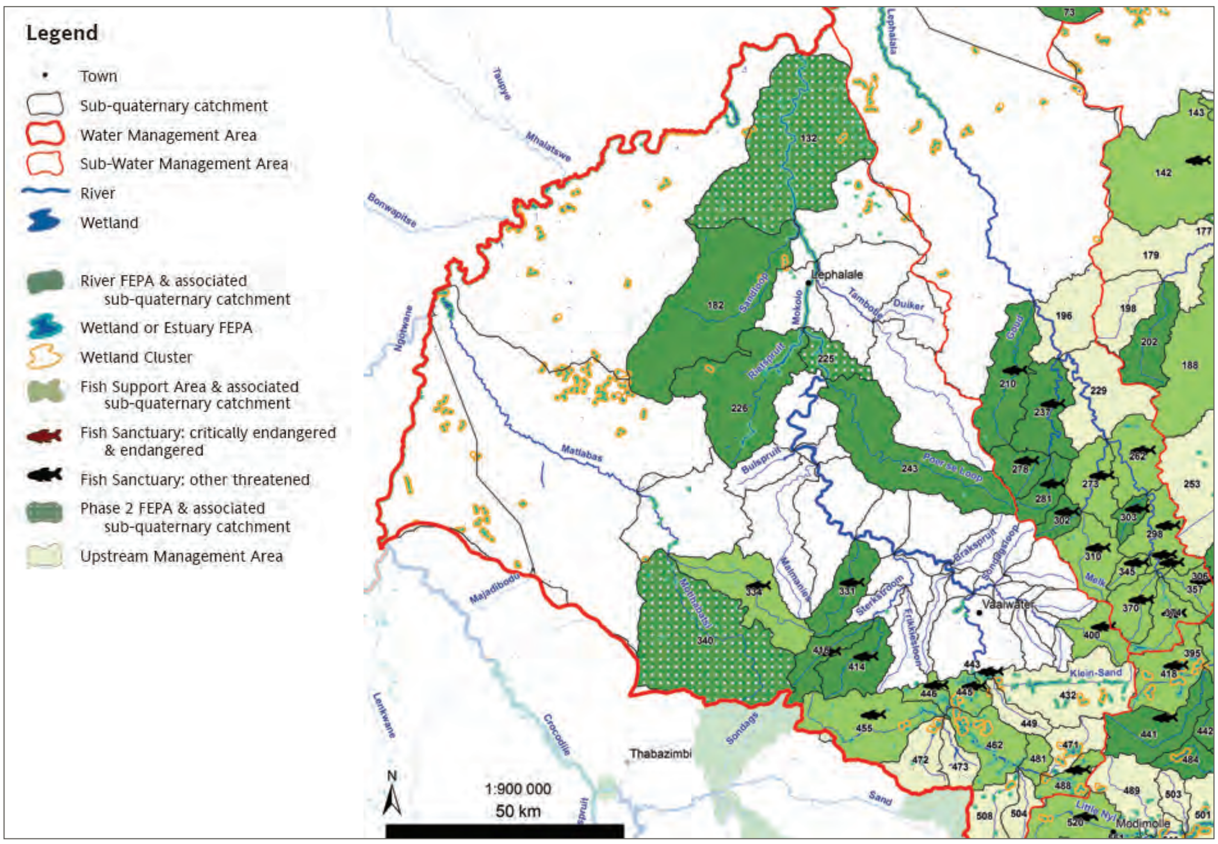
The Institute (SANBI) was established in 2004 in terms of Chapter 2 of the NEM: Biodiversity Act, with a broad mandate to champion the full spectrum of South Africa's biological diversity. Of particular importance to DWA in respect of the RDM is SANBI's remit to act as an advisory and consultative body on matters relating to biodiversity to organs of state and other biodiversity stakeholders. In 2005 SANBI participated in the development of cross-sector policy objectives for conserving the diversity of inland waters in South Africa (Box 3.8), a process that is intimately related to the application of the classification system for water resources.

In 2008, SANBI initiated the National Freshwater Ecosystem Priority Areas project (NFEPA), a three-year partnership project with CSIR, Water Research Commission, DWA, DEA, SANParks, SAIAB and WWF South Africa. This project developed maps of FEPAs as an aid to integrated water resource management (Figure 3.6)

3.5.3 Provincial environmental departments

Each of South Africa's nine provincial administrations has a department that deals with environmental matters. In general terms they are responsible for implementing policies for the conservation of biodiversity, and this responsibility includes reviewing environmental impact assessments and issuing records of decision (approvals, or otherwise), for proposed developments. For all but certain major projects that must be evaluated by the national department, the provincial departments are thus the "competent (environmental) authorities" in terms of NEMA.

The regulations relating to EIAs, mainly in terms of NEMA, but recently also in the NEM: Waste Act in respect of waste management activities, refer specifically to activities that are likely to impact on water resources, such as construction of dams, abstraction of water from ground and surface water



SANBI

Figure 3.6 The FEPA map for the Limpopo Water Management Area.

Box 3.8: Cross-sector collaboration for conserving the biodiversity of inland freshwater resources

If the primary RDM requirement, the classification system for water resources, is applied in an *ad hoc* manner, on a case-by-case basis, it is possible that all water resources will be classified at a uniformly low level – Class III in the South African system – so as to permit maximum use whilst maintaining the minimum level of ecosystem functioning. Such an approach will not address the variability among living organisms and their habitats required to represent all aspects of biological diversity, and a more strategic and systematic approach is required. Of course, it is not possible for all water resources to be afforded a high level of protection without prejudicing social and economic development, but it would be desirable for a decision to be made at national level to establish a quantitative operational objective of conserving a proportion of all water resources in a near-natural state. Identification of where these freshwater conservation areas should be located will require close collaboration with agencies and authorities responsible for terrestrial conservation, and implementation of such a system will require a high degree of institutional cooperation.

In 2005 a number of government departments in South Africa (representing water, forestry, agriculture, land management, environment, and provincial and local government) and SANBI took part in a process to develop a multi-sector policy to achieve cross-sectoral collaboration to conserve the biodiversity of South Africa's inland water resources. Among other things the discussion analysed water- and conservation-related policy, law and planning instruments at international, regional (Southern Africa), national and local levels [12]. It was concluded that the most urgent need for South Africa was to align and integrate conservation priorities for inland water ecosystems among the various sectors and levels of government. Five core policy objectives were developed, and around 50 policy-related recommendations were made to support the practical implementation of the policy principles, including a recommendation that 20% of water resources should be classified and managed as Class I resources.

Representatives of the government departments who participated in the development of the initiative were all relatively senior, and all expressed support and enthusiasm for the collaborative approach advocated. Co-operation among individuals at an operational level is of crucial importance for cross-sectoral co-operation and collaboration. Too often, however, too much reliance is placed on one or two people in each participating organisation. When they leave their organisation, or are moved on to other duties within it, their counterparts in the other institutions have to build new relationships with their replacements, or the collaboration fails for want of replacements. Creation and maintenance of a spirit of cooperation that pervades a government department is the responsibility of its senior management, and must be driven by an explicit commitment to this way of working by the government minister responsible for the department.

resources, and discharge of wastewater into water resources. There is thus quite a close relationship between environmental and water legislation in terms of assessing and mitigating the impacts of proposed developments on the aquatic environment.

The connection between EIAs and RDM is a little more implicit, but the essence is that the competent authorities will not issue a record of decision unless they are certain that all relevant aspects of water legislation have been taken account in the assessment. DWA provides this certainty by scrutinising a detailed account of the proposed water use from the developer, including assessing the impacts of the water use on the ecological functioning of the relevant aquatic ecosystem. The result is that, at least in theory, environmental approval will not be given for any development that affects a water resource unless the requirements of the Ecological Reserve and other RQOs are accounted for.

3.5.4 South African conservation agencies

Conservation agencies in South Africa operate at national level (South African National Parks – SANParks) or provincial level (such as Eastern Cape Parks, Ezemvelo KZN Wildlife and CapeNature).

Broadly speaking they are responsible for conserving biodiversity, biomes, landscapes and heritage resources in protected areas. Their remits include the aquatic environment, but this aspect of their work is almost certainly more difficult than their terrestrial work, since rivers are linear systems in which the condition of the river depends on the condition of the catchment, and the condition of the downstream components depends on the condition of the upstream reaches.

SANParks, for instance, has a keen interest in, among many other things, maintaining flows in the rivers that run through its flagship national conservation area, the Kruger National Park. The park is situated at the downstream end of the rivers' catchments within South Africa, and the flow regimes of the rivers are heavily modified by abstraction of water and discharges of wastewater upstream of the park's boundary. This led SANParks to establish consultative forums with upstream water users to raise awareness of the importance of the rivers that flow through the KNP and their vulnerability to over-abstraction and pollution, and to discuss ways in which upstream water use could be modified to maintain reasonable flow regimes through the Park, especially during low flow periods.

CapeNature and Eastern Cape Parks have been working closely with the C.A.P.E. project (Cape Action for People and the Environment) to develop management plans for the many estuaries of the Western and Eastern Cape coastlines. An important component of the plans is the determination and operationalisation of the Reserve to ensure an adequate flow of fresh water into the estuaries.

Lani van Vuuren

Brugspruit, a tributary of the Olifants River (Mpumalanga) near Witbank in 2010, with acid mine drainage from decanting abandoned coal mines.


Lani van Vuuren

Fishing downstream of Witbank sewage effluent, Olifants River, Mpumalanga, in February 2010.

3.5.5 Local government

Local government in South Africa is a constitutionally distinctive sphere of government.

Although local authorities do not have any legislative responsibility for water resource management[w], they are responsible for other water-dependent and water-impacting activities. Their most significant water related responsibility is to provide water and sanitation services (limited, according to Schedule 4 of the Constitution, to potable water supply systems and domestic waste water and sewage disposal systems) to the people living in their areas of jurisdiction, but they are also responsible for storm water management, refuse dumps, solid waste disposal and land-use-planning.

Local authorities therefore have an interest in water resources being kept in a good condition through operationalisation of the Reserve, since this will contribute to the facility with which they are able to purify water abstracted from rivers to drinkable standards for delivery to their citizens. They also have a responsibility to maintain rivers and wetlands in good condition by ensuring that the effluent from their waste water treatment works adheres to the conditions laid down in their licences to discharge, the conditions being derived from the RQOs for the resource into which the effluent is discharged. Regrettably many of South Africa's local authorities do not currently perform at all well in respect of the quality of the discharges from their waste water treatment works and, probably as a consequence, many of them also fail to consistently provide water to their customers that adheres to national standards for drinking water.

Their responsible management of solid waste disposal sites, as well as the siting of on-site sanitation systems, contributes to maintaining the quality of groundwater resources, on which an appreciable proportion of South Africa's population depends for its water supply.

[w] *Constitutionally the legislative competence for water resources lies with the national sphere of government. It is known as a residual competence, since the Constitution does not explicitly allocate it to either the provincial or local spheres of government.*

3.5.6 Water Boards

There are 15 water boards in South Africa. Together they provide water to around 25 million people in about 90 municipalities. They operate bulk water supply infrastructure to supply water to municipalities for subsequent distribution to consumers, and some operate retail infrastructure to supply treated water to individual consumers. Some also operate dams and waste water treatment works. They are established in terms of the Water Services Act (108 of 1997), and are accountable to the Minister of Water Affairs. They have similar interests in the Reserve as local government, since the quantity and quality of abstracted water influences their supply activities. They also have responsibilities to ensure that the quality of the effluent from their wastewater treatment facilities adheres to specified standards and does not prejudice the ecological health of the receiving waters, and also to ensure that their dams are operated with due regard for the flow and other requirements for maintaining the downstream river.

3.5.7 Non-Governmental Organisations

Environmental NGOs such as the Wildlife and Environment Society of South Africa (WESSA) and WWF South Africa often function as environmental watchdogs and educators. They provide their knowledge and expertise to government and conservation bodies, and are often outspoken critics of developments they believe to be unsustainable and/or damaging to the natural environment.

3.5.8 Summary

This section has discussed the large number of organisations, mainly within the three spheres – national, provincial and provincial – of the government system, but also including external organisations, that have an interest in the achievement of the NWA's environmental objectives, or who make a contribution to achieving them, or both. The links between the NWA and environmental legislation have also been outlined, particularly in respect of the ways in which water use and its effects on aquatic ecosystems is accounted for in environmental impact assessments. It is clear that success in operationalising the NWA's provisions for the protection of aquatic ecosystems and, ultimately, in achieving the sustainable use of water resources, will depend on cooperative government and cooperative governance. Successful and enduring cooperation cannot be coerced. All role players will have to work together in mutual trust and good faith, and DWA will need to invest considerable effort to establish and maintain cooperative and supportive working relationships with its many partners and collaborators.

3.6 Strengths

3.6.1 Protection of water resources

South Africa is part of, indeed a leader in, the growing international recognition that proactively managing the condition of aquatic ecosystems is a fundamental part of sustainable use of their resources. The NWA was and remains an internationally acclaimed piece of water management legislation.

The fundamental objectives of the law are to:

- achieve equitable access to water: that is, equity of access to water services, to the use of water resources, and to the benefits from the use of water resources


Gavin Snow

Scientists and managers investigating the biotic diversity of the salt marshes at the Bushmans Estuary, Eastern Cape, February 2007.

- achieve sustainable use of water: by making progressive adjustments to water use with the aim of striking a balance between water availability and legitimate water requirements, and by implementing measures to protect water resources

- achieve efficient and effective water use: for optimum social and economic benefit.

Although these objectives are stated separately they are inextricably linked, and ultimately depend on the ability of South African water resource managers to prevent the country's water resources from becoming depleted through uncontrolled abstraction of water and polluted through uncontrolled discharges of wastewater. The suite of Resource Directed Measures is central to the achievement of these aims. Although the NWA's provisions for protecting water resources are not unique among national water laws, they are among the most explicit in that they afford the highest priority, along with water to meet the basic needs of people, to maintaining the functioning of the aquatic ecosystems on which people so profoundly depend.

3.6.2 Scientific and technical capacity and collaboration

The scientific community rose to the challenge of 'speaking on behalf of the rivers'. Teams of hydrologists, open channel hydraulicians, sedimentologists, fluvial geomorphologists, and fish, macro-invertebrate, riparian vegetation, water bird, aquatic mammal, water-quality and socio-economic specialists, all led by specialist integrators, now routinely work across the country developing methods and providing information on the quantity and quality of water required to maintain specific aquatic ecosystems at specific condition levels; details are provided in Chapters 4 and 6. This has received international acclaim.

It is also important, however, to recognise the massive collaboration between the nation's scientists, DWA water managers, water engineers and social specialists, which has allowed the stated desire for sustainable use of the nation's aquatic systems to achieve such prominence.

Jackie King

Scientists from the Centre for Environmental Management, University of the Free State, developing a method for assessing the water requirements for ephemeral rivers.

3.7 Weaknesses

3.7.1 DWA's matrix management

During re-structuring, DWA identified matrix management as being the best way to manage complex functions involving its many organisational units. This meant that a number of units, in the Head Office and the ROs, shared responsibilities for particular functions. As a result, protocols needed to be put in place in order to ensure that reporting lines and responsibilities were clearly defined. With hindsight, it is clear that some current weaknesses in implementation (Chapter 7) are the result of weaknesses in matrix management. There are almost as many definitions of matrix management as there are matrix managers, and some shared responsibilities have become duplicated responsibilities, leading to turf wars, or neglected responsibilities.

3.7.2 Capacity challenges within DWA Head Office

The problems of insufficient human capacity in all areas of water management, and the urgent need to build capacity, are implicit in this chapter. There are simply not enough trained and experienced people in DWA's Head Office to do everything that the NWA requires, and the rate at which staff members have been recruited and trained to do the necessary work has not been as comprehensive or effective as was anticipated when the Act was written. In addition, in recent years many of DWA's older and more experienced staff have either retired or left the department for other endeavours, and there has also been a relatively high turnover of new staff. The result has been a lack of stability and continuity in DWA, and a net loss of institutional capacity and memory.

3.7.3 Capacity challenges in Regional Offices and CMAs

One of the perceived advantages of creating the CMAs was that it would reduce the pressure on DWA's Regional Offices because, although some DWA staff would be transferred to the new institutions, new staff would also be recruited by the CMAs. There has been an outflow of staff from the Regional Offices as well as from Head Office, however, and this, combined with the failure to establish and staff effective CMAs, has resulted in an inability by most Regional Offices to take on the new RDM commitments. With hindsight it is clear that new institutional arrangements are much easier to put on paper than to they are to implement, and that the complexities of CMA establishment were greatly underestimated. This has affected DWA, and ultimately, its ability to deliver on its legal mandate.

3.7.4 Capacity challenges in local government

Capacity constraints are not limited to DWA and are particularly acute in local government, with which DWA must work very closely in respect of the delivery of water services in terms of the Water Services Act[x]. Significant losses of experienced staff who can manage purification works and waste water treatment works, in local municipalities and especially the smaller ones, have resulted in water quality problems in many South African rivers. This will prejudice DWA's efforts to achieve RQOs when the time comes to impose them. DWA has invested considerable effort in programmes to build capacity in local government to manage water, but to date the programmes have been slow to show meaningful results.

3.7.5 The lack of water resource classification

The cornerstone of the RDM is the classification system for water resources that, when applied, provides essentially a catchment management plan that addresses among other things the protection of aquatic ecosystems. This in turn guides the target values for the Reserve and the other relevant RQOs. Without such a classification, an essential part of which is its comprehensive stakeholder engagement, decisions on the water required for ecosystem maintenance have been guided by small-scale Reserve assessments, which are probably most often based on an incomplete understanding of basin-wide water issues, or on catchment level Reserve assessments without full stakeholder involvement.

[x] *Act 108 of 1997. Water services are defined in the Act as water supply services and sanitation services.*

The classification has its parallel in strategic environmental assessments (SEAs), which support and greatly facilitate EIAs. SEAs assist the environmental practitioner to contextualise the proposed development in its larger geographic setting, and to assess the cumulative impacts of other similar developments. In the same way, as discussed earlier in this chapter, application of the WRCS provides a plan for the catchment that sets the Reserve and RQOs catchment-wide and thus the water available for offstream use, facilitating the speedy processing of licence applications.

SEAs are commissioned and funded by government authorities, not to facilitate development, but to ensure that the impacts of developments can be more readily assessed, and that the impacts do not unreasonably prejudice the natural and social environments. The same should apply to water resource classifications as a government responsibility. A classification system has now been promulgated and has begun pilot applications (Chapter 7), which should eventually reduce the months-long or even years-long waiting list of water use licence applications.

3.7.6 Issuing of licences

For several years now there has been a major backlog of water use licence applications within the Department, and there have been repeated, and often robust, complaints from prospective water users about the delays in processing licence applications[y]. The licence application process is complex, involving the completion of a large number of forms and then submission to the relevant DWA Regional Office. There may be delays at this stage due to incorrectly completed forms or to lack of capacity in the Regional Offices to process the applications before submitting them for review and approval or rejection to the Head Office in Pretoria. But there is no doubt that additional and often very extended delays have been incurred at the Head Office because CD: RDM does not have sufficient capacity to undertake (or to mobilise external expertise to undertake) the Reserve determinations that are required as part of the licence application review process. If DWA is to reduce the level of frustration experienced by applicants, and preclude the unlawful use of water that could arise from this frustration, these capacity issues will have to be addressed with urgency and vigour (Chapters 7 and 8).

3.7.7 Cross-cutting issues

DWA is faced with two challenges in this regard, both related to cooperative government. First, it is important that all departments and agencies in all spheres of government that have a mandate for the conservation of biodiversity or the use of natural resources know of the NWA's protection measures, and understand the implications for their activities. Specifically their laws, policies and strategies should take account of the NWA protection measures. In the government's understandable post-1994 haste to revise the inequitable laws of the apartheid era there was, in many cases, insufficient attention given to ensuring that the new laws were consistent one with another. Some of these inconsistencies remain, but in the cross-cutting field of water use and management it is of the utmost importance that there is greater co-ordination among all regulatory authorities, and that there is a proper definition and understanding of the roles and responsibilities of each.

Second, and closely related to the first, is the particular case of authorisations required for developments that use water, which may include an environmental authorisation (in terms of the National Environmental Act), a waste-management licence (in terms of the National Environmental: Waste Act), and a water use licence (in terms of the NWA). Developers who need to obtain two or more authorisations could reasonably expect the regulatory authorities to adopt a one-stop-shop approach to these multiple requirements, but, despite mentions of such an approach in various pieces of legislation, it seems not to have manifested itself to any significant extent.

Neither of these matters are the exclusive responsibility of DWA, but it is certainly in DWA's interest to promote greater cooperation among government departments and agencies to achieve its environmental objectives[z].

[y] *In DWA's Annual Report for the period 1st April 2008 to 31st March 2009 it was reported that 103 water use licences had been issued during the period, and that the turnaround time for dealing with licence applications had been reduced to 12 months.*

[z] *In the three cases mentioned the requirement for the authorisations arise from laws that are administered by the two departments that fall under the Ministry of Water and Environmental Affairs, but there is potential for inconsistency inasmuch as, in most cases, the environmental laws are administered by provincial government departments*

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Gavin Snow

4 TOOLS AND PROCEDURES FOR RESOURCE DIRECTED MEASURES

Cate Brown and Delana Louw

4.1 Introduction

Before the NWA, aquatic ecosystems had no legal standing in terms of water required to sustain them (Chapters 1 and 2), but by the mid-1980s DWA had already started to move ahead of the law of that time in terms of addressing water needs for maintaining the ecosystem in good condition. Several different initiatives, outlined in the next section, were spreading awareness of the declining condition of the nation's rivers and the need to address this, particularly for river systems targeted for future water-resource development.

By the 1980s, DWA was assessing the potential environmental impacts of their proposed water developments on aquatic ecosystems. As one of the most ecologically detrimental impacts of dams is likely to be a substantial change in the flow regime of the downstream river (such a flow change is, after all, what most dams are designed to achieve), DWA routinely began to fund workshops from the early 1990s where 'ecologically acceptable' flow regimes for the rivers to be dammed were compiled [1]. The required flow regimes were at that stage called 'instream flows', and the workshops that produced them named 'instream flow assessment' workshops. Today, these 'instream flows' have evolved into the Ecological Reserve, recognised in the NWA as one of a suite of Resource Directed Measures (RDM) (Section 2.4) and the assessment itself is now the Ecological Reserve determination. This chapter outlines this evolution of concepts and methods, their present status and where method development is heading into the future.

4.2 Early development of the South African approach to assessing water for ecosystem maintenance

Construction of the Pongolapoort Dam in the far north-east of South Africa in 1984 is seen by some as a key time and place in the country's growing awareness of the negative downstream impacts of dams. In the 1970s and 1980s, the dam triggered a series of studies of the downstream Pongola floodplain and how the impacts of the dam could be mitigated. The floodplain was seen both as unique in South Africa and as a vital support system for the 40,000 local residents who had close links with it [2,3,4,5].

Recommendations were made, *inter alia*, for flows to maintain the floodplain and for a fair balance to be agreed between the benefits of developing the river's water and the costs, including to local livelihoods, of altering the river ecosystem. The flow-assessment method was not documented and so it is not possible to detect the extent to which it might have influenced method development within the country [1]. The focused study on the dam and the river, however, did represent a milestone in awareness of the water needs for maintaining ecosystems, and in bringing together working groups of water engineers and aquatic scientists.

Following this, development of flow-assessment methods for routine application to rivers began in earnest in the mid 1980s, guided by two frameworks that emerged from workshops focussing on the problem of flow-degraded rivers: the 'Flow Simulation Method" and the 'Skukuza Method' [1,6,7]. These established some important criteria upon which all consequent flow-assessment methods for rivers were based:

- the flow regime is the 'master variable' dictating the nature of rivers, and so hydrological data would be the starting point of the methods, describing the nature of the natural, present-day and potential future flow regimes;
- different parts of the flow regime play different roles in supporting the river ecosystem, and so the complete flow regime would be considered (not just the low flows);
- the riverine ecosystem is more than the instream habitat, and the whole ecosystem, including banks and floodplains, would be addressed.

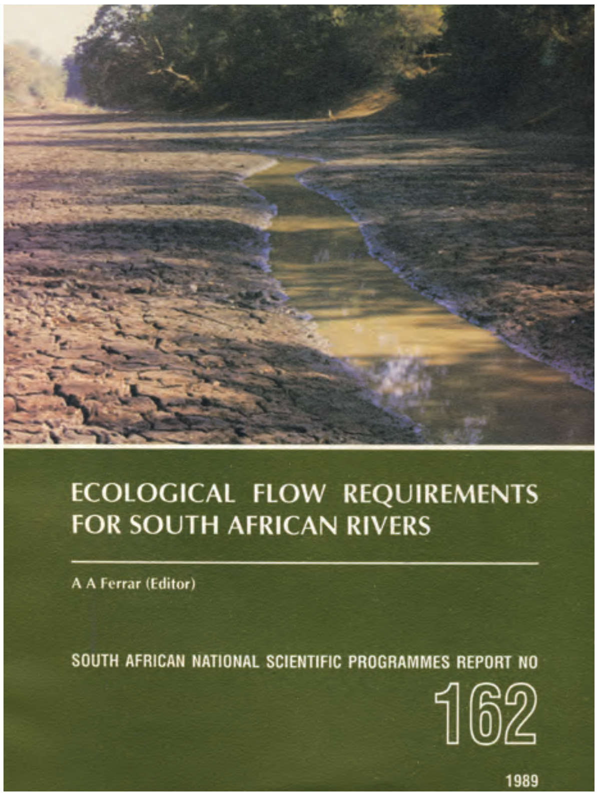
Kevin Rogers

Nguni cattle return to their kraal as a line of Fonya fishers fish into the evening on Tete Pan on the Phongolo Floodplain in 1977.

These three criteria paved the way for the development of suite of methods that were deemed holistic and multidisciplinary; and increasingly paid equal attention to biophysical and socio-economic aspects of the ecosystem. Several authors chart this progress [1,8,9]. In the early stages, method development for rivers benefitted from DWA's long list of dams that were in the planning stage. The river scientists teamed up with DWA officials and their engineering consultants and began to provide advice on ecosystem water needs in these real projects (Table 4.1).

Table 4.1 Some milestones in the development of holistic flow-assessments methods for rivers before the NWA. Not all assessments done are included.

Date	River	Contribution to method development
1992	Lephalala	Holistic Method created, which included hydrological, hydraulic and biological data. Fish, invertebrate and vegetation specialists attended
1992	Berg	Recognised the need to include geomorphologist in team and formally included a hydraulics component
1993	Olifants (W. Cape)	River Importance included to guide discussions on Desired Future State
1993	Olifants (Mpumalanga)	Recognised need to include sociologist in team to represent subsistence users of the river. Helicopter survey to assess conservation status
1994	Letaba	Procedures developed for delineation of study site and site selection. Hydraulic cross-sections adopted to provide depth and velocity data
1994	Luvhuvhu	Generally seen as the point where a successful flow-assessment method had been achieved – later to become the Building Block Methodology. Many procedures formalised and experienced hydrologists joined the team
1995	Koekedouw	First private flow assessment, all others having been funded by DWA
1995	Senqu (Lesotho)	First international flow assessment but run from inside South Africa with no Lesotho visits. Showed importance of site visits and participation by experienced scientists who could contribute general wisdom where data were sparse
1995	Mooi	Revealed a trend whereby more of the natural Mean Annual Runoff (MAR) seemed to be needed for strongly perennial rivers than for arid rivers
1995	Tugela	Used two multidisciplinary groups to cover a large number of sites across the river network rather than only the mainstem
1995	Mvoti/Berg	Preparations for the two workshops included a geomorphological reach analysis before the helicopter survey
1996	Mogalakwena	The first flow assessment for a non-perennial river and the first that included a geohydrologist in the team
1996	Sabie-Sand	Formally brought together the developers of the holistic method that would later be called the BBM and the Kruger National Park river researchers. It was attended by legal specialists writing the country's new water law
1996	Australia	First application of the BBM outside of southern Africa



The SANSP 1989 report that contained descriptions of the Flow Simulation Method and Skukuza Method.

In less than a decade, a considerable body of expertise on the water needed for river maintenance built up. The practical work was supported by substantial research funding, mainly by the Water Research Commission. This allowed an iterative process that benefited everyone: new research findings were incorporated into the DWA flow assessments, and in turn DWA planning needs helped guide and structure the research programmes (Chapter 6).

A key driver of the nature of the early methods was DWA's requirement for numbers – the quantity of water to be reserved for river maintenance – to insert into their planning and design activities. The response from river scientists was that there is no magic number that represents the amount of water required to keep a river in good condition (other than its natural flows), and that once flow manipulation begins a trade-off takes place between the benefits the development will bring and the costs that will result in terms of a declining ecosystem. Thus, the response to the question:

"How much water should be reserved for this river?"
is
"That depends on what you would like the river to be like in the future".


Jackie King

Berg River site 1, subject of an IFR assessment in 1995.

The answer to the question is thus not based on a scientific decision but on a value judgment by government and society on what they are prepared to lose in order to gain the benefits they desire. This judgement can then be transformed by scientists into a description of the amount of water required to maintain the river.

In the early stages of method development, the government had no structure for answering this question and so river scientists were asked to recommend the future condition for each river on DWA's planning list and define the flows to attain and maintain this [9]. This prescriptive approach, which later became known as the Building Block Methodology (BBM) (Figure 4 1) [8,10,11], was used in all the early flow assessment workshops, one of which – for the Sabie River in 1996 – was attended by representatives of the legal team writing the country's new water law. They were convinced by the workshop that water for ecosystem maintenance could be quantified and thus was enforceable, and so this principle became entrenched in the NWA.

The BBM was ultimately abandoned as flawed, as stakeholders questioned the right of scientists to define the future conditions of the nation's rivers. Additionally, its nature as a prescriptive approach meant that it could not easily answer questions on the consequences of not meeting the flows that it recommended. It nevertheless holds a unique place in the country's conceptual, legal and practical development of river protection because of its establishment of holistic, multidisciplinary thinking. Core disciplines used in its application were hydrology, hydraulics, geomorphology, water chemistry, zoology (fish, invertebrates), botany (aquatic, marginal and riparian vegetation), sociology and socio-economics. Other biophysical and socio-economic disciplines would be included later as required. It also established two other important principles.

1. Rivers can be held at different levels of health (ecosystem integrity), allowing a mosaic of river conditions to be maintained across the country that reflects society's different requirements from different rivers; the ecological categories A (pristine) to F (critically modified) represent these health levels (Appendix 4.1 and Table 6.3).

2. In developing countries such as South Africa very large numbers of rural people may be subsistence users of the rivers, and so their livelihood issues must be included in the flow assessment.

From about 1989, flow assessments also began for estuaries. As was the case with the rivers, the method for estuaries was developed through application to a series of estuaries (Table 4.2), each of which pushed thinking forward and meant that by 1999 a structured method for the assessment of the Reserve for estuaries had evolved.

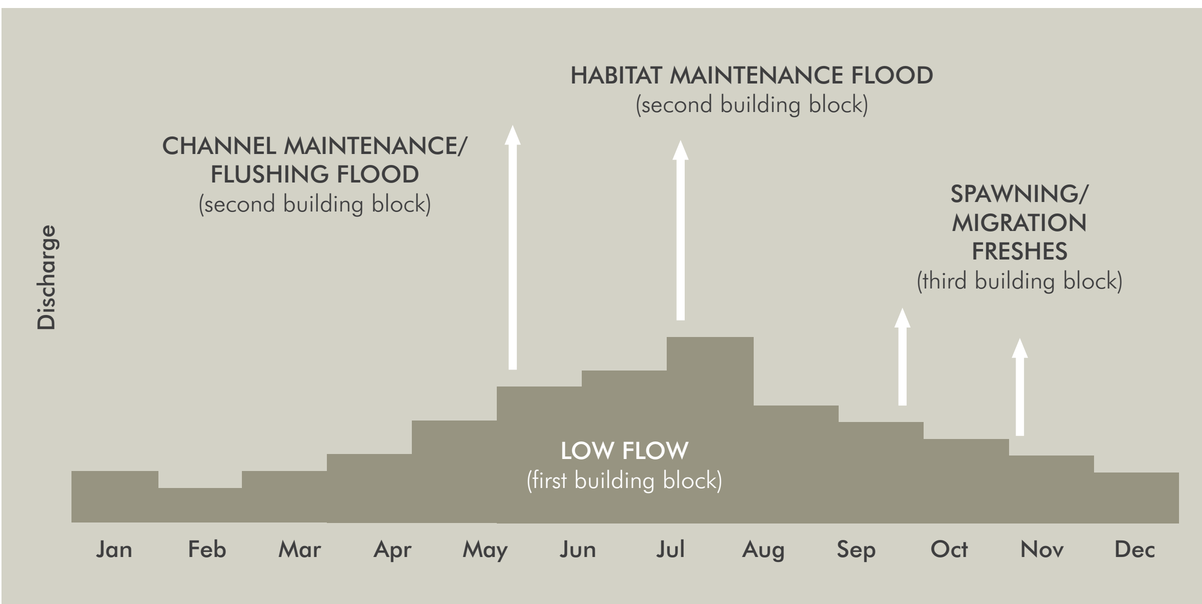


Figure 4.1 The building blocks of an environmental flow requirement as described by the Building Block Methodology [10].

Table 4.2 Some milestones in the development of holistic flow-assessment methods for estuaries before the NWA. Not all assessments done are included. EWR = Ecological Water Requirement

Date	Estuary	Contribution to method development
1989	Groot Brak	This was the first EWR study for an estuary and it resulted in the allocation of water releases from the Wolwedans Dam to keep the mouth open in spring / summer. From the outset a scenario approach was used to assess the freshwater inflow requirements for the estuary.
1993	Nahoon, Gqunube	The first time that specialists representing a full range of relevant disciplines were involved in a workshop environment. Prior to this, involvement of specialists was on an ad hoc basis.
1996	Sundays/Great Fish	The first time that a hydrodynamic model was used to assess the salinity changes linked to river inflow and tidal influences. The model used in this assessment was an uncalibrated one-dimensional numerical model.
1996	Mvoti	The assessments for these estuaries were done at different levels of complexity, with several running in parallel. Together they represent a gradual formalisation of the structured approach later known as the Estuarine Flow Requirement method. Calibrated one-dimensional numerical hydrodynamic modelling became the standard for permanently open systems.
1996	Keurbooms	
1997	Thukela	
1997	Olifants	
1997	Mkomazi	
1998	Swartkops	Water quality recognised as a specific driver of change, but was not fully incorporated into the method for the Swartkops assessment. However, the recognition led to the integration of water quality into subsequent assessments.
1998	Palmiet	First assessment where the river and marine influences on physical processes and water quality (water quality changes in the estuary under different retention times) were summarised as Abiotic State linked to flow ranges.
1998	Mhlathuze	First example of a system where the reference state was not the natural state but took cognisance of the (irreversible) changes brought about by the construction of Richards Bay harbour. However, the redefinition of a reference state meant that is was not possible to assess the processes that would be occurring naturally and the approach was later abandoned.
1998	Nhlabane	First time inflows translated into water levels were explicitly used to assess the implications of flow change. The water level data enabled specialists to assess issues such as inundation of key areas of the estuary (such as salt marshes), and highlighted the value of water level data and mouth condition data collected for the same time period. Translation of the flows into water levels also linked into historical water level records for some estuaries, as water-level records comprise some of the longest available records on estuarine physical processes.

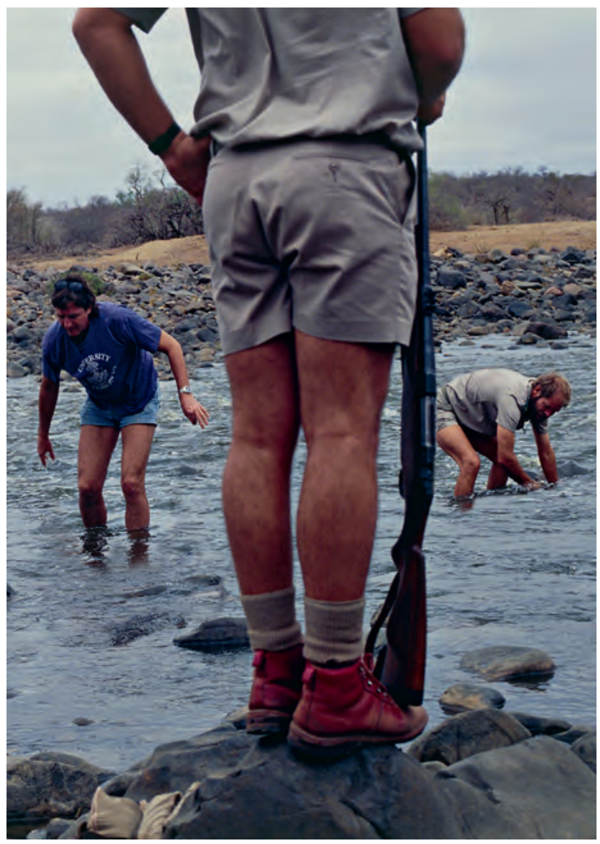
Jackie King

Confluence of the Luvhuvhu River (black bed) and Limpopo (white bed) Rivers in Kruger National Park in October 1992. The first Luvhuvhu IFR assessment took place in 1994, and was seen as the first successful application of the BBM.

Methods for assessing the water requirements for groundwater (Section 4.3.3) and wetland ecosystems were also beginning [12]. In the days before the NWA, groundwater was managed separately from surface water and the linkage between groundwater and aquatic ecosystems was seldom considered. Establishment and understanding of groundwater as a scientific discipline, particularly within the context of IWRM, was still in its very early stages. Two court cases, on the impact of groundwater abstractions on flow in the Vermaaks and Hex Rivers, though settled out of court, increased awareness of these links and gave impetus to the eventual linking of the two in the NWA, but there was no formal development of methods that would aid groundwater protection at this stage.

A suite of other techniques was also being developed in parallel, some of which directly supported the flow assessments while others were less relevant but important in terms of ecosystem protection. Some of these were formalised before the NWA and some after but they all became part of the RDM suite of tools.

The following sections outline the planned phased development of Resource Directed Measures after promulgation of the NWA and the suite of RDM tools and procedures produced (Section 4.3); the Water Resource Classification System (WRCS; Section 4.4) and the procedures for operationalising the Reserve (Section 4.5).



Jackie King

Jay O'Keeffe and Freek Venter work in the Olifants River, KNP, for an IFR assessment in 1993.

4.3 The planned phases of Resource Directed Measures to meet the requirements of the National Water Act

While the previous early development of methods made it possible to include environmental protection in the NWA, the Act in turn had a major impact on related scientific activities within the country. It became a legal requirement to classify every significant water resource in the country as[a]:

- Class 1 Minimally used
- Class 2 Moderately used or
- Class 3 Heavily used

and to then define the Reserve allocation of water for each and the Resource Quality Objectives (RQOs) that would be monitored for compliance (Chapter 2). These requirements are collectively known as the Resource Directed Measures (RDM). Their purpose is to help protect the donor aquatic ecosystems (the 'water resource') by informing on the water required for their maintenance (the Ecological Reserve), and thus how much is available for off-stream use, and by inserting conditions in the resulting water-use licences that will safeguard their agreed ecological condition (the RQOs).

Oddly, the first in this sequence, the classification of water resources, was not the first to receive attention in terms of development and most early work focused on Reserve methods. This sequencing was actually necessary because the classification system was intended to integrate with DWA's other integrated water resource management (IWRM) procedures, many of which were themselves not yet finalised. Meanwhile, with 'instream flow assessments' proceeding and Reserve flow-assessment methods evolving, considerable expertise was being created that could feed into the later creation of a transparent, defensible and consultative Water Resource Classification System [13].

The drafters of the NWA recognised that there would be a transition period before this classification system could be fully developed and implemented, and the Act therefore provided for the Preliminary determination[b] of the Class, Reserve and RQOs to support water-use license applications in the interim (Chapter 2). This was encapsulated in the four-phased approach that DWAF adopted to meet the RDM requirements of the NWA.

Gavin Snow

Groot Brak, the location of the first EWR study of an estuary.

[a] *Terminology introduced later (see Section 4.4 and Chapter 2).*
[b] *At this time the term 'determination' became commonly used for the process of assessing flows for ecosystem maintenance.*

Phase 1 The period leading up to the day when the NWA came into effect. In this preparatory period, relevant policies, strategies, systems, methods and guidelines would be put in place.

Phase 2 A three- to five-year period of transition. Transitional tools and procedures would be developed for determining Preliminary Reserves.

Phase 3 The first decade after the Act came into effect. Full-scale operationalisation of the Preliminary Reserves in selected areas or catchments.

Phase 4 Formalisation of the complete suite of RDM activities. Development of the Water Resource Classification System (WRCS) and refinement of methods to harmonise with it.

These phases are explained further below. The main difference between the planned and actual schedules (Table 4.3) is that the phases emerged as less discrete than envisaged and overlap between them became inevitable and indeed desirable.

4.3.1 Phase 1: The RDM documents

Phase 1 was launched in July 1997 when the methods and guidelines required for RDM work were identified. Many had already been developed in the preceding decade and these were published in a series of volumes known as the RDM Manuals (Table 4.4) [12]. Additional documents still needed are also listed in this table.

The build up to Phase 1 and the series of reports it produced confirmed some important attributes of the RDM concept.

1. Ecological Reserves would need to be set for rivers, standing waters and estuaries. Limits to groundwater use would also be set to protect the groundwater contribution to surface water ecosystems.

2. These would need to be nested within a wider catchment-level assessment of water allocations negotiated with stakeholders (the WRCS).

3. Basic Human Needs for water (Chapter 5) would need to be addressed.

4. Capacity building and communication would be important.

By the end of Phase 1 and the promulgation of the NWA many tools were thus in place ready to begin Preliminary Reserve determinations. They were applied and refined in Phase 2 as described in the next section.

Table 4.3 The planned and actual schedules for the RDM development phases.

Development phase	Start and duration	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Onwards
Phase 1	Planned															
	Actual															
Phase 2	Planned															
	Actual															
Phase 3	Planned															
	Actual															
Phase 4	Planned															
	Actual															

Table 4.4 The RDM policies, methods and guideline documents launched, or listed as needed, in Phase 1 [12]. EWR = Ecological Water Requirements.

Volume #	Title	Explanation of contents
1	Summary of RDM Policy	Not completed for Phase 1
2	Integrated manual for Resource Directed Measures for protection of water resources	The Integrated Manual provided an overview of the RDM procedures. It: • outlined a set of steps that every Reserve determination would need to follow • described the manner in which the methodologies for river, estuaries, wetlands and groundwater would be used • outlined rules for selection of the appropriate level (desktop, rapid, intermediate, comprehensive) of determination • described the actions needed after the Reserve is determined in order to implement RDM, including flow management plans, source-directed controls, and development of catchment management strategies It also described the administrative processes that support Reserve determinations, including examples of work programmes and human-resource budgets
3	Methods for Reserve determination for river ecosystems	Outlined the procedures for each level (desktop, rapid, intermediate, comprehensive) of Reserve determination. Also provided: • an ecoregion classification system for South African rivers • methods for assessing Present Ecological Status (PES), Ecological Importance and Sensitivity (EIS) and Social Importance (SI) for rivers • a conceptual framework for the incorporation of economic considerations into the determination of the Reserve • guidelines for selecting sites and providing biophysical data for Reserve determinations • procedures for setting Resource Quality Objectives
4	Methods for Reserve determination for wetland and lake ecosystems	Outlined the procedures for intermediate and comprehensive levels of determination for wetlands and comprehensive determinations for lakes, and provided a wetland classification system for South Africa
5	Estuarine ecosystems	Outlined the procedures for rapid, intermediate and comprehensive determinations for estuaries. Also provided: • an ecoregion classification system for South African estuaries • methods for assessing Present Ecological Status (PES) and Ecological Importance (EI) for estuaries
6	Groundwater	Although several documents were compiled for rapid, intermediate and comprehensive determination of the groundwater component of the Reserve, these were not collated in a single volume for Phase 1

Table 4.4 Continued...

Volume #	Title	Explanation of contents
7	Basic Human Needs	Not completed in Phase 1
8	Classification system for water resources	Not completed in Phase 1
9	Study Manager's Manual	Not completed in Phase 1
10	Implementation Strategy	Not completed in Phase 1
11	Crocodile River Pilot Study 1998	No report
12	Pienaars River Pilot Study 1999	No report
13	Communication Strategy	Not completed in Phase 1
14	Capacity Building Strategy	Not completed in Phase 1
15	Project Management Summary	Not completed in Phase 1

4.3.2 Phase 2: Preliminary Reserve determinations for surface waters

Pressure from the constant stream of new applications for water use licences meant that DWA could not develop the RDM measures in isolation. Although the WRCS – which will provide a comprehensive guide to how much water must be reserved for ecological maintenance anywhere in a catchment – was not yet in place, the NWA required that water be set aside for the Ecological Reserve before any new water licences were approved. This meant that urgent interim measures to quantify the Reserve had to be put in place in order to not unnecessarily hold up water use licence applications. The concept of Preliminary Reserves was adopted, whereby without perhaps having a catchment-wide view of water demand and supply, or of all biodiversity and social issues, an Ecological Reserve of water could be set for an interim period that would allow the licence application to be processed.

As with all RDM procedures, Preliminary Reserve determinations had to conform to a set of specifications (Box 4.1), and to be workable within the bigger picture of water licensing. To address this latter point, different levels of Reserve determination were developed.

Box 4.1 Design specifications for Preliminary Reserves

Preliminary Reserves should be based on the following RDM design specifications [12,14]:

- that they be legally defensible, since they had to serve as a basis for issuing legally valid water-use licenses;
- that they be scientifically defensible, and in line with the principles of IWRM;
- that they match administrative requirements, i.e. that the information be provided to the licensing agencies in a format that could be used as a basis for drawing up water-use allocation plans and catchment management strategies, and for setting individual water-use license conditions;
- that they provide conservative estimates of the water quantity and quality required to meet the Ecological Reserve, since they are intended to serve the transitional period and prevent irreversible degradation of water resources in that time, in line with DWA's protection policy;
- that there be options for rapid determinations in order to meet projected demands for licences.

4.3.2.1 Levels of Reserve determinations

Four levels of increasing detail and complexity of determination were established: Desktop, Rapid, Intermediate and Comprehensive (Table 4.5). A fifth level envisaged, the Flow Management Plan, was ultimately absorbed into the Intermediate and Comprehensive levels as they evolved into more sophisticated approaches.

The Desktop approach, needing as little at 15 minutes per site, is essentially a planning tool. The initial version used results from all flow determinations done up to 1999 to generalise on the percentage of Mean Annual Runoff (MAR) and its seasonal distribution required for rivers held at the different ecological categories A to D (E and F are unacceptable in RDM Policy as a future condition for any river in the country). The Desktop Model and supporting Desktop tools were designed specifically to produce quick results to inform the National Water Balance [15]. This was a country-wide water resource planning exercise embarked on by DWA after promulgation of the NWA, which led to the first version of the National Water Resource Strategy [16]. The Desktop tools allowed rapid Reserve determinations of the likely volume and timing of water required as the Ecological Reserve in order to maintain a particular ecological condition of a river reach. The Desktop Model was updated in 2003 [17], from more recent and higher confidence Reserve determinations, and is presently undergoing further development.

The Rapid approach, taking about two weeks, may be used in the evaluation of water use licence applications unless there is high conflict over water, or a potentially high impact to the resource, or where ecological importance and sensitivity are high.

Intermediate or Comprehensive approaches are used where potential water conflict is high, or where the river is of high ecological importance or sensitivity. Comprehensive determinations are also increasingly a component of basin-wide catchment reconciliation strategies (Chapter 7). They require between two and six months work, and can take up to three years to complete.

It was anticipated that the Desktop and Rapid approaches would have a relatively short lifespan, with Intermediate and Comprehensive determinations gradually replacing them [12]. This has not proved to be the case: the Desktop approach is still used extensively in Preliminary Reserve determinations and is likely to continue to be used well into the future, mainly because of its low time and monetary requirements. Whichever method is used, a generic RDM procedure is followed, which allows integration of results from different levels of determination and from different kinds of ecosystems.

4.3.2.2 The generic RDM procedure for Preliminary Reserve determinations

The eight-step RDM procedure (Table 4.6) was first developed for, and is most relevant to, rivers, but Reserve determinations for wetlands and estuaries follow a similar set of steps.

Note that the term Ecological Water Requirements (EWR) now appears. In any new science or procedure, many terms are created as deemed necessary, often poorly defined or with their relevance to other terms not well explained. Terms tend to become fewer and more refined with time. In the context of the RDM, some of the most important terms emerging, some synonymous, are (see Appendix 4.1 for definitions of these and others):

- Reserve study or Reserve determination study, or EWR study (originally the flow-assessment study or IFR study)[c]
- Reserve, or Ecological Reserve
- Management Class
- Setting the Reserve.

A simplified graphic of how these terms relate is given in Figure 4 2, reflecting key steps in Table 4.6. The Reserve determination study produces three or more scenarios – the present day, and usually one ecological category higher and lower than that. Each scenario has an EWR, that is, the water required for maintaining its ecological condition.

[c] *The methods, studies and manuals used have become known as Reserve methods, Reserve determination studies and Reserve manuals, but technically almost all are EWR methods, studies and manuals. This is because they focus on producing the ecological water requirements for a range of scenarios. Only after one scenario has been selected and approved by the designated authority within DWA does the EWR convert to the Ecological Reserve. Most Reserve methods thus, in effect, address the EWR and only one – the Water Resource Classification System – is a true Reserve methodology designed to address the whole process from assessing present state to setting a Reserve. In this chapter the terms Reserve and EWR have had to be used somewhat interchangeably, as they still are to date by many, because of the technically incorrect use of the term Reserve in many historical documents and communications.*

If the Present Ecological State (Table 6.3), for instance, is a C, EWRs will typically be provided for B, C and D levels of condition. Taking into account the condition, importance and sensitivity of the ecosystem, one of these will be forwarded as the Recommended Ecological Category, together with its EWR. After consideration of social and economic criteria, and possibly stakeholder consultation, DWA will decide whether or not to accept the Recommended Ecological Category or to approve one of the alternative options. The EWR linked to that approved scenario becomes the Ecological Reserve. Eventually, when the WRCS is in place, the perspective will become catchment wide with a decision after stakeholder consultations on a Management Class for individual catchment/sub-catchments (Section 4.4). At present, however, the Department is setting the Preliminary Ecological Reserve for individual river reaches.

4.3.2.3 The shift to scenario-based methods based on hydrological data

The above sequence of activities reflected the move just before the turn of the century away from the prescriptive BBM approach to new scenario-based ones for rivers that would allow DWA and stakeholders to assess many options for the future[d]. These options needed to include not only the ecological consequences of water-resource development but also the social and economic ones. The main methods developed for rivers were the Habitat-Flow-Stressor Response (HFSR) method [19,20,21] and the Downstream Response to Imposed Flow Transformations (DRIFT) method [22,23,24], both of which are still in use (Appendix 4.2). These brought the Reserve work for rivers more in line with that for estuaries, where a scenario-based approach had also been adopted [25]. The methods for groundwater [26,27], wetlands [28] and the water quality component of the Ecological Reserve [29] were also further developed, refined and tested at this time (Appendix 4.2).

Jackie King

Jim Cambray studying juvenile fish found after experimental flood releases from Clanwilliam Dam, Olifants River, January 1993.

Table 4.5 Levels of determination of the Ecological Reserve, with estimates of the work involved [12].

Level of complexity	Resources required	Time required	Field activities	Resolution of results
Desktop	Low	2 days	none	Low
Rapid	Low	2 weeks	field assessment of ecological condition	Low
Intermediate	Medium	8 weeks	detailed field assessment and data collection	Medium
Comprehensive	High	32 weeks		Medium/High
Flow Management Plan	High	32 weeks	See above	Medium/High

[d] *This shift was gradual, and later applications of the BBM (e.g. Mhlathuze in 1997; Olifants River in1999; Kubusi Buffalo River in 2002 and Thukela catchment in 2002) did incorporate flow scenarios for different ecological condition. However, the process proved cumbersome and was subsequently replaced by other methods.*

Table 4.6 The generic RDM procedure for Preliminary Reserve determinations [12,18].
EWR = Ecological Water Requirement

Step	Activity	Details
1	Initiate the Preliminary Reserve study	• delineate study area • choose the level of method to be used • appoint the study team
2	Define Resource Units	• delineate Ecoregions, geomorphological river zones and land use • use these to select Reserve sites
3	Eco-classification	• use to determine Reference Condition, Present Ecostatus, and Ecological Importance and Sensitivity • determine the recommended future ecological condition (A to E) and identify the alternative conditions on either side of that
4	Ecological Water Requirements	• collate flow, biological, hydraulic and water-quality data per site • describe the EWRs for all three conditions
5	Ecological consequences of operational scenarios	• evaluate the scenarios in terms of their impact on the ecosystem
6	DWA Management Class	• DWA reaches a decision on the ecological category that will be used to set the Preliminary Reserve
7	Reserve and RQOs specification	• Summarise the Reserve requirements in the Reserve Template • Set ecological RQOs (EcoSpecs)
8	Implementation strategy	• implement the Reserve flows and any other mitigation measures • design and implement a programme to monitor EcoSpecs

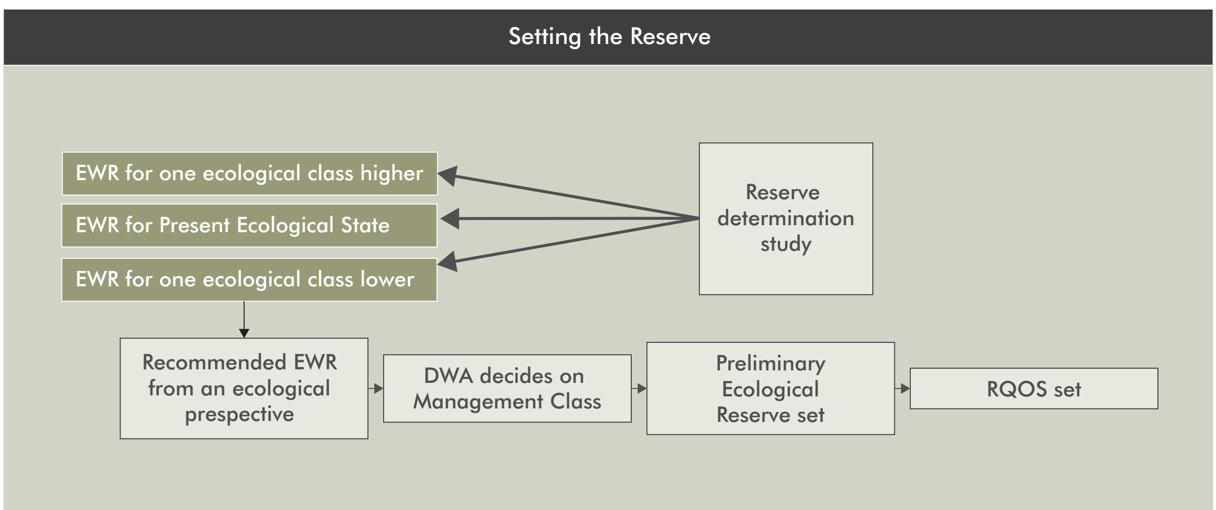


Figure 4.2 Simplified steps in setting the Reserve.

The strong focus on using the hydrological time series as the starting point for all river and estuarine Reserve determinations raised the bar with respect to hydrological data, which were not always available or accurate. It was recognised, in particular for rivers, that daily data were needed as river ecosystems respond to daily (or sub-daily) hydraulic conditions and not to monthly averages. As hydrological modelling improved, techniques were developed for converting daily time series into ecologically-relevant flow statistics. One example of this is flow seasons, which may be characterised annually by their date of onset, their duration and any other important feature [9]. These kinds of techniques, teamed with systems hydrological models, provided deep insights into the past and present nature and inherent variability of the flow regime, and how these could change in future scenarios (Chapter 6). This provided a good starting point for ecologists and socio-economists to provide predictions of change for the scenarios.

Procedures were also suggested for facilitating the integration of Reserve results for rivers, estuaries, wetlands and groundwater [30].

Delana Louw

Delana Louw, who formed apart of the group that developed HFSR in its current form.

Cate Brown

Alison Joubert (left) and Cate Brown, lead developers with Jackie King, of DRIFT.

4.3.2.4 Resource Quality Objectives and Ecological Specifications (EcoSpecs)

RQOs represent the requirements for agreed water quantity, quality, and habitat and biotic integrity to be maintained in aquatic ecosystems. They are targets that can be measured/audited, and are used as benchmarks to monitor a combined resource that may have several licensed users. RQOs may encompass ecological, economic, social and political objectives, and include objectives for both resource protection and user requirements. A formal procedure for setting RQOs is currently being developed. It is likely that this will be incorporated into the WRCS as it is implemented.

In Phase 2, Intermediate and Comprehensive Reserve determinations tended to focus on just one of these sets of objectives: the ecological objectives for maintaining aquatic ecosystems at agreed condition levels. These RQOs consist of two parts:

1. EcoSpecs: descriptors of the ecosystem (sometimes called indicators elsewhere);

2. Thresholds of Potential Concern (TPCs): points along the continuum of change for each EcoSpec that are of concern and need management action. Such action may involve attention to the causes of change or a reassessment of the validity of the EcoSpecs or TPCs, as part of an adaptive management strategy.

EcoSpecs (indicators) and TPCs are recognised for several major aspects of the ecosystem, including hydrology, geomorphology, water quality, vegetation, macroinvertebrates and fish. The hydrological EcoSpecs comprise the Reserve requirements and are usually in the form of exceedance curves, although monthly low flow requirements are also often provided for monitoring (Appendix 4.3). Explanations of EcoSpecs and TPCs, and generic guidelines procedures for their development, have been produced [31].

Jackie King

The Matsoku River in Lesotho, a headwater stream of the Orange River, where one of the first international IFR assessments done with South African methods was completed in 1998.

4.3.2.5 Reserve templates

For the Preliminary Reserve to be considered legally 'set', the Minister of Water and Environmental Affairs, or a delegated authority, must make a decision on the ecological category, on the volume and distribution of water required to maintain that category and, where applicable, on the EcoSpecs for other components of the Reserve, such as water quality. Between 1998 and 2008, such decisions for Preliminary Reserves were delegated to DWA's Director General and, since 2008, to DWA's Chief Director: RDM.

The information is prepared for the deciding authority in the form of a Reserve template, which provides information for the recommended category[e]. Typically this comprises (Appendix 4.3):

- a summary section that gives the volume of water required as a percentage of MAR, the water-quality EcoSpecs, the ecological category for the resource and a list of the supporting documentation

- a series of annexures that detail:

  - the volumetric and distributional requirements for the Ecological Reserve

  - the EcoSpecs for the water quality component of the Ecological Reserve

  - the volumetric requirements for the Basic Human Needs Reserve (Chapter 5)

  - background information and the record of decision

  - the methods used

  - a map of the study area

  - a list of relevant specialist reports.

Reserve templates differ slightly for rivers, estuaries and wetlands, and also depending on whether the Reserve determination was Rapid, Intermediate or Comprehensive, with the latter containing significantly more information. Water quality, for instance, is not normally considered in a Rapid Reserve determination.

The format of the Reserve templates is currently under review and it is expected that it will be adjusted in accordance with the requirements of the WRCS. This will mean that the Reserves for several types of ecosystems and at many different locations will be integrated into a single Reserve template for a catchment/sub-catchment (Section 4.4).

Once it is signed-off by the deciding authority, the Preliminary Reserve becomes legally binding.

4.3.3 Phase 2: Preliminary Reserve determinations for groundwaters

Before 1998, groundwater was regarded as a private resource and was seldom included in management of the country's water resources. Recognition by the NWA of a unitary hydrological cycle meant that all components of the hydrological cycle, including groundwater, had to be included in Reserve determinations.

The objective of RDMs for groundwaters (GRDMs) is fourfold:

1. to ensure that sufficient groundwater remains in aquifers to sustain dependent surface water systems

2. to ensure that the quality of groundwater is not compromised

3. to protect terrestrial ecosystems dependent on groundwater supplies

4. to protect the structural integrity of aquifers.

The documentation mentioned in Section 4.3.2 details how this should be done. Ideally the groundwater component of the Reserve should be set in conjunction with that for linked rivers, estuaries or wetlands as this would integrate, and promote a better understanding of, the various parts of the hydrological system. Some groundwater assessments are done in response to licence applications, but a few large scale studies have been commissioned by DWA in catchments considered to be stressed (in terms of either quantity or quality) or of strategic importance in DWA's integrated catchment reconciliation studies (Chapter 7).

[e] Recommended by CD:RDM staff. Depending on the level of determination the category is decided on the basis of discussions with other DWA officials and various stakeholders.

4.3.3.1 Levels of groundwater Reserve determinations

The levels of determination set out in Section 4.3.2.1 and Table 4.5 also apply to the groundwater component of RDM. While the actual method used at the four levels of determination is the same, the amount of data used and fieldwork undertaken increase with each level.

It is often assumed that the longer one takes on a determination, the greater will be the confidence in its results but this is not necessarily the case. Rather, the amount of existing data available for a determination usually defines the level of confidence in its findings, and so a desktop determination can yield high-confidence results if the area has previously been well studied.

To facilitate consistent groundwater Reserve determinations at a desktop and rapid level, software has been created that provides the user with data sets on which to base the determination and appropriate tools to use [26].

4.3.3.2 The generic RDM procedure for Preliminary Reserve determinations

To facilitate integration of groundwater and surface water Reserve determinations, and in the absence of an established groundwater approach to such assessments, a similar approach to that used for Reserve determinations of surface waters has been adopted (Table 4.7). The need to be able to complete the steps prompted research into surface water-groundwater interactions and a Reserve determination methodology, as detailed in Chapter 6.

RQOs are specified but the concept of Ecospecs has not yet been adopted, probably because development of the groundwater Reserve process is trailing that for surface waters.

The GRDM template contains similar elements to that for surface water determinations (Section 4.3.2.5). An example of the template is provided in Appendix 4.3.

4.3.4 Phase 3: Full operationalisation of the Preliminary Reserve

Operationalisation of the Preliminary Reserve, planned to start in 2004, moved the focus from DWA's central planning units to the Regional Offices. The concepts, methods and protocols devised over the last decade or more now had to be able to work and be used on the ground in order for the Reserve to become a successful reality. Progress made in this phase is the subject of Chapter 7.

Table 4.7 The procedure for the determination of Groundwater Resource Directed Measures (GRDM) [27].

GRDM Activities	Preparatory Phase Description of Study Area Delineation of Units Resource Classification Quantifying the Reserve Resource Quality Objectives
Post-GRDM Activities	Giving Effect to the Reserve Allocation and Licensing GRDM-driven Monitoring

4.3.5 Phase 4: Formalisation of the complete suite of RDM activities

Phase 4, planned to begin in 2008, actually began earlier, in 2006, with the development of the prototype WRCS, which is described in more detail in Section 4.4. The important concept embraced in this phase is that because water-related activities done in isolation in small sections of the catchment could have catchment-wide repercussions, water resource planning and management, including licensing, have to operate at the catchment level. Tools and procedures for RDM Phases 1-3 were developed to perform aspects of the eight-step generic RDM procedure for Preliminary Reserve determinations, in six main fields:

- support in study initiation and design
- models and guidelines for the assessment of ecological condition
- Reserve determination methods
- guidelines for the biophysical descriptors of RQOs and monitoring
- models and tools to assist with input to the water-quality component of the Ecological Reserve
- socio-economic assessment methods.

Table 4.8 and Appendix 4.2 provide more detail, together with a summary of their significance, efficacy, success and present status.

Many additional sets of discipline-specific guidelines, models and other tools, too numerous to mention, were, and are still being, designed to assist individual specialists with their tasks in Reserve determinations. These include a manual for the Building Block Methodology [11] and a range of software that supports Reserve determinations, including:

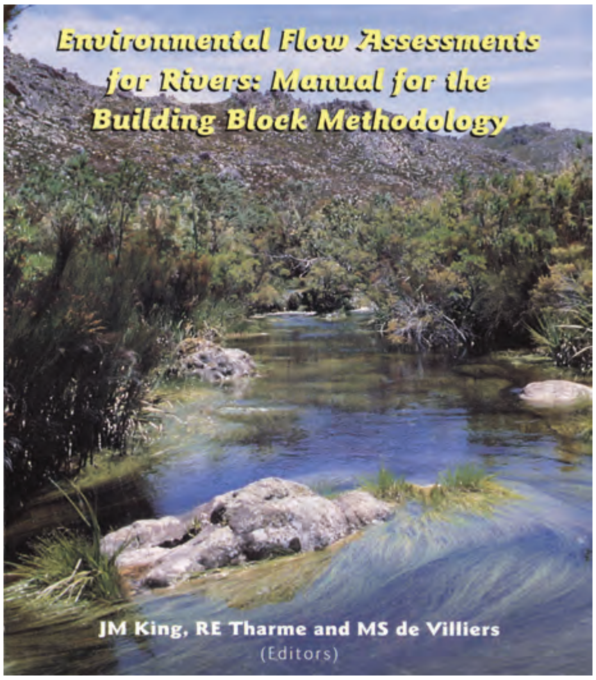
Hydrology: software for SPATSIM [32] and DRIFT-HYDRO [23] that, *inter alia*, can provide ecologically relevant summary statistics from hydrological time series.

Water quality: TEACHA, the Flow Concentration Model and various other water-quality modelling tools (Appendix 4.2). A draft manual for the water-quality component of the Ecological Reserve, which consolidates several different approaches, was produced in Phase 2 [29]. The paucity of appropriate water-quality modelling methods or a systems model for the water quality component of the Ecological Reserve, however, is a critical gap in the current suite of methods (Section 4.6.1).

Geomorphology: a sediment-transport modelling procedure for identifying the flows needed for long-term channel maintenance [33,34].

Socioeconomics: a method for evaluation of aquatic ecosystem services [35]

They also include rapid-bioassessment procedures that assist with developing a statement of the Present Ecological State, such as the South African Scoring System for macroinvertebrates (SASS5 [36]) and a fish index [37], as well as a database providing expected frequency of occurrence of indigenous fish species under natural conditions for rivers across the country (FROC [38]), and other tools that help produce the statement of Present Ecological State (Appendix 4.2). Still more methods have been developed to various levels on-project or in WRC-funded research projects. A pilot Reserve method for ephemeral rivers has been written up and is being further developed [39] (Section 6.4.4), whilst the current Reserve method for groundwater has been formally written up, reviewed and approved by DWA [27]. A method for economic assessment for river catchments is under development [41]. Chapters 6 and 7 detail of progress made and challenges faced in applying the methodes.



Manual for the Building Block Methodology.

Table 4.8 Examples of RDM tools and procedures developed for the eight-step generic RDM procedure for Preliminary Reserve determinations (various authors – see Appendix 4.2). DSS = Decision Support System

Tool or procedure	Details
DSS for the selection of determination level (desktop, rapid, intermediate, comprehensive)	Guidance on at what level the Reserve determination should be done, based on criteria such as time and budget constraints, availability of information and the potential for collecting additional required information
(Ecological) Resource Unit delineation	Guidelines for delineating sub-catchments, reaches or zones of an ecosystem (e.g. river reaches[f]; hydro-geomorphic wetland types) that are relatively homogeneous in terms of morphological, biotic and anthropogenic conditions
Importance and sensitivity	A range of methods for assessing importance and sensitivity for rivers, estuaries and wetlands, which guide the choice of Recommended Ecological Category in Reserve determinations
Habitat Integrity	Rapid assessment methods for ecological condition that can be done with minimal training
River EcoClassification Index Models (various authors – see Appendix 4.2)	A suite of models used for assessing the condition of physical and biological features of the river relative to natural; includes hydrology (HAI), geomorphology (GAI), water quality (PAI), vegetation (VEGRAI), macroinvertebrates (MIRAI) and fish (FRAI)
Estuarine Health Index	A method for determining the ecological condition of an estuary, using changes in the frequency and duration of mouth closures, which is then used to assess the biological response
Building Block Methodology	A prescriptive environmental flows methodology for rivers, which is no longer widely used in RDM, but does form the basis for the Desktop Method
Desktop Model	A desktop planning tool that uses the relationship between the outcome of previous Reserve determinations and hydrology to predict EWRs for new systems
HFSR	A scenario-based approach that predicts the biophysical impacts of proposed water-resource development on rivers
DRIFT	A scenario-based approach that predicts the biophysical and socio-economic impacts of proposed water-resource development on rivers
RDM method for estuaries	Procedures for Rapid, Intermediate and Comprehensive Ecological Reserve Determinations for estuaries. The use of multidisciplinary scientific panel workshops, integral to the method, is a strength of the approach
Rapid Reserve determination methods for Wetlands	Uses a similar approach to BBM to define lowflow and flood requirements for wetlands
Hydrological approach to determine pan inundation	An hydrological approach using rainfall-inundation correlations for determining the patterns of pan inundation
Herold Method	A model that calculates diffuse salt loads associated with runoff and is used to calculate groundwater contribution of the baseflow and surface runoff
Groundwater Resource Directed Measures (GRDM) method	Alternate methods for determination of the groundwater Reserve, which are currently being compared and evaluated
Groundwater Yield Model for the Reserve (GRYM) Method	

[f] *For the purpose of this document, "reach" is broadly defined as "the length of channel characterised by a particular channel pattern and channel morphology, resulting from a uniform set of local constraints on channel form"* [40]. *Reaches can be hundreds of metres to a few kilometres long.*

4.4 The Water Resource Classification System

The above activities have existed, somewhat uneasily, in a partial vacuum. Reserves may have been set and licences issued without formal consideration of bigger catchment-wide water issues. The WRCS, a central vision of the NWA, is designed to address this issue. Defined as '…a set of guidelines and procedures for determining different Management Classes'[g], the WRCS will be applied at the catchment level to describe the economic, social and ecological implications of various permutations of the three recognised Management Classes (Section 2.3.3 in Chapter 2) across the catchment (Table 4.9) [13,42]. Through a consultative process with stakeholders, finality will then be reached on the Management Class for each part of the catchment. This mosaic of Management Classes will describe the agreed condition of the water resource in each part of the catchment, and thus implicitly define the degree to which each part can be utilised and the level of protection each part will be afforded. Small catchments may have one Management Class for their whole area.

The Management Class for each Integrated Unit of Analysis (IUA) will have a set of RQOs, one of which will be the water requirements for the Ecological Reserve (Figure 4.3). It will thus establish not only the boundaries of the volume, distribution and timing of the water needed for ecosystem maintenance in that part of the catchment but also the amount of water consequently potentially available for off-stream use. This is an important attribute when dealing with water-use licence applications and will negate the present labour-intensive and timing-consuming situation of every licence application having to have a Reserve determination completed or a previous determination for the same area linked in. The Management Classes, with their RQOs, once set, are legally enforceable conditions signed off by the Minister or delegated authority. They are binding on all authorities or institutions when exercising any power or performing any duty under the NWA.

The WRCS was designed to use the comprehensive array of tools, procedures and data developed in RDM Phases 1 to 3 but some new tools were needed. These primarily addressed scale issues because Preliminary Reserves focussed on river-reach level flow determinations whereas the WRCS would be operating at the catchment level. To address this problem, the WRCS framework is designed to be able to extrapolate and interpolate data from earlier comprehensive Preliminary Reserve determinations to wider geographical areas [43,44]. Thus, Preliminary Reserves already done in isolation can be absorbed into its catchment-wide approach and, as it becomes part of integrated catchment planning, its seven-step approach will replace the existing eight-step RDM procedure (Table 4.6) [12].

The next section further explains these steps and the underlying IWRM concept.

Table 4.9 The three Management Classes recognised by the NWA and the catchment-wide configuration that each must meet [13]. IUA = Integrated Units of Analysis

Management Class	Description	Configuration guidelines
Class 1: Minimally used	The configuration of water resources within an IUA results in an overall water-resource condition that is minimally altered from its pre-development condition.	At least 60% of the freshwater ecosystems in an IUA are in an A or B ecological category.
Class 2: Moderately used	The configuration of water resources within an IUA results in an overall water-resource condition that is moderately altered from its pre-development condition.	At least 40% of the freshwater ecosystems in an IUA are in an A or B ecological category.
Class 3: Heavily used	The configuration of water resources within an IUA results in an overall water-resource condition that is significantly altered from its pre-development condition.	No requirement for A or B ecological categories.

[g] *Originally called 'classes' in NWA.*

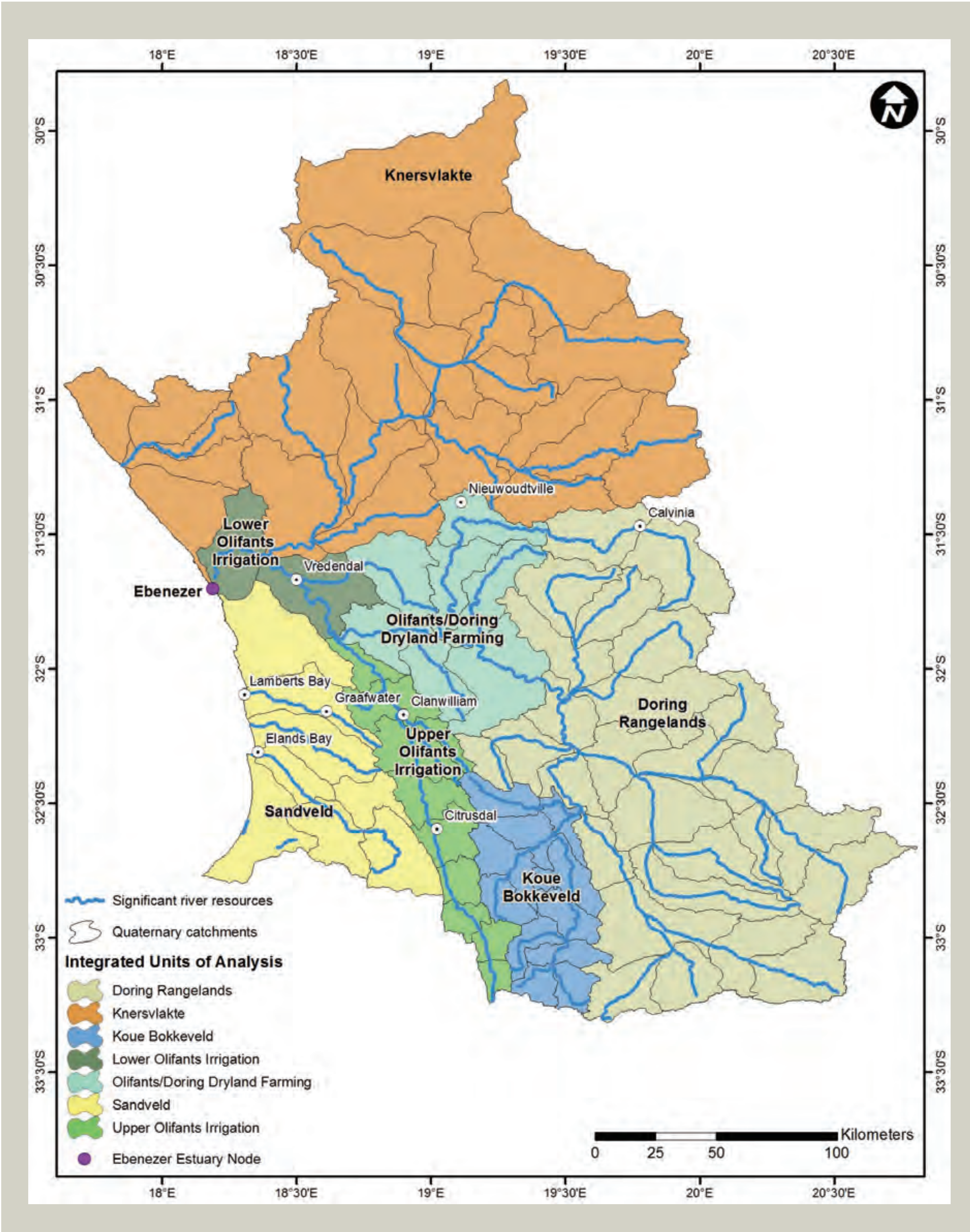


Figure 4.3 The Olifants/Doring catchment, showing the Integrated Units of Analysis (IUA) each of which will have a Management Class, Reserve and RQOs set. IUAs are based on hydrological sub-catchment boundaries and socio-economic zones, and are characterised at a finer scale in terms of the river ecosystem at nodes.

4.4.1 The seven-step WRCS procedure and the D configuration

Steps 1 to 4 are technical ones done by water-resource scientists and engineers (Box 4.2), and closely mirror the existing RDM Steps 1 to 5.

Steps 5-7 broaden and formalise stakeholder participation, focussing on scenario evaluation and selection of favoured Management Classes.

The catchment-wide configuration of Management Classes has to stay within certain limits in order for the status of the class for each IUA to be met. An IUA designated Management Class 1 (minimally used), for instance, must have 60% or more of its nodes in an A/B ecological category or better and not more than 1% of its nodes in a D category.

The requirements of the NWA, that no part of a water resource may in future be below a D Ecological Status [12], exert further limitations to the configuration. To aid consideration of this, the hydrological model set up for any catchment where the WRCS is to be applied can produce one or more configurations of flows that maintain as many parts of the system as possible at a D level – the so-called 'bottom line' scenario [43]. Typically, this requires some parts of the system to be higher than a D category in order to support downstream sections at that level.

The 'bottom-line' scenario, in its various forms, represents the furthest extent of water use/ecosystem degradation allowable under the NWA. Stakeholders, including irrigation boards, dam operators, municipalities, conservation bodies, subsistence users of the water resource, and others, then negotiate with DWA regarding a final configuration for the catchment that could result in some or many parts of the catchment being much higher than a D status. Once the configuration has been decided upon, then focus turns to its on-the-ground operationalisation in the catchment.

The WRCS was promulgated as Regulation 810 of 17 September 2010 (No. 33541 Government Gazette) allowing water resource classification to formally begin. In anticipation of this, DWA issued the first calls for proposals for Classification Processes in key catchments in August 2010 (Chapter 7).

Delana Louw

James MacKenzie and Drew Birkhead installing a data logger in the Orange River downstream of Boegoeberg Dam to measure water levels for use in hydraulic modelling as part of the EWR determination, March 2010.

Box 4.2 Steps in the Water Resource Classification System

Step 1 Delineate the units of analysis and describe the status quo of the water resource or water resources
Identify and describe all significant water resources (e.g. rivers, wetlands, aquifers) and existing lawful water users, and then represent them at the catchment level as a simplified network of spatial units defined by nodes. A modeling 'node' represents each upstream section. Nodes are grouped into homogeneous sub-regions called Integrated Units of Analysis (IUAs) on the basis of social, economic and hydrological similarity. Step 1 equates to Step 1, 2 and 3 of the Generic RDM procedure (Table 4.6).

Step 2 Link the socio-economic and ecological value and condition of the water resource or water resources
Define the links between ecosystem condition and the social well-being of the people in the catchment, and the links between water use and the region's economy. Although social inputs were increasingly being incorporated into Reserve determinations, this was not a formal step in the Generic RDM procedure.

Step 3 Quantify the Ecological Water Requirements at each node
Step 3 is a major step that involves describing the EWRs that will maintain each IUA in a range of ecological conditions. The methods used differ depending on the type of ecosystem, location and data availability. Step 3 equates to Step 4 of the Generic RDM procedure.

Step 4 Determine an ecologically sustainable base configuration scenario and development scenarios
Develop a set of approximately 6 to 10 scenarios that capture a range of possible future mosaics of Management Classes for evaluation by DWA in Step 5. Step 4 narrows the scope of the discussions to a manageable set of future scenarios that can include water resource development options and also conservation planning or other issues. It equates to Step 5 of the Generic RDM procedure.

Step 5 Evaluate scenarios within the integrated water resource management process
Present scenarios to DWA officials who will decide on the final suite of scenarios to be presented to stakeholders. WRCS Steps 5 and 6 are part of the larger suite of IWRM processes in a catchment, and are the steps where the economic, social and ecological trade-offs will be made. The WRCS distinguishes between the technical aspects of constructing the scenarios and the management aspects of deciding which of those constructed will be presented in Step 6. This step was previously part of Step 5 in the Generic RDM procedure.

Step 6 Evaluate the scenarios with stakeholders
Consult with stakeholders on the scenarios and their implications, and make recommendations on suitable scenarios. Step 6 is necessary to meet the public participation requirements of the NWA. Limited stakeholder engagement was included in Step 6 of the Generic RDM procedure but the process is more formalized and structured in the WRCS.

Step 7 Gazette and implement the class configuration
Present recommended scenarios to the Minister of Water and Environment Affairs for a decision on Management Classes. When published in the Government Gazette, this decision on the desired condition of water resources in the catchment becomes legally binding. Step 7 equates to Steps 7 and 8 of the Generic RDM procedure.

4.5 Procedures for operationalising the Reserve

Meeting the full RDM requirements will entail applying the WRCS and setting and enforcing the RQOs – including the Ecological Reserve – for every catchment in the country. At present the focus is almost exclusively on achieving some level of compliance with the Ecological Reserve (not the full suite of RQOs) and even this is still at a rudimentary stage. Very few Ecological Reserves are being managed and monitored adequately, which is not surprising when one considers that full implementation of such measures has been reckoned to take two to three decades [9]. The following sections outline some areas where progress has been made.

4.5.1 Putting Reserve flow regimes into operation

In 2009, DWA commissioned the development of a framework for Reserve operationalisation [45]. As part of the supporting project, pilot programmes were implemented in several river catchments (Chapter 7) and thus, despite a general paucity of experience, some tools and procedures have begun to emerge to support operationalisation of the Reserve. These include the following.

- Operating rules for run-of-river abstractions, which necessitate limiting the timing and volume of water abstracted directly from a river through curtailment rules, thereby ensuring that sufficient water remains in the river to meet the Reserve.
- Operating rules for dams, which require new kinds of design thinking to allow the release of both low flows and floods from impoundments. Reference sites with natural or near-natural flow patterns (either in the same catchment or in a neighbouring one with similar hydrology) are used to guide the volume and timing of releases.
- Software to support the implementation of the low flow component of the Ecological Reserve, which relies on real-time rainfall data.
- Communication with stakeholders about the nature and purpose of the Reserve, so that they understand and support it.
- Communication with catchment managers and dam operators about the nature and purpose of the Reserve, so that they understand and support it, and also understand the tools and procedures that are becoming available to assist them with operationalising the Reserve.
- Understanding the legal obligations raised by the NWA.
- An integrated ecological water resource monitoring approach (Section 4.6.2).

Appendix 4.2 and Chapters 6 and 7 provide further information.

The above activities relate to rivers and estuaries, but similar efforts are being made to operationalise Reserves for groundwater systems and wetlands.

4.5.2 Monitoring for RDM

Each step of putting new legislative measures into place is important, but none more so than the last, often neglected step, of monitoring compliance. In terms of RDM requirements, the EcoSpecs include measures of water quantity (the flow regime), water quality and ecosystem condition, all of which should be monitored at selected points, with the objective of assessing if the following are being achieved:

- the Ecological Reserve flow regime
- all the other Ecospecs
- the agreed ecological category
- the overall Management Class for an IUA.

If some or all of these targets are not being achieved – for instance, if the required flows are in place but are not producing the required ecological category/management class – then in a process of adaptive management, the information should be used to inform discussions on whether or not to adjust either the flows, or the EcoSpecs and target ecological condition.

Procedures for monitoring the EcoSpecs are available for rivers [31,46] and estuaries [47,48] but not yet for wetlands and groundwater systems. River-specific and site-specific recommendations for what to monitor in terms of Ecospecs also emanate from every Comprehensive and Intermediate Preliminary Reserve determination.

There has thus been technical progress with formalising monitoring procedures, and some monitoring has been done, but this has not yet evolved into dedicated and formalised RDM monitoring programmes (Chapter 7).

RQO monitoring is in its infancy, and could benefit considerably from experiences in other physical, chemical and biological aquatic monitoring programmes underway in the country. Initial indications are that the National Aquatic Ecosystems Health Monitoring Programme (NAEHMP) and the Ecological Reserve programme may be integrated into an Ecological Water Resources Monitoring Programme to reduce the resources required to implement them. This topic is re-visited in Chapter 8, while the following concluding sections review the strengths and weaknesses of the procedures and methods developed to date.

4.6 Strengths of the RDM tools and procedures

4.6.1 The four-phase RDM approach

DWA has followed a phased approach to implementing the RDM provisions within the NWA that, for the most part, has remained on schedule.

4.6.2 Research funding

Method development has been well-supported with funding from both the Water Research Commission and DWA.

4.6.3 Methods for determination of the Reserve

Well-documented, tested methods have been developed within the country for assessing EWRs for rivers and estuaries, and some progress is being made on methods for wetlands and groundwater. In many cases these are supported by manuals and/or have been published in the scientific literature (Chapter 6). The methods are mostly structured, repeatable, holistic, and produce outputs reached by consensus among technical experts.

4.6.4 The WRCS

The RDM procedures are operating at some level of fulfilment. Recent promulgation of the WRCS should help coordination and streamlining of this work.

4.6.5 Capacity building

An enormous amount of capacity and awareness has been built countrywide around use of the RDM tools and procedures. There have been dedicated training courses for Reserve determinations, as well as some training built in to most Intermediate and Comprehensive Reserve studies. Additionally, the general level of awareness of the sustainability concepts epitomised by the RDM part of the NWA among water professionals of all kinds in the country is now widespread and high compared with most other developing (and developed) countries.

4.7 Weaknesses of the RDM tools and procedures

4.7.1 Uncontrolled method development

As with any new science, methods are still evolving, not easily available to others and it is difficult to keep track of their different versions. Some change with every Reserve determination, with the updates being communicated *via* word-of-mouth among practitioners. There is a need to bring some order into this runaway situation.

4.7.2 The Desktop Model

This is an attractive option to use for Reserve determinations because of the speed and low cost of outputs, but its use is often inappropriate, with incorrect or inappropriate hydrological data being used. Quaternary level hydrological data are at best relevant for the mainstem river, for instance, but are often erroneously used for tributaries. It was intended that the Desktop Model would be used by highly experienced personnel, precisely to avoid the production of nonsensical answers but, because it is so easy to use, the opposite may occur with inexperienced practitioners often undertaking Desktop and Rapid Reserve determinations.

4.7.3 Mainstem Reserves

Preliminary Reserve determinations have focused on mainstem river reaches. This is likely to prove a major stumbling block as the WRCS is applied because extrapolations of the modelled links between flow on the one hand and water quality, ecosystem condition and subsistence links to the system on the other, will not be valid for the major part of the drainage network represented by tributaries.

4.7.4 Water balances

For many catchments, there are incomplete hydrological records, particularly for tributaries, and thus little or no information on the balance between water that is abstracted each month and water that remains in the system. It is thus difficult, if not impossible, at present to formally assess the catchment-wide implications of issuing a water-use license, and yet such licences are being issued daily. Some DWA Regional Offices are completing some form of supply and demand assessment before issuing licenses, but the overall nationwide paucity of accurate catchment-wide water balances remains a problem.

4.7.5 Groundwater RDM

The role of groundwater in supporting aquatic ecosystems and the implications for them of abstraction are still poorly understood. This threatens successful inclusion of the groundwater component in the RDM determination for a catchment.

4.7.6 The Recommended Ecological Category

Particularly for estuaries, the REC is often based on a conservation dictum, that is, it is driven by conservation thinking rather than by comprehensive considerations of water resource supply and demand. The WRCS would change the situation by requiring catchment-wide negotiations among all stakeholders. From this will emerge a recommendation to the government of the agreed optimum trade-off between development and resource protection for each and every part of the catchment's water resources.

4.7.7 Compliance monitoring

There is no formalised, ongoing compliance monitoring programme. Used effectively, this would support the RDM activities, inform adaptive management strategies, and improve the often untested assumptions made when Reserve determinations are done.

4.7.8 Climate change

To date, climate change predictions have not been included in Reserve determinations. It is thus unclear what the approach will be if and when the mean annual runoff of a river changes as a result of climate change.

4.7.9 Science-management interface

Communication between scientist and water managers has progressed beyond what was thought possible in the last two decades but still requires improvement. Two important areas of concern are as follows.

- RDM templates are poorly structured, repetitive and do not provide information that can easily be understood or used by managers or dam operators. They also do not allow for explanations of exceptions.
- Staff of the CD:RDM do not routinely take part in the nation-wide catchment reconciliation strategies being run by DWA's Chief Directorate: Integrated Water Resource Planning (CD: IWRP) nor are they required to. These strategies include many stakeholders but may not have a formal RDM presence.

4.7.10 Staffing and capacity issues

CD:RDM has been historically critically understaffed, with some staff poorly trained or under-capacitated for the work, and staff turnover quite high. This has resulted, *inter alia*, in poor record keeping at times although efforts are being made to address this. Unfortunately, documents relating to some of the work done before the NWA have been permanently lost.

4.7.11 Lack of understanding among clients and funders

Advising on the management of ecosystems is a complex science that takes years of training and, where data are few, relies on the wisdom of experienced professionals. Clients and funders search, to some extent, for simplification of the science to the point where it can be written as a set of commands to be followed by a technician. It would be more constructive to recognise that a high level of skill is needed, and to guide the mass of activity presently happening into refining procedures and collaborations that best speak to the needs of the country.

4.7.12 Non-flow-related management impacts

Some impacts on rivers are not related to flow changes. These are poorly dealt with in the present set of Reserve methods and yet are important aspects of Reserve determinations as better catchment management, for instance, could reduce the need for Reserve flows.

4.7.13 Access to data

Reserve-related data and reports are central to operationalisation of the RDM but are presently not well curated. The CD: RDM has recognized the need for better management of electronic and physical documents, and GIS information [49], but this management, though planned, is not yet in place.

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Sharon Pollard

5 RDM AND BASIC HUMAN NEEDS

Adhishri Singh, Toriso Tlou and Greg Huggins

5.1 Introduction

All people are users of inland waters in some form, but human links with rivers and wetlands are strongest in developing countries. Here, rural livelihoods respond to the annual water cycle; cultural, religious and recreational ties to the ecosystems have deep meaning; and the natural resources may provide a back-up in times of family trauma such as death of a bread-winner or loss of a job [1].

The basic human needs of such people in terms of river resources go far beyond the simple supply of water. In this chapter, these two aspects of basic human needs are addressed.

5.2 Basic Human Needs – water

More than a decade has passed since the Reserve with its two components, Ecological and Basic Human Needs, was introduced into South Africa. During this time most of the focus has been on the Ecological Reserve.

The Basic Human Needs Reserve (BHNR) has received much less attention. This has resulted in limited development of the concepts and methods that underpin it. There is no acceptance as yet of a standard approach to ascertaining the quantities of water involved or how they should be managed.

DWA recognises the significance and importance of the BHNR, and the calculation of the quantity of water involved appears to be straightforward (number of relevant people times 25 litres per person per day), but there is still no universal agreement of what it actually means and how it should be implemented.

A fundamental and major gap is the lack of alignment between the BHNR as a water resource concept governed by the National Water Act (NWA) and Free Basic Water (FBW), which is a water services concept governed by the Water Services Act (108 of 1997) [2,3]. Both recognise the need for a basic supply of clean and adequate water for health and welfare purposes.

The following sections analyse the situation, starting with the legislative background, an explanation of the intent of the BHNR and its links with the FBW. This is followed by an outline of the present status of the BHNR in Reserve assessments, and a discussion of how a coherent approach to the BHNR can be achieved.

5.2.1 The legislative framework for the BHNR

Water has a profound influence on human health. At a very basic level, a minimum amount of water is required for consumption on a daily basis for survival and therefore access to some form of water is essential for all people. Water has a much wider significance for health and wellbeing, however, and both its quantity and quality are important influences of individual and community health.

Section 27 (1) (b) of the Bill of Rights and 1994 Constitution of South Africa states that "Everyone has a right to have access to:......sufficient food and water;.….". The Constitution further prescribes that the onus is on the state to progressively realise this right, whether it be in the form of legislation or some other measure.

The concept of a right to water is deeply entrenched within the NWA. In Chapter 1 (Interpretation and Fundamental Principles) the NWA states that *"Sustainability and equity are identified as central guiding principles in the protection, use, development, conservation, management and control of water resources.*

*"These guiding principles recognise the **basic human needs** of present and future generations, the need to protect water resources, the need to share some water resources with other countries, the need to promote social and economic development through the use of water and the need to establish suitable institutions in order to achieve the purpose of the Act."*

Part 3 of the NWA gives effect to this Constitutional right in the form of the BHNR (Box 5.1), which is an attempt to ensure that individuals are guaranteed access to sufficient water for life support. The definition contained within the NWA is that the *'BHNR provides for the essential needs of individuals served by the water resource in question and includes water for drinking, for food preparation and for personal hygiene'*.

The Water Services Act supports the Constitutional right by requiring the enactment of reasonable measures to provide access to a basic water supply, which should be described in a water services plan. According to the definition provided in the Water Services Act, the 'basic water supply' means the prescribed minimum standard of services necessary for the reliable supply of water, of a sufficient quantity and quality, to households, including informal households, in order to support life and personal hygiene. This minimum volume of water for each and every person is thus protected by the Act. All other water uses are allocated through water use licenses.

Derick du Toit

A youth collects water for his family from an open agriculture canal near Thulamahashe in Mpumalanga Province. These canals are a reliable source of water although this may be shared with animals and other users upstream.

Box 5.1 Definition of the Basic Human Needs Reserve within the wider context of the Reserve

Extracted from the NWA, Chapter 1, section 1(1) (xviii)(a)

"Reserve" means the quantity and quality of water required:

(a) to satisfy basic human needs by securing a basic water supply, as prescribed under the Water Services Act, 1997 (Act No. 108 of 1997), for people who are now or who will, in the reasonably near future, be

(i) relying upon;
(ii) taking water from; or
(iii) being supplied from, the relevant water resource; and

(b) to protect aquatic ecosystems in order to secure ecologically sustainable development and use of the relevant water resource;

5.2.2 To whom and for what does the BHNR apply?

The NWA does not quantify the BHNR in any individual or community terms, but simply states that it includes water for drinking, food preparation and personal hygiene. In essence, then, the BHNR aims to promote equity amongst all the people of the country in terms of their basic right to water. It does not include or address water required for additional household or productive needs, subsistence crops or small-scale productive use, such as garden vegetables and livestock production[a].

5.2.3 BHNR and Free Basic Water (FBW)

The aim of the BHNR in the NWA is to protect water for basic needs from other potential water users and elevate it as the only right to water, together with the Ecological Reserve.

FBW, introduced in 2000, is designed to ensure that every household – urban and rural, rich and poor – receives a specific amount of water per month at no cost. The minimum amount settled upon is 25 litres per person per day based on a family of eight and this is delivered to communities by means of a piped water supply and provided either through yard/household connections or through standpipes. Municipalities are expected to recover the costs of any additional water supplied through water services tariffs.

BHNR and FBW are clearly similar and in both cases the purpose is to ensure that everyone has water to meet basic needs such as cooking, washing and drinking, but a level of misalignment arises because of their origins in different Acts. The BHNR can be seen as the concept of ensuring water for all, whilst FBW is the tool to give effect to the concept by providing the means of delivering the water to the communities. FBW is taken out of aquatic ecosystems by water service provisioners and delivered to houses, yards or standpipes along with any greater amount supplied for other needs. Ideally, all people should receive FBW in this way, through infrastructure that delivers at least the legally required minimum amount of water at an appropriate level of water quality. But with a high proportion of the country's population living in scattered rural settings, delivery for all is a problem and will take time. In these situations, surface or groundwater ecosystems still directly cater for some people's basic water needs and these people exercise their rights by accessing water from the ecosystems. For this reason, the concept of basic water for all must in the interim include ensuring that there is 1) enough available for FBW in the nation's delivery systems and 2) enough available directly in the nation's ecosystems for those without formal delivery systems.

The provision of the delivery systems, and thus of the FBW, is the mandate of local government, whilst protection of the volume of water within the nation's ecosystems needed for providing basic water for everyone – the BHNR – is the mandate of the national DWA and specifically of the Chief Directorate: Resource Directed Measures (CD: RDM).

[a]*see full list in Schedule 1 of the NWA*

In order to provide for FBW, the municipalities who are responsible for water service provision – the Water Services Authorities – must have the water available. They obtain this water through licences provided by DWA, which allow them to abstract either surface water or groundwater for FBW and additional demands. The licences do not necessarily distinguish between FBW and other demands in excess of free water and both may simply be included in an overall allocation. The FBW thus is not guaranteed separately.

5.2.4 Initial methods for determining the BHNR

5.2.4.1 Overview and general nature of the BHNR

Each time a water use licence is applied for or a water resource development is identified as essential, an Ecological Reserve determination is completed or an earlier determination is referred to.


Paul Jagals

Rural women carrying water from a communal tap to their homes – a 500 m trip completed at least twice a day.

In order to comply with the terms of the NWA and in an attempt to protect the water required for basic human needs, DWA also determines the BHNR at the same time. Together, these inform the decision on whether or not the licence will be granted or the development proceed, and under what conditions. Ecological Reserve determinations can be done at different levels of resolution, from desktop through to comprehensive (Chapter 4), and this has tended to dictate when and how the BHNR is calculated. None of the approaches used in the determination of the BHNR has been formally approved by DWA to date, unlike the general approach used for Ecological Reserve determinations.

The BHNR has both a quantity and a quality component, as both of these attributes of water are important for sustaining life. In all cases the focus is on water for basic drinking, food preparation and hygiene purposes.

5.2.4.2 Assessing the quantity component of the BHNR

Although the NWA gives the reader clues as to the importance of the BHNR and what it encompasses, it does not set the quantity of water deemed to be adequate to satisfy basic human needs. The Water Services Act is no more insightful in this regard, and the topic continues to generate vigorous debate.

Some guidance was provided by the Reconstruction and Development Programme (RDP) launched by South Africa in the 1990s with the aim of ensuring that all communities have access to basic services. The RDP established a standard allocation of 25 litres per person per day as the requirement for basic needs, in line with international benchmarks [4]. This has been varied on occasion to take into account climatic conditions, lifestyles, culture and conditions of access, but essentially the RDP target of 25 litres per person per day has been accepted as the standard quantum for the purposes of the BHNR.

Initially the determination of the BHNR was seen as a relatively simple arithmetic exercise. The size of the population within the relevant quaternary catchment(s) was ascertained from sources such as the 2001 Population Census, the Municipal Water Service Development Plan population figures or aerial photographs. This figure was then simply multiplied by 25 litres per person per day. Although there were variations on the theme this pragmatic approach appeared, at least initially, to suffice.

The figure was then expressed as a percentage of the Mean Annual Runoff (MAR) of the river at each ecological assessment site in order to be consistent with the approach used in the Ecological Reserve determination. The BHNR was then seen as a volume of water over and above the requirements for ecosystem maintenance that had to be met at set points along the water resource. Where the BHNR was calculated from groundwater resources it was expressed as a percentage of the recharge of the quaternary catchment.

Given the relatively small amounts of water required for the BHNR the figures produced, in many cases, tended to be almost inconsequential. Nevertheless, some problems with the approach began to emerge. The two main ones were as follows.

- On occasion, a BHNR set for an arid area required water to flow in a non-perennial system at times and places where there would naturally be no flow. This ran counter to the natural functioning of the system and so was at odds with the water requirements determined for the Ecological Reserve.

- Even in some perennial systems the BHNR set requirements for river flows that exceeded recorded natural drought or low flow conditions.

Of more concern, however, was the fact that the scenarios created as part of Ecological Reserve determinations always included allocations for existing water uses and thus included the volumes already being abstracted through licences for FBW. As the BHNR was then added as a routine volume over and above this for everyone in the catchment, double accounting was taking place. In systems that are heavily populated, such as parts of the Vaal River basin, this double accounting can have a major impact on the projected yield of the system.

With this in mind, a DWA-driven workshop held in October 2008 motivated for a revised and standardised method. Section 5.2.5, outlines such a method.

Derick du Toit

Villagers in an arid part of Venda depend on local government for the delivery of domestic water by truck – an expensive, inefficient and ineffective venture.

Jackie King

Many rivers are still used for washing clothes.

5.2.4.3 Assessing the quality component of the BHNR

The physical and chemical quality requirements of the BHNR are based on the guidelines for the Drinking Water Quality Standards of Domestic Water Supplies [5]. Water taken out of the water resource for basic human needs should be treated, where necessary, to potable levels before it can be used, but it is not clear how this should happen if people are themselves accessing the water directly from the ecosystem.

An additional major flaw in the current assessment of the BHNR is that the microbiological quality of the water resource is not specified in the BHNR parameters. Poor microbiological quality can lead to outbreaks of infectious, water-related diseases and may trigger serious epidemics. Indicators of microbiological water quality, such as coliforms and specifically *E. coli*, should be included as BHNR parameters.

5.2.4.4 RDM templates

Results of the BHNR and Ecological Reserve determinations are provided to the DWA Regional Offices in a custom-designed RDM template document (Appendix 4.3). For the BHNR, the template provides the following data:

- the relevant water resource and the quaternary catchment;
- the volume of water to be allocated to the BHNR, and as a percentage of the natural mean annual runoff of rivers or a percentage of recharge of groundwater;
- the quality of the water resource to achieve the BHNR, given as the maximum or range for physical, chemical and toxic water quality variables.

The BHNR determinations, once approved, provide the legal grounding that will ensure that the water is allocated to basic needs and cannot be utilised by other water users.

The current practice is that the BHNR is then retained in the river, together with the Ecological Reserve. It is not necessarily related to and aligned with the FBW, and not specifically worked into the water balance of the catchment. In most cases the volume of the BHNR is so small that it does not make much difference to the available yield of the system, although the quality requirements for the BHNR could be quite different from those for the ecosystem.

5.2.4.5 Summary of present approach for the BHNR

The BHNR is calculated as the volume of water of a specified quality that must be reserved for basic needs. In most cases, this is presently calculated as 25 litres per person per day for the total population in a quaternary catchment. Amendments to this approach were applied where comprehensive catchment-wide Reserve determinations were undertaken, such as for the Thukela, the Inkomati and the Mokolo Rivers. In these cases attempts were made to identify those communities directly dependent on run-of-river flow. The BHNR was then calculated only for these communities.

5.2.5 Proposed improved method for determining the BHNR

At the October 2008 DWA workshop, two refined approaches were proposed. The first is relevant to large or complex catchments in which a fine-grained analysis of the population and its degree of dependence on direct abstraction of run-of-river flow is either impossible or too expensive. The second is for smaller catchments where it is fairly easy to establish the population numbers and their dependence on run-of-river flow.

5.2.5.1 Suggested BHNR approach for large and complex catchments

The population of the catchment at a quaternary level is determined using the 2001 National Census, as this contains the only nationally consistent data. The catchment boundaries are overlain upon the smallest aggregations of data available from the 2001 census, known as *sub-places*. All sub-places either wholly or partially within the quaternary catchments are then captured.

Where sub-places are partially within a quaternary catchment then the percentage area that falls within is applied to the population. For instance, where a sub-place is only 50% within a quaternary catchment then only 50% of its population is deemed to fall within the area. This exercise is usually undertaken at a desk-top level and using GIS technology. The numbers are checked against the Water Situation Assessment Model (WSAM) for compatibility. The WSAM is a decision support tool that contributes to an understanding of the status of water resources at a national scale.

Those sub-places receiving water from a recognised formal water source and therefore not likely to be dependent on run-of-river flow are then excluded from the BHNR analysis. This would include all formal urban areas, and some informal urban settlements whose numbers can be gleaned from the census data and recent Integrated Development Planning (IDP) documents developed by the Municipalities. The remaining areas represent the *qualifying population* in terms of the BHNR, which essentially consists of rural people and those residing in informal urban settlements with no formal water supply.

This is a relatively crude classification. More detailed analysis of the population could reveal that many of those regarded as rural do in fact have access to fairly secure water sources that are not run-of-river. Additionally the percentage of informal settlements could be inaccurate. Such a detailed analysis could be prohibitively expensive, however, and of limited relevance because of the dynamic nature of rural and informal urban settlements[b].

For the qualifying population, the river can then be used as a geographical cue to demarcate how many people are potentially dependent on it as a water source. In effect, a corridor of 5 km width on either side of the river is demarcated and the number of qualifying people living within it is used in the BHNR calculations.

Having calculated the qualifying population per quaternary catchment the next step is to project the population to a sensible target date such as 25 years hence, using generic growth rates applicable to the kinds of municipalities in the resource area. This is done to provide some spare allocation of water that will cater for population growth. Ideally, a population projection exercise involves an analysis of all settlement types within the study area and the application of different rates of growth based on settlement type, economic forecasts and historic trends. This type of demographic analysis is, however, a study on its own and usually beyond the scope and means of a BHNR determination.

Derick du Toit

Growing water needs superimposed on inadequate or dysfunctional infrastructure mean that many rural communities in Mpumalanga and Limpopo spend many hours a day queuing for water at communal standpipes.

Using the projected population numbers to the target date a BHNR for the qualifying population is then calculated per quaternary catchment at an allocation of 25 litres per person per day. Higher allocations can be recommended, with motivation. Figures can be expressed as a flow or as cubic metres of water per day consumption that must be available at the Reserve assessment site, which is used as a convenient point in the ecosystem at which to stipulate the BHNR.

[b] *A critical issue is whether or not the water supply infrastructure is included in the system setup that is used to undertake scenario analyses. If it is then the BHNR does not need to be included as part of the Reserve, while if not it will need to be included.*

5.2.5.2 Suggested BHNR approach for small and medium-sized catchments

Communities/areas likely to be reliant on run-of-river flow are identified within the catchment using GIS-based or 1:50 000 topographical maps. The accuracy of the information is checked, perhaps with guidance from district or local municipal planners, as they should have the latest information. If necessary, the communities/areas are visited for on-site verification of dependence on the water resource.

The population numbers of the communities/areas are calculated, again using the 2001 National Census at sub-place level, the WSAM model, municipal data, IDP documents and ward-level Demarcation Board data *(www.demarcation.org.za)*. As in the last example, the population numbers are projected to a future date, and this is used to calculate the BHNR.

5.2.5.3 Shortcomings of the revised approach

The BHNR, as well as quantifying the water needed, should also specify where it should come from. For instance, if communities are, or can be, supplied from groundwater, then the BHNR must be set aside from the groundwater resource. This will likely be the situation where communities are far from the rivers or not reliant on them for water.

It should not be necessary for the BHNR determination to delve into the detail of whether or not the water is supplied to the people. The aim of the NWA is to protect the BHNR in the resource and to ensure that it is reserved for its intended purpose. The means by which the water is provided to the people is the function of the Water Service Act. Ensuring the reserved water is used for its intended purpose will require close cooperation between DWA's Chief Directorate: RDM, Chief Directorate: Integrated Water Resource Planning and Chief Directorate: Water Services and Regional Offices. A tool to manage this is water use licensing (Chapter 3).

5.2.6 Strengths of the BHNR

5.2.6.1 Flexibility

BHNR assessments that detail a range of basic water allocations depending on the availability of water in the system are sensitive to the realities of the situation, and allow the water resource manager to decide if higher entitlements than 25 litres per person per day can be considered. The Mokolo and Crocodile River BHNR assessments took this approach, considering the level of service requirement set out in the municipality's Water Services Policy as well as the amount that consumers in the catchment could afford to pay for water.

5.2.7 Weaknesses of the BHNR

5.2.7.1 Standardisation of approach

At present there is no standard approach to a BHNR assessment. The assessments might be at the quaternary or sub-quaternary level, and include all people within those geographical areas or just those within the 5 km corridors along the mainstem. There is also no recognised list of criteria to consider. Climatic conditions, cultural influences, complexity of access to water and current levels of development all influence water availability and use and are candidates for inclusion in the assessment, but there may be other criteria not yet considered that should also be included.

5.2.7.2 Surface water versus groundwater

The main focus of all the BHNR assessments to date has been the 5-km corridor along the mainstem of the river, because this is a distance that people could be expected to travel if necessary to collect water. The approach assumed that people within the 5-km corridor use surface water from the resource and not from other sources such as groundwater. Groundwater, however, is a very important water source in many rural areas, and may or may not be connected to the surface run-of-river flow. A more holistic approach to BHNR determination needs to take into account the different sources of supply and not focus on surface water resources alone. Future BHNR determinations should address both surface and groundwater resources.

5.2.7.3 The 5-km corridor

The 5-km geographical limitation does not fully comply with the purpose and intention of the BHNR. It creates the perception that only those within the corridor may be allocated water for basic human needs from the resource. Other communities that can be supplied from this resource, with infrastructure, are not considered, while those within the corridor with alternative sources of water are included. Determining the BHNR using the population within the corridor can thus overestimate or underestimate the volume of water needed.

Sharon Pollard

Fishermen along the Limpopo River show their day's catch.

5.2.8 Administration and Management of the BHNR

5.2.8.1 Overview

As with the Ecological Reserve, there have been some problems with the administration of the BHNR.

Within DWA, the CD:RDM is responsible for protection of the nation's water resources and the Regional Offices for the allocation of basic water supplies to communities as FBW. At a lower level of government, the municipalities, in terms of the Water Services Act, have the duty to deliver the water, through appropriate infrastructure.

Currently this shared function between government departments can result in the overall management of water for basic human needs being inappropriately or inadequately aligned.

5.2.8.2 Measures for alignment

A basic minimum allocation of water for human needs should be determined and approved by the CD:RDM. With this amount set, and after an assessment that such water is available by the CD:IWRP and the Regional Office, it should be included separately in the water use licence of the Water Services Authorities (WSAs) issued by the Regional Office. The WSAs can then access the water from either surface or groundwater sources as stipulated in their water use licences and provide it to the citizens. Treatment to acceptable standards for drinking, food preparation and personal hygiene will then be the responsibility of the WSAs. In remote areas without water supply infrastructure, it is essential that sufficient water of appropriate quality is maintained within the water resource. This management of the resource to supply communities directly from surface or groundwater sources is a key function of the DWA Regional Offices.

5.2.8.3 Protection of the BHNR

At present, water use licences awarded to local authorities specify the total amount of water that may be taken including, but not distinguishing, that allocated for FBW, which is the BHNR when delivered to consumers via infrastructure. In future, the licence should distinguish FBW from the larger allocation of which it is part, and also specify the amount allocated. The licence will then be the vehicle to guarantee the FBW from a water allocation perspective and allow DWA to include it in water balance models.

Water for basic needs that is accessed directly from ecosystems needs more protection as there is poor control and monitoring of whether or not it is indeed available.

5.3 Basic Human Needs – river resources other than water

People who are subsistence users of inland waters are among the more vulnerable members of society. They are usually poor and likely to be impacted most and to gain least from water resource development that is biased toward offstream use and does not adequately consider the benefits they glean from the water bodies [1].

These benefits may include protein (fish, birds, frogs, reptiles, invertebrates, mammals), wild vegetables, cooking herbs, spices, medicines, building and craft materials (e.g. papyrus, palms, reeds, sedges, wood, clay, sand) or firewood. They may use the banks, margins and floodplains as grazing areas for livestock and for flood-recession agriculture. Without conscious recognition, they may be depending on water-loving plants and riparian trees to protect banks and shorelines, where they act as a buffer between the aquatic ecosystem and human land-use activities, and provide shade, habitat, breeding areas and nursery grounds for wildlife that may be important as food or for conservation purposes. They – indeed all of us – also depend on floodplains and wetlands to recharge aquifers and store floodwaters that thus protect downstream properties from flood damage, and more (Table 1.2).

Each of these benefits is linked to specific seasonal patterns of floods/inundation and low water levels, and specific water chemistry, temperature and sediment regimes. If these change through water resource development or catchment and land use changes, then the benefits will decline and may disappear.

From the earliest beginnings of instream flow assessments (Chapter 4), Reserve specialists have always been aware that subsistence issues can, if not addressed with care,


Donovan Kotze

Madumbe cultivation at Mbongolwane wetland.

‘fall in the gap’ between delivering water on the one hand and focusing on ecosystem health on the other. There was concern with the early instructions from DWA that river scientists should focus on flows for river health and DWA would take care of the people – which essentially meant that the department would provide access to safe, clean water (Chapters 1-3). By the mid-1990s it was clear that subsistence issues were important and were, indeed, falling in the gap, and so they started to appear in the instream flow assessments from about 1994.

Today, all Ecological Reserve assessments include information on subsistence use of the water bodies, but the process needs further formalisation to ensure that all river resources used, and the importance of them to people, are captured in the process and their values known. The Water Resource Classification process (Chapters 6 and 7) should help address this.

5.4 Conclusion

Since the Reserve was introduced into South Africa the BHNR, in terms of water, has received relatively little attention. There has been a great deal of uncertainty around the concepts and implementation of this important aspect of the NWA. It is essential that DWA develop a common understanding of the intention of the BHNR and a focussed strategic plan for ensuring its successful implementation. This requires careful consideration of the close relation between the BHNR and FBW concepts, which need to be re-aligned. Achieving this would resolve the majority of the current problems. Basic Human Needs, in terms of other river resources, are loosely catered for *via* the Ecological Reserve and should be more formally catered for within the Water Resource Classifications.

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Jackie King

6 KNOWLEDGE AND SKILLS DEVELOPMENT

Steve Mitchell, Kevin Rogers and Janine Adams

6.1 Introduction

This chapter summarises the main activities over the last three decades in terms of knowledge and skills development related to water allocations for sustaining aquatic environments. Literature cited in the text is listed at the end of the chapter. Appendix 6.1 contains a more comprehensive national list of published papers, teaching and training activities and many other relevant items, provided by practitioners in September 2010 as a result of a national call for information. For practical reasons the information has been organised under four main headings – research, capability development, capacity building and awareness raising – although inevitably much of it has elements of all four.

6.2 Research

6.2.1 Background to water research in South Africa

South Africa has a long history of water research. The Council for Scientific and Industrial Research (CSIR) was established by an act of parliament in 1945 and at the time was the leading science and industrial research organisation in Africa. Prime Minister Jan Smuts had recognised that the Union of South Africa needed a scientific research organisation and recalled Dr Basil Schonland from the Second World War in January 1945 to develop the draft mandate for such an organisation.


Jackie King

Bryan Davies and Mark Chutter at Langrivier in the Hottentots-Holland mountains in 1985. Although many aspects of rivers were well studied by then, the links with flow were only just beginning to be investigated.

The CSIR was established to 'advise the minister on all aspects of scientific and technological methods affecting the utilisation of natural resources of the Union and the development of its industries and of the proper coordination of and employment of scientific research to those ends' [1].

The initial policy of the new organisation was to encourage research by industry, develop co-operative industrial research institutes, establish national science laboratories, foster research through grants and bursaries to universities and maintain a central library. One of the national science laboratories established as part of the CSIR was the National Institute for Chemical Research. From the inception of the CSIR, this Institute was involved in research into the management of the nation's water resources, in recognition that South Africa is a dry country and that the rapid population increase during the post-war period was inevitably leading to increasing pressure on and pollution of the nation's aquatic resources.

In 1958, the National Institute for Water Research (NIWR) was elevated out of the National Institute for Chemical Research, and initially its focus was on water treatment and water quality in the environment. Its early research thrusts were the reclamation of effluent to a potable standard (piloted at full scale in Windhoek, Namibia), biological removal of nutrients from sewage, recycling of treated effluent through the Cape Flats aquifer, chemical analyses of water quality and biological monitoring of water quality. The NIWR led the world in the development of technologies for the first two of these thrusts, and the diatom collection started by Dr B. J. Cholnoky and built onto by Dr R.E.M. Archibald and others is now amongst the five largest in the world. Through all its restructurings the CSIR has maintained a research capability in water.

By the 1960-70s South Africa faced an impending water crisis as the combination of drought cycles and a growing population placed an ever-increasing stress on the nation's water resources. Triggered by the 1966 drought, the government initiated the Commission of Enquiry into Water Matters whose findings were published in 1970 [2]. As a direct result, the Water Research Commission (WRC) was established in 1971, with Dr Gerrie Stander as the first Director (see also Chapters 2 and 4). Funds for the WRC come from a levy of bulk sales of water to water boards and government irrigation schemes, thus providing the commission with an independent source of funding.

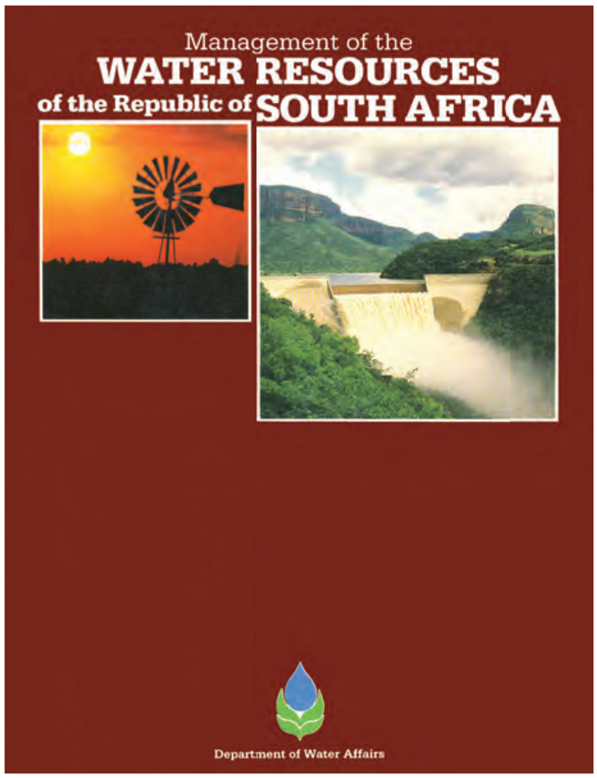
Establishment of the WRC came at a time of growing recognition of the urgent need for research that would "put the planning, management and utilisation of inland waters on a scientific footing in order to best meet the often conflicting needs of the agricultural, industrial, urban, recreational and fisheries sectors" [3]. At that stage, there was no recognition of the needs of non-urban, or subsistence, users of the aquatic ecosystems or of the need for water to maintain the ecosystems themselves, and the main research areas of the WRC were water reclamation for potable use, nutrient removal from sewage effluent, eutrophication and hydrology.

In addition to the CSIR Institutes, the CSIR also established funding arms to stimulate the national research capability. The South African National Scientific Programmes (later renamed the Co-operative Scientific Programmes (CSP)) were established in 1975 around the existing activities of the CSIR. This initiative provided funding to promote joint development projects between industry and the science councils, state departments, museums and universities. Additionally, the CSIR administered the Research Grants Division (RGD), which funded research at universities. The functions of the RGD and the CSP were amalgamated in April 1984 to form the Foundation for Research and Development (FRD) [4].The CSP, of which a newly-formed Inland Water Ecosystems Research Programme (IWE) was part, developed a virtual college of environmental expertise in South Africa without any costly infrastructure; contributed to a forum in which environmental problems and research priorities could be debated; and also raised the general standard of ecological research [5].

IWE was established with the aim of developing the understanding necessary to predict the effects of natural events, planned development and management actions on inland water ecosystems. It also aimed to improve the scientific basis for utilising these systems as well as the search for solutions to particular environmental and management problems related to them. IWE supported ground-breaking research on reservoirs, rivers and wetlands and made a substantial contribution to the development of limnological expertise in South Africa [5]. Through various programmes such as the Kruger National Park Rivers Research Programme, it also established close links with the WRC.

The SANSP were phased out during the latter part of the 1980s, in part due to the restructuring of government support of research, as happened in many countries at that time influenced by what is sometimes called Thatcherism.

The National Institutes of the CSIR were disbanded and replaced with technical divisions, one of which was Watertech, which dealt with water issues. These divisions were increasingly expected to source their own funding, turning the CSIR from an organisation focused on research to one that had to compete for part of its funds in the open market. At the same time, the FRD split away from CSIR, terminated its IWE programme and changed its name to the National Research Foundation (NRF). This was a critical turning point for water research, which to that point had relied heavily on FRD-IWE funding but which now saw some research programmes prematurely halted mid-term.



The 1986 publication by DWA summarised current knowledge on the country's water resources.

By the end of the 1980s, there was a growing – though still rudimentary – recognition that water was needed for 'management of the environment' [2] and, perhaps partly because of the IWE programme terminating, the WRC re-aligned its support to include research on aquatic ecosystems. It has been a strong supporter of such research ever since, often working in collaboration with DWA, WWF and a number of other bodies that share concern for the environment.

In the background, long-term monitoring programmes, many with decades-long records, were and to varying extents remain active, managed by DWA and the Department of Environmental Affairs through the South African Weather Service. With river flow gauged at over 1 000 stations[a], well over 300 national water-quality monitoring stations as well as a number of others[b], country-wide coverage of meteorological stations and, more recently, national microbial, eutrophication, aquatic-ecosystem health and toxicity monitoring programmes, the suite of national monitoring programmes is a rich source of data available to researchers, although the future of some of these activities remain uncertain.

The concepts and processes that drove their research are discussed below followed by a summary of how, against the background of evolving understanding and concern, research on environmental water needs originated and developed in South Africa. The following sections then focus on the role research has played in building capability and capacity in, and awareness of, such water-related issues, and the spreading of these skills and knowledge into the international arena.

6.2.2 The research process and the development of research on aquatic ecosystems

Reflecting international trends, early research in South Africa on aquatic ecosystems tended to concentrate on recording what was where, producing information on the distribution and abundance of species and of various physical and chemical characteristics of the systems. Terms were developed and honed that could be used to characterise their morphology, water chemistry, biotas, and global distributions, and taxonomists supported the work with descriptions of species that enabled the identification of communities with different faunal and floral compositions.

Research gradually moved on to exploring why the water bodies and biotas were where they were, using concepts such as freshwater ecoregions ('large areas encompassing one or more freshwater systems with a distinct assemblage of natural freshwater communities and species' [6], the longitudinal, lateral and vertical biophysical zonation of rivers, lakes and other wetlands, and the geomorphological, chemical and hydraulic aspects of habitat. Then came an era of studying the functioning of ecosystems – how they 'worked' – and exploring ecological concepts such as disturbance, competition and nutrient cycling. This produced insights on primary and secondary productivity, trophic structures, species' life cycles, predator-prey relationships and more.


Jackie King

Scientists from the University of Cape Town and the Cape Department of Nature Conservation study fish-flow relationships in Noordhoekrivier, a tributary of the Olifants, in 1989.

To this point, about the 1970-80s, much of the limnological research in universities was of this more fundamental nature, providing an invaluable understanding and historical database of the country's aquatic systems. A strategic decision then taken in the early 1970s moved the research institutes of the CSIR, including the NIWR, toward more problem-solving research on, for instance, biological indicators of water quality and, as a result, to closer collaboration with water managers. During the 1980s, the water managers,

[a] *http://www.dwaf.gov.za/hydrology/flow%20gauging.htm*

[b] *http://www.dwa.gov.za/iwqs/wms/data/000key.asp*

registering the growing concern over the deteriorating condition of the country's aquatic systems and starting to understand that some, if not much, of this deterioration was linked to water-resource developments such as dams, began to ask the question "How much water is needed to maintain the health of aquatic ecosystems?".

For the first time in the 1980s, river scientists became involved as a national body in water management issues. More applied than much that went before, some of their research shifted to address the most pressing management needs of the country in an iterative process where the ideas, methods and technologies were continually being honed to deliver what was needed.

One manifestation of this developing research process over the last three decades has been the growth of academic and other dedicated water-related research units (Table 6.1). An analysis of the outputs of just one of these (Table 6.2) reveals the changing focus of ecosystem research over the last three decades, showing a trend in the growth of research on practical water management issues, such as environmental flows and biomonitoring.

Contributing to such a strong growth in aquatic ecosystem research has been the consistent availability of research funding. Initially available through IWE, much of the funding in this field was later provided by the WRC. The WRC has an independent and reasonably predictable source of funds although there are some fluctuations, as less water is sold both in drought years when water is rationed and in very wet years when higher rainfall reduces the demand. This is not, however, an open-ended source of funds. The nation's water resources are already heavily developed and so the budget will not substantially increase in the future through increased water sales, although it does increase annually by roughly the national inflation.

During the financial year 2001/02 the water research levy realised an income for the WRC of R86,608,630 and in the 2008/09 financial year an income of R127,813,765 [7,8]. This latter represented 84% of the total income of the WRC, as during the decade 2000 to 2010 the policy of sourcing additional funding from other sources such as government departments was implemented. The additional income so sourced amounted to more than 12.5% of the WRC's total income in that financial year. In total, 75% of the WRC's income is committed to support research [8]. This then, although not the only funds available for water research, has been one of the main sources tapped during the last two decades by South African aquatic researchers, including those focusing on environmental water requirements. DWA, in its drive to implement the NWA, and consultants through contract projects, have also contributed a considerable body of related work, which has further increased the size of the funding pool and the development of skills.

Water Research Commission

The WRC project managers are a crucial component of the research activities. Providing strong and innovative support to the WRC-funded research on RDM since 1990 have been, chronologically, Peter Reid (top), Steve Mitchell (middle) and Stanley Liphadzi (bottom).

Table 6.1 Examples of units and research consortia established at universities since 1965 for research into aquatic ecosystems and related aspects of water resource management.

Name of aquatic research unit	Institution	Date established (and closed)
Freshwater Research Unit	University of Cape Town	1984
Institute for Environmental Sciences	University of the Free State	1972 (1985)
Centre for Environmental Management		1994
Water Cluster – Water Management in Water-Scarce Areas		2008
Research Unit for Fish Biology	University of Johannesburg	1980 (1990)
Research Unit for aquatic and terrestrial ecosystems		1990 (1997)
Research Niche in Aquatic Ecotoxicology		2008
Centre for Aquatic Research		2009
Institute of Natural Resources	University of KwaZulu-Natal	1980
Centre for Environment and Agricultural Development		1996
Integrated Estuarine and Coastal Management	Nelson Mandela Metropolitan University	1984
African Water Issues Research Unit	University of Pretoria	1999
Institute for Freshwater Studies	Rhodes University	1965 (1991)
South African Institute of Aquatic Biodiversity (was JLB Smith institute of Ichthyology)		1968
Hydrological Research Unit		1974 (1991)
Institute for Water Research		1991
Stellenbosch University Water Institute	Stellenbosch University	2010
Water Research for Improved Quality of Life (Research Niche Area)	University of Venda	2007
Institute for Water Studies	University of the Western Cape	2009
Centre for Water in the Environment	University of the Witwatersrand	1992
Coastal Research Unit of Zululand	University of Zululand	1987

Table 6.2 Aquatic research in the Freshwater Research Unit at the University of Cape Town over the last three decades, from an incomplete list of peer-reviewed international publications.

Topic/Decade	1980-1989	1990-1999	2000-2009
Techniques	1	1	1
Taxonomy	1	1	
Species biology	2	5	6
Ecology	12	8	5
Conservation		4	1
Ecosystem health; biomonitoring		1	9
Water quality	1	10	5
Flow regulation; environmental water	2	8	10
Social; historical	1	2	3

6.2.3 Early development of understanding on environmental water requirements

The earliest interdisciplinary research into the integrated management of water resources for socio-economic and environmental purposes in South Africa, and perhaps in the world, was conducted on the Pongolo floodplain in the mid-1970s. The Pongolo River was impounded during the 1970s to provide water for an irrigation scheme on the downstream Makatini Flats (27° 08′ S, 32° 15′ E). Research was initiated in response to a conflict that was foreseen between the water needs for the downstream floodplain ecosystem and the subsistence economy that it supported, and those of the proposed irrigation scheme. A phased transition from the pre-impoundment water usage to the full implementation of the proposed irrigation scheme was envisaged, and the study aimed to anticipate and smooth this transition [9,10].

During the research, water requirements were used as a vehicle for resolution of the conflicting values placed on water. A conceptual modelling approach was used to integrate knowledge from a variety of disciplines on the impact of impounding the river on the downstream floodplain. The biophysical processes of the floodplain assessed included those linked to geology, geomorphology, hydrology, sedimentology, water chemistry, climate, primary production and nutrient cycling within both the aquatic and terrestrial plant communities, secondary production with an emphasis on fish, and the dependence of the ecosystem on the flood regime.

The socio-economic processes examined included the current floodplain use, particularly flood-recession agriculture, fishing and livestock grazing, but also the harvesting of building material and food from the floodplain. Estimates were made of the asset value of the floodplain, based only on activities that generated tangible income at the time, and of the potential loss to irrigated agriculture if the required water was provided to the floodplain rather than to the irrigation scheme.


Kevin Rogers

A woman fishing with fonya basket on the Pongola River.

Based on the research, four different resource management options were presented to DWA. These demonstrated that the monetary value of ecosystem services linked to the river was greater than that of irrigated crops per unit of water used. This was a very important step in creating awareness among senior policy makers of the value of ecosystem services (Table 1.2) and that aquatic ecosystems needed water for their own maintenance.

On the same theme, in 1983 Paul Roberts, a senior DWA water engineer, projected the future freshwater demands for South Africa. Within those demands, he introduced the concept of "11% for conservation", this being a percentage of the estimated total water requirements for all sectors in the year 2000 [11,12,13]. His 11% (later increased to 13% [2]), however, was not based on the water requirements to sustain the nation's aquatic ecosystems, but on a coarse estimate of the countrywide needs for estuaries, lakes and nature reserves. It could thus not be used to calculate the water requirements for individual systems. Roberts acknowledged that his estimate was simplistic, but its significance was the recognition that water for maintenance of aquatic systems is a legitimate and essential use of water and that the benefits these ecosystems supply will gradually disappear if they are over-exploited.

By the late 1980s, understanding had progressed to the point that aquatic systems were becoming a recognised water-use sector. This concept was promoted both by the publication of DWA's book *Management of the Water Resources of the Republic of South Africa* [2] and by a CSIR-hosted national workshop in 1987 *The ecological flow requirements for South African rivers* [14]. The former called for engineers and scientists to undertake extensive research as soon as possible to obtain accurate values on the water needed for the maintenance of aquatic systems, and the latter responded by collating all available local understanding on this topic.

Of interest was the multi-disciplinary nature of the workshop, which was attended by DWA staff as well as specialists in hydrology, water quality, channel geomorphology, riparian and floodplain vegetation, macrophytes, aquatic invertebrates and fish. There was recognition of the importance of inputs from specialists on the subsistence use of the ecosystems but they were not included at that stage.

6.2.4 The development of flow assessment methods and supporting research

The first stages of local method development, for assessing the water needs for aquatic ecosystems, emerged from the 1987 workshop [14]. These led to a global first: a fully-fledged holistic method, the Building Block Methodology (BBM) [13], with a comprehensive user manual [15]. The activities were driven by the recognition that available international methods for assessing environmental water needs did not meet South Africa's requirements. The method most widely used at that time, the American Instream Flow Incremental Methodology (IFIM [16]), was visionary in bringing together water engineers and biologists – mainly hydraulic modellers and fish biologists – but essentially it focused on the wetted river and fish habitat. At that stage, it did not recognise or cater for the complete ecosystem, most importantly flood flows, water quality, or those parts of the system not under water.

South Africa's focus, however, was on whole ecosystem health and on the importance of this for subsistence users of the ecosystems' natural resources, conservation and ecosystem services in general. Hence, local holistic methods such as the BBM emerged, closely followed by two scenario-based approaches: Flow-Stressor Response (FSR) and DRIFT. This process of method development is discussed further in Chapter 4 and later in this chapter.

Jackie King

Rebecca Tharme surveying channel shape in 1990 during the testing of IFIM for use in South Africa.

The Kruger National Park Rivers Research Programme (KNPRRP) [17,18] arose from the same 1987 workshop, and ran from 1988 to 2000. Recognising that method development for flow assessments in the form of the BBM was underway, it focused on:

- improving the interdisciplinary understanding of rivers as ecosystems
- contributing this knowledge in BBM flow assessments that were done for the KNP rivers
- forward thinking toward the operationalisation of the water allocation agreed on for the rivers within a broader framework of river management.

Mindful of the National Parks goal of the maintenance of biodiversity at all scales from genetic to landscape, the KNPRRP used a conceptual modelling approach to integrate relevant knowledge and identify knowledge gaps requiring research. Phase 1 consisted of a number of fundamental ecological projects (Figure 6.1), but the focus of Phases 2 and 3 shifted to management. Key achievements over the 12 years of the programme were:

Kevin Rogers

Pool-Rapid channel type on the Sabie River in KNP with alternating sandy bottomed pools and rocky rapids (1999).

Kevin Rogers

Bedrock Anastomosing channel type, with river channels splitting and merging around rocky outcrops, on the Sabie River in KNP as it passes through the Lebombo Mountains on the western boundary of KNP at the South Africa/Mozambique border (1999).

- development and implementation of a Strategic Adaptive Management (SAM) process, which included processes for defining the desired state, development and auditing of goals for environmental management, institutionalisation of SAM within the KNP management structure and enhancement of the capacity of stakeholder river forums [19,20]

- development of a fluvial geomorphological approach to river studies that provided input to Environmental Flow (EFlow) assessments [21,22,23,24,25]

- a series of biotic, sedimentological and geomorphological rule-based models [26]

- the use of river hydraulics to describe flow-ecosystems relationships [27,28,29,30,31]

- an integrated hydrological, hydraulic and sediments modelling system

- an integrated catchment information system [32]

Additional complementary research on the Sabie-Sand River system focused on predicting impacts of a proposed dam on the KNP [33,34].

The twin threads of developing flow-assessment methods and the need to better understand how river ecosystems functioned and would react to flow manipulation triggered a wealth of new kinds of research in the country. Specialists contracted to contribute to the flow assessments (Table 4.1; 4.2) were highly experienced professionals in their fields but still found themselves challenged with questions that their research lives had not prepared them to answer, such as "what combination of flows does a specific community of riparian vegetation need in order to survive?", or "what would happen to a specific guild of fish if small intra-annual floods ceased?" or "what maintains deep in-channel pools and why are they where they are?". They responded with research programmes on a rapidly widening range of topics, producing over the last 15 years more than 170 papers in peer-reviewed journals, 24 chapters in books and more than 130 peer-reviewed research reports (Appendix 6.1).

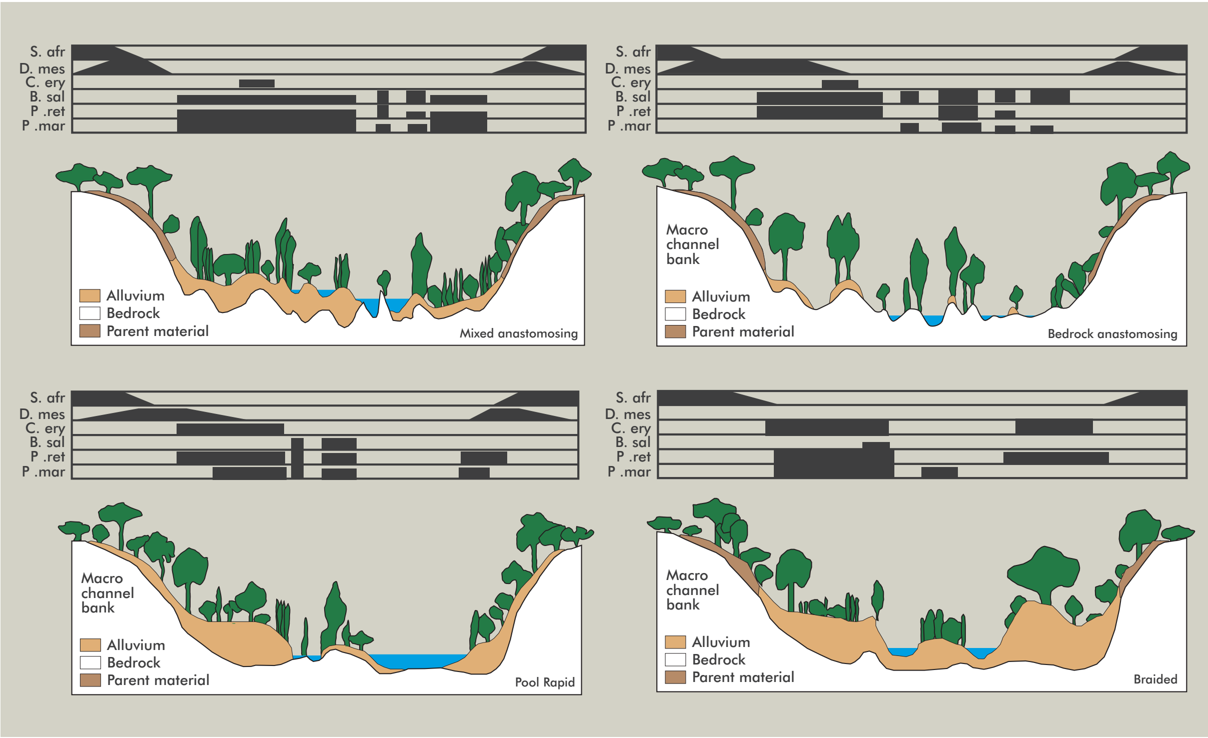


Figure 6.1 An example of how vegetation communities change through the riparian zone and between channel types: six major vegetation communities supported by four different channel types are shown for the Sabie River within KNP. Communities are: S. afr = *Spirostachys africana*, D. mes = *Diospyros mespiliformis*, C. ery = *Combretum erythrophyllum*, B. sal = *Breonadia salicina,* P. ret = *Phylanthus reticulata,* P. mar = *Phragmites mauritianus*.

6.3 The closing gap between researchers and managers

The increasing contact with water managers, water engineers, nature conservators, social specialists and economists offered aquatic scientists an on-going opportunity to align their research with the end users of the research and to test their thinking in practical field situations. WRC's positioning near to managers, and IWE's earlier similar role, helped improve the applicability of the research, with the WRC's strong focus on applied research managed in a way that encouraged exploratory and innovative investigation.

The freshwater scientists operated in a challenging world of academic teaching, research and national water development projects, with these feeding from each other. Where knowledge or skills were needed but lacking in the applied work, they were incorporated into research projects and postgraduate studies. The results were then fed back into subsequent consultancy work. This opportunity to pilot new ideas full scale offered the almost unfettered opportunity to develop scientific thinking that delivered usable results for the end user, in this case DWA (Box 6.1), and to develop the capability to inform the decision-making process.

Box 6.1 Serendipity

The relationship between the funders, researchers and end users is critical. In any country, researchers can suggest topics that they think are essential for the country to address, but these will not be effective unless funders understand the necessity for the research. Funders can fund the research but this has no application unless managers see its use. Managers can wish for more informed ways of doing things but this help will not be available unless researchers and funders are receptive. Having all three in harmony is serendipitous and fortunate.

In South Africa the three groups seemed to get it right, increasingly working together and providing funded research that has been used. Two characteristics of the country may have helped.

Firstly, it is sufficiently technologically advanced to be able to teach and use complex technology and yet small enough for people across the water-related field to know each other, which helps collaboration. Secondly, South Africa experienced scientific as well as political isolation during the dark days of apartheid, which forced independent thinking, not least that focused on the country's water problems.

6.4 Developing capability

The collaboration between a wide range of water professionals has resulted in an approach to environmental protection that reflects the country's developing-world roots and its need to move forward in data-poor situations. In effect, many of the country's leading water specialists have been involved in a nation-wide, mass learning-by-doing exercise that has tested to the limit and beyond their understanding of the country's water resources, and has challenged them to turn their thinking around.

Dr Jackie King reflected at a recent international conference that "one of the most difficult tasks we faced initially was to persuade scientists to stop relying on standard research and data and instead to start providing new kinds of information collected and analysed in new ways". (Third International Environmental Flows Conference, Port Elizabeth, February 2009). Some of the major areas where capability has advanced are summarised below.

6.4.1 Rivers and flow regimes

Table 4.1 lists local milestones in the development of the actual flow assessment methods. Major challenges faced during this process and the responses to this are outlined below and further referenced in Appendix 6.1.

1. **Challenge:** Early hydrological models simulated mean monthly data. In DRIFT, monthly data were deemed inadequate for assessing the impacts of flow changes on river ecosystems, as they could not describe the day-to-day conditions in the river that the biota experience and respond to.

   Response: Models that could simulate daily data (or disaggregate it from monthly data) were developed for use in flow assessments and elsewhere and, most recently, hourly data have started to be used for scenarios linked to peaking hydropower plants.

2. **Challenge:** In the DRIFT methodology, the simulated daily data produced were difficult for ecologists to work with.

   Response: The daily data were transformed to ecologically-relevant summary statistics in order to be of use in scenario predictions of ecological impacts. For different kinds of rivers, the data were summarised by flow categories [35], or by flow seasons [36] (Box 6.2).

3. **Challenge:** In the FSR (now known as HFSR – Habitat Flow Stressor Response) methodology, which uses either daily or monthly hydrological data, ecological responses to changes in the flow regime needed to be transformed into responses to changes in the flow duration curve.

   Response: The FFHA (Fish Flow Habitat Assessment) model was developed to assess changes in habitat suitability from the natural stress situation, by converting flow duration curves to stress duration curves [37]. It is now used to predict flow-related changes in both fish and invertebrates. Ecological Categories (Table 6.3) are allocated by percentile on the stressor duration curve allowing predictions of how the ecosystem could change.

4. **Challenge:** It is difficult to predict how a river ecosystem with higher than natural flows could change with further planned increases in flow. This is a common situation in highly regulated rivers with inter-basin transfers of water

   Response: The HFSR process and the FFHA model were adjusted to cater for this [38], based on the assumption that as flows increase above natural the health of the ecosystem will decrease, with a resultant change in community composition and lowering of the Ecological Category.

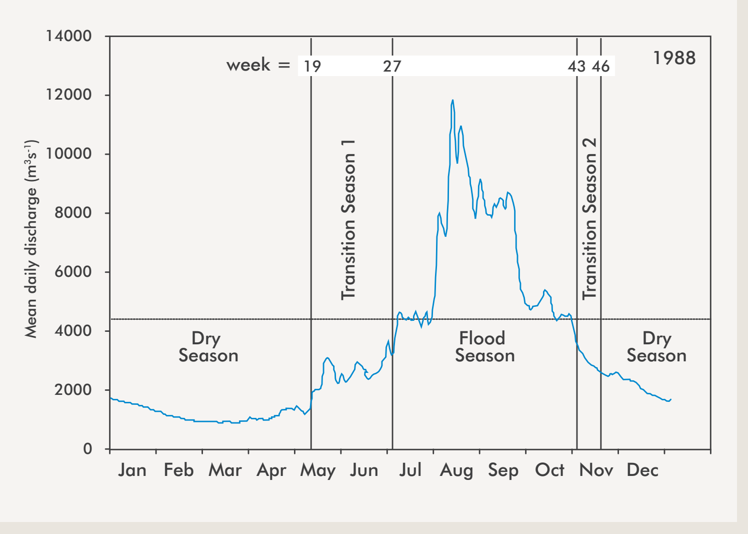
5. **Challenge:** Some hydrological attributes summarised in the statistics directly affect the biota (e.g. start of flood season) whilst others affect the biota more through the hydraulic conditions they provide (e.g. minimum flow in the dry season). Hydrological data thus need to be converted into hydraulic data that describe the conditions that the aquatic biota face – water depths, current speed, width of wetted channel and extent of inundation of floodplains. Early hydraulic models were of coarse resolution, used mainly for modelling flood heights, and they could not describe the complexity of natural streambeds or instream habitat [39, 21].

   Response: New high-resolution low-flow hydraulic models were developed for use in EFlow assessments [29,31,40].

6. **Challenge:** Further development of the hydraulic models mentioned above was required because biotas respond to combinations of hydraulic parameters rather than single parameters.

Box 6.2 Flow seasons recognised for a large flood-pulse river [36]

After identification of ecologically relevant flow seasons by experienced ecologists, rules are inserted into the hydrological model that allow the start and end days of each season to be identified year by year: the graphic shows that at a specific site on a specific river the flood season started in week 27 in 1988 and ended in week 43. The start and end weeks would be different in other years. The model also provides annual values for other key indicators of each season, such as the minimum dry-season flow or the type of flood season. The yearly values for each indicator give expression to the natural variability of the flow regime and allow scenarios to be assessed in terms of how these values and variability would change.



Response: Flow classes were introduced, each of which consists of broad, pre-defined, discrete categories of velocity, depth and/or substratum that are thought to be relevant for the various groups of organisms [41].

7. **Challenge:** Different channel structures support different plant and animal communities and also respond in different ways to flow changes. Riffles do not support the same species as pools, for instance, and are maintained by different kinds of physical processes. The geomorphological nature and sediment dynamics of rivers needed to be described in ways that were ecologically relevant so that organisms could be related to the habitats they occupied and potential development-driven geomorphological changes could be predicted.

   Response: The links between flow and physical habitat were recognised in the Pongola study [9] and the 1987 workshop [14]. They were explored during the trial application of the Instream Flow Incremental Methodology in 1991 [13] and the visit of one its developers, Dr Robert Milhous, to the KNP in 1992.

Jackie King

Bob Milhous, one of the developers of the Instream Flow Incremental Methodology, and Sharon Pollard on the Marite River in 1992 during its test application.

   Local research and application proliferated through several local research groups through the 1990s and 2000s [42,22,43,44,45,46,47,48,49], leading to structured methods for describing physical habitat and predicting how it could change.

8. **Challenge:** Aquatic and riparian physical habitats and associated biotic communities of rivers are sculptured largely by the water and sediment regimes, and as flows and/or sediment inputs change (such as in response to dams) they will inevitably change in response. Stakeholders and decision makers need to know what the potential changes caused by water-resource developments could be so they can negotiate and make informed input.

   Response: The links between flow and physical habitat, species, guilds, populations and communities are increasingly being ascertained through research on major ecosystem components, *inter alia*:

   - flow and channel structure [50,51]
   - flow and sediment transport [46,52]
   - flow and vegetation [53,54,55,56,28,57,58,59]
   - flow and aquatic invertebrates [60,61,62,63,64]
   - flow and fish [33,34,65,66,67,68].

The knowledge gained is being used in Reserve assessments across the country. Procedures have been developed that can bring together all the relevant information as predictions of how different water resource management options would affect the aquatic ecosystems as well as local subsistence users and economies (Box 6.3 and 6.4 and see also Chapter 4).

9. **Challenge:** The Reserve is set for a specific ecological state. These states, known as the Ecological Categories A (natural) to F (highly modified), need to be used consistently by Reserve practitioners.

   Response: Models were produced that supply an Ecological Category for each ecosystem driver (hydrology, physical habitat, chemical habitat, geomorphology, habitat integrity) and responder groups (fish, macroinvertebrates, riparian vegetation). The process also supplies an integrated Ecological Category, called the EcoStatus [69,70].

Box 6.3 Describing flow-biota relationships – Habitat Flow Stressor Response approach

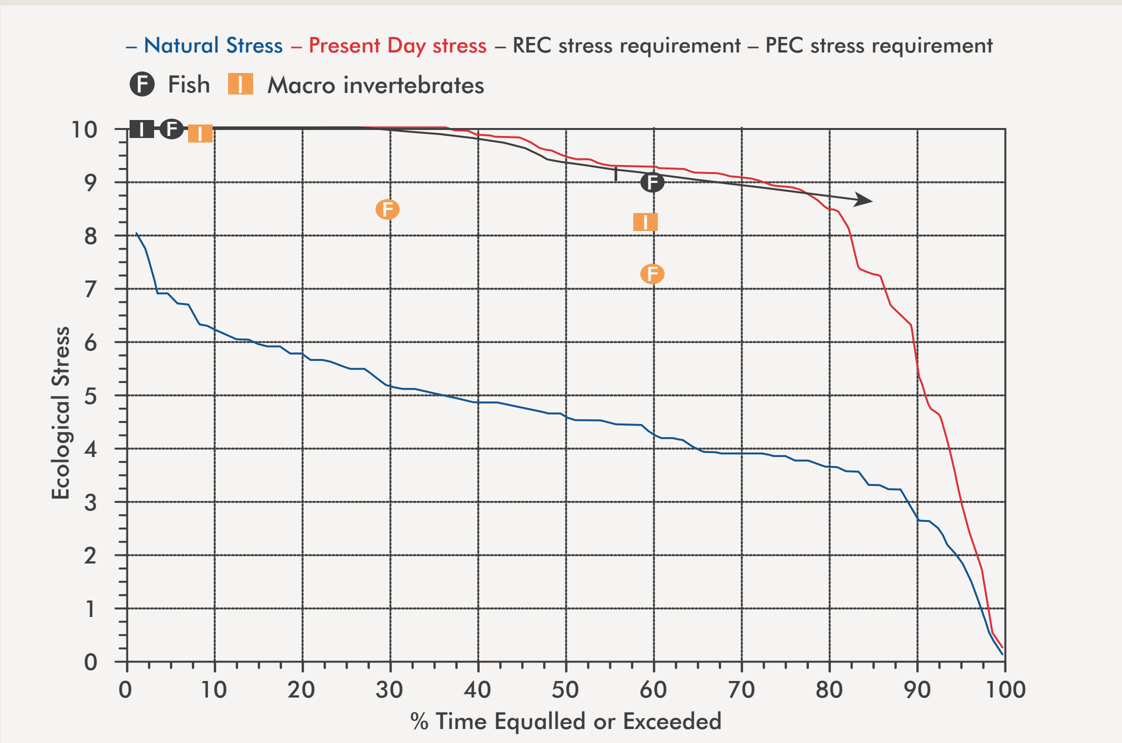
The Habitat Flow-Stressor Response (HFSR) approach [71,72] addresses the problem of few data on flow-biota relationships by using hydraulic habitat as a surrogate for the biota and evaluating how this would change under a range of low-flow conditions.

Determine the Present Ecological State and describe other improved or degraded states → Define a flow regime that would maintain or achieve each of these scenarios

↓

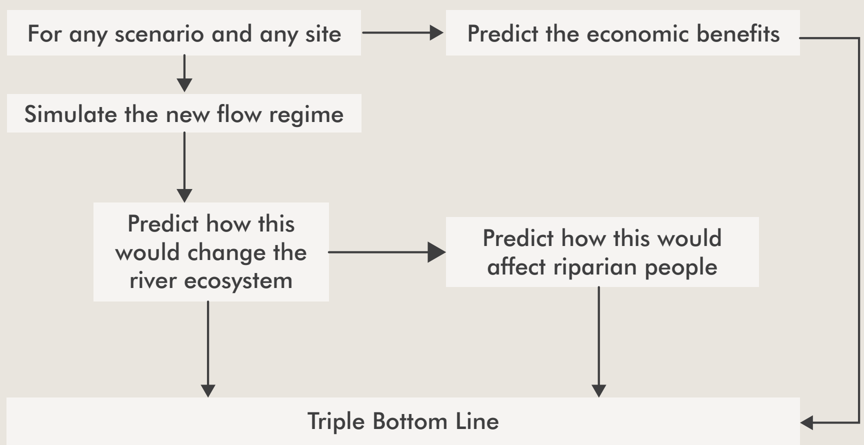
Provide information to decision maker ← Evaluate the ecological and economic implications of each scenario

It assumes that changes in habitat conditions (stress) will be reflected in a change in the components of the biota (response) as their degree of discomfort or damage changes with changes in low flows. It calculates a stress index for each relevant low flow, allowing conversion of flow duration curves to stress duration curves. It uses these to advise on flows for specified ecological conditions, or to evaluate low-flow scenarios in terms of the resulting ecological conditions. Floods are addressed using flood classes, with those required for each Ecological Category added to the low-flow requirement.

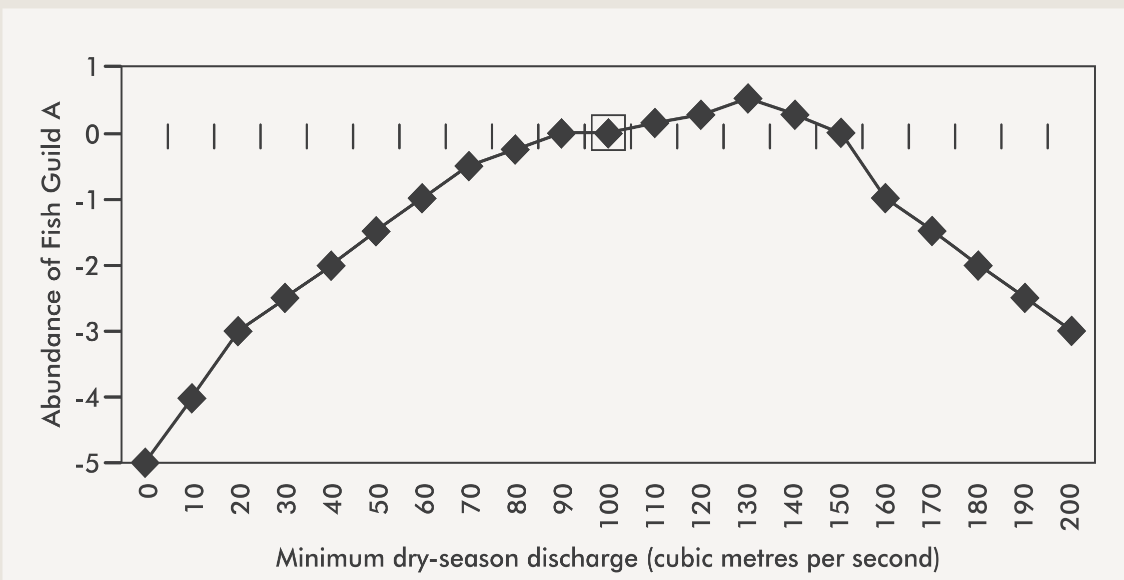


Box 6.4 Describing flow-biota-people relationships – DRIFT

DRIFT [36] predicts the ecological, social and economic consequences of proposed water resource actions.



It uses the concept of severity ratings (on a scale of -5 to +5 with 0 as Present Day condition) and response curves to describe flow-ecosystem relationships. Response curves show the relationship between a responding indicator (in the graph below, Fish Guild A) – and a driving indicator (in the graph, minimum dry-season discharge). The square on the plot indicates mean present day flow conditions. Hundreds, sometimes thousands, of response curves are created by the multidisciplinary team of specialists for one river to capture their understanding of the nature of its functioning, and housed in custom built software that can provide a prediction of ecosystem change for any development scenario of interest.



6.4.2 Estuaries

Estuaries are particularly vulnerable because of their location at the downstream end of river systems. All upstream land use and water use may affect them and maintaining their ecological health requires careful planning and management at the catchment level.

1. **Challenge:** The method for Reserve determinations for estuaries has been evolving since 1999. The various activities needed to be consolidated and streamlined into one structured set of activities.

   Response: The method is being streamlined as explained in Box 6.5.

2. **Challenge:** In estuaries, one of the key abiotic responses to flow modification is the change in salinity. There are very few long-term historical data of inflows and related salinities in South Africa, which makes it difficult to predict how salinity of permanently open estuaries could change in response to changes in inflowing freshwater.

   Response: Commercially available (e.g. Mike 11), 1-dimensional numerical models were customised to predict salinity distributions in permanently open estuaries under various flow conditions. This approach was further refined using 3-dimensional models (e.g. Delft 3D) for estuaries with a high degree of stratification to more accurately predict retention/flushing times and salinity distribution [75].

3. **Challenge:** Estuaries function as integrated ecosystems, with physical, geochemical and biological processes occurring over a range of temporal and spatial scales. These scale differences make it very difficult to extrapolate the findings from one estuary to another without a substantial amount of measured, or modelled, data to describe the possible range of interactions occurring under different flow scenarios.

   Response: The concept of 'Abiotic States' was developed whereby the abiotic conditions likely to be present in an estuary under various flow conditions were integrated into a simplified format that characterised salinity of the water column, flushing time and condition of the mouth. This approach is applied in both data-poor and data-rich systems [76,77].

4. **Challenge:** The complex nature of estuarine ecosystems makes it very difficult to link the responses of the biotic components (microalgae, macrophytes, invertebrates, fish and birds) directly to past, present or future river inflow.

   Response: Some progress has been made towards the development of simple models (e.g. use of salinity to predict responses of fish communities to changes in abiotic state [78]), and more comprehensive systems models [79]. While the initial development of such models is data hungry and expensive, ongoing improvements in data availability and experience will ultimately make this avenue worth pursuing. Meanwhile, there is still much reliance on expert opinion.

5. **Challenge:** South African estuaries range from nearly permanently closed to permanently open and, in terms of salinity, from freshwater dominated to marine dominated. This diversity of types and functioning has to be addressed when developing methods that can be used for all types of estuarine systems.

   Response: An Estuarine Health Index was developed as part of the RDM methods that can be applied to all estuarine types [80,81,82,83] and has recently been updated [84]. However, the diversity of types still presents a challenge in terms of developing predictive models.

6. **Challenge:** Reserves for estuaries cannot be set without knowing their importance and conservation status. The higher these are, the more stringent the Reserve flow requirements will be.

   Response: All South African estuaries were assessed in terms of their ecological importance and conservation [85], and the findings were later refined through a number of national and regional projects [86,87,88].

Table 6.3 Ecological status categories (see Appendix 4.1).

Category	Description
A	Unmodified, natural
B	Largely natural
C	Moderately modified
D	Largely modified
E	Heavily modified
F	Critically modified

6.4.3 Wetlands

Determining the Reserve for wetlands has proved difficult and research on suitable methods is ongoing. Two troublesome areas being addressed are the ecoclassification of wetlands and the use of hydraulic information.

1. **Challenge:** Ecoclassification. The methods and models for deriving the Ecostatus – A to F Ecological Categories (Table 6.3) – for rivers are well developed. Some parallel tools exist for wetlands, such as WET-Health [89] and the Wetland IHI [90], but the former is time consuming, expensive to apply, has no water-quality module and is not necessarily appropriate for all parts of the country. The latter is simpler but only suitable for some kinds of wetlands and has only a rudimentary water-quality module.

   Response: An integrated Ecostatus assessment approach with a water-quality module was developed as part of a joint WRC/DWA funded study [91].

2. **Challenge:** Hydraulics of wetlands. The approach used for rivers, whereby river discharge is translated *via* hydraulic cross-sections to information on hydraulic habitat conditions, is not appropriate for wetlands with weakly defined or heavily vegetated channels. Incorporating an hydrology-hydraulic link of some nature into the methods remains important, however, as without it discharge data cannot be linked to ecosystem form and function and so the ecological implications of different flow scenarios cannot be predicted.

   Response: Specific hydraulic and/or hydrological approaches for translating discharges into ecologically relevant parameters such as wetted width, area or depth, have been developed and tested for wetlands. Whilst the river methods are relatively easily adapted to floodplain systems, the more densely vegetated (hydraulically 'rough') channelled and unchannelled valley-bottom wetlands rely on modified approaches based on earlier WRC-funded research [28,92,93,94,31].

   An approach for linking pan inundation extent and duration with rainfall [95] has provided a cost-effective way of linking hydrology to ecologically meaningful parameters for these wetland types.

Mark Rountree

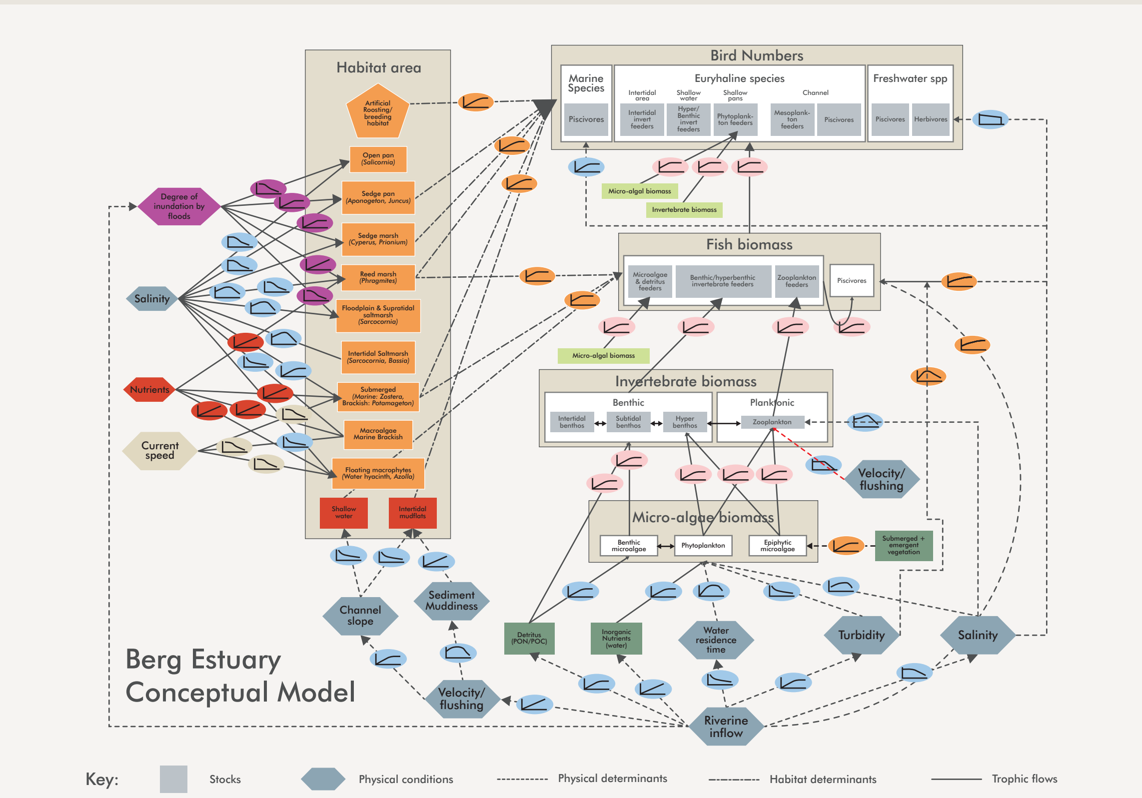
Shael Koekemoer (centre) explaining the diatom sampling methodology for wetlands to Heather Malan (left) and Nonkanyiso Zungu (right) during the rapid Reserve Determination study of the Bedford Wetland in the Upper Vaal Water Management Area.

Box 6.5 Determining flow requirements for estuaries

The process for advising on the Reserve for estuaries involves:

- estimating the reference or natural condition of the estuary, using historical data and/or an understanding of the relationships between the main drivers and responders of the ecosystem (see figure) based on any available knowledge from expert opinion to data-derived mathematical models
- estimating its present ecological status (PES) as a percentage similarity to the reference condition, using existing data and/or data collected for the purpose and following a set of methodological guidelines [73]
- setting the Recommended Ecological Category (REC) on the basis of the PES and on its importance
- predicting how estuarine health would change under a range of flow scenarios
- recommending the scenario that most closely matches the REC as the Reserve.

The reference and potential future conditions are estimated for a range of abiotic (hydrology, hydrodynamics, water quality and physical habitats) and biotic (microalgae, macroalgae, invertebrates, fish and birds) components by a group of specialists. Quantitative predictions are made as far as possible for each component in this order of disciplines order, starting with hydrology. Thus, at each stage, predictions are based on the predictions for preceding components (e.g. the abundance of a particular element of the avifaunal community is predicted on the basis of the predicted abundance of a particular element of the invertebrate community). At each level, the confidence of the specialist is recorded. No purpose-built software is used.



Main drivers and responders of the Berg estuary ecosystem [74]

Box 6.5 Continued...

Janine Adams

Lara van Niekerk (left) and Susan Taljaard sampling the Sundays Estuary for the RDM study in 2008.


Barry Clark

Collecting fish with a beach seine net at the head of the Berg estuary on Kliphoek Farm during development of the Reserve method for estuaries

6.4.4 Non-perennial rivers

About two-thirds of South Africa has non-perennial rivers, with complex hydrological interactions of surface waters and groundwater. Flow assessment methods for perennial systems do not necessarily work well for such systems, and a new approach, building on the knowledge gained working with perennial rivers, is under development. The work is in its early stages, but some of the major challenges being addressed are as follows [96].

1. **Challenge:** Hydrological models suited to perennial rivers may be inappropriate for simulating the hydrological nature of non-perennial rivers [97].Their catchments have few, if any, rainfall and runoff gauge sites, and any existing rainfall-runoff data sets are usually of insufficient length to detect trends. Calibration of the hydrological models is thus difficult. The links between surface water and groundwater in these systems are poorly understood, although groundwater appears to play a significant role in their hydrological nature. The disaggregation of simulated monthly data to describe individual flood events in such systems requires a high degree of specialisation, is not usually feasible and may be quite inaccurate, so flood events are poorly described, if at all.

   Response: An international integrated surface water-groundwater hydrological model has been obtained and is being adapted for local use, with hydrologists, geohydrologists, soil scientists and catchment specialists working together to calibrate it.

2. **Challenge:** Flow-assessment methods for perennial rivers that are based on default Reference Conditions do not work well for the more extreme non-perennial rivers as these may naturally be very poor in species and sensitive species. The Reference Condition software used in South Africa incorrectly indicates that even pristine ephemeral rivers are degraded because of their low species counts [98].

   Response: A method that does not rely on Reference Condition, but that makes present-day conditions the starting point, is being tested and further developed for non-perennial rivers. Supporting this, new or modified ways are being developed for describing the Present Ecological State (PES) (see Ecoclassification in Chapter 4) of the full suite of biophysical indicators [99]. Either the Reference Condition, or the PES, or both, is used in scenarios to describe how the river condition could change with proposed management actions.

3. **Challenge:** Isolated pools are one of the most distinguishing characteristics of non-perennial rivers and are important refugia for many riverine plant and animal species. It is usually not known why they occur where they do and so it is not possible to easily predict where they are likely to occur in an unstudied river reach or how they would change under proposed management plans. Groundwater is likely to significantly influence both the water quality of the pools and their persistence in dry times, but it is not possible to confidently predict the chemistry or biota of individual pools, or even of pools within one river reach or longitudinal zone, as each pool is likely to be distinctive.

   Response: Scientists are investigating a landscape-level approach linked to the surface-groundwater integrated hydrological model to provide insights into the distribution and nature of pools.

Jackie King

Ockie Scholtz, Marinda Avenant and Jurie du Plessis sampling the fish community in a pool on the Seekoei River at the farm Welgedacht, during development of the Reserve method for non-perennial rivers in March 2006.

Jackie King

Justine Ewart-Smith studying the links between flow, water quality and algal communities on the Berg River in 2008, in order to be able to predict algal changes with potential water management actions.

4. **Challenge:** Connectivity between pools is one of the most important attributes of non-perennial rivers. Connected flow along the whole river occurs intermittently, but when it does sediments and nutrients are transported along the system, gene pools mix, organisms are able to move to other refugia and poor-quality pool water is diluted. Because of the poor coverage of flow gauging stations and uncertain nature of hydrological data for such systems, connectivity is not well recorded and cannot be simulated with great accuracy.

   Response: The integrated hydrological model is being assessed in terms of how well it can describe connected flow along the system.

5. **Challenge:** Under the high levels of physical, chemical and biological unpredictability, extrapolation of ecosystem attributes over long stretches of river is of uncertain value mostly because many of the data will be from isolated pools that are behaving differently from the others. For any extrapolation to be true it would have to be at such a coarse level that it could well be meaningless as, for instance, by predicting that a pool would have aquatic invertebrates (of unknown families, genera and species).

   Response: At present, understanding of non-perennial rivers remains at the level of individual study sites and no extrapolation of data is recommended from studied to unstudied reaches. Long-term data are being collected from various non-perennial rivers to improve understanding that can be used to predict present conditions at unstudied sites and potential development-driven change.

6.4.5 Water quality

1. **Challenge:** Water quality variables, other than nutrients, were historically expressed as median concentrations in water-quality assessments. Medians do not describe the variability in concentrations of variables such as salts and toxins in flowing waters.

Response: Variable concentrations are now expressed as percentiles to adequately capture their variability under changing hydrological conditions.

2. **Challenge:** The Nitrogen to Phosphorus ratio (N-P ratio) and the Soluble Reactive Phosphate to Total Phosphorus ratio (SRP-TP ratio), as used in studies on eutrophication, do not adequately reflect the nutrient status of rivers.

   Response: SRP and Total Inorganic Nitrogen (TIN) are now used as they more accurately reflect the nutrient status of riverine environments.

3. **Challenge:** Nutrient concentrations, as measured by TIN and SRP, do not always reflect the trophic status of a riverine system.

   Response: Indicators of algal abundance, particularly periphyton, are now included to more accurately reflect nutrient loading in a system.

4. **Challenge:** The water-quality methods of assessment provided a qualitative method of reaching an overall water-quality category but quantification was needed.

   Response: The Physico-chemical Driver Assessment Index (PAI) model was developed to provide a quantitative way of determining an integrated assessment of water quality.

5. **Challenge:** The 2002/2003 manual for this model assessed water quality as Natural to Poor, which is not consistent with the A-F categories used by other disciplines.

   Response: A-F water-quality categories were developed so as to be consistent with all other indicators.

6. **Challenge:** In data-poor situations, there may be few data with which to assess the present state of water quality for the Ecological Reserve.

   Response: Qualitative cues were developed that provide an assessment of present water quality in the absence of quantitative data.

7. **Challenge:** There was no method available that could reliably generate the aggregated salt profile of a water body.

   Response: TEACHA was developed as an analytical tool that could generate an aggregated salts profile [100].

8. **Challenge:** A method was needed to estimate salts in the absence of aggregated salts information.

   Response: Electrical conductivity was introduced as the metric for estimating salinity in the absence of aggregated salt data.

9. **Challenge:** Diatoms are good biological indicators of water quality. Diatom indices that have been developed for use in the Northern Hemisphere have been shown to be usable in South Africa.

   Response: Expertise in diatom taxonomy has been developed and training in the use of the indices is available. Diatoms have been incorporated into the suite of methods used for assessing water quality for Ecological Reserve studies.

6.4.6 Aquifers and groundwater

Under the 1956 Water Act surface waters and groundwater were considered and modelled separately, and moves to integrate the work of the two disciplines represent a relatively recent initiative aligned with the requirements of the NWA. The focus has turned to four main concerns:

- to ensure sufficient groundwater to sustain surface water systems
- to ensure the quality of groundwater is not compromised
- to protect terrestrial ecosystems dependent on groundwater
- to protect the structural integrity of aquifers.

The concept of the Reserve is relevant only to the first of these concerns, with the others best addressed through wider RDM activities such as classification and RQOs.

The NWA requirements revealed that links between surface and groundwater are not well understood or documented, with almost no quantified data. This has prompted research into groundwater systems, particularly regarding understanding and quantifying surface-groundwater interactions [101,102] and developing a better understanding of groundwater dependent ecosystems [103,104].

Some characteristics of groundwater have made integration with surface waters in Reserve determinations particularly difficult. For example, the surface water determinations focus on sites, such as along a river or estuary, which represent longer stretches of water, but it is inappropriate to represent groundwater in this way. Its subsurface distribution and links with surface waters may be intermittent and not well known and so the relationships between the two may be uncertain. Additionally, these relationships may also range from 'no links' to 'profound links' over quite short distances. In some cases, groundwater abstractions may have no measurable effect on nearby surface waters, whilst in other cases there could be immediate impacts on springs and streams, and it is not readily apparent which will be the case in any situation.

As a result, it is difficult to predict how water resource developments might affect groundwater and its support of surface waters, and thus to set a suitable groundwater Reserve. A similar problem has arisen in setting Reserves for ephemeral rivers (Section 6.4.4), where pools are a vital feature but their occurrence and persistence, and their links with groundwater, vary widely and are poorly understood. In both cases, it is not presently possible to confidently extrapolate over large distances what the relationship between ground and surface waters is and such an understanding remains mostly limited to the local areas where studies have been done. The integrated surface-groundwater hydrological model presently being tested by the non-perennial rivers group may prove helpful.

Despite these difficulties, a methodology has been developed to quantify the groundwater component of the Reserve [105,106]. It is prescribed by DWA but remains a work in progress as the following challenges illustrate.

1. Challenge: Develop a standardised method for groundwater RDM determinations that could be consistently used and would have the same level of acceptance as have the surface water determination methods.

   Response: The Groundwater RDM (GRDM) method was developed as a standardised approach and a GRDM Manual written (Box 6.6) [106] to guide practitioners in its application. Software was developed by the Institute for Groundwater Studies (IGS) at the University of the Free State to facilitate Desktop and Rapid GRDM determinations using standard data sets. The method has the same seven-step approach as for surface water Reserve determinations (Section 4.4) and the same four levels of assessment (Table 4.5). After creation of the Water Resource Classification System in 2006 (Chapter 4), the GRDM Manual was reviewed and adapted as part of the FETWater initiative (Section 6.5.2) in order to incorporate the RDM concepts of Classification, Reserve and RQOs into groundwater studies. The manual is presently under review again by IGS because the scale of GRDM assessments has proved problematic, as has the quantification of the groundwater contribution to baseflow.

2. Challenge: Groundwater Reserves, as with surface water Reserves, require water quality to be considered as well as water quantity.

   Response: Incorporation of water quality aspects is currently addressed through setting RQOs using percentiles from groundwater quality data housed in the National Groundwater Database. This is not an appropriate approach and setting water quality standards remains a challenge requiring research and method development. It remains an accepted principle, however, that water quality standards cannot be set higher than those of the natural groundwater source.

3. Challenge: Inconsistent use of terminology by different scientific disciplines has led to confusion and a poor understanding of the role of groundwater in supporting surface water ecosystems. It was recognised, for example, that not all baseflow in rivers is derived from groundwater. Distinction needs to be made between baseflow as defined and quantified by hydrologists and the groundwater contribution to baseflow, to promote a better understanding of hydrological systems and allow hydrologists and geohydrologists to quantify the component parts.

   Response: Terms frequently used by hydrologists and geohydrologists were defined [101], and later included in a groundwater dictionary compiled by IGS and included in the GRDM software.

4. Challenge: Obtaining sufficient data and information about a significant groundwater resource is a perennial problem. About half the budget of large-scale GRDM projects is used to source existing data.


Johan Wentzel

A piped spring feeds into Verlorenvlei at Elands Bay on the West Coast. The spring is monitored by DWA on a regular basis, hence the pipe.

Response: As an outcome of the Groundwater Resource Assessment Programme Phase 11, DWA prepared a set of 1:500 000 hydrogeological maps of the country, most with a supporting information booklet. The collated data, entered into the National Groundwater Database at a quaternary catchment scale where possible, were built into the GRDM software as a default data set. Provision has been made for practitioners to import their own (presumably more detailed and localised) data into the GRDM software for use in a particular study.

5. **Challenge:** The National Groundwater Database does not adequately capture good quality hydrogeological data or national and local monitoring data. The data are often incorrectly referenced and / or incorrectly captured and so their use in the GRDM process is problematic.

   Response: In some provinces DWA has embarked on a programme to facilitate the capture of good-quality groundwater data by practitioners and researchers.

6. **Challenge:** There is a trend to complete groundwater Reserve assessments at the spatial scale of a primary or secondary catchment. This can result in excess of 200 quaternary catchments being included in one rapid level groundwater Reserve assessment.

   Response: This remains unresolved. It may be that setting large-scale groundwater Reserves is not appropriate. Research is needed on the merits of moving away from quantifying the groundwater component of the Reserve on a large scale and instead setting the Reserve on a local scale where a clear link between groundwater and aquatic ecosystems can be shown.

7. **Challenge:** Despite some research, there is still very little information available regarding aquatic ecosystems that have been impacted by groundwater abstraction

   Response: This remains unresolved and requires focused research to enhance understanding of the merits of extrapolations from studied to unstudied situations.

Box 6.6 Quantifying the groundwater component of the Reserve

Setting the groundwater component of a Reserve requires the following information [106]:

- classification of the groundwater resource in terms of its degree of use
- quantification of the Reserve
- setting of other RQOs (numerical and/or descriptive) to meet the requirements of the Management Class.

The first step, classification, involves setting a Stress Index, which indicates all water use including all current abstractions. This Stress Index is then used, along with an assessment of system integrity of the resource, to classify it in terms of its present Management Class.

Stress Index	Management Class
<20%	I Minimally used
20-40%	II Moderately used
40-65%	III Heavily used

Knowing the present Management Class, the groundwater component of the Reserve and other RQOs are then set to specify conditions for present and future use that it is understood will not compromise the integrity and overall state of the resource, not induce a drawdown, and not reduce the groundwater in terms of its contribution to dependent rivers or wetlands or its availability for BHN.

The Stress Index is then used to calculate the Groundwater Allocation. This must be done in such a way that the SI does not exceed 65%. Where there is no ecological link or BHN requirements, 65% of recharge may be allocated for use. If there is a Reserve requirement, this volume of water must first be subtracted from the recharge fraction before the Groundwater Allocation can be determined. It must, however, also be ensured that this calculated Groundwater Allocation will not impact on the system's integrity.

It remains a problem that the RQO normally set is groundwater level whereas the user is actually allocated an abstraction volume. The two need to be reconciled through careful water level monitoring (see Chapter 8).
It has been found that the Stress Index is more useful at a local scale than at a quaternary catchment scale.

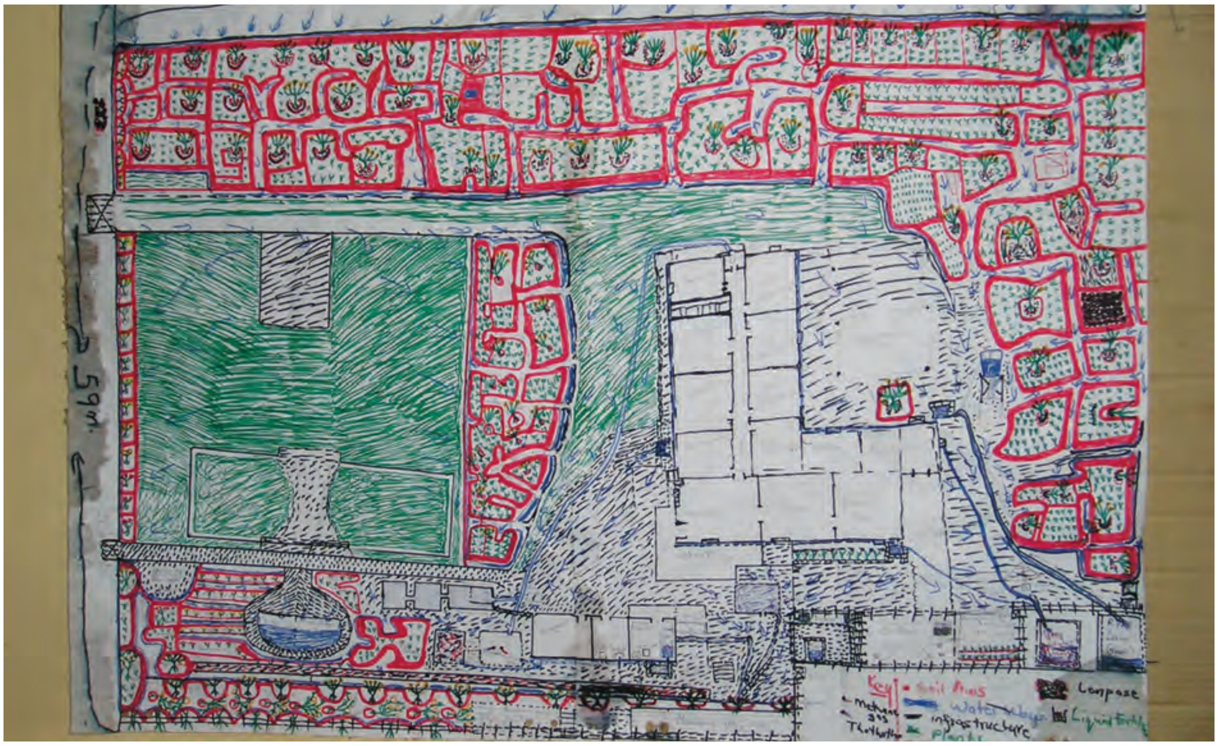
6.4.7 Social and economic links

1. **Challenge:** The Basic Human Needs Reserve (BHNR) is poorly conceptualized and methods to calculate it have not been applied consistently.

   Response: A statement was drawn up for DWA that describes the suggested method for calculating the BHNR under different scenarios [107].

2. **Challenge:** Recognition of the importance of ecosystems services, particularly for vulnerable socio-economic groupings, was not well incorporated into Ecological Reserve studies.

   Response: A method was developed that delivers the appropriate level of detail on social use of ecosystem services and the potential impacts of water-management options. This method aligns with other Reserve work [108].



Derick du Toit

A 'helicopter plan' – as MmaTshepo Khumbane calls the map of her plots near Cullinan outside Pretoria. She uses this to understand water movement and thus its efficient use in food production.

Derick du Toit

An NGO staff member explains the 'five fingers' of good wetland management to encourage sustainable use of the wetlands of Bushbuckridge, South Africa.

6.4.8 Software and Decision Support Tools

Flow-assessment methods have evolved from the original prescriptive BBM to scenario-based ones (Boxes 6.3 and 6.4) that provide management options, that is, scenarios. Software to apply these methods and to develop scenarios has been developed, allowing various measures of standardisation, integration and automation.

1. **Challenge:** The knowledge provided by specialists needed to be captured in a form whereby it could be used in flow assessments to investigate the potential ecological outcomes of any management actions.

   Response (1): DRIFT was developed to be able to capture the information in custom-built Excel-based software and use this for scenario creation [109,110]. DRIFT HYDRO generates summary flow categories from daily hydrological data. DRIFT SOLVER generates, for any given volume of water, the optimal distribution of different magnitude flows for ecosystem condition [111]. DRIFT CATEGORY provides a graphic of the relationship between flow volumes/distributions and river condition [112]. These and other procedures are presently being programmed as a formal Decision Support Tool [113].

   Response (2): HFSR uses the Fish Flow Habitat Assessment model (Section 6.4.1).

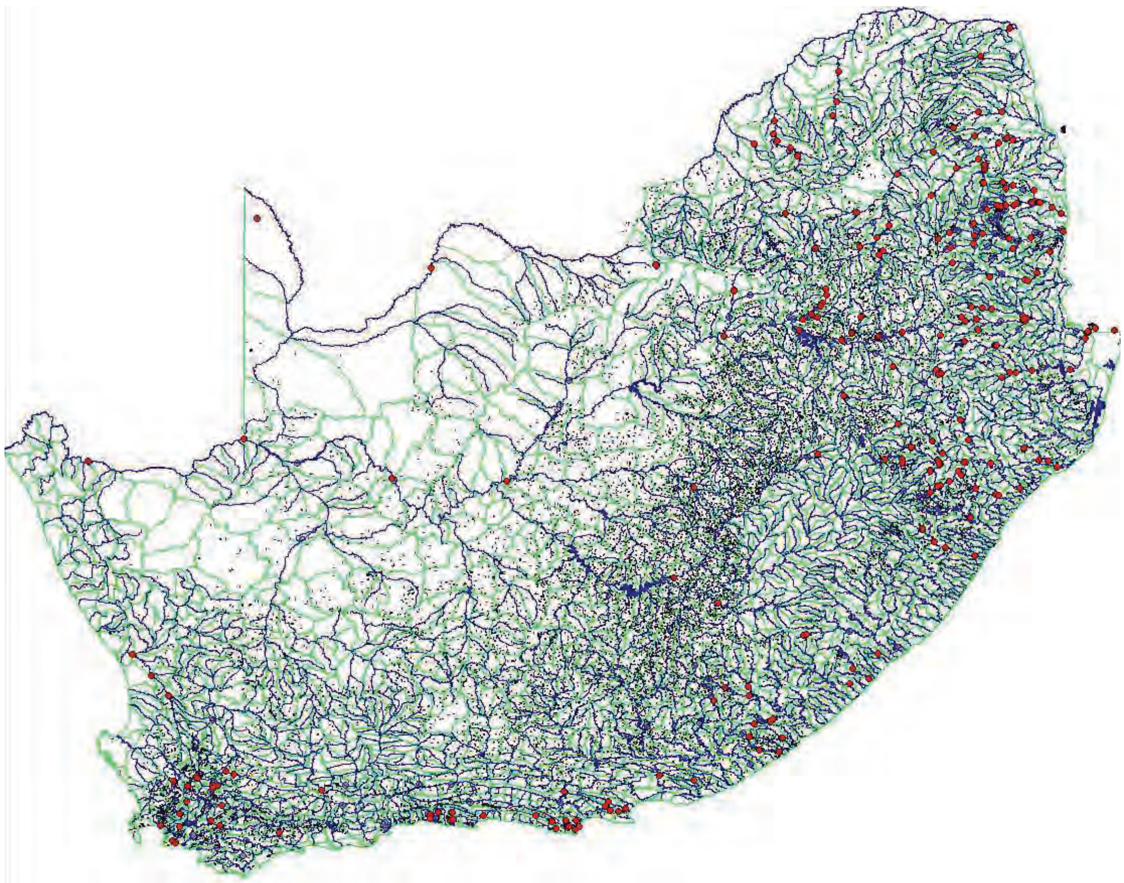
2. **Challenge:** If the outputs of all flow assessments done within the country could be collated, they could provide a general coarse set of rules for strategic planning purposes on the volume of water required to maintain rivers in the different hydrological regions of the country at specified ecological condition levels.

   Response: The Desktop Reserve model was created for rapid flow assessments [114,115], using as its primary data the results of the flow assessments done to date across the country. It is based on an Hydrological Index (HI) that reflects the relationship between base flow and total flow at any river point – thereby providing an insight to the different hydrological regions of the country and their degree of perenniality. It then provides the volume of low flows and higher flows up to the 1:2 year flood that would be needed for rivers within any of the HI regions to maintain an A, B, C or D class ecological status (Table 6.3). It is widely used to provide rapid low-confidence estimates of Ecological Reserve requirements.

3. **Challenge:** The proliferation of flow assessments methods, and updating of them, was becoming unwieldy. A single integrated software package was needed for flow assessments where greater confidence was required than provided by the Desktop Reserve model.

   Response: The SPATSIM (Spatial And Time Series Information System) framework [116,117] was developed to incorporate a range of tools that would support the determination and operationalisation of the Ecological Reserve. It is a generic hydrology and water-resources information management system that includes links to a range of different modelling and data analyses. A revised version was released in 2010 [118]. As well as various hydrological models, a wide range of tools developed specifically for Reserve studies has been included as part of the system, as follows.

- The Desktop Reserve model.
- An hydraulics calibration, interpretation and visual display model. This model uses measured channel cross-section data and some discharge observations to assist with calibrating the stage-discharge relationship of the cross-section. It can also be used to identify frequency distributions of depth and velocity at various discharges.
- The Flow Stressor-Response model.
- The small scale licensing model [119], which is a simple model that uses flow duration curves of natural, present day and future flows compared with pre-defined Reserve flow requirements to provide a decision support tool for water managers and assist them with processing abstraction licence applications. The model is designed for use in small to moderate sized catchments without large storage facilities (i.e. reservoirs with downstream release capabilities).
- The real-time Reserve implementation model [120,121]. This model consists of two components. The first is a procedure to capture daily satellite rainfall data from the NOAA website in the USA and convert these into catchment average monthly



A screen shot of one section of SPATSIM, developed by Denis Hughes and colleagues, as a framework for incorporating a range of tools that support RDM activities.

rainfall time series. The conversion is based on a set of 'calibration' parameters that are established through other procedures available in SPATSIM. The second component runs a pre-calibrated version of the Pitman monthly rainfall-runoff model [116] and generates real-time estimates of the natural flows. Operating rules established as part of a Reserve study are then applied to determine the rate of release from the dams in the system (i.e. all sub-catchments within a major drainage basin), any water user restrictions that need to be applied and the target low-flow Reserve for various points within the system. Pilot studies to operationalise the Reserve have been conducted in a number of catchments in the country [122].

Apart from these specific Reserve tools there are also several supporting models and data analysis tools. These include methods to generate time-series summary statistics (including flow duration curve data) and time-series of separated baseflows [123] using regional parameters. A comprehensive time-series graphical display facility linked to the database is also provided. SPATSIM is widely used in South Africa and in the SADC (Southern African Development Community) region.

4. **Challenge:** Catchments and water resources cannot be managed piecemeal because upstream activities affect downstream aquatic ecosystems and their users. Integrated water resource management (IWRM), with stakeholder-centred consensus of the future configuration of use/protection categories across whole catchments, is essential.

   Response: The Water Resource Classification System (WRCS) was developed, as required in the NWA, and promulgated in the Government Gazette in September 2010.

6.4.9 Operationalisation, monitoring and adaptive management

The major activity in the field of environmental flows over the past two decades has been developing methods to provide management-orientated scientific input to the discourse on sustainable use of aquatic ecosystems. This is entirely understandable, as the country's water professionals learnt to work together and to apply their minds to this new science. Attention is now moving to the application of this knowledge in the areas of decision-making, monitoring and adaptive management. There is a strong awareness that the challenges now being faced dwarf the earlier ones. It is too soon to detect the overall direction of activities and achievements, but isolated examples of progress are emerging.

1. **Challenge:** There was no means of formally describing the desired state of the ecosystem being managed despite it being a requirement of the NWA. Setting such a desired state requires stakeholder engagement and cooperative decision making. In conservation areas, management decisions were based largely on personal experience and were made in an *ad hoc* manner. There was no written record of the decisions and actions taken. This made it impossible to assess the effectiveness of management actions or modify successful actions for future use in different contexts.

   Response: The development and implementation of Strategic Adaptive Management (SAM) instituted a process involving research, management and monitoring in a way in which management goals are defined and management decisions, and the rationale underpinning them, are recorded. Monitoring feedback informs on the degree of success of the management action and allows modification as necessary to achieve the identified goal. This iterative process provides an effective method for 'learning by doing' [19,124,125].

SAM embraces stakeholder-centred planning in which guidelines are set for the achievement of a desired state. It is now the basis for management of all 22 of South Africa's National Parks, with river management as an integral part. The most advanced and tested system is in the Kruger National Park. SAM has been accepted by the Inkomati Catchment Management Agency as its central decision making system and is used as the basis for IWRM in the Inkomati Catchment. It is also used as the basis of estuarine management in the Eastern Cape. International examples of the application of SAM are in Holland, Namibia and Australia.

2. **Challenge:** Ecosystems naturally vary over space and time. This variability is an essential part of their resilience. Methods were needed that could assess ecosystem state in a way that catered for the variability.

   Response: The concept of thresholds of potential concern (TPC) was developed to provide a way to put auditable limits on any ecosystem indicator of interest. A red flag is raised if variability exceeds these limits, initiating a predetermined management action. TPCs form the basis of the monitoring programme that provides feedback into the SAM process [126].

Mark Rountree

Donovan Kotze traversing a wetland whilst sampling the vegetation as part of the Rapid Reserve Determination study of the Bedford Wetland, 2010.

3. **Challenge:** More than one department has jurisdiction over the water of river and estuarine systems. The aims of the various departments are not the same and may be in conflict, with DWA developing the resource and the Department of Environmental Affairs and Tourism mandated to preserve biodiversity. Policies need to be formulated so as to address the needs of water-resource management as a whole rather than the needs of individual departments.

Response: The Water Resource Classification System, within the strategy of IWRM, is designed to address this and, with its recent promulgation, its application is just beginning.

4. **Challenge:** Once an Ecological Reserve has been set, there is a need for real-time management of it.

   Response: An approach has been developed for the Thukela River that allows real-time water resource management, catering for both the Ecological Reserve and other water users [120,121]. The approach is generic for any catchment, explaining how real-time systems can be set up, and has also been applied to the Letaba, Luvuvhu and Kat Rivers. A pioneering monitoring programme has been initiated for the Crocodile River by the Inkomati Catchment Management Agency.

5. **Challenge:** Will the Ecological Reserve achieve its intended purpose of sustainable use of aquatic ecosystem?

   Response: Time will tell. Some monitoring techniques are in place: the SASS test of invertebrate community composition can provide insights on ecosystem health in the short term, riparian vegetation assessments for the medium term and geomorphological indicators for the long term [127,128].

6.4.10 Resource Quality Objectives

Research on RQOs has trailed behind that on the Ecological Reserve. The lack of a formal procedure for specifying them has hindered the licensing process as management objectives could not be set. There was a strong movement from those working on the Ecological Reserve to use EcoSpecs (Chapter 4) as RQOs, but these are focused on a recommended ecological condition and may not cover indicators of interest to other users.

1. **Challenge:** While methods are well developed for specifying EcoSpecs, a formal method for specifying User Specs does not exist.

   Response: This remains a challenge. Approaches to date are relatively *ad hoc* but are contributing experience that will allow a formal approach to be developed.

2. **Challenge:** South Africa cannot afford to undertake comprehensive countrywide monitoring of RQOs.

   Response: An Excel-based DSS has been developed that prioritises the locations to be monitored and the indicators that should be considered as RQOs [129].

Jannie Coetzee

Multi-species fish kill: tilapia (*Oreochromis*), yellowfish and minnows (*Barbus*), carp (*Cyprinus*), catfish (*Clarias*) and others at Loskop Dam inlet on 20 September 2006, because of industrial pollution from the Middelburg-Witbank catchment area.

Jan Myburgh

Dead crocodiles from Arabie and Loskop Dams (Olifants Catchment) are taken to the laboratory for post-mortems to ascertain cause of death. RQOs are designed to set standards that can be monitored to manage ecological health of the nation's inland waters.

3. **Challenge:** RQOs need to support DWA's Adaptive Management approach to water resources management and not become fixed and prescriptive objectives that would lock management into a non-adaptive approach.

   Response: A procedure has been introduced whereby the RQOs published in the Government Gazette are generally narrative and so can be changed [129]. Numerical limits, not gazetted but closely managed by DWA and potentially upgradeable, describe in greater detail the quantitative and qualitative characteristics of the water resource that need to be achieved. Part of the procedure details how to prevent alterations to RQOs happening for the wrong reasons.

4. **Challenge:** RQOs will be used by DWA or other water resource managers in monitoring the condition of the water resource. It is the duty of the resource manager to manage all of the activities in a catchment so that the total stress imposed on the resource is acceptable as determined by the RQOs.

   Response: The 2010 procedure gives some direction on how RQOs are to be applied, but further development needs to be done.

6.5 Capacity building

As senior professionals developed their capability to address new challenges in the field of water research and management, passing on their knowledge through relevant education and training of other water practitioners and young people became vital. Such capacity building took place, and is still taking place, in three main ways.

Jan Myburgh

Acid mine drainage from surrounding coal mines contributes to pollution levels in the Olifants River.

6.5.1 Postgraduate studies

Research funding awarded to senior academics has allowed many postgraduate students to study aspects relevant to the Ecological Reserve. Most have studied specific flow-ecosystem or flow-social system relationships because such topics can be clearly delineated and limited to manageable levels of work. It is much more difficult to train people to become integrators and organisers of the process of flow determinations as this requires a broad but quite specific general knowledge of all the disciplines involved, and the ability to communicate with and organise the full team of discipline experts to produce a useable result.

A frequent request from postgraduates to be able to 'do an EFlows determination for a PhD' is thus impossible to satisfy. It requires many different experts to 'do an EFlows determination' and the leaders of the process build up expertise over many years in their chosen speciality field before becoming process leaders. Postgraduates are thus usually advised to focus on one area of a flows determination, such as the link between the flow regime and migratory fish species, or flow and riparian vegetation, and learn their way into an understanding of how aquatic ecosystems function through that route. They can then contribute this specialist knowledge to future flows determinations and, at this stage if they wish, start to specialise in managing the process.

Postgraduate studies have been supported by the requirement from the WRC and DWA that capacity building is built into every research project and consultancy. WRC projects, in particular, may run for up to three years, allowing a full thesis to be researched and written as part of them. In total, more than 50 postgraduate theses on Reserve-related topics have been registered or completed in the country in the last 15 years (Appendix 6.1), building capacity in a range of topics from hydrology to resource economics.

The teaching has spread further, through WATERNET, a SADC-wide network of university departments and research and training institutes that offers a taught MSc aimed at developing capacity in integrated water resource management (IWRM). Several core modules and additional optional modules are each hosted by an academic institution in a different country, and both students and teachers travel to the host country to work together on a specific module. The Environmental Flows optional module, which was based on South African activities, has been hosted by Malawi since its inception in 2004, and the social component by the University of the Western Cape in South Africa.

Jackie King

First intake of Waternet MSc students for the EFlows module, from Mozambique, Namibia, Tanzania, Zimbabwe and Zambia, in Zomba, Malawi, July 2004 with course leader Jackie King (centre back) and lecturer Washington Mutayoba (right back).

6.5.2 Training courses

6.5.2.1 FETWater

FETWater (Framework Programme for Research, Education and Training in the Water Sector – www.fetwater.co.za) was initiated in 2002. It was supported by DWA, the United Nations Educational Scientific and Cultural Organisation (UNESCO), the Flemish Government, the WRC and numerous education and training providers in South Africa. Under the banner of FETWater several networks have been established to address capacity building in the water sector in southern Africa, primarily through the development of training material and provision of training courses.

The first network, established in January 2003, focused on Resource Directed Measures (RDM). Its purpose was to identify and assess capacity requirements related to water resource protection, with a specific focus on the Reserve. Its training courses, run by a network of academics, government officials and consultants, have been attended by water specialists from South Africa and other SADC countries. From 2004 to 2009 close to 600 people attended the RDM training courses [130].

The FETWater RDM network has also developed the curriculum for an envisaged modular Masters course in integrated environmental water management (IEWM), with a focus on academic capacity building for working with the Reserve. The Masters course has not yet been offered by a university but some of its modules have been offered as short courses at the Freshwater Research Unit, University of Cape Town and at the University of Johannesburg. Most participants are DWA staff responsible for RDM-related tasks [131].

The FETWater Groundwater network focused on groundwater issues, and facilitated a series of GRDM training courses between 2004 and 2011. A key purpose of the courses was to develop capacity in the DWA Regional Offices. The courses focused on the theory and concepts of GRDM and training in the use of the GRDM Software developed by the Institute for Groundwater Studies at the University of the Free State.

6.5.2.2 Other courses

Increasingly, WRC projects are embracing some level of training of professionals and postgraduate students in a process of technology development and transfer. Examples are training on:

- estuary ecology and management – Section 6.4.2
- the Reserve in non-perennial rivers – Section 6.4.4
- the Reserve in groundwater systems – Section 6.4.6
- SPATSIM – Section 6.4.8.

6.5.3 Hands-on training

DWA requires that trainees be included in all the larger Reserve studies. Although exposing a number of people to Reserve assessments, this needs to be viewed in the broader context of the country as a whole. In addition to the normal attrition rate of scientists starting out in their careers, the opportunities that have become available to young scientists following the 1994 elections, combined with the policy of employment equity, has resulted in a high rate of movement of people through this field and a low percentage staying the course to become recognised experts. Because of the high attrition rate, larger numbers of people than would normally be expected need to be trained, but too few school leavers choose a career in science to satisfy this demand.

One example of successful hands-on training lies within a WRC project dealing with estuaries [132]. The core Cape team worked on a Reserve project in KwaZulu-Natal with the local estuaries specialists, who have now developed a slightly different approach of their own and use it to do all Reserve determinations in their province.

6.5.4 Conclusion on capacity building

Capacity building in the research laboratory or work place is not an automatic by-product of the activities underway but is a significant target in its own right that needs an investment of time and funds. Experience has shown that senior personnel may experience 'capacity-building overload' as they try to move research and management agendas forward while guiding those in training. Time and energy previously spent identifying the research and management needs of the country and striving to meet them may become diverted into training, or maybe not. There is an implicit trade-off: the country's ability to foresee and address problem areas before they become critical versus the skills development of young people. The situation needs more focused management.

Roger Parsons

FETWater-sponsored GRDM training course in Port Elizabeth, November 2004.

Mark Rountree

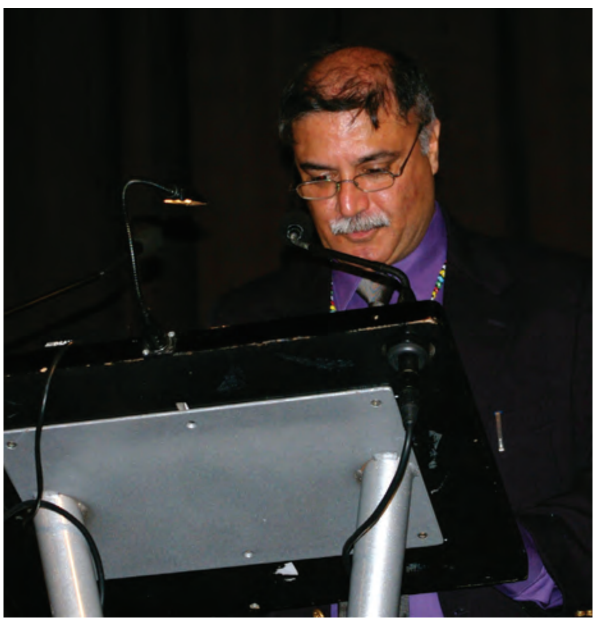
Field training in wetland delineation and management, run by DWA in KwaZulu-Natal in 2006 to raise awareness within DWA and other regional government departments about wetland protection and management.

6.6 Awareness raising

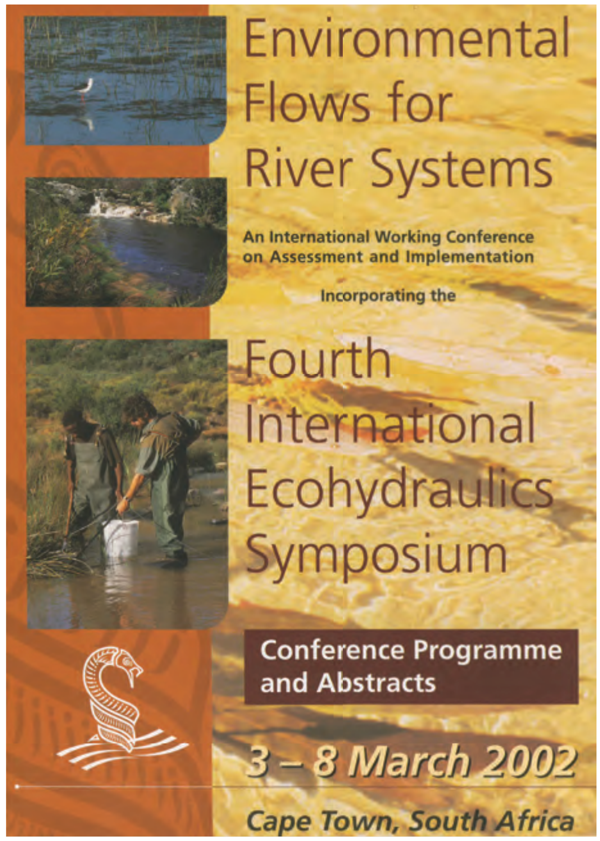
It is often difficult to assess how much awareness raising has been done on EFlows and how effective it has been. One measure is to compare a country to others in terms of how many people in the water field know of the topic and how readily and easily it is debated between politicians, scientists, engineers, social groups and water managers. South Africa must rank quite highly in this respect, with many activities in addition to those mentioned in previous sections having contributed to a growing awareness in the country of the need to reserve water for environmental maintenance.

6.6.1 Conferences and symposia

South Africa has hosted two of the three international conferences held to date on environmental flows. The first, held in Cape Town in March 2002 in conjunction with the 4th International Ecohydraulics Conference, was titled Environmental Flows for River Systems. Themes included Country Reviews on EFlows; EFlows in IWRM; links between flow and ecosystem processes; and monitoring the outcomes of managed flow regimes. One hundred and thirty six papers were presented and the conference was attended by 290 delegates from 40 countries. The third conference and second one in South Africa, Implementing Environmental Water Allocations, was held in February 2009 in Port Elizabeth. It focused on the practical application of the science to date in water management, attracting 381 delegates from 25 countries. Ninety-four papers and 18 posters were presented (Appendix 6.1).


WRC Archives

Dr Rafik Hirji, World Bank, presented the opening keynote address at the Port Elizabeth conference, 2009.



First international conference on environmental flows, Cape Town, 2002.

6.6.2 Undergraduate teaching

Young people have been made aware of RDM through tertiary educational institutions.
The WRC convened a workshop at the request of the research community during the early 1990s to address the need to formally insert Reserve-related courses into universities, but this was not done at the time as the training was considered too specialised and the market too small. Meanwhile, through the activities of the academics themselves, undergraduate courses on freshwater ecology or similar were initiated at many of the nation's academic institutions, and many of those do include modules on EFlows, river management or similar (Appendix 6.1).

6.7 International links

Despite being designed to answer the needs of DWA (Chapter 4), the BBM, or its local adaptations, have been used in many countries across the world – through Europe, the Americas, Africa, Australasia and Asia.
Its User Manual has proven to be a useful starting point for several countries entering this field of water management, and it has remained popular despite method development having moved on. Liaison with Australian scientists during its early stages [133] and application to the Logan River in Australia in 1996 benefitted both the BBM and the Australian equivalents, WAMP and FLOWRESM [134].

International use of the South African flow assessment methods by local scientists began with a DWA-funded BBM application on the Senqu River in Lesotho in 1995, and followed with a World Bank-funded application of the developing DRIFT methodology on the Senqu-Orange system in 1997/8. DRIFT applications that followed include:

- the Lower Mekong Basin (Cambodia, Lao PDR, Thailand, Viet Nam) in 2004-7, funded by the World Bank and the Mekong River Commission

- the Zambezi Delta (Mozambique) in 2006, funded by the Liz Claiborne and Art Ortenberg Foundation, the International Crane Foundation and the Carr Foundation

Delana Louw

Hippos standing on a shrinking sandbank on the lower Kafue River in Zambia as the upstream Kafue Gorge Dam releases test flows mimicking peak power production during planning for a new Lower Kafue Gorge hydropower project, July 2008.

Delana Louw

Mark Rountree measures bank slumping in the lower Kafue River after the test floods.

- The Mzingwane River (Zimbabwe) in 2007, funded by IUCN
- The Phuthiatsana River (Lesotho) in 2007, funded by Lesotho Department of Water Affairs
- the Pangani Basin in Tanzania in 2006-8, funded by IUCN and the Tanzanian government
- the Nile River (Sudan) in 2008-9, funded by the Sudanese Dams Implementation Unit
- the Okavango Basin (Angola, Namibia, Botswana) in 2008-10, funded by GEF/UNDP
- the Lower Zambezi River in 2009-10, funded by Riversdale Mining
- the Kunene River (Namibia and Angola) in 2009-10, funded by the Angolan and Namibian Governments through the Permanent Joint Technical Commission
- the Neelum River (Pakistan) in 2010 funded by the Government of Pakistan.

Jackie King

Laura Namene, Namibian representative on the Okavango Basin Steering Committee, and Jackie King in the dry Kuiseb River, Namibia, during the Okavango Basin environmental flows (EPSMO) project.

Cate Brown

Members of the DRIFT team setting off from Abu Hamed on the Nile River to do EFlow fieldwork for the Dagash and Mograt Hydropower Projects, January 2009.

Jackie King

The Tonle Sap Great Lake in Cambodia is a vital part of the Mekong River Basin, which supports the greatest inland fishery in the world. It is now threatened by a multitude of proposed dams. An Environmental Flow Assessment using an early and partial version of DRIFT was done in 2005.

Helen Dallas

Helen Dallas identifies aquatic invertebrates as part of an Environment Flow Assessment for the Pangani system in Tanzania in 2006.

Modified applications also took place in Zimbabwe in the mid-1990s and elsewhere. Through the early international work, Jackie King served as member and then team leader of the World Bank-Netherlands Water Partnership Window on Environmental Flows from 1999 to 2002, an initiative that was designed to introduce useful technologies to the Bank's global team of project managers and provide assistance where needed. She then resigned that position to lead the Mekong flow assessment work.

The Ecoclassification and/or Flow-Stressor Response approach has been used for the:

- Usuthu River and tributaries (Swaziland) and the Maputo River (Mozambique) in 2006, as part of the Joint Maputo Basin River Study, funded by the EU
- Mkurumudzi River (Kenya) in 2006, funded by Tiomin Mining
- Kafue River, a tributary of the Zambezi (Zambia), in 2008-2009, funded by the International Finance Corporation
- Orange River, currently underway, funded by the EU.
- Fish and Nossob Rivers (Namibia) Namibia, currently underway, funded by the EU.

There have been several international applications of the Desktop Reserve model including in Mozambique, Tanzania, UK and Nepal [135] and Malawi (J. King pers. comm.). Some of these have included comparisons with other methods, but very few have been formerly reported in the scientific literature.

Links have strengthened and widened through the years, as shown by the general level of invitation for South Africans to speak at conferences, run international workshops and act as resource persons at international meetings. All of the above activities are detailed in Appendix 6.1.

6.8 Strengths

6.8.1 Policy and law

A very real strength in South Africa is the fact that the Water Resource Classification System, the Ecological and Basic Human Need Reserve and the related Resource Quality Objectives are embedded in national policy and law.

6.8.2 Research

The science underlying the Ecological Reserve, in particular, has received considerable attention, and that underpinning the WRCS and RQOs is progressing. Research into the specialist disciplines involved in Reserve assessments has been supported and the research findings have been successfully incorporated into the methodologies.

This has enabled the development of good decision support system (DSS) models. These DSS models have been developed by researchers in conjunction with the managers who would use them, and so they are practical and implementable.

6.8.3 Capability

There is a corps of people in the country that is highly skilled in the determination of EWR.

6.8.4 Collaboration

There has been good collaboration with senior officials from DWA, and more recently with the staff of the newly forming catchment management agencies, with regards to determination (Chapter 4) and operationalisation (Chapter 7) of RDM. Training in the necessary skills has been developed, is available and, to a very limited extent, is given where needed.

Jackie King

By the turn of the century, water research and management increasingly embraced transboundary issues. The Orange-Senqu is South Africa's largest transboundary river and a basin-wide agreement between Botswana, Lesotho, Namibia and South Africa to jointly address threats to the river system led to the formation of the Orange-Senqu River Commission in 2000. An environmental flow assessment is presently being done for the whole system.

6.8.5 Awareness

There is a general high awareness about RDM among the country's water practitioners and, to a lesser extent, among some sectors of the public.

6.8.6 International relevance

The flow assessment methods developed locally for several kinds of rivers (perennial flashy; ephemeral; flood-pulse monsoonal) work equally well internationally and are being used in a wide global range of countries.

6.9 Weaknesses

6.9.1 Fundamental research

During the early days of method development, scientists agreed to step forward with their 'best available knowledge' and start to provide advice quickly in order to meet management timelines. There was concern at the time, and there still is, that research funds and energy are being diverted from fundamental research on the functioning of rivers, estuaries and wetlands. It is now felt that the younger generation of researchers may not understand the value of fundamental research, may not be getting training in the concepts and techniques of such research and may soon lose to retirement a generation of researchers who can train them, thereby weakening institutional memory. Funding for research into ecosystem processes has lost emphasis with funding agencies, and so the country is living largely on its capital of knowledge, which is not adequate.

6.9.2 Operationalisation

The focus to date has been research into the development of methodologies for flow assessments and, understandably, not on how the outputs will translate into action on the ground. It was originally agreed that scientists would provide numbers (i.e. modified flow regimes for rivers targeted for development) and then the water managers would take over from there. It is now clear that the partnership between managers and scientists needs to continue through this second phase of on-the-ground operationalisation in order for the Ecological Reserve to become a reality within a system of IWRM. This work is in its infancy (Chapter 7).

6.9.3 Complexity of methods

The methods for determining the Ecological Reserve are complex and only a small body of people can apply them. Some call for the approaches and outputs to be simplified whilst others support the science to continue to develop in its complexity but with the management interface simplified. The transfer of skills from a core body of practitioners is slow.

6.9.4 Scientific outputs

The outputs from Reserve determinations have been seen as not user-friendly by many who work at the local level to operationalise them (Chapter 7). The scientists who have designed the Reserve outputs feel that what has been provided is not a major deviation from the operating rules that are successfully being applied for other aspects of water resource developments. A focused and substantial programme of two-way learning, with scientists working hands-on with regional managers to apply the Reserve information in their working conditions, is clearly needed.

6.9.5 Decision making

The outputs from the determinations should become inputs to a process of decision making on how much water is to be allocated to which water-use sectors (including the ecosystems themselves). This has not been done adequately to date because the Water Resources Classification System (Chapter 4) has only just been promulgated (September 2010).

6.9.6 Evolving methods

As a young science, the concepts, methods and terminology for EFlows are still evolving. This is very confusing for scientists and managers newly entering the field.

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Thomas Peschak

7 GIVING EFFECT TO RESOURCE DIRECTED MEASURES

Harrison Pienaar and Jackie King

7.1 Introduction

The previous chapters outline a wealth of activities over the last three decades that have focused on how to better achieve protection and sustainable use of the country's inland waters. While a substantial body of knowledge, skills and re-structuring has been produced, the test of its effectiveness is its successful application.

The situation facing DWA in terms of water resource protection as the NWA came into force was that the three Resource Directed Measures (RDMs) needed to be put in place for significant water resources (Chapter 3):

- a classification of all parts of all significant water resources into one of the three Management Classes[a]
- a Reserve of the water quantity (flow or inundation regime) and quality for each part of each such water resource to meet its designated Management Class
- Resource Quality Objectives (RQOs), which are numeric or descriptive goals emerging from the process that can be monitored for compliance with the Management Classes, for each part of each such water resource.

[a] *Based on the Present Ecological State of the water resource; the ecosystem services that it provides; the role it plays or could play in economic development; its cultural and social value; international obligations; strategic planning and development considerations; and the level of protection required to meet the vision that stakeholders have for the system.*

The classification exercise for any one water resource has profound implications for the allocation – and in many, if not most, cases re-allocation – of water through compulsory licencing (Chapter 3). For this reason, the RDMs cannot exist in isolation and, indeed, have emerged as a central tenet of Integrated water resource management (IWRM). Setting them will be part of the process of balancing water demand and use and of putting in place pro-active measures for areas of high conservation status.

IWRM in the South African context is manifesting as an increasingly iterative process with stakeholders in order to set and manage the vision for a catchment. Water resource management options – scenarios – are compiled in terms of their economic, social and ecological implications, with each offering, in effect, different pathways into the future. Each scenario represents a different trade-off between water resource development and use on the one hand and protection of the resource to ensure its sustainable use on the other. After public consultation, DWA is mandated and has the authority to decide on what that future will be in terms of water resource management. It is intended that this iterative process will ultimately be captured in a countrywide coverage of catchment management strategies. At present, these are represented by DWA's internal strategic perspectives (ISPs; see Section 3.3.1), but the catchment management strategies will eventually be produced and managed by the newly-forming catchment management agencies (CMAs).

The overall strategy in terms of the move toward IWRM, as envisaged by DWA, illustrates the importance and consideration of four key phases of water management (Figure 7.1). First, water availability (top left box) represents the current situation with Preliminary Reserves – and limited stakeholder engagement – included. This, together with water use requirements (top right box), provides information on the existing water balance (Chapter 1) for each catchment. Second, the planned in-depth investigations and activities linked to water resource classification, with much greater stakeholder involvement, will result in recommended Management Classes for the various parts of a catchment and a linked schedule for the allocation of available water. Third, the ensuing information will be itemised and made available for publication and appeals. The information will include details of the Management Classes, Reserves and other RQOs set for various parts of the catchment, any details regarding compulsory licencing emanating from the allocation schedule, and any proposed new water resource structures or revision of design and operating rules for existing ones. The fourth and final phase will be the monitoring, enforcement and evaluation activities that will provide for on-going management of the process.

This comprehensive approach will take considerable time and funds, and will require close cooperation

ICMA

Representatives of all stakeholders from the Sabie-Sand, Crocodile and Komati sub-catchments gather at the final phase of consultation on the catchment management strategy, run by the Inkomati CMA.

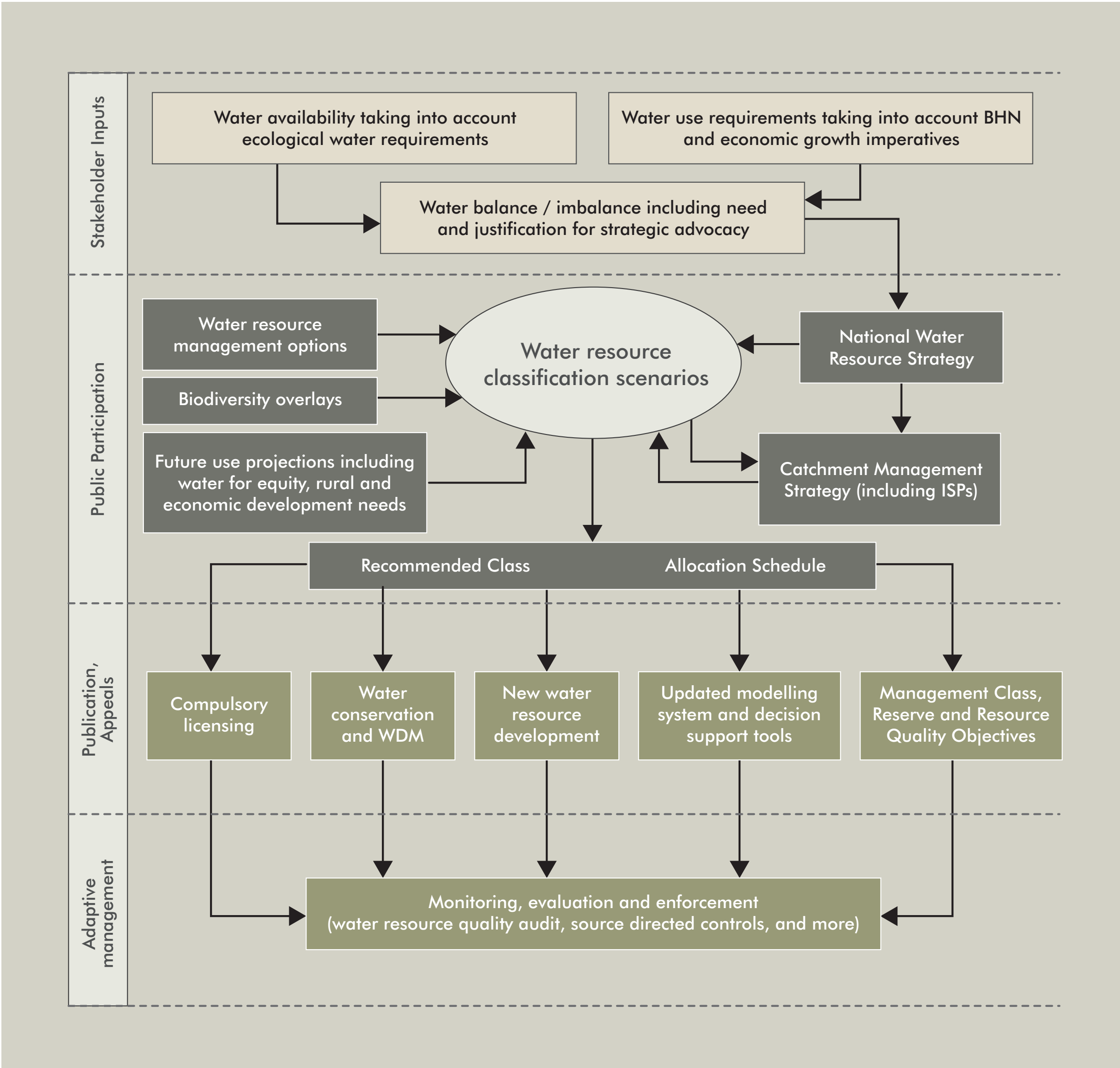


Figure 7.1 DWA's approach to integrated water resource management, showing the positioning of the Management Class, Reserve and RQOs. WDM = water demand management. ISP = internal strategic perspectives. BHN = Basic Human Needs.

between many parts of DWA including those dealing with resource protection (CD:RDM), water use (CD: Regulation), planning (CD:IWRP) and information (CD: Water Resources Information Management). It will also require greater emphasis on sector-wide collaboration through the strengthening of well-established and on-going partnerships such as the Water Sector Leadership Group, which includes senior members from mining, energy, industry, environment, agriculture, NGOs, organised business and key government departments.

How far toward completion is the plan for sustainable use? This chapter begins by outlining the early work done ahead of the NWA to establish some level of protection against over-exploitation for aquatic ecosystems. It then presents the response of DWA to the NWA from 1998 onwards, including the current situation in terms of national planning, the role that RDM plays in planning and water use licensing, and the move to operationalisation. It then discusses the situation and needs in terms of present capabilities and capacity building.

7.2 Early protection measures for aquatic ecosystems

7.2.1 Prior to 1995

Formal environmental flow assessments for rivers and estuaries, as an integral and visionary part of DWA's planning studies, began in 1991. At this stage the RDM unit did not exist, water resource classification had not been thought of and the work was initiated and funded by other DWA directorates, most prominently Project Planning as part of their dam planning exercises (Table 7.1). During this early phase scientists were beginning to develop methodologies (Chapters 4 and 6) and so the outputs were of gradually improving, but still somewhat questionable, quality. They also produced a prescriptive single statement of the flow needs from the perspective of the river scientists, addressing only those river reaches that it was thought might be significantly impacted by the proposed dam (Chapter 4). Because of the uncertain quality of some outputs, largely due to out-dated monthly-averaged hydrological data, coarse-resolution hydraulic modelling and sparse ecological data, the results were used selectively and in many cases the flow assessments were repeated in later years. In those early days, the results were a challenge to use and were crudely incorporated by the planners into systems analyses, usually as a single number or a minimum flow[b].

7.2.2 From 1995 to 1998

By 1995, method development was beginning to produce more confident results, albeit mostly still for a single prescribed 'desired state'. For the next three years, until the NWA was promulgated in 1998, DWA continued to initiate and fund flow assessments without there being any legal requirement to do so, mostly through its Project Planning Directorate (Table 7.2).

7.3 From 1998 onwards: national water imperatives and the role of RDM

Following the promulgation of the NWA in 1998, several major initiatives reflected important elements of the vision for water management for the country.

7.3.1. The Water Situation Assessment Model

One year after the NWA, in 1999, DWA compiled and calibrated a Water Situation Assessment Model (WSAM) to determine how much water was available for use in South Africa. One input needed for the model was the amount of water likely to be needed for the Ecological Reserve. To do this, DWA coordinated the countrywide compilation, by freshwater ecologists, of the Ecological Importance and Sensitivity (EIS) and Present Ecological Status (PES) of each of the 1946 quaternary[c] catchments in the country. These data were used to assign a preliminary planning category (the precursor of the three Management Classes) to each quaternary catchment. A tentative Ecological Reserve was then calculated for each quaternary, using the Desktop Model [1]; this had been calibrated using approximately 25 sets of results from comprehensive environmental flow assessments already done in the country as inputs to planning studies for individual basins or dams (Table 4.1). The Desktop Model was also used in the ISPs (Chapter 3) that are the forerunners of the planned catchment management strategies.

Denis Hughes

Denis Hughes (left), lead developer of the Desktop Model and SPATSIM, with students.

[b] *The breakthrough came later when Prof. Denis Hughes and colleagues converted those early 'instream flow requirements' into flow duration curves to make them compatible with the methods used for yield analysis.*

[c] *Quaternary – a fourth-order catchment*

The Desktop Model output indicated that approximately 40% to 50% of its natural MAR was required for an unmodified (Ecological Class A) river, 30% to 40% for a largely natural river (Class B) river, 20% to 30% for a moderately modified river (Class C), and 10% to 20% for a largely modified river (Class D). These guidelines seem very low compared to those from some other countries, and many feel they also do not adequately cater for the natural differences in South African river systems whereby, for instance, some kinds of Class B rivers may require more of their MAR than other kinds of Class B rivers. Nevertheless, the generalisations have led to the perception among some water managers that deviations from them are incorrect and over-protective, making it exceedingly difficult to obtain approval for higher volumes of water for river systems that may require higher percentages of their natural run off to achieve a certain condition.

The Desktop Model was intended for planning purposes only as it used and provided data that were too coarse in resolution for detailed management and decision making on individual river reaches. It should gradually be replaced by countrywide Comprehensive Reserve determinations as part of the water resource classifications. The format of the Desktop output, adopted by DWA as the standard legal format for submission and approval of the Ecological Reserve, has led to some of the interpretation difficulties now being voiced at some DWA Regional Offices where there may not be the necessary capacity and training to use it (Section 7.9.2).

Table 7.1 Flow assessments completed between 1991 and 1995.

Drainage area	River or estuary	Project name	Year	DWA Directorate
A50	Lephalala River	Lephala River Catchment Water Resources Development Study	1991	Project Planning
A91	Mutshindudi, Luvuvhu, Barotta and Mambedi Rivers	Hydrology of Luvuvhu River	1990-94	Project Planning Hydrology
B73	Sand, Olifants (Mpumalanga) Rivers	Olifants Sand Transfer Scheme	1993	Project Planning
B81	Letaba, Letsitele, Nwanedzi and Molototsi Rivers	Letaba Water Resources Development Study	1994-96	Hydrology
E10	Olifants River (W. Cape)	Proposed Rosendal Dam	1993	Project Planning
G10	Berg Estuary	Western Cape System Analysis	1994	Project Planning
K60	Piesangs and Keurbooms Estuaries; Keurbooms River	Plettenberg Bay Coastal Catchment Study	1994 -95	Project Planning
L82	Kouga, Tsitsikama, Groot and Elands Rivers	Algoa Water Resources System Analysis	1993-95	Project Planning
R30	Buffalo and Nahoon Rivers	Amatole Water Resources System Analysis	1993-95	Hydrology
R30	Buffalo, Nahoon, Gqunube, Toise and Kubusi Rivers	Amatole Water Resources System Analysis	1993-95	Hydrology Project Planning
S32	Black River Kei	Kei River	1994	Project Planning
X14	Lomati, Crocodile, Komati Rivers	Driekoppies Dam	1994	Project Planning
X24	Luvuvhu, Shingwedzi, Letaba, Olifants, Sabie, Crocodile Rivers	Kruger National Park Rivers Planning studies	1994	Project Planning

Table 7.2 Flow assessments completed between 1995 and 1998.

Drainage area	River or estuary	Project name	Year	DWA Directorate
A63	Nyl River, Sterk, Mogalakwena Rivers	Mogalakwena Ritolaver Dam Feasibility Study	1996	Project Planning
D11	Malimabamatsho, Senqu River	Senqu River IFR	1995	Project Planning
D14	Orange River	Orange River Development Project	1996-9	Project Planning
D17	Senqu , Malimabatsho, Matsoku, Senqunyane Rivers	Lesotho Highlands Water Project	1997	Project Planning
G40	Palmiet and Steenbras River	Palmiet River IFR	1995	Design Services
H10	Koekedouw and Dwars Rivers	Ceres Dam / Koekedouw Irrigation	1995	Hydrology
K60	Piesang River	Plettenberg Bay Coastal Catchments Study	1995	Project Planning
W12	Mhlathuze and Nseleni Rivers; Mhlathuze Estuary; Mangeza, Nsez, Chubu, Msingazi, Nhlabane Lakes	Mhlathuze Ecological Study	1998	Project Planning
W42	Bifane and Pongola River	Paris Dam	1997	Project Planning
V14	Thukela River and Boesmans River	Thukela Vaal Transfer Scheme – Vaal Augmentation Planning Study	1995-97	Project Planning
X31	Sabie River	Sabie Sand IFR Workshop	1996-97	Design Services

7.3.2 Reconciliation strategies

Running in parallel to the WSAM, Chief Directorate: IWRP continues the planning studies that funded the early flow assessments (Table 4.1) in the form of catchment reconciliation strategies. These update and project into the future information on the water resources available and used within a catchment, with catchments being prioritised for these months-long exercises depending on their importance and potential water conflicts. There is a level of social input into the reconciliation strategies from stakeholder forums, but the automatic inclusion of an Ecological Water Requirements team by CD:IWRP, as in the 1990s studies, was gradually reduced with the advent of the RDM unit. A cooperative approach has since developed between CD: RDM and CD:IWRP, which is beginning to promote a more integrated approach toward water management as well as allowing the sharing of skills and capacity. Within this approach, CD:RDM is taking an increasingly leading role in all matters related to RDM within the planning process.

There remains a perception among some stakeholders that this internal DWA process with limited stakeholder involvement supports a pro-development decision making process, because some decision makers view the Ecological Reserve as anti-development and hindering decision making. Others feel that there has been satisfactory stakeholder consultation in the more stressed catchments where more recent Comprehensive Reserve assessments have been done, and the Reserves approved for those areas have reflected a balanced and considered agreement on the future state of the aquatic ecosystems. Delays experienced over the last few years in the formal promulgation of the Water Resource Classification System (WRCS), as well as in the initiation of the compulsory licensing process, have perpetuated these opposing views.

7.3.3 RDM – Water resource classification

There is widespread agreement among water professionals that water management should take place within the all-encompassing area of the catchment because of the different scales at which economic, social and ecological processes operate.

As water resource classifications, required by the NWA, get under way (Figure 7.1), they will be done at the scale of integrated units of analysis (IUA), and all relevant information regarding the economic, social and environmental issues will be made available simultaneously in the form of comprehensive scenarios for scrutiny by the public during the process of formally setting the Management Classes, the Reserve and other RQOs. These last will form the foundation of catchment-wide water management plans, providing the necessary starting information for RDM monitoring and indicating how much water will be available for allocation or re-allocation through licences. It is thus an essential prerequisite for compulsory licensing.

Much of the work already done during Comprehensive Ecological Reserve determinations may be used in these future classification exercises, although some of the Preliminary Reserves and RQOs set will need to be revisited.

The WRCS was promulgated in the Government Gazette in September 2010, but has not yet been applied to completion in any catchment. There seem to have been three main reasons for the five-year delay since the system was developed:

- it is complex
- it is seen as an integral part of a greater move toward IWRM, which is being gradually adopted within several other parts of DWA, and so it has to evolve in harmony with that
- it will require considerable stakeholder consultation as the catchment-wide configuration of Management Classes is negotiated, which will be costly in terms of time and funds.

With its promulgation, some classification exercises have now begun (Section 7.8.1).

Gavin Snow

Anusha Rajkaran takes samples from the mangrove forests at Mngazana Estuary, south of Port St Johns , which are heavily harvested by subsistence users. Her work provides valuable input into Reserve determinations for mangrove estuaries and can inform classification exercises that aim to balance resource protection and use.

Sanjay Singh

Harrison Pienaar (right), Chief Director of RDM from its inception in 2002 until 2011, at an Inter-Governmental Committee meeting in 2006 between South Africa and Russia during a handover ceremony of a signed joint action plan on water and forestry cooperation between the two countries.

7.3.4 Compulsory licensing

DWA's water resource protection measures cannot be effectively implemented until it is possible to regulate (in most cases, to curtail) existing water use by imposing conditions of use in water-use licences. The principal means provided in the NWA for this is compulsory licensing on the geographic scale of a catchment or group of catchments. Although there has been much work in preparation for compulsory licensing during the last six years or so, under the auspices of the Water Allocation Reform programme, it has not yet been instituted anywhere in the country because of the need to first formally classify each catchment's water resources. Thus, to date there has been no reallocation of water use completed in any catchment.

As and when reallocation begins, the process and the results must be able to withstand legal challenges. The NWA does not allow an appeal[d] against the results of a Reserve assessment, but does allow appeals by responsible authorities against classification results and licensing decisions. Given that such decisions are influenced by the results of Reserve assessments it is essential that these results are scientifically credible and legally defensible.

7.3.5 Water for Growth and Development

In 2008, DWA began to formulate a Water for Growth and Development (WfGD) framework. This responded to concerns about the state of water in the country over the past few years with regard to:

- expected severe water shortages by 2025
- dams in poor condition
- severely polluted rivers
- failing municipal infrastructure, in particular waste water treatment plants, with impacts on rivers
- a serious lack of skilled capacity within the water sector.

[d] *That is, an appeal to the Water Tribunal in terms of s148.*

Johan Wentzel

Acidic mine water drains from a shaft near Krugersdorp, known as the ‘Chinese shaft’. This was the first occurrence of AMD on the West Rand.

The WfGD framework takes stock of the country’s present water situation and offers a new approach to resolving the emerging problems. DWA presented it to the South African Cabinet (President and Ministers) in January 2009, after which the Cabinet Committee supported it and directed DWA to consult with the public on it. A country-wide stakeholder consultation process, now concluded, led to a draft revised WfGD framework, which is presently being considered by DWA. It is designed to guide informed decisions and trade-offs on water, as part of cross-sectoral planning and development initiatives. CD:RDM plays a central role in this.

7.3.6 Climate change

There remains huge uncertainty of the impacts of climate change, but a common prediction is that South Africa may experience higher temperatures with lower rainfall in the interior and in the west, and increased rainfall and rainfall intensity in the east, especially in the late summer (Chapter 1). Rainfall is generally expected to become more variable, floods to become more common, droughts to become more intense and last longer, and sea levels to rise. If this is an accurate prediction, then the net effect will be reduced availability of water (surface and groundwater) and reduced security of supply for most of the country. This could have significant negative knock-on effects for the economy, human health, infrastructure, population dynamics and migration, social wellbeing, ecosystems and biodiversity. DWA recognises the urgent need for a water sector climate-change response strategy that considers both mitigation and adaptation, but is already well positioned to meet the challenge of climate change through its IWRM process (Sections 7.1; 7.3.3). Specifically, water resource classification requires the compilation of scenarios of the economic, social and ecological implications of proposed water management options for consideration by stakeholders. Although the scenarios are usually based on various resource development or rehabilitation options, they can also be presented with and without the projected added effects of climate change. This allows an assessment of the possible impacts of climate change alone on future ecosystem health, water availability, water security and licensing, to inform decisions and possible mitigatory measures.

7.3.7 Integration

The restructuring initiatives and reorganisation of cross-cutting departmental programmes within DWA are a serious attempt to achieve an integrated approach to water management. As part of this, the evolution of CD:RDM from a small specialised unit into a more structured chief directorate is testimony to DWA's commitment to sustainable use of water resources. More coherent project steering committees have been established that incorporate both water services and water resources expertise, thereby enabling DWA managers to engage more meaningfully and resolutely on RDM aspects and their role in IWRM. Resource requirements for the Water Use, IWRP and RDM chief directorates have been streamlined through an internal budget reallocation that is facilitating CD:RDM taking a larger role in IWRM.

The RDM template is being revised to incorporate reviews by CD:IWRP and CD: Water Use prior to authorisation of a recommended Management Class. Project steering committees for water resources classification projects are being led by CD:RDM and make provision for key internal and external stakeholders to participate during the conceptual and developmental stages of these projects, as well as in the process of determining the recommended configuration of Management Classes. DWA strives to ensure that the same stakeholders participate in both classification and catchment reconciliation projects, for continuity and so that group discussions leading toward decision-making are well informed.

7.4 Progress with RDM for surface waters in the context of national planning

The new legal requirement to put in place the three RDMs for every significant water resource resulted in the Ecological Reserve beginning to be assessed for water bodies at one of four different levels of resolution with related levels of confidence in the outputs: Desktop, Rapid, Intermediate or Comprehensive (Table 4.5). The level of resolution of the assessment, based on several criteria[e], is now chosen by the Directorate: Reserve Requirements using the DWA guide [2]. Sections 7.4.1-7.4.3 below outline progress in Reserve determinations for surface waters as part of national planning studies. The process of approving, signing off and final decision making that follows each determination is explained in Section 7.4.4.

7.4.1 Planning studies – rivers

The national planning exercises for river systems have primarily employed Comprehensive and Intermediate level Reserve assessments. Most of those done before 2003 continued to provide a single prescriptive Reserve recommendation but due to the problems this caused (Chapter 4), all Reserve assessments from 2003 onwards produced multiple scenarios. These were usually the Present Ecological State (PES), the Recommended Ecological Category (REC) and at least one additional scenario. The additional scenario(s) are designed to illustrate the situation with the ecosystem in one category higher or one category lower than the PES if either is not already covered by the REC.

This was a time of increasing technical energy and funding, with the RDM unit now established and beginning to take over responsibility for the assessments (Table 7.3). The catchment reconciliation strategies being undertaken by CD:IWRP were, to a large extent, driving the selection of catchments for the Reserve studies, which encompassed both water quantity and water quality components.

Each entry in Table 7.3 represents a complex web of work. The Reserve assessment done for the Letaba River (Water Management Area 2 in Table 7.3), for instance, driven by the proposed Namitwa Dam and irrigation demands, was completed for seven sites along this river system (Table 7.4; Figure 7.2), each representing a quaternary catchment.

7.4.2 Planning studies – estuaries

Of the 370 stream outlets along the coast, 291 are classified as functioning estuaries. At present just over 10% of these have had some level of Reserve determination (Table 7.5). Some were completed as part of bigger planning studies at the same time as the river and groundwater studies, while some smaller scale EWR studies were undertaken for specific estuarine systems, usually in response to specific licence applications to use those water resources (Section 7.6).

[e] *Criteria used in choosing the level of resolution for a Reserve assessment for an aquatic ecosystem include the availability of relevant data, water demand from the ecosystem, potential new developments of it and its conservation and protection status.*

Table 7.3 Comprehensive (C) and Intermediate (I) Ecological Reserve studies for rivers completed since 1998, showing the responsible DWA directorate and the dates when the Reserve was completed and approved.

Water Management Area (WMA)	Catchment	Assessment level	Responsible Directorate	Date completed	Date approved
1. Limpopo	Mokolo*	I	RDM	2011	2011
2. Luvuvhu & Letaba	Letaba	C	RDM	2006	2006
3. Crocodile West & Marico	Apies/Pienaars	I	RDM	2010	2011
4. Olifants	Olifants	C	NWRP	2001	2001-2003
5. Inkomati	Crocodile East*	I	RDM	2005	2006
	Sabie/Sand*	I	RDM	2004	2004
	Elands*	I	RDM	2005	2006
	Inkomati*	C	RDM	2005	2006
6. Usutu to Mhlatuze	Mhlatuze*	C	NWRP	2003	2003
7. Thukela	Thukela*	C	NWRP	2003	2004
8. Upper Vaal	*	C	RDM	2011	
9. Middle Vaal	*	C	RDM	2011	
10. Lower Vaal	*	C	RDM	2011	
11. Mvoti to Umzimkulu	Mkomazi	I	NWRP	2001	2003
12. Mzimvubu to Keiskamma	Kubusi, Buffalo & Nahoon	I	RDM	2002	2004
13. Upper Orange	Modder/Riet	I	RDM	2009	2009
14. Lower Orange					
15. Fish to Tsitsikamma	Kromme/Seekoei*	I	RDM	2006	2006
	Kat	I	RDM	2008	2008
16. Gouritz	Sout/Matjies*	I	RDM	Start 2011	
17. Olifants Doorn	Olifants Doorn*	C	RDM	2008	2008
18. Breede	Breede*	I	RDM	2004	2004
19. Berg	Berg*	C	NWRP	2003	2003

NWRP = National Water Resources Planning *includes some wetlands where relevant

Table 7.4 Quaternary catchments for which EWR determinations were done for the Letaba in 2006.

Quaternary catchment	Water resource	River name
B81B	Site 1: Groot Letaba (Appel)	Groot Letaba
B81C	Site 2: Letsitele River	Letsiteli
B81F	Site 3: Groot Letaba (Hans Marensky)	Groot Letaba
B81J	Site 4: Groot Letaba (Letaba Ranch)	Groot Letaba
B82F	Site 5: Klein Letaba	Klein Letaba
B83A	Site 6: Groot Letaba (Lonely Bull)	Letaba
B83D	Site 7: Groot Letaba (Letaba Bridge)	Letaba

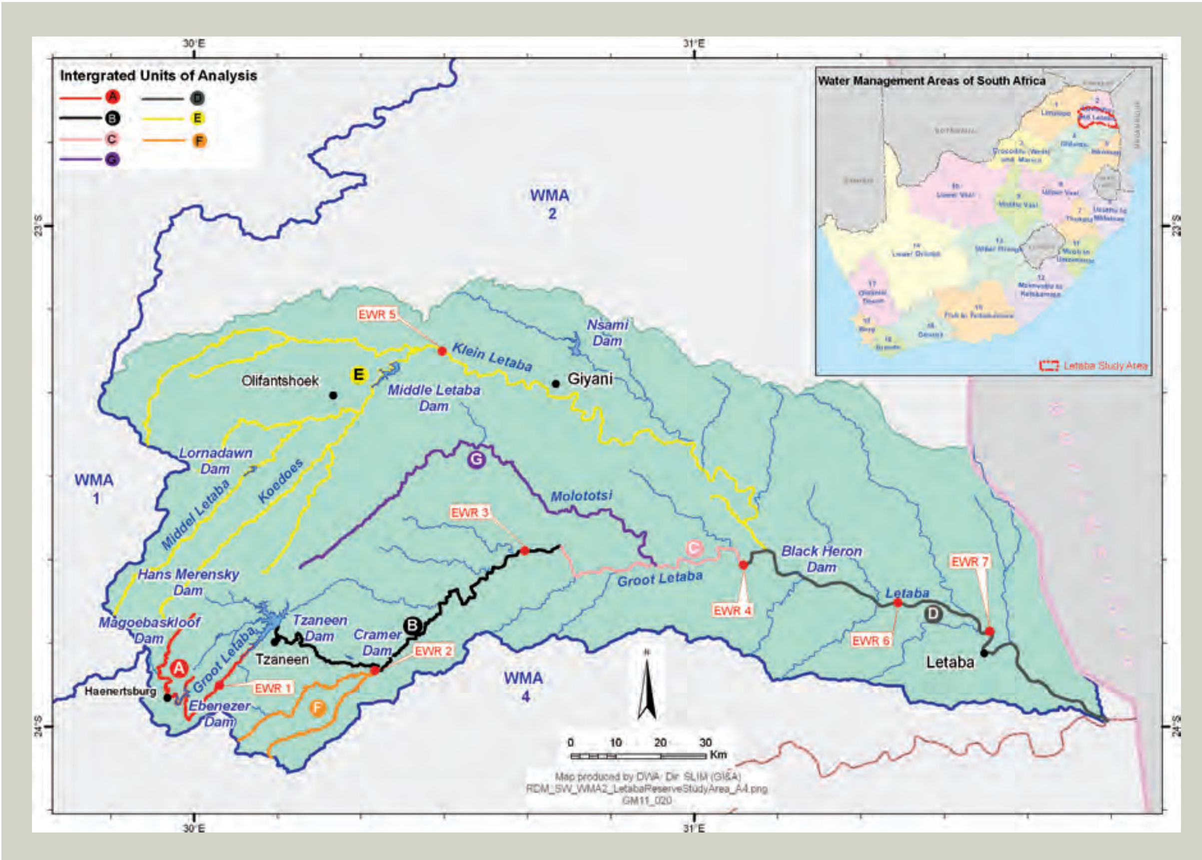


Figure 7.2 The Letaba catchment, showing the position of the EWR sites. EWR = Ecological Water Requirement. Source: DWA

7.4.3 Planning studies – wetlands

Several Reserve assessments for wetlands have been completed as part of bigger catchment studies at the same time as the river, estuary and groundwater studies (Table 7.3). Smaller scale EWR studies are also undertaken for specific wetland systems, but these are usually in response to specific licence applications to use those ecosystems (Section 7.6).

7.4.4 Use of the Reserve assessments in planning studies

Initially, the decision on an Ecological Reserve for a surface water system was guided by an RDM precautionary approach. This specified that no water resource should deteriorate below its present condition and if that present condition is unacceptable (with no clarity on whom it should be unacceptable to because of the absence of formal classification of water resources) then it should be enhanced.

This approach was often challenged by some of DWA's senior managers, whom may not have understood the intention of the RDM to promote truly sustainable use of the systems and instead voiced their concern that it would prevent or slow down development.

A more considered and wide-ranging approach has gradually evolved, along with the move to multi-scenario Reserve assessments. The first step, based on the findings of the scientific activities (Table 7.3 and 7.5) and the completion of the Reserve template (Section 4.3.2.5), is approval of a Preliminary Reserve for the various parts of the catchment, and the corresponding flow regimes and RQOs. This approval is given by the designated authority , which originally was the Director-General of DWA and now is the Chief Director of the CD:RDM in consultation with CD:IWRP; in other words, the water resource protection and the water resource management chief directorates liaise on this decision.

Table 7.5 Comprehensive (C), Intermediate (I) and Rapid (R) Ecological Reserve studies for estuaries completed since 1998.

Water Management Area (WMA)	Estuary	Assessment level	Date completed
6. Usutu to Mhlatuze	Siyaya	R	2007
	St Lucia	R	2004
7. Thukela	Thukela	I	2004
11. Mvoti to Umzimkulu	Little Amazintoti	R	2011
	Mbokedeweni	R	2011
	Mhlanga	R	2003
	Mdloti	I	2007
	Tongati	I	2007
	Mzimkulu	R	2011
12. Mzimvubu to Keiskamma	Nahoon	I	2000
14. Lower Orange	Orange	R	2003
15. Fish to Tsitsikamma	Tsitsikamma	R	2003
	Kromme	C	2006
	Seekoei	R	2006
	Sundays	I	2008
	Bushmans	R	2010
	Kleinemond Oos	I	2008
16. Gouritz	Groot Brak	I	2008
	Swartvlei	R	2008
	Goukamma	R	2008
	Knysna	I	2008
	Keurbooms	R	2008
	Matjies	I	2007
	Sout (Oos)	I	2007
17. Olifants Doorn	Olifants	C	2006
18. Breede	Breede	I	2004
	Palmiet	R	2010
	Bot	R	2011
19. Berg	Berg	C	2010

Until recently, the resulting catchment-wide configuration of Preliminary Ecological Reserves was an internal DWA decision based on limited stakeholder consultation, supported by a comprehensive report (Table 7.6) describing the process followed and the conclusions reached. In an emerging IWRM approach, stakeholders are increasingly involved as explained in Section 7.3.7. The approach will be further formalised with application of the newly promulgated Water Resource Classification System.

Once the configuration of Preliminary Reserves has been approved, the ecological and basic human needs water requirements are legally binding and must be factored into the planning scenarios being conducted by CD: IWRP.

In terms of the Promotion of Access to Information Act (Act 2 of 2000), the CD:RDM is preparing to store all approved Reserve determination reports on the DWA intra-website once its re-design is complete.

Table 7.6 Example of the kinds of ecosystem information provided as part of the Reserve determinations: in this case for the Olifants-Doorn River system in 2008.

Tertiary catchment	Quaternary catchment	Level of confidence	EWR (%)	REC	PES	EIS
E10	E10A	Low	13.58	D – largely modified	C – moderately modified	High
	E10B	Med/Low	21.24	B – largely natural	C – moderately modified	High
	E10C	Med/Low	39.48	B – largely natural	B – largely natural	Very high
	E10D	Med/Low	13.56	D – largely modified	C – moderately modified	Moderate
	E10E/F	High	26.66	D – largely modified	D – largely modified	Moderate
	E10G	Med/Low	14.99	C – moderately modified	D – largely modified	Moderate
	E10H	Med/Low	21.25	C – moderately modified	C – moderately modified	Moderate
	E10J	Low	13.69	D – largely modified	D – largely modified	Moderate
	E10K	High	43.47	B – largely natural	B – largely natural	Moderate
E21	E21A	Low	12.47	D – largely modified	E/F not acceptable	Low
	E21B	Low	19.36	C – moderately modified	E/F not acceptable	Low
	E21C	Low	19.35	C – moderately modified	E/F not acceptable	Low
	E21D	Low	12.47	D – largely modified	E/F not acceptable	Low
	E21E	Low	19.42	C – moderately modified	B – largely natural	Low
	E21F	Low	21.24	C – moderately modified	B – largely natural	Low
	E21G	Low	20.35	C – moderately modified	B – largely natural	Low
	E21H/J	High	43.76	B/C largely natural – moderately modified	B/C largely natural – moderately modified	Low
	E21K/L	Low	19.79	C – moderately modified	C – moderately modified	Low

EWR% = percent of the natural Mean Annual Runoff recommended to maintain the recommended ecological category.
REC = Recommended Ecological Category; PES = Present Ecological State; EIS = Ecological Importance and Sensitivity rating

7.5 Progress with RDM for groundwater in the context of national planning

Water used within South Africa currently comprises 77% from surface waters, 15% from return flows and 8% from groundwater. In the long term, surface water will remain the dominant water source but DWA expects a reduction in the dependence on this source accompanied by a potential increased use of groundwater. This will be especially important in rural areas where there is a dire need to explore the potential for groundwater to ensure more and better access to water for basic human needs without the need to wait for costly infrastructure to supply it from distant surface waters.

The expected increased reliance on groundwater has placed Reserve determinations for groundwater systems in the spotlight, to support the necessary strategic planning decisions (Table 7.7). These may be done as part of surface water Reserve determinations if the potential contribution of groundwater to surface waters was identified as important during the scoping phase, but they are also increasingly being done independently in response to a growing number of groundwater license applications (Section 7.6).

An emerging trend is that GRDM assessments are being undertaken at the scale of Water Management Area, or primary or secondary catchment (as opposed to quaternary catchment), because an aquifer and/or groundwater resource unit may cover more than one quaternary or have different boundaries than the surface water systems.

Some recent GRDM assessments have included in excess of 200 quaternary catchments and are, in effect, no more than Rapid level assessments. Such exercises illustrate the reality of insufficient groundwater expertise, unreliable groundwater data for management purposes and limited funding to address groundwater related problems in a more holistic and proactive manner [3].

Results are provided as recommended Management Classes, Reserves and RQOs (Section 6.4.6), with the same process of approval then followed as for surface water Reserve assessments (Section 7.4.4).

Table 7.7 Summary of groundwater Reserve determinations to December 2010 for planning purposes.

WMA	Catchment	Assessment level	Responsible Directorate	Date to completion	Date approved by CD:RDM	Percent area of WMA covered
4. Olifants		I	RR	2009	2009	100
5. Inkomati		R	RR	2009	2011	100
6. Usutu to Mhlatuze	St Lucia	I	RR	2009	2009	100
7. Thukela		I	RR	2009	2009	100
8. Upper Vaal		I	RR	2011	-	100
9. Middle Vaal		I	RR	2011	-	100
10. Lower Vaal		R	RR	2010	2011	100
16. Gouritz	Outeniqua Coastal area	R	RR		2011	100

R = Rapid; I =Intermediate; RR = Reserve Requirements Directorate within CD:RDM

7.6 Water use licence applications: a new need for Reserve determinations

Until 1994, water allocation to support the various economic sectors, such as municipalities, industry, agriculture, hydropower and recreation, was done without formal consideration of the role of water in maintaining ecosystem health. Since the promulgation of the NWA, the attention of the CD:RDM's staff, in addition to its work linked to national planning, has also turned to another major issue – the entirely new requirement to set a Reserve prior to the approval of any water use licence or the transfer of any water use authorisation. Some water uses (Schedule 1, existing lawful use and general authorisations – Chapter 3), although registered by DWA, do not need a licence. All other uses require a water use license.

The system for issuing such licences was cumbersome, as illustrated by the water use licence application (WULA) procedure used up to 2010 (Appendix 7.1), and recently superseded by the process now linked to Letsema (Section 7.6.2). The procedure for Reserve determinations was equally complex (Appendix 7.2) but has now been simplified (Appendix 7.3). Bringing the two together, five basic steps are now taken for each WULA that would substantially impact a water resource. The WULA could be for abstracting water, diverting water, releasing effluents into a water course or modifying the banks of the water course, and will be for a limited area.

7.6.1 The five steps

7.6.1.1 Step 1

The WULA is received by the relevant DWA Regional Office and checked for completeness. The current availability and allocation of water in the region of interest is then considered using ISPs – DWA's forerunners to catchment management plans. If present water demand exceeds availability, a water resource management plan should be drawn up by the Regional Office to highlight the need for intervention through compulsory licensing. If sufficient water is available for further allocations to be made then, first, the Reserve must be ensured because it enjoys priority of use and, second, other criteria such as equity and redress must be considered as prescribed in S. 27(b) of the NWA[f]. Because of the Reserve requirement, the Regional Office first checks if a Reserve determination has already been done for the area of interest and, if it has not, applies to CD:RDM for this to be done, supplying appropriate background information and the relevant WULA. Where the necessary skills exist, the Regional Offices may conduct Reserve determinations themselves with support from CD:RDM although to date these have tended to be restricted to Desktop level Reserves. In all cases, CD:RDM makes the final decision as to who will complete the Reserve determination and what the recommended EWR will be.

7.6.1.2 Step 2

Upon receipt of the WULA from the DWA Regional Office, CD: RDM determines the level of Reserve determination that should be done and also checks if one has already been completed for the area of interest. If it has, then this is assessed to ensure it was done at an appropriate level and to add more conditions and recommendations where necessary. If no Reserve exists for that area then, for proposed small water uses with an expected low impact in unstressed systems, a Desktop assessment is completed by CD:RDM and the completed RDM template forwarded to the designated authority[g] to be considered for approval. Conversion of the quaternary value the Desktop Model produces into the required Reserve value at the location of the WULA may be done using linear scaling or an approach that has been developed for estimating the hydrological characteristics of small catchments [4]. For proposed larger water uses, or in stressed catchments, CD:RDM completes a higher confidence Reserve determination.

Whether from a new Reserve determination or a re-visited one, the outputted Recommended Ecological Category from CD:RDM is discussed with key decision-makers within DWA (i.e. CD:IWRP, CD: Water Use and CD: Water Resources Information Management) prior to a final decision on, and thus approval of, the Preliminary Reserve by the Chief Director RDM[h]. The decision on the Reserve and the attached conditions (RQOs) are forwarded to the relevant Regional Office with copies to other key sections at DWA Head Office such as CD:IWRP and CD:Water Use.

[f] *S. 27(b) of the NWA states that in issuing a license, a responsible authority must take into account all relevant factors including the need to redress the results of past racial and gender discrimination*

[g] *Designated authority: Although this could be either the DWA Director General or the Chief Director of RDM, it is assumed here for simplicity that it is the latter unless stated otherwise.*

[h] *This decision is based on the best available data and knowledge of the water balance of the catchment*

7.6.1.3 Step 3

With a Preliminary Reserve approved, the WULA itself now moves toward a decision. The draft licence forwarded to the CD:Water Use by the DWA Regional Office, together with the approved Preliminary Reserve, RQOs and other conditions, is considered by the Water Use Assessment, Adjudication and Advisory Committee (WUAAAC). WUAAAC makes a recommendation on the licence to the CD: Water Use, who makes a final decision to approve or reject the licence.

Interestingly, of the licence applications rejected at this stage, most are not because there is no water available to allocate but because they do not comply with section 27(b) of the NWA (Stephen Mallory pers. comm.), which states that in issuing a license, a responsible authority must take into account all relevant factors including the need to redress the results of past racial and gender discrimination.

7.6.1.4 Step 4

Upon receiving the decision on a license, the relevant Regional Office informs the WULA applicant. An approved license issued by the Regional Office would typically specify the following: the approved Reserve; specific conditions, including any other relevant RQOs; when and how much water the user may abstract; and the conditions under which restrictions will be imposed to ensure sustainable use of the water resource. These specifications remain a challenge: some tools to help address them have been developed [5,6], but the Regional Offices do not necessarily have the full suite of tools or the necessary technical capacity to help them decide what to monitor or when to enforce restrictions.

7.6.1.5 Step 5

The DWA Regional Office also has the responsibility for ensuring that compliance monitoring takes place, and enforcing non-compliance. In this it has the support of two Directorates: RDM Compliance within CD:RDM and Compliance Monitoring and Enforcement within CD:Regulation. Monitoring also plays a vital role in adaptive management, providing the data upon which to decide if management strategies need to change. In terms of monitoring the Reserve and RQOs, this step has yet to become a reality.

7.6.2 Intervention by DWA to eliminate the WULA backlogs

The complexity of the licensing process, combined with DWA's weak capacity to deal with it and the users' weak ability to follow the guidelines when making their applications, has resulted in an ever-growing backlog of WULAs. At times this backlog has reached several thousand WULAs, with applicants waiting up to a year or even two for a decision to be reached. DWA has employed several strategies to deal with the backlog, including the recent Letsema ('working together') project established in October 2009.

Run by a section within CD: Water Use, Letsema is not without its own challenges but as at 31 March 2011 had finalised 612 WULAs in the preceding year. Added to this, 1843 water use licenses were issued and 47 rejected under the NWA prior to the Letsema initiative. All 2455 of these water use licences had some level of Reserve input as part of the water use licensing process, a significant work load for CD:RDM in addition to the Reserve determinations also being done as a contribution to national planning.

The backlog remains a moving target, with WULAs constantly being received and considerable pressure to fast track applications. To meet this challenge, Letsema seems set to become a permanent feature of DWA, with a recent expanded mandate to assume the role of WUAAAC for all backlogged and future WULAs.

Letsema has created immense awareness and understanding within DWA of the complexity of work being done by CD:RDM and the resources required for the latter to meet its brief. At present, CD:RDM has a modest though growing budget (Section 7.10), which is nevertheless low compared to those of other chief directorates in the same DWA branch (i.e. Policy and Regulation) and especially so as water resource protection is one of the key mandates of DWA (NWA Chapter 3).

Letsema and the general revised RDM and WULA approaches are a step in the right direction, but there is room for improvement and a more pro-active, coherent, integrated and streamlined approach is essential. This topic is revisited in Chapter 8.

7.6.3 Conclusion

Some WULAs do not need a Reserve assessment (e.g. pipelines that discharge into the sea, a proposed water use that will alter the banks, alteration of the channel or alteration for recreational use) and yet all of these have in the past been placed in the RDM queue. To ease this load, activities that have a low impact on water quantity and quality have been diverted into general authorisations (Section 3.3.3) since 2003, where they should be managed through conditions set with the authorisation. In reality the general authorisations do not distinguish between sensitive aquatic ecosystems that should be protected and those water ecosystems that are very resilient or have a very low ecological importance, and so the move has relieved the pressure in the licencing queue but not necessarily been a positive move forward in terms of resource protection.

For those WULAs requiring a Reserve determination, the activities described above have allowed DWA, to some extent and until catchment-scale compulsory licensing is in place, to progressively meet the requirements of the NWA through a phased implementation of the Reserve. There are drawbacks, however, to dealing with new water use applications in this way. The Reserves so set are for relatively small geographic areas – a river reach, or perhaps a small portion of a quaternary catchment – and, in the absence of the formal framework of knowledge and understanding provided by a catchment-scale assessment, it is difficult to assess and properly take into account the cumulative impacts of a large number of water licences on aquatic ecosystem functioning or indeed on other downstream licence holders. This is exacerbated by the fact that countrywide almost all existing abstractions have not been verified and so the overall availability of water and the overall impact of the new licenses cannot be assessed.

Such Reserves are also set with due consideration of existing lawful uses of water (an interim measure under the NWA – Section 3.3.3) that may not have been subject to any kind of environmental assessment. Some of these latter water allocations, perhaps many, could quite possibly be reduced in a catchment-wide classification and compulsory licencing exercise. Until then, some Preliminary Reserves could favour existing lawful uses over potentially equally beneficial new uses as well as potentially perpetuating a piecemeal over-allocation of resources to the detriment of aquatic ecosystem health. In this regard, it is still early days to judge how well, or if, Letsema is supporting sustainable use of water, whether or not it is contributing meaningfully to well-managed aquatic ecosystems or how it will engage with the water resource classification and compulsory licensing processes as these gain momentum (Section 7.3).

Delays in processing WULAs are most keenly felt by the aspirant users. Departmental processes for dealing with licence applications can become a source of great frustration to them if an unreasonable period of time elapses between submitting the application and achieving a decision[i]. There is a real danger, if delays are unacceptably long, that prospective users will simply decide to use the water without authorisation, thereby adding to DWA's burden of compliance monitoring and enforcement.

7.7 Geographical coverage of completed Reserve determinations

7.7.1 Surface water Reserve determinations

In order to meet the various demands, surface water Reserve determinations for 1194 sites were finalised by CD:RDM between October 1999 to December 2010[i]. This number includes water-use applications for all 11 water uses, from rivers, wetlands and estuaries (Table 7.8 and Figure 7.3). Due to budgetary, time and capacity constraints, 765 of the assessments done were of low confidence using the Desktop Model, usually in response to WULAs. The 193 Intermediate and Comprehensive Reserve assessments were mostly done as a contribution to catchment reconciliation strategies. At the end of 2010, 43% of the total area of the country had had some kind of Reserve determination; this is somewhat of an overestimate as it refers to the area of quaternary catchments in which Reserve determinations were done although some determinations may not have covered complete quaternaries.

[i] Time periods specified in legislation for environmental authorities to respond to applications for environmental authorisation vary depending on the nature of the application, but the time period that the authorities "must strive to meet" in respect of communicating a decision on a full EIA, if all is found to be in order, is 60 days from the date of receipt (section 35, NEMA Regulations, GN R385, April 2006). No such time frames are specified in the NWA for dealing with applications for a licence to use water.

[i] This number had risen to 1467 by June 2011

Table 7.8 Number of sites for which surface water Reserve determinations were completed: Oct 1999 to Dec 2010.

WMA	Desktop	Rapid	Intermediate	Comprehensive	Total	Percent area of WMA covered
1. Limpopo	26	1	0	0	27	45
2. Luvuvhu & Letaba	23	2	0	19	44	56
3. Crocodile West	29	4	1	0	34	53
4. Olifants	49	2	1	17	69	44
5. Inkomati	46	16	12	13	87	66
6. Usuthu	88	12	1	4	105	79
7. Thukela	41	19	1	16	77	63
8. Upper Vaal	48	21	0	0	69	56
9. Middle Vaal	17	6	0	0	23	52
10. Lower Vaal	12	4	0	0	16	28
11. Mvoti	87	17	5	0	109	86
12. Mzimvubu	134	30	9	0	173	66
13. Upper Orange	49	16	0	0	65	54
14. Lower Orange	28	7	0	0	35	16
15. Fish	46	16	8	1	71	22
16. Gouritz	16	29	2	0	47	22
17. Olifants/Doring	4	11	0	72	87	84
18. Breede	16	3	8	0	27	41
19. Berg	6	20	2	1	29	78
SUB TOTAL	765	236	50	143	1194	43
Awaiting approval*						
1. Mokolo River		9	5			
3. Crocodile West River		3	8			
3. Groot Marico River		1	5			
5. Crocodile East River			7			
5. Sabie Sand River			8			
8-10. Vaal River				19		
13-14. Orange River			8			
16. Outeniqwa River	13	9	10			
SUB TOTAL	13	22	51	19	105	0
TOTAL	778	258	101	162	1299	

* Reserves in approval process

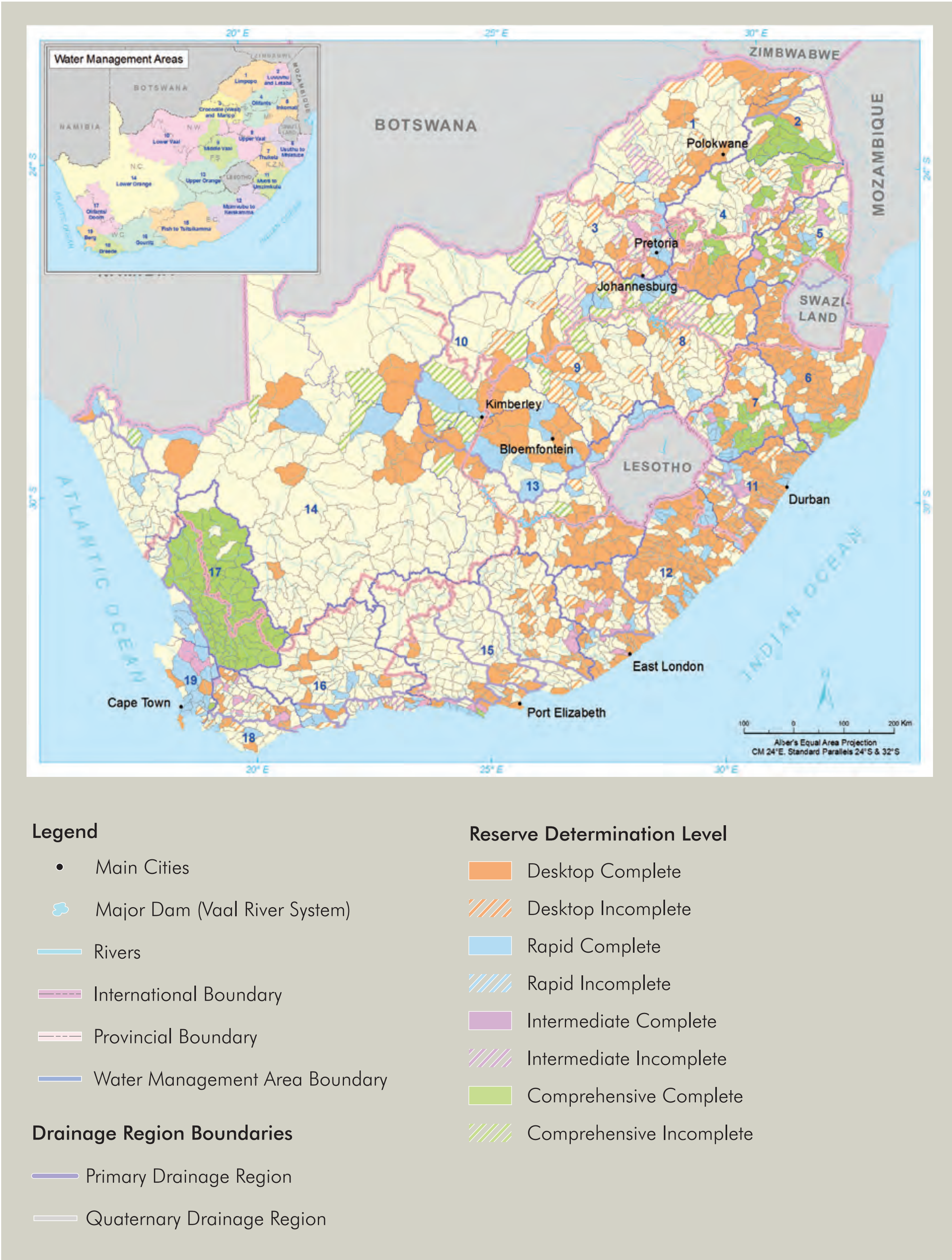


Figure 7.3 Geographical coverage of surface water Reserves completed as at December 2010.

Janine Adams

Wavecrest, the combined mouth of the Ngqusi and Nxaxo estuaries, is a small open estuary with mangroves on the east coast. It is a priority estuary because of its geographical location, but has not had a Reserve determination done to date.

7.7.2 Groundwater Reserve determinations

From October 1999 to December 2010, 485 requests for groundwater Reserve determinations were finalised by CD:RDM (Table 7.9), covering 59% of the country (Figure 7.4)[k].

Table 7.9 Number of sites for which groundwater Reserve determinations were completed: Oct 1999 to Dec 2010.

WMA	Desktop	Rapid	Intermediate	Comprehensive	Total	Percent area of WMA covered
1. Limpopo	46	0	1*	0	47	100
2. Luvuvhu & Letaba	36	1	0	0	37	88
3. Crocodile West	33	0	0	1#	34	69
4. Olifants	37	0	1	0	38	100
5. Inkomati	21	0	1	0	22	100
6. Usuthu	15	0	1	0	16	100
7. Thukela	9	0	1	0	10	100
8. Upper Vaal	31	0	0	1#	32	100
9. Middle Vaal	19	0	0	1#	20	100
10. Lower Vaal	33	1	0	0	34	94
11. Mvoti	11	0	1*	0	12	100
12. Mzimvubu	36	0	1*	0	37	100
13. Upper Orange	32	0	0	0	32	39
14. Lower Orange	13	0	0	0	13	11
15. Fish	36	0	0	0	36	17
16. Gouritz	23	0	0	0	23	20
17. Olifants/Doorn	11	1	0	0	12	22
18. Breede	13	1	0	0	14	25
19. Berg	16	0	0	0	16	83
TOTAL	471	4	6	0	485	59

* Intermediate determinations in progress # Comprehensive determinations in progress

[k] *This number had risen to 1306 by June 2011.*

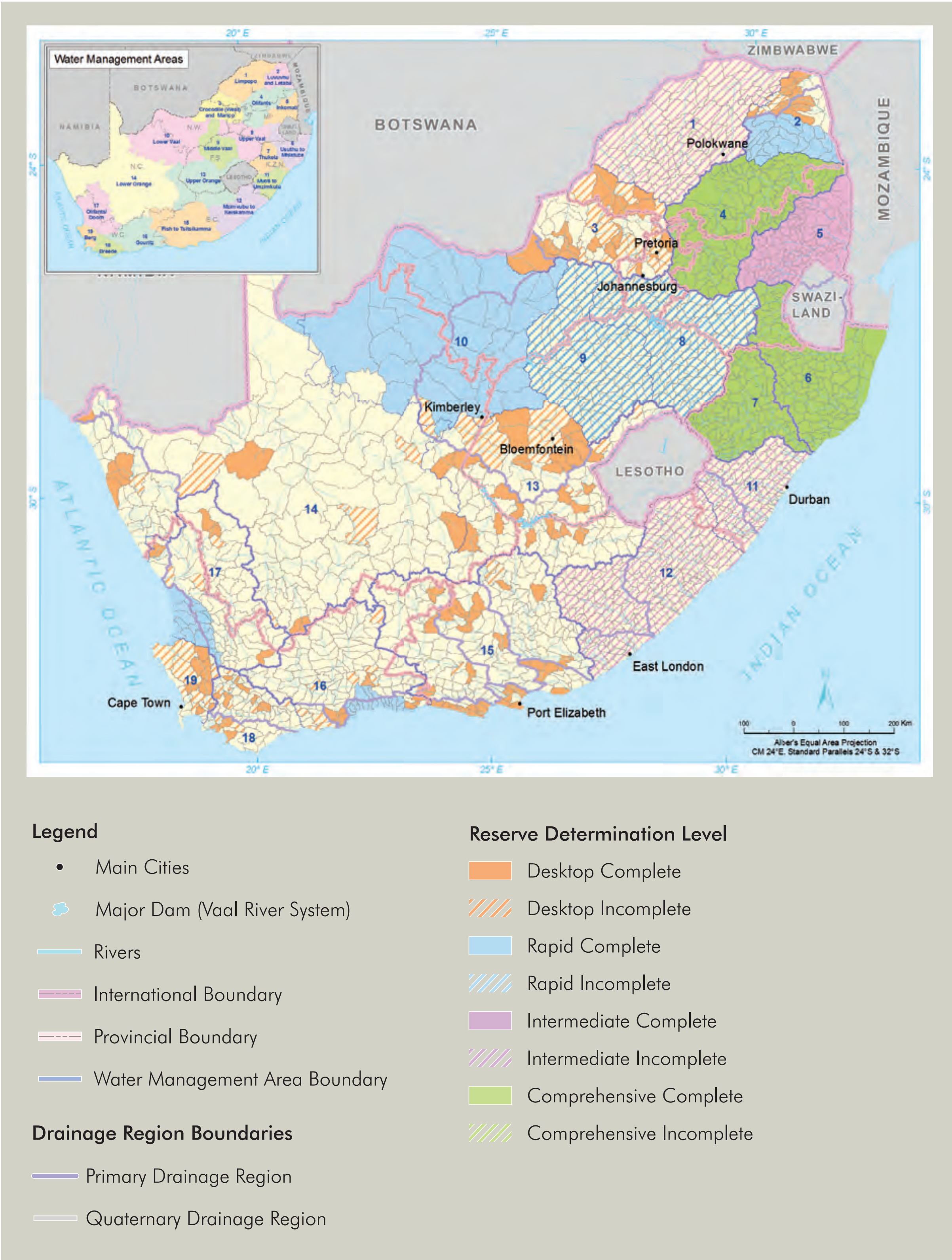


Figure 7.4 Geographical coverage of groundwater Reserves completed as at December 2010.

7.8 Operationalisation

During the Water Law Review process it was acknowledged that implementation of the NWA would be neither quick nor easy; worthwhile endeavours of this magnitude seldom are.

The time required for its full implementation, through organisational changes, the development of technical skills and arrangements to ensure that the required amount of water would be in the right places at the right times, was generally reckoned to be around 15 to 20 years.

Although the NWA would benefit from a systematic review – some of its provisions could be made clearer, and some of its administrative processes simpler – it is theoretically possible to implement it, largely in its present form, within the timeframes anticipated when it was written. But in reality is this possible? Does the country have the capacity to achieve it?

This section assesses what is happening to move past the planning and licensing phases to making RDM work on the ground. Major challenges emerging for operationalisation fall into six main categories, expanded upon in the following sections.

1) Water resource classification: in consultation, setting a configuration of Management Classes, Reserves and RQOs into place for all major catchments.

2) Interpreting Reserve templates for rivers: accepting that the Reserve is expressed as a percentage of natural flow, ascertaining what that amount, and thus the Reserve, should be for any one place and time.

3) Releasing Reserve flows from dams: ensuring that dam releases help meet downstream Reserves.

4) Monitoring and enforcing Reserve flows: ensuring that the right amount of water is present in the right place at the right time.

5) Systematic development, updating and refinement of RDM methodologies.

6) The integration of groundwater and surface water Reserves.

All of these challenges are intimately linked to the paucity of skilled people available to do the work, an issue that is addressed in Section 7.9.

7.8.1 Water resource classification

With the recent promulgation of the WRCS, the classification of significant water resources has begun, although certain elements of classification have been included in at least 27 high-confidence Preliminary Reserve determinations already completed and now holding legal status (Box 7.1).

Five WMAs were identified by CD:RDM in late 2010 as pilot areas for formal classification; in each WMA the exercise will take about two years.

- The Western Cape Olifants/Doorn WMA (Figure 4.3), because a high confidence Reserve determination was in place that would allow classification to be fast tracked.

- The Mpumalanga Olifants WMA, in synchronisation with the catchment reconciliation strategy being done by CD:IWRP.

- The Vaal system (Upper-, Middle-, and Lower Vaal WMAs), which is an over-stressed catchment feeding the industrial heart of South Africa, in synchronisation with the catchment reconciliation strategy being done by CD:IWRP.

Jackie King

Amanda Driver of SANBI (left), one of the lead developers of the Freshwater Ecosystem Priority Areas, and Shane Naidoo, Director of Water Resource Classification at CD:RDM, at the Olifants-Doorn Project Steering Committee meeting in May 2011.

In the process, for each catchment, the required catchment-based hydrological modelling will be done, the water availability and economic, social and ecological implications of water management options assessed in a series of scenarios, and the future state for the WMA and its aquatic systems discussed with stakeholders.

The Management Classes, Reserves and RQOs will emanate from this, ultimately forming part of the catchment management strategy. Current approved Preliminary Reserves will be incorporated into the exercise where appropriate but, as most of these were done for the mainstem river they cannot be extrapolated to tributaries, which is where most water-use license applications tend to originate.

The catchment management strategy will outline the monitoring, auditing and corrective actions and interventions required to manage the system according to its selected Management Classes. These could include compulsory licensing tariff adjustments (Water Allocation Reform or WAR[i]), water conservation and water demand management.

Institutionalisation of the above through the establishment of the relevant CMAs is urgently needed, in order to ensure effective water management. This will define the various roles and responsibilities, help ensure that the required capacity and funding are made available, and involve the stakeholders in the management of their water resources. Agriculture, conservation, industry, urban areas, local authorities and other sectors will be represented through forums, the Water Users Associations and the CMA boards, and public-private partnerships will re-instate co-operative governance structures so that managing the nation's water becomes a shared responsibility and not only a DWA responsibility.

Bruce Paxton

The Clanwilliam yellowfish *Labeobarbus capensis* is a large migratory fish species endemic to the Olifants-Doring river system. Its conservation status is vulnerable due to loss of habitat, blockage of its migratory route by dams and changes in the river's flow regime.

[i] *Most of the entitlement to water resources in South Africa sits with historically advantaged persons and groups. In many cases these entitlements are in the form of water rights and not water use licenses. As a response to the imperative of allocating water to historically disadvantaged persons and for accelerating economic growth, DWA's water allocation reform (WAR) programme employs all permissible water use instruments (i.e. schedule 1, existing lawful use, general authorisation and water use licensing) to achieve equitable, efficient, fair and sustainable use of water across all sectors.*

Jackie King

The water resource classification exercise for the Olifants Doorn WMA will include consideration of potential modifications to the design and operation of Clanwilliam Dam

Box 7.1 An early example of water resource classification done before promulgation of the Water Resource Classification System: the Breede Overberg catchment management strategy

The Breede-Overberg Catchment Management Agency (BOCMA) is one of the first two CMAs created. As required by the NWA, in 2010 it developed a catchment management strategy for the Breede Water Management Area (WMA 18). One of the early requisites for this was to decide on the volume and timing of water that should be allocated to the Ecological Reserve, so that the water available for other uses could be established.

Working ahead of the formal water resource classifications now being initiated by DWA, and not being one of the catchments chosen for this exercise, it adapted the approach described in the Water Resource Classification System (Section 4.4) to meet its time (< 6 months) and budget constraints. The investigation focused on the Breede River Basin within WMA 18, as a Comprehensive Reserve assessment had been completed in 2001 [7].

In summary, the process adopted was:

1. Delineation of the basin into broadly similar ecological units, with similar land use.

2. Assessment of the present (2009) ecological status of individual rivers within each ecological unit and for the units as a whole, in order to guide the future choice of scenarios and the discussions with stakeholders.

3. Comparison with ecological status assessments from 1999, for the same reason.

4. Development of three future scenarios of ecological condition with a 10-year horizon, for consideration by stakeholders:

    i. Scenario 1 Business as Usual: Estimated condition if activities that had led to the changes between 1999 and 2009 continued unabated;

    ii. Scenario 2 Midway. All rivers in their 2009 condition, unless that condition was less than a D-category, in which case those rivers would be improved to a D-category;

    iii. Scenario 3 Restoration. All rivers that had deteriorated between 1999 and 2009 restored to their 1999 condition, except for the Buffeljags River, which would be restored a further category higher to a B-category, as recommended by DWA [8].

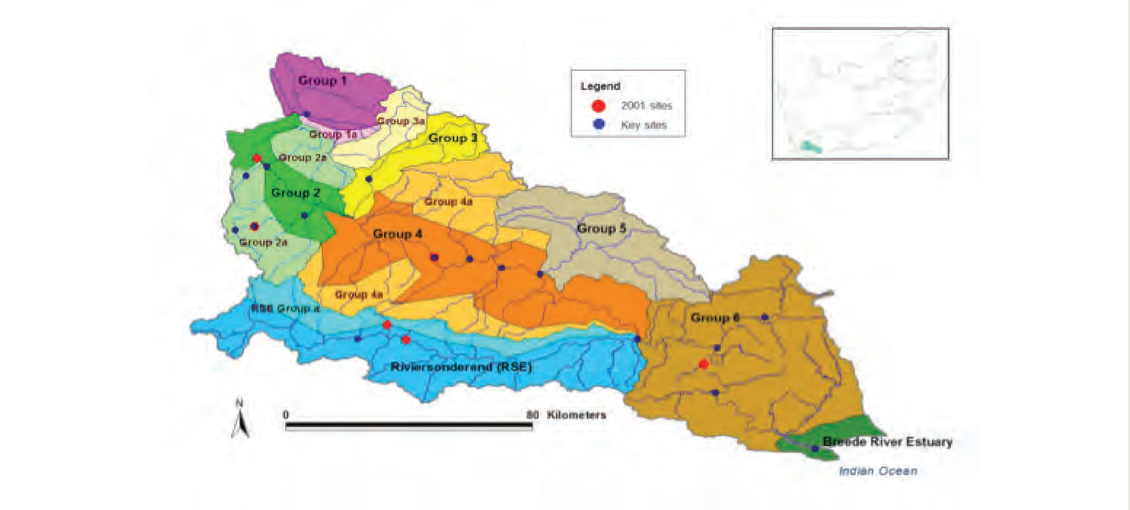
5. Extrapolation of existing information on Ecological Water Requirements (EWR) from the six sites used in the 2001 study, to provide an estimate of the EWRs needed to maintain a greater number of key sites in the ecological state represented in each scenario. The 14 key sites, situated on rivers close to DWA streamflow gauging weirs, had up-to-date hydrological information; each was linked to one of the original EWR sites. The EWR extrapolation to these key sites made it possible to provide coarse-level water balances for different parts of the basin for each scenario, which were used to evaluate the impact of the EWRs on agricultural and urban water supply. The extrapolations were done using the Desktop Model (Chapter 4), which produced monthly flows at the extrapolated sites for each scenario that were in the same proportion as those at the corresponding 2001 sites.

6. Presentation of outputs to stakeholders of the predictions of future ecological status under each scenario and the EWRs to meet these, plus the coarse-level water balances for key parts of the catchment. Economic and social information was not formally included, although considerations such as water needed for equity distributions and the implications of reducing water supply to farmers formed part of the discussions.

7. Identification by stakeholders of their preferred future scenario.

8. Based on the above, compilation of Preliminary Reserve templates for submission to DWA.

Box 7.1 Continued...



The Breede River Basin, showing broadly similar ecological areas

Example of the assessment of ecological status of individual rivers in Group 2 (Upper Breede), showing the trend over ten years

Group	River	1999	2009
Group 2	Breede	D	D
	Smalblaar	C	D
	Hartbees	C	E
	Bothaspruit	C	D
	Wabooms	D	D
	Tierstel	C	D
	Holsloot	C	D
	Slanghoek	D	D
	Wit	D	C
Group 2a	Witels	B	B
	Krom	B	B
	Elands	B	B
	Hartbees	B	B
	Bothaspruit	B	B
	Wabooms	B	B
	Molenaars	C	B
	Tierstel	B	B
	Holsloot	B	B
	Slanghoek	B	B
	Wit	B	B

Box 7.1 Continued...

Overall ecological condition for ecological units in the Breede Basin in 1999 [8,9] and in 2009 [10]

Management Area	Group	1999	2009	Trajectory	Comments
Ceres Area	1	D	D	None	Limited clearing of invasive alien vegetation
	1a	C	B	Positive	
Upper Breede	2	C	D	Negative	Extensive clearing of invasive alien plants, but also over-abstraction and channelization of rivers
	2a	B	B	None	
Hex	3	D	D	None	Over-abstraction, channelisation of rivers, removal of indigenous riparian vegetation, invasion of alien vegetation
	3a	C	C	None	
Central Breede and Koo	4	C	D	Negative	Over-abstraction, manual manipulation of channels often with bulldozers, water quality (salinity – agricultural return flows)
	4a	B	B	None	
Montagu	5	C	E	Negative	Over-abstraction, channelisation of rivers, removal of indigenous riparian vegetation, invasion of alien vegetation
Tradouw/ Buffeljags	6	C	C	None	Channel incision, erosion of banks, alien vegetation, abstraction
Riviersonderend	RSE	C	D	Negative	Over-abstraction, manual manipulation of channels often with bulldozers, removal of indigenous riparian vegetation, invasion of alien vegetation
	RSEa	B	B	None	
Estuary	BrRest	B	B	Slightly negative	Low summer flows

At the stakeholder meetings, the implications, in terms of water supply for other sectors, were discussed for all three scenarios. It was recognized that adoption of Scenario 2 would mean there was little or no additional water available for future developments and that summer abstraction would need to be reduced in some parts of the basin. Nonetheless, there was unanimous agreement that it was unacceptable to allow the rivers to decline further, and Scenario 2 was chosen as the future scenario for the basin. This indicated that the stakeholders care about the natural systems on which their livelihoods depend, and may also have reflected the growing importance of ecotourism in the basin economy.

The EWR allocations for individual rivers for Scenario 2 were compiled in a Reserve Template and submitted to DWA for approval as the Preliminary Reserves for the Breede River Basin.

Box 7.1 Continued...

The estimated overall ecological condition (projected to 2020) of rivers in the Breede River under three scenarios

Management Area	Group	1999	2009	Scenario 1	Scenario 2	Scenario 3
Ceres Area	BrGr1	D	D	D	D	D
	BrGr1a	C	B	C	B	B
Upper Breede	BrGr2	C	D	C	D	C
	BrGr2a	B	B	C	B	B
Hex	BrGr3	D	D	D	D	D
	BrGr3a	C	C	C	C	C
Central Breede and Koo	BrGr4	C	D	D	D	C
	BrGr4a	B	B	C	B	B
Montagu	BrGr5	C	E	E	D	C
Tradouw/ Buffeljags	BrGr6	C	C	C	C	B
Riviersonderend	RSE	C	D	D	D	C
	RSEa	B	B	C	B	B
Estuary	BrRest	B	B	C	B	B

7.8.2 Interpreting Reserve templates

7.8.2.1 The surface water Reserve template for WULAs

The Reserve template used in water use licence applications describes the approved Reserve and recommends conditions that need to be included in the license. It includes two hydrological parts (Appendix 4.3), which are designed to inform on (a) the bulk amount of water encompassed in the Reserve and how much would be needed at different assurance levels, and (b) the means of transforming that information into flows that can be monitored and managed.

The first part expresses the Ecological Reserve in terms of maintenance low flows, maintenance high flows, drought low flows and drought flood flows, each as monthly percentages of the Mean Annual Runoff of the river at that point and as monthly volumes of water in millions of cubic metres of water. The figures thus describe volumes of water that can be used in water resource planning, and emphasise that the amount needed in the river varies through the year.

At best, Reserves described in this way tend to be incorporated into licence conditions as a single maintenance low-flow figure per month that represents the minimum flow that must pass the abstraction point of the user throughout the year (Stephen Mallory, pers. comm.) In some cases, the drought low flow is the single figure inserted into a licence, with the implication that the resource can be pulled down to permanent drought conditions. By definition, these are conditions that could not sustain the ecosystem: adult plants and animals might be able to survive for limited times but little or no recruitment would take place for most species and so the ecosystem would essentially change to one that was more degraded and presumably less acceptable. No Reserve flood flows are entered into the licence.

The single-figure monthly volumes can easily be converted to instantaneous flow in cubic metres per second but these do not satisfactorily adhere to the concept that Reserve flows should maintain flow variability by tracking the intra-month, inter-month and inter-annual flow variations that would happen under natural conditions. The second part of the Ecological Reserve template addresses this need by expressing the full Reserve requirement as monthly flow duration curves, each with an accompanying natural flow duration curve. Each flow duration curve contains a range of discharge values, with the highest flow shown on it probably being relevant only in natural wet years and the lowest in natural droughts. The Reserve flow on any day is calculated by ascertaining what the natural flow would have been on that day and reading off the equivalent percentile value on the Reserve flow duration curve. Though simple in concept, it is more complex to implement in real-time since it requires knowledge of the natural flow that would be occurring at any specific time and place. Techniques are being developed to estimate natural flow in real or near real time, as explained below.

Estimating natural low flows in real time to guide Reserve low-flow targets

There is usually no immediate information of what the natural flow would be at relevant points along a system. There are too few rainfall gauges transmitting real-time data and a paucity of appropriate hydrological systems models set up that could provide an insight into natural flows. Nevertheless, because Reserves are expressed – day by day and month by month – as a proportion of natural flow this information is vital for successful RDM operationalisation.

Perhaps the easiest method to estimate natural low flows is to select a representative catchment that is undeveloped and install a gauge to measure the flow. Since the catchment is in a natural condition, the measured runoff is natural; the percentile represented by that flow can be read off the flow duration curve and used to determine the flow needed in nearby catchments through a reversal of the process using their flow duration curves. This method was applied in the Sabie catchment [11], which has a mostly developed upper catchment. Releases from dams with undeveloped upstream catchments and thus natural runoff, however, can be based on simple measurements of inflow, as happens with the Berg River Dam (Section 7.8.3).

Another approach is to set up a real-time[m] hydrological model of the rainfall-runoff process. This was done in a WRC study [12] and in development of a framework for implementing the Reserve in four pilot catchments [13] (Box 7.2). A real-time rainfall runoff model requires real-time rainfall and this is a serious setback in South Africa due to the dearth of reliable real-time rain gauges. Where rainfall data do exist, these are usually made available a day later and so the Reserve so calculated will always be at least one day out of synchronisation, which is not a critical issue for low flows but could be for flood releases.

A third method, currently being used by the Inkomati Catchment Management Agency to implement the Reserve in the Crocodile River, is to estimate the natural flow in real time from observed flow and a good knowledge of water use in the catchment over the period influencing the flow at the point of observation [14] (Box 7.3). This method requires reliable real-time flow gauging and good information on water use in the catchment.

The limited success achieved in giving effect to the Reserve in the Groot Letaba and Crocodile catchments can be attributed to the presence of a champion, SANPARKS, driving the process and an active CMA. SANPARKS actively monitors flows entering the Kruger National Park and has a response system that is deployed if these flows seem to be less than those specified for the Reserve at any time. SANPARKS also carries out biological monitoring in the river reaches where Reserves have been set to ascertain the response of the riverine ecosystem to the implemented flow regime.

Estimating natural high flows in real time to guide Reserve flood targets

The three methods described above can help estimate the amount of low flow that should be present with a Reserve in place. Of them, only the first, which uses a real-time gauge, has been applied successfully to make flood releases from a dam for the Ecological Reserve (Section 7.8.3). The other methods operate on daily or weekly time-steps, which are not sufficient to guide appropriate flood releases because they provide data at too coarse a resolution or that become available too late. Also, larger catchments pose the challenge of synchronising flood releases from dams with floods occurring naturally in downstream tributaries. To achieve this would require a sophisticated network of real-time flow gauges linked with a real-time (hourly) hydrological model. This level of sophistication has not yet been attempted in South Africa.

[m] *Near real time data are transmitted from a measuring station to a webserver via satellite or gsm modem. The data can be viewed on a web page or downloaded by software applications. The data on the web page can be as recent as tens of minutes, depending on the upload frequency set on the transmitting device at the measuring station.*

Box 7.2 Delivering the Ecological Reserve in the Groot Letaba River

Giving effect to the Reserve in the Groot Letaba River catchment was initiated by CD:RDM through the study Development of a Framework to Operationalise the Reserve [13]. A near-real-time hydrology model was set up to estimate the natural flow at Reserve sites in the catchment. The model is driven by daily satellite rainfall data downloaded from the NOAH website. These natural flow data, together with data on the state of storage in the system, were used in a water resources model to develop generic monthly catchment operating rules that inform the catchment manager on the interventions required to meet the Reserve. Interventions could entail releases from the Tzaneen Dam and/or imposing restriction on irrigators.

The decisions made by the catchment operators are communicated to the irrigation board and the Kruger National Park. SANPARKS staff monitor flow and feed the information back to the catchment operators through a process of adaptive management.

Andrew Deacon

Andrew Deacon (seated) and Stan Rogers apply the RHAM (Rapid Habitat Assessment Method) in the Letaba River in 2010 during testing of the National Ecological Reserve Monitoring project spearheaded by DWA.

Box 7.3 Delivering the Ecological Reserve in the Crocodile River (East)

The high confidence Reserve determination done for the Crocodile River (East) is being used by the Crocodile River Operations Committee (CROC) of the Inkomati Catchment Management Agency in its operating rules and interactions with stakeholders. The lower reaches of this river form the southern boundary of the Kruger National Park, and a key requirement is to ensure that Reserve flows reach this part of the system. There is no real-time hydrological modelling for the river and so the approach relies on good measured flow data for the Reserve sites and a good knowledge (supported by a database) of water use and storage within the catchment.

The natural flow is estimated as the observed flow plus the estimated water use and the change in dam storage over the time period under consideration. With the natural flow estimated, the Reserve requirement can be read off the rule curve for the month in question. If the Reserve flows are not being met, the irrigation board imposes restrictions on users.

Referred to as Real-time Naturalisation, this exercise can be carried out at daily, weekly or monthly time intervals, with weekly or monthly time-steps seeming appropriate for this river. As with the Letaba River, KNP staff closely monitor flows for compliance. The process is well-managed through the Inkomati Catchment Management Agency, which chairs the Crocodile Operation Committee. This committee, in close consultation with key stakeholders, ensures that operational decisions are implemented.

Delana Louw

(l.to r.) Jackie Jay, Christa Thirion, Neels Kleynhans and Colleen Todd, all of DWA, sampling fish in the Lupelele River, a tributary of the Crocodile, in 2006 to enhance understanding of the flow requirements for very small rivers.

7.8.2.2 The groundwater Reserve template for WULAs

The groundwater RDM template (GRDM) breaks the determination process down into the following six steps, each of which has the same four sub-steps: Who, Purpose, How, Key Outcomes.

1. Project background and objectives.

2. Assessment of the study area.

3. Delineation of units: Integrated Unit of Analysis (IUAs) are the relatively homogeneous geographically based units of analysis, which, where possible, should coincide with quaternary catchments [15].

4. Resource classification: setting of the present Management Class.

5. Quantification of the Reserve: when setting the allocable portion, it is more important to focus on the water level that must be maintained to ensure that the Ecological Reserve is not compromised rather than on recharge, which is the current indicator of groundwater availability.

6. Setting Resource Quality Objectives: both Management Class and the Reserve are used to set RQOs that will ensure that the allocable portion is not exceeded and that system integrity is not compromised.

The steps apply to all levels of GRDM determination, with the main difference being the level of confidence attached to the RQOs that are set. There are several problems in interpreting the template.

1. The allocable portion of water. The amount given in the template applies to the whole catchment although groundwater is probably only used in a small part of it. The extent to which the allocable portion could be distributed unevenly within the aquifer is a function of many parameters and the local manager has to apply expert judgment to decide to what extent water can be allocated without compromising the goals set by RQOs.

2. The Stress Index (Box 6.3). This is of necessity conservative because it is based on inadequate data and because recharge (or rainfall) can vary dramatically from year to year. Until more accurate data are available to calculate average recharge, the percentages that the Stress Index allocates to each Management Class are adhered to as a precaution.

3. The current use of quaternary catchments to delineate IUAs. There is sometimes very little correlation between aquifer boundaries and quaternary catchment boundaries. The latter are used purely to ensure that the outcome of the groundwater study refers to the same geographical area as that of the surface water study, but they are of questionable relevance in managing the aquifer based on RQOs.

4. Lack of data. This makes it impossible to calculate the allocable portion of water accurately. In the long term this could be addressed by making the water user responsible for providing more accurate data. Users should be required to monitor their water resource and report water use and water levels to DWA on a regular basis, as a licensing condition (Chapter 8).

7.8.2.3 In summary

Management of the Ecological Reserve needs to be technically correct and done by adequately trained staff. The fact that some feel that the Reserve templates are impossible to understand and apply, while others feel that they are perfectly straight forward and present no difference in principle to the operating rules already in place for managers, indicates a wide chasm of miscommunication characterised by rejection of others' views, inappropriate or no training and understaffing, which needs urgent and sympathetic intervention. The methods and templates continue to evolve and are currently under review, but a more pro-active and focused programme of training needs to be done. This issue is re-visited in Chapter 8.

7.8.3 Reserve flows and dams

Reserve-type releases from dams already existed in some places ahead of the NWA. Pongolapoort Dam, for instance, has been releasing water into the Pongola River since the mid-1980s to support downstream floodplains and communities [16], although social conflicts and confusion about the purpose of the managed flows still persist (K. Rogers, University of the Witwatersrand, pers. comm.). The annual flood release may be mis-timed in terms of maintaining the downstream river ecosystem (D. Grobler, Blue Science pers. comm.). Wolwedans Dam on the Groot Brak River has been releasing water since 1990 to support the Groot Brak Estuary. Following promulgation of the NWA, the Berg River Dam was designed and is operated to release Reserve flows (Box 7.4).

Of the methods for estimating natural flow, only the first, which uses a real-time gauge, has been applied successfully to make flood releases from a dam for the Ecological Reserve. This requires very intense monitoring during flood events, down to an hourly time step, so that at any one time the precise proportion of the natural flood that was specified as the Reserve could be released.

An increasing number of other dams have been influenced by RDM in terms of design or operation. Information on this is scattered, and corporate memory within DWA is being lost, but there is progress (Table 7.10).

In a few instances environmental releases of some kind are being made without a formal Preliminary Reserve determination, perhaps because they were set before the NWA came into force or because of an urgent known ecological need (e.g. Clanwilliam Dam). In other cases, Preliminary Reserve determinations have been done but releases may not adhere to the agreed EWR because the water resources within the catchments are presently over-utilised. In these catchments, long-term water management plans to be set by the CMAs will gradually increase the volume of water allocated for ecosystem maintenance and so the Reserve will be met with time.

The main message from the table is that a considerable investment is being made in designing and operating dams that have fewer detrimental ecological impacts, but monitoring and enforcement of the agreed EWRs are still essentially non-existent.

Table 7.10 Examples of water resource infrastructure where design or operation has been influenced by RDM.

WMA and River	Structure	RDM Influence on design	RDM Influence on operations	Reserve compliance monitored
1. Luvhuvhu	Nandoni Dam	EWR was incorporated into design.	EWR was taken into account in releases from the dam.	No
1. Mokolo	Mokolo Dam	N/A	Operating rules have been adapted to improve delivery of the EWR. When the reservoir is below 50% full, the EWR releases continue but irrigation releases stop.	No
2. Groot Letaba	Tzaneen Dam	N/A	Time scales for operational planning have been reduced from monthly to daily.	No
4. Olifants (Steelpoort trib.)	De Hoop Dam	Outlet works designed to facilitate releases of high and low flows and allow fluctuations.	Under construction.	No
5. Sabie (Mariti trib.)	Inyaka Dam	Rudimentary EWR was incorporated into design.	This was the first dam in South Africa where a specific study was done beforehand to determine the EWR. A rudimentary methodology was used and the EWR was incorporated into the water allocation planning. The work has recently been reviewed to enhance the quality of the EWR to RDM standards.	No

Table 7.10 Continued...

5. Komati	Maguga Dam	EWR was incorporated into design.	South Africa and Swaziland share the water released from the dam. EWR was incorporated into the operating rules.	No
5. Komati (Lomati trib.)	Driekoppies Dam	Outlet works designed to facilitate releases of high and low flows and allow fluctuations.	Releases as per the agreed EWR have been incorporated into the operating rules.	No
6.Pongola	Pongo-lapoort Dam	Built before NWA.	EWR now taken into account, with annual flood releases to recharge pans. Where possible more than one flood per year is released to increase flow variability.	No
7. Thukela (Mooi trib.)	Spring Grove Dam	Outlet works designed to facilitate releases of high and low flows and allow fluctuations. Construction has begun.	Releases as per the agreed EWR have been incorporated into the operating rules.	No
11. Umgeni	Inanda Dam	N/A	Compensation flows are being reviewed to better accommodate the EWR.	No
11. Mdloti	Hazelmere Dam	Dam wall being raised (starting soon) to meet increased demand, including for the Reserve.	The EWR to meet the Recommended Ecological Category cannot be met at present, but a water resource management plan is being compiled with stakeholders to gradually make water available for the Reserve over the next few years.	No
11. Mhlanga estuary	Waste Water Treatment Works release	N/A	Too much water being released into the estuary and so, as per the EWR, that from the WWTW is now diverted via the Piesangs River to the large Umgeni River.	No
16. Groot Brak	Wolwedans Dam	N/A	One million cubic meters per annum being released as the EWR, but this is not an agreed Reserve flow and may not be adequate. This arrangement needs to be revisited.	No
17. Olifants (W. Cape)	Clanwilliam Dam	Raising of the dam is under consideration. The EWR is being catered for in the design.	Environmental flow releases are presently being made for fish as per a requirement from CapeNature, but no formal Reserve is yet in operation between the dam and Bulshoek Weir.	No

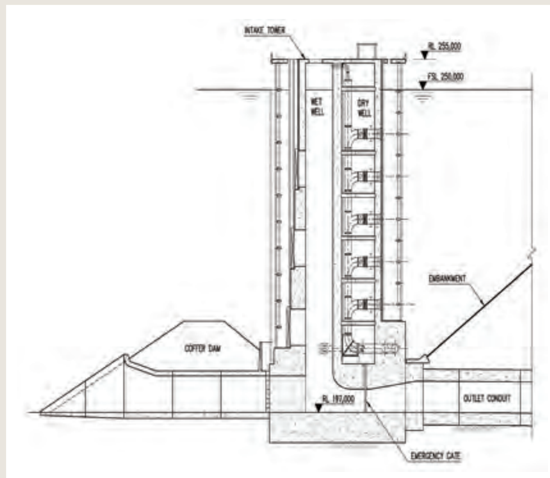
Box 7.4 The Berg River Dam, Water Management Area 19, Western Cape

It is predicted that Cape Town, in the Western Cape of South Africa, will be the first major metropolitan area in South Africa where water demand will exceed the available water supply. The final shortlist of options to increase water supply include water demand management, re-use of sewage effluent, removal of water-consuming alien vegetation, desalination of sea water and the construction of the Berg Water Project (BWP).

The BWP comprises the 65 m high, concrete-face-rock-fill Berg River Dam and a Supplement Scheme located 12 km downstream. The 1MAR dam is designed to capture and store winter runoff from the mountainous upper reaches of the Berg River catchment and transfer it to the existing Western Cape Water Supply System. The BWP contributes 81 million cubic metres of water, equivalent to 18% of the total bulk water storage of this supply system. The Supplement Scheme consists of a 1.6 m high diversion weir that will divert a portion of the winter high flows from three downstream tributaries into an off-channel balancing dam, from where the water will be pumped back into the Berg River Dam.

TCTA

The Berg River Dam under construction with (l. to r.) the rectangular flood release conduit, duplicated small and larger outlets at centre for Reserve and other low-flow releases, and the spillway



TCTA

In accordance with the NWA, the dam must release a pre-agreed Ecological Reserve of water for maintenance of the downstream river ecosystem. Completed in 2007, it has become the first large water resource infrastructure in South Africa designed, constructed and operated within the framework of the NWA and according to the guidelines of the World Commission on Dams. It is the first dam in South Africa designed specifically to allow delivery of Reserve flows for maintenance of the downstream river, and the first (perhaps internationally) designed to allow flood releases for that purpose. It is also the first bulk water resource development in South Africa that is directly linked to water demand management.

Following a Comprehensive Reserve assessment a Preliminary Reserve of 31,1% of the MAR (44,061 million cubic metres) was approved by DWA. This volume would be released as a sequence of high and low flows, guided by natural inflows to the reservoir and designed to maintain the downstream river in an ecological category C [17].

Low flow releases of 0.3-12 m^3/s are continuous, with the magnitude adjusted weekly as a proportion of natural inflows to the reservoir from the mountains. The proportion is guided by the duration curves in the Reserve template.

Flood releases are timed to synchronise with existing natural floods. Flood inflow to the reservoir is tracked until it reaches its peak, and then the shape of the flood hydrograph to be released is confirmed. Typically smaller flood releases begin about five hours after the peak inflow measurement has been confirmed. The yearly quota specified in the Reserve is for three floods of the following magnitudes:

Box 7.4 Continued...

1. Daily average peak 65 m^3/s: 3 days = 10,11 million m^3 (160 m^3/s instantaneous peak);

2. Daily average peak 30 m^3/s: 3 days = 4,67 million m^3;

3. Daily average peak 5 m^3/s: 3 days = 0,78 million m^3.

To allow for the releases, the north section of the intake tower is a dry shaft through which low flows are released *via* multilevel inlets (see drawing). The south section consists of a wet well, a concrete conduit through the dam wall, and control gates all specifically designed for Reserve flood releases. The radial arm gate system for flood flows is able to make releases of up to 200 m^3/s, purely for Reserve requirements.

The intake tower and outlet works were specifically designed to release Reserve flows of the appropriate quality and temperature as well as quantity. In the intake tower, a water quality monitoring system consisting of a probe and data logger at each inlet level provides automatic readings of temperature and conductivity. It can be set to provide instantaneous and timed-interval records. The water quality records from the upstream gauging weir and the tower are compared and releases are then made from the inlet level that has the closest readings to the upstream free-flowing water.

In summary, the special features of the dam are [17, 18, 19]:

- designed to be able to release both low and high Reserve flows for maintenance of the downstream river;
- sensors automatically record water quality at the inlet levels of the tower;
- a specially built gauging weir immediately upstream of the reservoir to continuously record incoming natural flows, with the hydrological data placed on DWA's website;
- a specially built gauging weir immediately downstream of the dam to continuously record dam release down the river, with the hydrological data placed on DWA's website;
- low flow Reserve flows adjusted weekly guided by incoming flows and record of adjustments kept;
- floods of up to 200 m^3/s, as specified by the Reserve, released in synchrony with natural floods.

Despite the above, and the development of a monitoring programme, the final vital step of actually applying this monitoring programme to ascertain whether or not the Reserve is being met is not taking place.

TCTA

The conduit used for flood releases

Barry Clark

Reserve (small outlet) and irrigation (larger outlet) water being released downstream during April 2011.

7.8.4 Monitoring and enforcing Reserve flows

The development of appropriate indicators, monitoring systems, reporting protocols, and guidelines for use of these in a process of adaptive water management, is DWA's responsibility.

At present, although some monitoring of water-use licences occurs, there is no formal RDM monitoring. Without it there will be no means of knowing if the agreed Management Classes are being maintained and so no assurance that the agreed level of protection is being sustained.

Four kinds of monitoring are needed.

- Water use compliance monitoring, which ensures that users comply with the conditions given in their licences.
- Channel flow and water quality compliance monitoring (some of the RQOs), which ascertains if the Reserve is being met (Boxes 7.5 and 7.6).
- Monitoring of water resource condition (the remaining RQOs), which will show if the ecological objectives are being achieved. The indicators will be different to those used in river health monitoring, but the same team within a DWA Regional Office could be trained to do both.
- Compliance with the operating rules by the dam operator.

Section 7.9.1 details the plans to develop this auditing function.

Gavin Snow

Participants in an estuary monitoring training workshop at the Kowie Estuary at the Port Alfred marina in 2009. Left to right: Vanashrie Govender (eThekwini Municipality), Gavin Snow (NMMU) and Siyanda Mzileni (DWA). RDM workshops include, as a final step, a list of thresholds of potential concern as well as a proposed long-term monitoring programme, which need to be understood by those who will implement them.


Johan Wentzel

Students from the Universities of Venda and Pretoria during a groundwater field trip sponsored by the FETWater programme.

7.8.5 Systematic development, updating and refinement of RDM methodologies

The RDM methods require refinement as experience grows with operationalisation. This is not presently being done in a controlled and structured way and updating tends to occur in an *ad hoc* fashion, to the confusion of many practitioners and of the RDM staff tasked with managing the RDM processes. This topic is re-visited in Chapter 8.

7.8.6 Integrating surface and groundwater in Reserve determinations

The proper integration of surface water Reserves and the groundwater component of Reserves remains a challenge for several reasons:

- geohydrology is a fairly new science
- there is a poor understanding of the contribution of groundwater to low flows in rivers and differences of opinion on how baseflow should be calculated
- the link between surface and groundwaters was recognised in a weak fashion in the first edition of the NWRS. This is being addressed in the current revision of the NWRS.

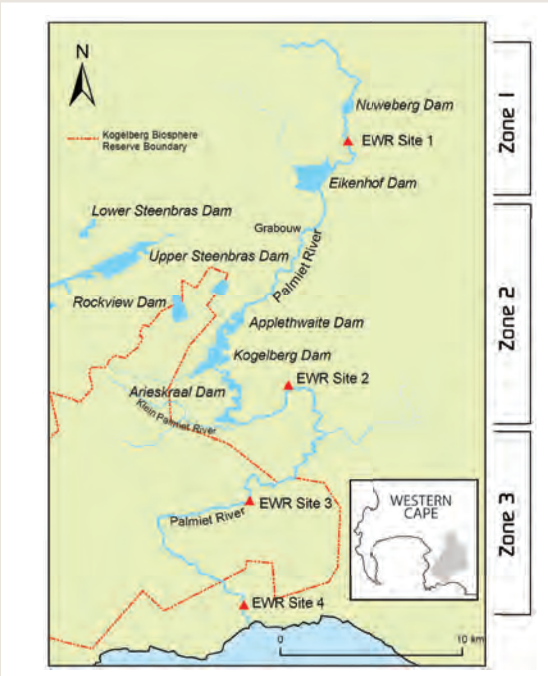
7.8.7 Summary of progress in operationalisation

Many diverse activities are unfolding, as momentum builds to operationalise RDM.

Experience in these early stages is providing a clearer picture of what is needed to synchronise effort. This topic is revisited in Chapter 8.

Box 7.5 Monitoring the Ecological Reserve on the Palmiet River, Western Cape

The lower reaches of the Palmiet River in the Western Cape flow through one of the most pristine and botanically diverse areas of the Cape Floristic Region – the Kogelberg Biosphere Reserve. In addition, and despite its short length (70 km) and small size (MAR = 250 Mm^3/a), the Palmiet River is an important source of water not only for agriculture activities within its catchment, but also for hydropower generation and domestic water supply for Cape Town. As a consequence it is heavily regulated by six major dams.



Bruce Paxton

The most upstream dams, Nuweberg and Eikenhof, are used for local agricultural and industrial purposes. Downstream of the town of Grabouw, there is a series of four larger dams that occupies roughly 15 km (24%) of the total length of the river: the Peninsula, Applethwaite, Kogelberg and Arieskraal Dams. Kogelberg, the largest of these, is linked to the off-channel Rockview Dam as part of the Palmiet Pumped Storage Scheme that generates 400 MW of power for distribution to the national ESKOM grid. In this scheme, water is pumped from Kogelberg into Rockview at a rate of 2.5 Mm^3/day during off-peak periods, and released back into Kogelberg over peak periods at a rate of 3.5 Mm^3/day). Water is also moved from Kogelberg *via* Rockview to Steenbras Dam (22 Mm^3/a) for onward transmission to Cape Town.

In a Reserve study for the Palmiet River in 1999, the Ecological Reserve was addressed for each of four zones between the headwaters and the estuary [20]. A decade later, as part of the Cape Action for People and the Environment (C.A.P.E.) Ecological Reserve Implementation (ERI) Programme, an audit of compliance was undertaken [21]. This focused on the lower reaches, downstream of Arieskraal Dam, because:

- there are no weirs gauging streamflow upstream or downstream of Nuweberg Dam and so compliance could not be assessed for the river upstream of Grabouw;
- the river immediately downstream of Grabouw is quite degraded, and instead of a Reserve assessment, a situation assessment was completed, which indicated that water quality is the major issue [22];
- setting an Ecological Reserve for the river reaches between the series of large dams was not feasible because almost all of this zone is covered by reservoirs.

The major focus for the Ecological Reserve was therefore the lower reaches downstream of Arieskraal Dam, which are included in the Kogelberg Biosphere Reserve. The 2009 ERI audit of this zone identified two impediments to the correct operationalisation of the Reserve: the limitations of the outlet valve on Arieskraal Dam and the requirements of hydropower generation linked to Kogelberg Dam.

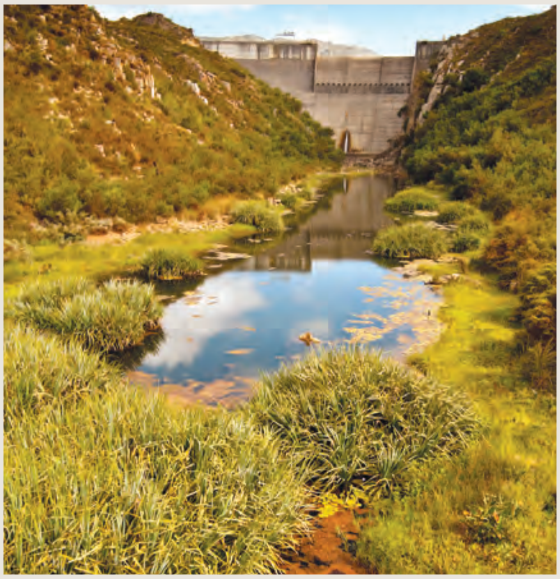
In terms of dry season flows, Arieskraal Dam is capable of releasing up to 2 m^3/s, and is therefore well able to meet the Reserve requirement for each dry-season month of 0.92 m^3/s, but an orifice plate has been welded onto the outlet pipe that limits the release to 0.2 m^3/s. Much of the water released downstream through this orifice pipe is abstracted for irrigation and so the Reserve for the remainder of the Palmiet River downstream of the Arieskraal Dam has to be met by incremental runoff from the downstream Klein Palmiet, Huis and Krom tributaries whose flows are also utilised for irrigation and diverted into off-channel storage.

Box 7.5 Continued...

The Reserve low flow of 4.33 m^3/s for the whole wet season is also not met until Arieskraal reservoir is spilling because of the limitations of the outlet pipe. In addition, Class 3 floods are delayed early in the wet season (May-Jun) whilst Arieskraal reservoir is filling and there are no Class 1 floods late in the dry season (Jan-Apr) when the dam ceases to spill.

Further, the Reserve set could not be monitored for some of the more conservation-worthy rivers or river segments because of the absence of gauging weirs, and could not be operationalised in tributaries such the Klein Palmiet that had not been included in the Reserve assessment. In addition, the Water User Associations (WUAs), with their background as Irrigation Boards, had limited understanding of the principles underlying RDM and the need to make changes in the timing and magnitude of Reserve flows during the year. The complex Reserve documentation was interpreted for them *via* the suggested catchment management plan, but there were still communication challenges.

It can be concluded that in several ways the Reserve will not be fully complied with unless the inadequacies of the infrastructure and the lack of capacity among the stakeholders (in particular the WUAs) to understand and act on the RDM requirements are addressed [22]. A workshop targeted specifically at the Palmiet River catchment and the problems it faces with operationalising the Reserve would greatly contribute to successful compliance.



Bruce Paxton

Modified flow conditions downstream of Kogelberg Dam before it flows into Arieskraal Dam

Preliminary Reserves set for Zone 3A of the Palmiet River and the degree of compliance at Sites 3 and 4 downstream of Arieskraal Dam [21].

Preliminary Reserve set	Compliance
Wet Season lowflow (June-November) – constant 4.33 m^3/s	The percentage of days per month on which flows exceeded the capping flow of 4.33 m^3/s was highest in the middle of the wet season (Aug – 76%) and lowest at the beginnings (Jun – 30%) and ends (Nov – 9%) of the wet season.
Dry Season lowflow (December-May) – constant 0.92 m^3/s	Releases from Arieskraal Dam are limited to 0.2 m^3/s, which means that the dry season EWR flow rates are not being met.
Class 1 intra-annual floods	50% were met at the start of the dry season (Nov-Dec), but only 11% during the remainder (Jan-Apr).
Class 2 intra-annual floods	80-100% were met in the wet season, but compliance declined to 4-20% during the dry season (Nov-Dec)
Class 3 intra-annual floods	Almost fully complied with in July-Aug, but only 67% of the time in May-Jun (the start of the wet season) as this is the period when Arieskraal is filling and not yet spilling.
Class 4 intra-annual floods	These floods are being met between 60-70% of the time in the middle of the wet season (Jul-Aug), when they are expected.
1:2 year inter-annual floods	Not known

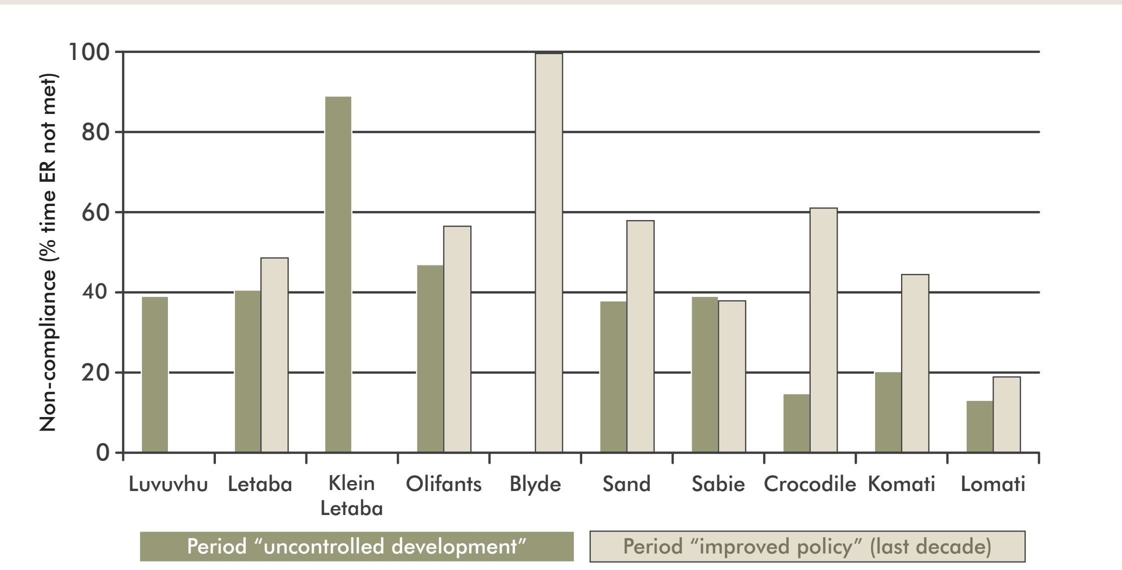
Box 7.6 Compliance monitoring – a case study

When the Olifants River in north-east South Africa ceased flowing in 2005, widespread calls were made for an integrated focus on all of the easterly-flowing rivers of the lowveld of South Africa. These are the Luvuvhu, Letaba, Olifants, Sabie-Sand, Crocodile and Komati Rivers in Water Management Areas 2, 4 and 5 (Figure 1.5 in Chapter 1). Most of these rivers appeared to be deteriorating in terms of water quantity and quality despite the NWA. As most of the rivers flow through Kruger National Park and all of them form part of international systems the implications of their degradation are profound and of international significance [23].

A study of compliance with the Ecological Reserve was completed for the mainstems of these rivers and some of their tributaries [24]. This focused on water quantity, comparing the monthly flow duration curves signed off for specific points along the rivers as the Ecological Reserves with monthly flow duration curves compiled from measured daily flow data. This revealed the months in which flows were on average lower than the Reserve. Where possible, two or more different time periods were analysed to assess if the situation was improving with time since the NWA.

The results are probably an under-estimate of non-compliance because they do not show individual days when Reserve flows might not have been met. The summary in the table does not provide details of the margin by which the Reserve was not met – any number under the flow duration curve was taken as non-compliance – but the ratings in the fourth column suggest that most of the time non-compliance was quite substantial. None of the rivers consistently met the Reserve requirements for flow, with the highest level of non-compliance (88% of the time) being for the Klein Letaba. In most cases the situation has worsened since the NWA came into effect.

Sharon Pollard with ICMA Board members.



A summary of the incidence of non-compliance with the flow component of the Ecological Reserve in the lowveld rivers over two developmental periods (pre- and post-NWA) [24].

Box 7.6 Continued...

Non-compliance in meeting the quantity component of the Ecological Reserve in lowveld rivers [24].

River	Months of non-compliance	Non-compliance (% time)	Magnitude of failure	Worst month	Incidence of compliance to Reserve
Luvuvhu	All months	38	Moderate	August	Not known
Groot Letaba	All months except January	46	Moderate	February	Improving
Klein Letaba	All months	88	High	September	Not known
Lower Olifants	All months except January	47	High	August, September	No improvement
Blyde	All months	73	Moderate	April to October	Not known
Sand	All months	58	Moderate to high	September	Declining
Sabie	Mostly May to October	38	Low	August, September	Uncertain due to technical constraints: some areas/seasons improving, some declining
Crocodile	All months	46	High to moderate	September	Declining
Komati	Most months	44	High, possibly decreasing	July	Declining
Lomati	All months	19	Low	June, July	Improving

Regulators, water users, operations and maintenance staff, researchers and other stakeholders were consulted regarding the reasons for non-compliance. A lack of communication between water resource managers, water-supply managers and major water users such as mines was seen as a substantial problem. IWRM is still largely a concept rather than a practicality in the area, except in the new Inkomati CMA where it is emerging through the development of the Inkomati catchment management strategy (Section 7.9.3). A poor understanding of the Ecological Reserve and an inability to use the information on the approved Reserve sent to DWA Regional Offices (Section 7.9.2.) was another commonly identified problem, as were the lack of clear local leadership and the limited scope that good leaders have to apply IWRM because of poorly defined or restricted roles.

Transformation toward collective stakeholder understanding through a shared, catchment-based vision and management strategy should be sought and could be provided by the water resource classifications (Section 7.8.1) and ensuing catchment management strategies [24]. The Reserve cannot be achieved without a compliant and lawful catchment-based system where water use is authorised, regulated and monitored against agreed objectives. There are many unlawful uses of water and a dearth of legal and regulatory skills to manage the situation.

7.9 South Africa's capability to manage the RDM

During the next few years DWA intends to begin to decentralise the responsibility for RDM to the Regions, starting with ad hoc Reserve assessments for individual water-use licence applications. This will require the development of significant additional human capacity within the Regions, some of which do have staff with the skills to carry out such work but most of which do not. It is uncertain that such a pool of expertise exists within the country. In this section a brief overview of available relevant capability within the various levels of water management and their technical consultants is addressed.

7.9.1 The situation at DWA Head Office

Until the end of 2009, the CD: RDM had 22 technical positions dealing with surface and groundwater Reserves, and two administrative positions. In 2010, three new Directorates were formed within it (Section 3.4.2) and in April 2010 a Director was appointed to each. The current staff complement of the Chief Directorate is 43 with the three new Directorates having the following responsibilities[n]. The overall aim is to lay foundations over the short term that will streamline and enhance their work in the medium term.

7.9.1.1 Directorate: Water Resource Classification

With responsibility for water resource classification, this Directorate will oversee, monitor and audit the work, and build capacity within the Regional Offices where the ultimate responsibility for operationalisation will lie. It has seven technical and administrative staff members. It has promulgated the regulations that prescribe the three Management Classes and the seven-step Water Resource Classification System. It has begun classifying significant water resources in the Olifants WMA (Mpumalanga), three Vaal WMAs (Upper, Lower and Middle Vaal) and the Olifants-Doorn WMA (Section 7.8.1), and has prepared for similar work to be done for the Crocodile-West Marico WMA, Mokolo catchment, Umvoti to Umzimkulu WMA, Usutu and Tugela WMAs.

The classification work is complex, highly technical in nature and requires a skilled workforce. The directorate has embarked on a plan to increase its capacity in these skills but success will depend on the DWA staff being willing to be trained and having the appropriate basic science background. At present, CD:RDM has to rely heavily on consultant water scientists to undertake the classification exercises and build capacity of the Directorate's technical staff where possible.

7.9.1.2 Directorate: Reserve Requirements

This Directorate is responsible for initiating, managing, coordinating and carrying out Ecological Reserve determinations for surface waters, groundwaters, wetlands and estuaries. It prioritises areas needing Reserve assessments, and completes or updates such assessments. Strangely, it does not have responsibility for developing the methods used for Reserve assessments, which sits with the Directorate of RDM Compliance. It has a staff of 25 technical and administrative personnel, including four graduate Reserve trainees on a full-time contract basis.


Mark Rountree

Barbara Weston, scientific manager in the Directorate: Reserve Requirements, at the Groenvlei wetland near Sedgefield in 2008 during the Outeniqua Reserve Determination

[n] *In addition to the three Directorates, there is a Strategic Support Sub-Directorate with four personnel, and the Chief Director and Secretary*

Stephen Mallory

Emmet flow gauge on the Sabie River was built specifically to record the natural flow of the Sabie River and hence enable operators to estimate the required releases from Inyaka Dam to meet the Ecological Reserve. The system operated for six months but has now stopped because of lack of human and other resources.

Working with the other directorates, its aim is to set Reserves in place for the whole country. At present it is:

- contributing the required Reserve information to Letsema (Section 7.6.2), to enable the assessment of the WULAs, as an aid to reducing the current WULA backlog
- managing comprehensive Reserve determinations for the Umgeni, northern Olifants, and Umkomaas catchments, linked to the CD:IWRP reconciliation strategies, and for Lake St Lucia estuary to aid protection management of this important conservation area
- commissioning an update of data on the Present Ecological Status (PES) of all quaternaries in the country, which will allow an assessment of whether or not the ecosystems have deteriorated since the last assessment in 1999, and which will be used in future *ad hoc* low confidence Reserves
- commissioning further development of the water-quality method for the Reserve, the SPATSIM-HDSF modelling framework (Chapters 4 and 6), and the Wetlands DSS
- participating in development of an estuarine management plan for the Groot Brak estuary, because of concern over the operation of Wolwedans dam and the social impacts that occur if the opening of the estuarine mouth is not managed correctly
- addressing difficulties due to capacity constraints in terms of Water Quality Reserves, wetland Reserves, poor processing of WULAs by DWA Regional Offices, and the demands of the Letsema project as it attempts to reduce the WULA waiting list
- incorporating into its work new Reserve methodologies still being developed for complex systems such as floodplains and helping in the refinement of existing methods.

7.9.1.3 Directorate: RDM Compliance

This Directorate has an auditing and oversight function. It has five technical and administrative posts. Its main focus is auditing the monitoring and reporting of RQOs including the Reserve. This cannot be achieved until several prerequisites are in position because at the moment the DWA Regional Office staff do not know how to monitor RQOs and are not attempting to do so. It is presently focusing on five priorities.

1. Developing closer liaison with other DWA directorates involved in strategic planning and issuing of licences, so that the information needed can be streamlined into one dataset that informs the issuing, monitoring and enforcement of licences.

2. Motivating for more flow-gauging stations for use in real-time monitoring and for maintenance of existing ones.

3. Training and creating awareness among Regional and CMA staff on the importance for people of maintaining healthy freshwater ecosystems; how and why to expand their traditional monitoring and enforcement activities to address RQOs; and how to adaptively manage drought periods.

4. Revising the Reserve template that provides information on the signed-off Reserve, so that Regional Office staff members can better understand and use the information.

5. Early planning for the standardisation of Reserve determination methods to meet the needs of the Water Resource Classification System and the setting of appropriate RQOs, especially water-quality ones.

Operationalising and thus monitoring Reserves is neither simple nor straightforward. Most Reserves probably fall into one of three categories (only the quantity of flow in a river is used as an example here for simplicity):

1. They were approved linked to a WULA. The Reserve is an amount of flow that must remain in the river and as such it does not have to be 'delivered'. At present none of the Reserves set as conditions linked to licenses are being monitored and so there is no knowledge of whether or not they are being met.

2. They are delivered through dam releases. These Reserves are probably the ones that most people think of as Environmental Flows and some are being released, for instance in the Berg, Palmiet and some KNP river systems. Some monitoring has begun but mostly through public-private partnerships. There is no structured DWA monitoring anywhere in the country of Reserves that are being released from dams.

3. They were agreed during the process of water resource classification. None of these have been finalised yet although some may have been approved as part of the CD:IWRP catchment reconciliation strategies. These Reserves will be operationalised through a mixture of dam releases and control on abstractions. RQOs are being planned in the priority WMAs where classification is underway.

The three Directorates are working together to develop a framework of what needs to be done. Early activities will include liaising with universities and other tertiary institutions to establish appropriate training modules, and development of a Decision Support System that will enhance internal decision making within DWA. This does not seem to be a sufficiently urgent approach to the escalating situation of resource degradation: the topic is revisited in Chapter 8.

7.9.2 The situation at the DWA Regional Offices

The DWA Regional Offices are visited each year by RDM staff to ascertain their status and activities. During 2010 they were also visited by one of the authors of this chapter, who is not DWA staff and who provides this analysis.

7.9.2.1 RDM representation

None of the Regional Offices has a dedicated RDM unit, but three do have units that are dedicated to a range of activities linked to protection and management of aquatic ecosystems. The most advanced of these is the Resource Protection Section in the Western Cape Regional Office, which was formed in 2002. It deals with the Western Cape's aspects of RDM matters, and with the River Health Programme and Adopt a River. There are nine posts allocated to the Section, six technical (Deputy Director, two Assistant Directors and three Aquatic Scientists) and three administrative posts. The allocated budget from the Regional Office rose from R2.1 million in 2008-09 to R3.5 million in 2010-11. The Eastern Cape Regional Office has RDM representation through two technical posts designated for hydrologists but occupied by biologists. This capacity was established in 2008 but has no funds allocated by the Regional Office and so is limited in what it can achieve. The Limpopo Regional Office created RDM capability in 2009, with three technical and one administrative post. The senior post – Assistant Director – is presently occupied. There was a budget from the Regional Office, above that required for the filled post, of R100,000 for 2010-11.

The other six Regional Offices do not have a formal RDM capability although there are people in each Regional Office who bear some of the RDM-linked responsibilities, and most personnel linked in any way with licensing have some knowledge of RDM matters. Establishing a dedicated in-house RDM capability appears to be a decision of individual Regional Offices, with the primary reasons for not doing so being the lack of an appropriate organisational structure, funds and technical expertise, or a view that all is adequately covered by Head Office. DWA interns gaining experience in a wide range of DWA activities spend some time on RDM work as part of a broad training on all aspects of Regional work, and so awareness and understanding is slowly growing.

The links with the CD:RDM in DWA Head Office appear to be strongest and work best where formal RDM posts exist, presumably because in the other Regional Offices personnel have other main jobs and deal with RDM matters as and when they can.

7.9.2.2 Regional understanding of and capacity in managing RDM

Water resource classification

Understanding of water resource classification ranges from very good to poor. In general, Regional Offices with designated RDM posts have a better understanding than those without, but there are several examples in the latter Regional Offices of personnel with a very good understanding. On some visits to Regional Offices, personnel with the best knowledge of RDM matters were not available, which may have affected the general level of understanding offered at the meetings.

Most people understood that water resource classification was related to the condition of the aquatic ecosystem. While a few thought it was a way of describing the present condition of the ecosystem and one person thought 'it was about invertebrates', most understood quite clearly that it was a way of using the present situation as a starting point to plan and manage the future condition in a way that allowed responsible development, and that it involved stakeholders, as revealed by the following explanations:

- Western Cape: "All water resources must be classified through public participation where stakeholders agree on the level of use of their water resources"
- Limpopo: "Classification of water resources must be done so as to understand their status and put in place management options"
- Mpumalanga: "Classification is about developing a model to link water quantity, water quality and the environment as well as public and private enterprises".

There were some Regional Offices, however, who said they did not understand water resource classification or only understood it in broad general terms.

When asked how they judge if there is sufficient water remaining within a catchment for granting a water-use licence, most replied that this was very difficult where there is no catchment water-balance[o] in place, and that it is not being done satisfactorily at present. The more severely water-stressed catchments do have a water-balance model, and in some of these new licences may no longer be issued. Most Regional Offices, however, responded that they have incomplete coverage of water-balance models in their regions, if any, and so they have a poor understanding of how much water might be available for licenses.

Similarly, when asked how they judge if the ecosystem would have sufficient assimilative capacity to absorb an additional effluent discharge and thus allow approval of a new discharge licence, most indicated that they used the current effluent standards as a guide. In other words, licences are issued based on the traditional approach of assessing the quality of the effluent and not on a sustainability approach of judging the ability of the ecosystem to absorb the additional effluent load.

[o] *A water balance is an estimate of: all the water inputs to a catchment; all its water uses, including for the Reserve; water use by vegetation; surface and groundwater exchanges. In summary, this provides information on whether or not the catchment presently has water that can be allocated to potential users. Most water balances that exist have been done as part of CD:IWRP's catchment reconciliation strategies; none have been done by CD:RDM.*

Only one Regional Office (Limpopo) indicated that it had staff experienced in water-balance models, RQOs and ecological assessment, and most said they had no capacity to do this and would need extensive training. One Regional Office commented that all the paperwork is just sent to Head Office with a recommendation based on the work of the consultants, and that they have no control over the quality of the consultants and perhaps poor insight of the implications of the consultant's recommendations.

When water resource classification was discussed further with them, all agreed that it would be a significant step forward, allowing stakeholders and government to work to a pre-agreed catchment development/use plan. It should greatly expedite the processing of water use applications and help streamline interaction with other government departments such as the provincial and national environmental authorities.

The Ecological Reserve and RQOs

The Ecological Reserve is the best understood part of the RDM, presumably because scientific teams have actively been completing Preliminary Reserve determinations for more than a decade. Everyone saw the Ecological Reserve as involving leaving some water in the water resource to sustain ecosystem health, and most also knew that there are water quantity and water quality aspects to it. There was, however, a generally poorer understanding of the context of the Ecological Reserve in those Regional Offices without dedicated RDM staff, and many saw the Reserve work as one more paper task to be coped with without any real opportunity to understand how the Reserve determinations are done, how licence applications are decided on, how the licencing decisions should be translated into conditions that can be monitored or what the 'reason for doing the job' is.

RQOs are clearly defined goals relating to the quality of the water resource as agreed (eventually) through the water resource classification exercise. They can cover all aspects of water quantity, water quality and aquatic ecosystem health, including the condition of instream and riparian habitats and aquatic biotas. They are well understood in a few Regional Offices (W. Cape: "the set of conditions that must be adhered to in order to keep a water resource at a recommended (management) class") but less so in others ("they cater for quality and quantity"; "they are for managing abstraction, release and effluents").

In terms of keeping track of Reserve work done, six Regional Offices said they have some kind of database or were establishing one, while two had nothing (one Regional Office did not answer this question). Those with a database, register in it every licence application sent to Head Office as well as the approved Reserves received back from Head Office. Those with such a database also have a countrywide map of the coverage of Preliminary Reserves done at all levels of resolution.

The Regional Offices felt that the approved Reserves for water quantity received from Head Office are in a user-unfriendly format that is difficult (if not near impossible) to use in compliance monitoring at a specific point in the catchment. The Reserve is given as a flow duration curve for each calendar month (Annexure 4.A; Section 7.8.2), which indicates in a summary form what the spread of flows should be over that month but does not help understanding of the flows that should be met at a specific place on a specific day. Similarly, the RQOs set for water quality may not bear any relevance to the issues at stake (e.g sodium and chloride levels given (among others) when *E.coli* or heavy metals are perceived to be the problem).

The Basic Human Needs Reserve is included in every Reserve that is set. It is a small volume of water and the Regional Offices mostly do not understand how it works or what they are supposed to do with it.

7.9.2.3 RDM training

Training received at Regional Offices ranges from none to quite comprehensive. In most cases, the training seems to consist of presentations, which the Regional Office staff members say do not help them. A few have received hands-on training in the Desktop model, Rapid Reserve assessments, SPATSIM, the water-quality Reserve, and the estuary and groundwater RDM methods. Where training has been offered, it happened only once and the methods and concepts remain poorly understood. Some of the major problems identified by Regional Offices at a training workshop in 2004 (D. Grobler, pers. comm.) were:

- Reserves set at the scale of quaternary catchments were 'inappropriate and un-implementable' and needed to be set at a finer geographical scale
- difficulties in translating quantity, quality and groundwater Reserves into licence conditions
- difficulties in giving effect to the Reserve where most water is already over-allocated as existing lawful use (Section 3.3.3)
- no understanding of how to do compliance monitoring.

To help them move forward, all say that they urgently need further training. This should not be in the form of further presentations, but rather a structured programme of hands-on training where they can work side-by-side with mentors over some significant time period to help them increase their capacity to do RDM work. This programme should help them with the training modules mentioned above, and also guide them in how to use the RDM template document they receive after a Reserve study, how to contribute to revision of the template if necessary, and how to use it in licensing, monitoring and enforcement activities. This need ties in with the view of the new Director of RDM Compliance who commented that at present it is impossible to address one of her responsibilities – auditing monitoring activities – because most Regional staff allocated to monitoring work do not understand the RQOs and the Reserve template and so ignore them.

7.9.2.4 Regional Offices score sheets

Seven Regional Offices assessed how well the RDM are working in their regions, using a scoring system of 1 (very poor) to 5 (very good). Available funding and skills scored between 1 and 3 (Table 7.11), with some commenting that they needed help with job descriptions and that they had an acute lack of funds and skilled personnel.

There was widespread dissatisfaction with the speed at which Reserve determinations are completed as part of water use licence applications, with no Regional Offices scoring more than two, and two of them scoring minus one! There is a perception that the applications are held up at DWA Head Office (i.e.at CD:RDM or CD:Water Use), while CD:RDM perceives that the Regional Offices are not processing applications efficiently and many have to be sent back for amendment. One Regional Office commented that water resources classification should help streamline and speed up the process considerably – if handled well.

The score for whether or not licences are issued with a view of the wider basin-wide water picture seemed to depend on who was providing the score and how closely they work with the licencing process. One Regional Office thought this was working quite well while the others that scored this item thought that it was working where comprehensive Reserve assessments had been done as these are mostly catchment wide, but not elsewhere. One Regional Office indicated that it was not notified of licences issued and did not know what process was followed in the licencing decisions.

Licences are being monitored in some areas but not in others. Traditional water-quality monitoring seems to be working better than abstraction monitoring, perhaps because there have historically been well-tested techniques and teams for this in place. In terms of RDM monitoring all Regional Offices scored 1 – it is not happening – and some Regional Offices said they did not know what to monitor. RDM monitoring is not the same as river health monitoring, although it could easily be done by the same team if appropriate procedures were in place.

In a final set of questions, most Regional Offices without dedicated RDM units responded that nothing linked to RDM was working well. Regional Offices with dedicated RDM staff were more optimistic, as RDM matters tend to receive a higher priority and are considered as part of IWRM. All agreed, however, that funds, skilled staff and hands-on training are urgently needed, and all agreed that more responsibility for doing Reserve assessments should be given to the Regions. This latter reflected both their wish to be more involved in work done by DWA Head Office in their Regions and also their frustration about the lengthy wait for decisions on water-use licence applications.

Table 7.11 Regional Office scores for how well RDM is working in their regions.

RDM-related issue	Scores from individual Regional Offices						
Funding and skills	2	2	1	2	3	2	3
Reserves linked to WULAs completed quickly	1	<1	1	<1	1.5	2	2
Licences issued with consideration of basin water availability	-	2	2	2	>4	-	-
Monitoring of licences	-	3	2	3	4	1	-
Monitoring of RQOs, including the Ecological Reserve	1	1	1	1	-	1	-

1 = Very poor. 5 = Very good.

7.9.3 The situation at the catchment management agencies

Catchment management agencies (CMAs) will be the critical front line in terms of daily water management. Whilst policy matters will rest with DWA's Head Office and the Regional Offices will assume an overseeing and regulatory role, the CMAs will be responsible for water licensing, liaison with water user associations (WUAs), monitoring compliance and other routine matters. They will initially receive offset funds from DWA, but this will be progressively reduced over the years as they are expected to operate as financially viable institutions.

To date, only two CMAs have been formed, the Inkomati CMA (ICMA) in Mpumalanga Province and the Breede-Overberg CMA (BOCMA) in the Western Cape Province, although others are operating as proto-CMAs.

7.9.3.1 The Inkomati Catchment Management Agency

The Inkomati Catchment Management Agency (ICMA) was formed in 2005, the governing board was appointed in September 2005 and the CEO appointed in May 2006. ICMA has two senior staff members with RDM knowledge and training. The ICMA promotes catchment-wide Reserve determinations, and feels that individual *ad hoc* Reserve determinations are of limited value because they do not encompass basin-wide thinking on water management and do not provide the information and techniques needed for hands-on management of the resource.

The ICMA aims to work with catchment-wide water resource models that can produce scenarios for use in stakeholder consultations and feels that to achieve this a widespread training in basic hydrology and water resources modelling is vital in the region. It seeks consensus with stakeholders on the way forward and feels this may take years of gradually improving the condition of the aquatic ecosystems, supported by explicit operating rules for all and monitoring for compliance. Good Water User Associations (WUAs – Section 3.3) will be essential to assist with the management of users.

The ICMA has already produced a catchment management strategy [25, 26], as required by the NWA, which outlines the above vision. To support this work it sees the following as essential:

ICMA

The Inkomati Catchment Management Agency: Kevin Rogers facilitating the stakeholder consultation forum for development of the catchment management strategy for the Sabie-Sand sub-catchment.

- specific DWA responsibilities to be delegated to the CMAs
- appropriate funds and skilled personnel
- catchment-wide Reserve determinations completed as part of water resource classification
- future ecosystem condition and operating rules agreed with stakeholders
- establishment of good, working WUAs
- uniform monitoring process.

A pilot study to develop and implement a framework for operationalisation of the Reserve has already been completed for four of its river systems [13].

7.9.3.2 The Breede/Overberg Catchment Management Agency

The governing board for BOCMA was appointed in October 2007 and the CEO appointed in May 2008. It has developed its catchment management strategy as required by the NWA (Box 7.1).

7.9.3.3 Conclusion on CMAs

For the CMAs to become successful, a considerable investment has to be made to enhance their capability to manage the various local aspects of water resources. Establishment of CMAs has been very slow, at least partly due to a lack of clarity in the Regional Offices of the proposed roles and responsibilities of the CMAs, which has delayed the delegation of powers and functions to the CMAs. As a result most water resource management functions in most parts of the country still reside with DWA. The worryingly small pool of expertise will be felt in the CMAs, but catchment classification, once done, should help as it will lay out, for a decade or more, the basin catchment plan that the CMA will follow.

The CMAs will face financial implications regarding who pays for the water that must be left in ecosystems to meet the Reserve requirements. They are ultimately expected to fund themselves entirely from the revenue from water use charges, and the more water used in their areas the higher will be their revenue. CMAs with high levels of protection imposed for their aquatic ecosystems will have to allocate more water to the Reserve, with less water available for use in other ways, and so less income received. Long-term sustainability of the aquatic ecosystems could be compromised by the CMAs needing to generate income. Their financial models will have to take account of the protection measures in place for their water resources, but there is no clarity as yet on how this will be done.

7.9.4 The situation among RDM practitioners

Compulsory licensing and its precursor water resource classification have fallen behind the schedule envisaged in the NWRS (Figure 7.5). The former is taking longer than anticipated due to the complex process of verification and validation of present water uses that is now underway. This gives the process of classification some breathing space in which to make progress, but such progress is still slow because classification is expensive to do because of its multidisciplinary nature, takes a long time per catchment, and requires teams of highly-skilled practitioners. The process needs some lateral thinking and streamlining – this topic is revisited in Chapter 8.

7.9.5 The situation with stakeholders

As water management increasingly moves toward IWRM, meaningful input from stakeholders becomes critical. Recognising this, the CD:RDM produced a guide to public participation in 2003. This was to aid stakeholder involvement in the activities and discussions that precede setting of Preliminary Reserves and eventually Final Reserves. The guide is for use during comprehensive Reserve assessments as they were done until 2010 and, from 2011, during their application as part of water resource classification.

The guide focuses on determination of the Management Classes, Reserves and RQOs, drawing on DWA's Generic Public Participation Guidelines. It also recommends that the technical findings of the Reserve determination be summarised in a discussion document and workshop in language and with visual aids that are understandable to all interested stakeholders (water use sectors). Stakeholder groups, through mandated representatives, can then make informed input to the future they desire for their catchment. To do this, the stakeholders themselves will almost always need careful educating to help them understand the technical issues. The critical need for developing this capacity is highlighted in the Palmiet monitoring project (Box 7.5).

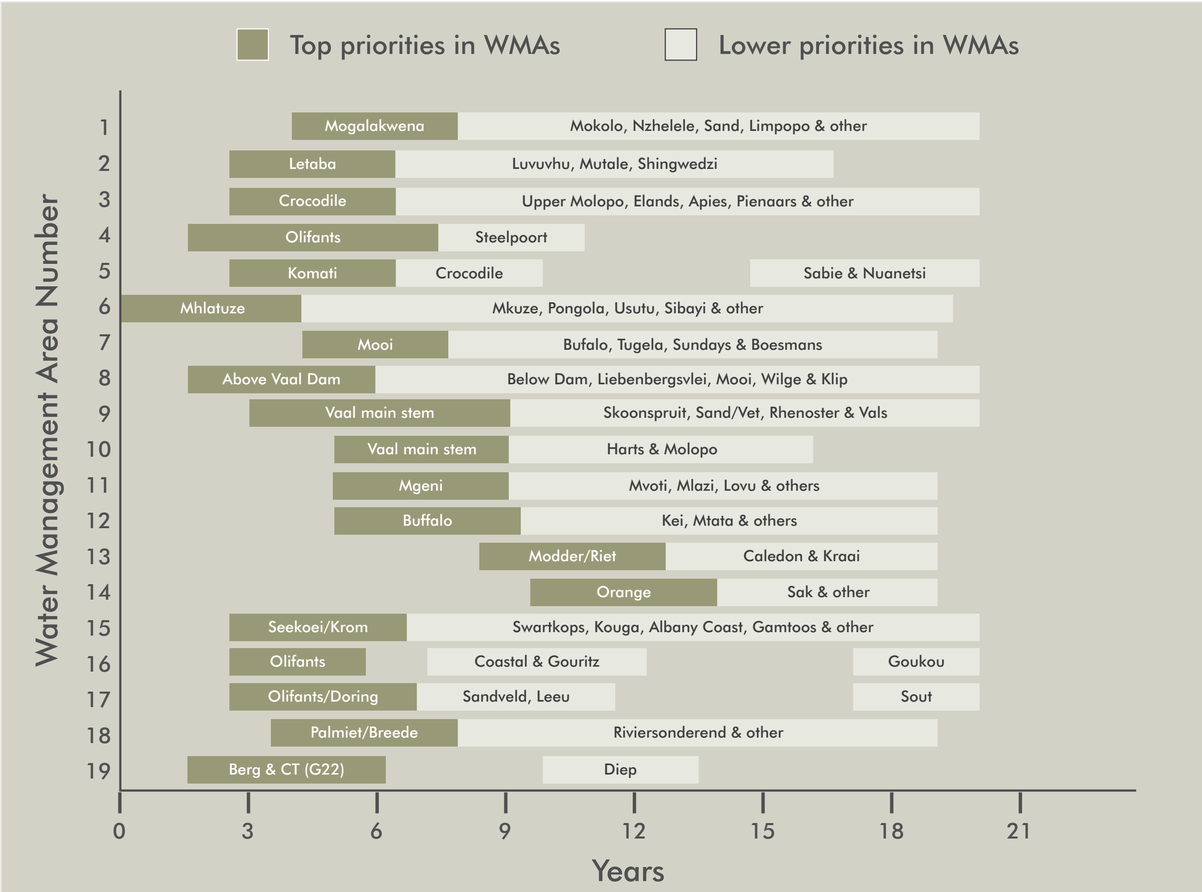


Figure 7.5 Indicative programme for when catchments should complete compulsory licensing, as shown in the 2004 NWRS.

7.9.6 Summary

Due to the highly specialised field and the experience required to implement IWRM, and the lack of commitment to provide hands-on coordinated IWRM training, capability in this field is sparse. The water sector as a whole is limited in numbers of highly trained technical people, with numbers not growing sufficiently fast. High staff turnover in DWA is a contributing factor to the lack of experienced personnel in the department. DWA officials working in the regions may not be able to manage the water resources efficiently because many catchments have a paucity of support tools such as catchment water balances, hydrological systems models and monitoring programmes. Many DWA personnel are also ill-equipped in terms of relevant skills and experience, or unwilling to learn to use the tools. Stakeholders are poorly equipped to understand and make meaningful input into water resource classification and catchment management strategies. Nevertheless, the country has made significant strides forward in all these aspects over the last two decades, is well aware of the challenges, and has an exceptionally able core of dedicated and skilled professionals who are trying to carry the work forward – it now requires some inspired leadership.

7.10 Financial investment in RDM

Although DWA has a substantial budget overall, CD:RDM has been and still is underfunded in terms of its business planning requirements (Table 7.12). Several strategies have been adopted to attempt to move forward under these financial shortcomings, including cooperation on key projects with other DWA line function units at Head Office and the Regional Offices, and collaboration with the Water Research Commission regarding the development and refinement of scientifically robust RDM methods. In some instances, particularly with the more costly Comprehensive Reserve determinations, a public-private-partnership (PPP) approach has been used. An example is the Reserve determination done for the Crocodile and Elands Rivers, which was co-funded by DWA and SAPPI (Pty) Ltd and led by CSIR.

The RDM approach to balancing resource use and protection is in its early stages; it is visionary, ambitious and vital for the welfare of the country. The vision can become a reality that benefits all the people of the country, and have wider influence. South Africa is a globally significant contributor in this field and well placed to help other African and wider-spread developing countries toward their goal of sustainable use of water. To move the vision closer to reality CD:RDM needs a more realistic budget and brave revision of its strategy to meet the emerging circumstances (Chapter 8).

7.11 RDM and transboundary waters

Several of South Africa's river systems are shared with neighbouring countries, notably the lowveld rivers (Box 7.6), which flow variously into Swaziland and Mozambique, and the Orange-Senqu system, which flows out of Lesotho and reaches the sea as the border between South Africa and Namibia. Ideally, the RDM set within South Africa should be part of a wider integrated and cooperative agreement set at the basin level and organisations such as the Orange-Senqu River Commission (ORASECOM) and the Komati Basin Water Authority (KOBWA) are in place already to facilitate this. Transboundary basin strategies have not yet been formulated but are in planning. CD:RDM, for instance, commissioned a study during 2008-2010 to assess the environmental water requirements for the Orange River, as part of Phase 2 of the ORASECOM Basin-wide IWRM plan. The Inkomati Comprehensive Reserve determination done in 2006 (Table 7.3) involved extensive consultations with KOBWA stakeholders prior to its approval by DWA.

Table 7.12 Financial investment to develop procedures, methods and complete Reserve determinations[p].

Year	Status of the DWA function	Budget allocation (Rands)	Estimated budget required (Rands)
1999-2000	Office in Scientific Services	2 000 000	3 000 000
2000-2001	Office in Scientific Services	3 000 000	4 000 000
2001-2002	Office in Scientific Services	3 500 000	5 000 000
2002-2003	RDM Directorate	10 505 000	13 530 000
2003-2004	RDM Directorate	13 404 000	15 605 000
2004-2005	RDM Directorate	20 305 000	22 405 000
2005-2006	RDM Directorate	19 504 000	24 515 000
2006-2007	RDM Chief Directorate	20 250 000	27 356 000
2007-2008	RDM Chief Directorate	17 997 000	31 312 000
2008-2009	RDM Chief Directorate	24 323 000	37 212 000
2009-2010	RDM Chief Directorate	23 000 000	43 917 000
2010-2011	RDM Chief Directorate	24 505 000	46 876 000
2011-2012	RDM Chief Directorate	39 583 000	65 606 000

[p] *The Water Research Commission has also made a considerable financial investment in the procedures and methods; see Chapters 4 and 6.*

7.12 Analysis

7.12.1 Capacity building

The intention when the NWA was promulgated was to initiate comprehensive capacity building programmes in DWA and in the water sector as a whole, to meet the broader skill requirements for the new law. These programmes are not producing sufficient numbers of people of appropriate capability to keep pace with the new demands of the NWA as well as cater for the loss of senior, experienced water resource managers and practitioners and of younger staff through career moves or for other reasons. Major changes in the senior management of DWA, together with six changes of Minister and three changes of Director-General since 1994, have also not contributed to maintaining continuity of direction or the momentum of implementation activities that existed in the early days of the NWA.

Today, insufficient human capacity is probably the biggest obstacle to be overcome before all the NWA's provisions can be successfully operationalised everywhere in the country. Moves are being made to build capacity but much remains to be done (Chapter 8).

7.12.2 Influence of the National Water Act on catchment management

The nature of the NWA initially speeded up the move toward truly sustainable use of the country's aquatic systems, because its visionary provisions created great awareness of the need to protect the nation's aquatic resources for the benefit of all the people and triggered a significant surge of related activity. Its momentum has now slowed. This is because it is framework legislation and so does not provide sufficient detail to enable all of its provisions to be fully implemented. Instead it relies on a range of subsidiary regulatory instruments such as regulations, general authorisations, operational policies, guidelines and procedures to add flesh to the bones of the Act's framework. This approach facilitated the preparation of the NWA in a very short time, but the time to develop and establish the necessary regulatory instruments to give effect to its provisions, most of which are of considerable technical complexity, will take longer and is still far from complete.

The intention to make the process for establishing regulations simple and relatively speedy was also confounded by the introduction of the requirement, by the Parliamentary Portfolio Committee on Water Affairs and Forestry, that all proposed regulations must be the subject of public consultation and must also be reviewed by committees of the National Assembly and Council of Provinces. Although this requirement was designed to prevent 'executive law-making' by the Minister and DWA, without mandatory reference to the legislature, it has complicated and extended the process of establishing the regulatory instruments necessary to fully implement the NWA, such as water resource classification and compulsory licencing.

7.12.3 Integration within DWA

The restructuring initiatives and development of cross-cutting programmes within DWA, and the evolution of the RDM unit from a small specialised unit into a Chief Directorate, reflect a serious commitment to IWRM and to protection of the nation's water resources. Several signs of integration are emerging.

- More comprehensive project steering committees for the reconciliation strategies are evolving, with both water services and water resources experts serving on them. This is enabling DWA to engage more meaningfully on key water management issues, RDM and challenges experienced throughout the water value chain.

- Key internal and external stakeholders are increasingly participating during the conceptual and developmental stages of the reconciliation strategies; DWA strives to retain the same stakeholders for both the reconciliation strategies and the water resource classifications, in order to streamline the flow of information and decision-making. These stakeholders have the opportunity to participate in, and respond to, the setting of the configuration of Management Classes for their catchment.

- There has been an internal re-allocation of budgets between the Water Use, IWRP and RDM Chief Directorates, which has directed more funds to CD:RDM to support its role of leading all RDM work.

As a result, the recommended Management Classes, Reserves and RQOs are increasingly an output of all three Chief Directorates, reflecting a considered and balanced trade-off between future resource protection and water use.

7.12.4 Strengths of South Africa's approach to sustainable use of its water resources

1. The policy, and to some extent the organisational structures, are in place to promote sustainable use of the nation's aquatic ecosystems.

2. There is a considerable body of relevant scientific knowledge and skills to support water managers in this endeavour.

3. The Water Resource Classification System has been promulgated; it provides the means whereby IWRM can be mainstreamed into water management.

4. Where DWA Regional Offices have committed funds and staff to RDM, there is a good understanding of RDM and a growing capacity to manage the measures.

5. Two catchment management agencies are operational, both with good links to DWA staff and/or scientists familiar with RDM.

6. Forty-three percent of the country has been the subject of some level of river Reserve assessments, which has provided an unprecedented level of knowledge about them.

7.12.5 Weaknesses of South Africa's approach to sustainable use of its water resources

1. There is a serious lack of capacity and skills at every level within the water management sector. In terms of RDM, sporadic training of Regional Office staff has taken the form of presentations, whereas hands-on mentoring is actually needed.

2. There is weak (albeit increasing) integration between DWA's water resource managers and water supply managers, and between all of these and major water users, such as the mining industry.

3. The requirement to complete a Reserve determination for every WULA has overwhelmed CD:RDM despite the move to use the Desktop Model to speed up the process. The link between IWRM, licensing and RDM is weak, and is delaying or confounding decision-making.

4. Where DWA Regional Offices have not committed funds and staff to RDM there is a poor understanding of the measures and virtually no attempt to work with them.

5. Most Preliminary Reserves have been set with an incomplete understanding, if any, of the catchment-wide implications.

6. Notification to the DWA Regional Offices of approved Reserves is in a form that most do not understand or attempt to use. This may be due to the content of the document or due to a lack of relevant training and support: there are strong opinions on both sides, and this is clearly an area needing sympathetic and dedicated attention.

7. There is poor understanding in the wider society of the need to protect water resources, and so weak buy-in to measures that do this and weak capacity among stakeholders to contribute meaningfully.

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Jackie King

8 THE WAY FORWARD

Jackie King and Harrison Pienaar

8.1 Introduction

South Africa's growing population, urbanisation and industrialisation, and the legitimate expectation of the majority for an elevated standard of living, are creating increasing demands for water and imposing increasing stresses on aquatic ecosystems. But the country – indeed the world – is coming to understand that developments that do not take environmental sustainability into account will not be successful in the medium to long term. This is as true of water resource developments as of any other.

Recognising this, the NWA encapsulates a vision for integrated water resource management that embraces strong stakeholder participation, and careful and considered use of the nation's aquatic ecosystems. Such complex, country-wide visions are difficult to implement and take time, patience, dedication and the willingness to learn and adapt. In this chapter we review the vision and reality of sustainable water-resource use in South Africa, and suggest some critically important actions for meeting the vision.

8.2 The vision for aquatic ecosystem management

An atmosphere for change was created in 1994 by the successful political negotiation of a new South Africa. This, in turn, created the space for changing legislation, including the inherently iniquitous water law of 1956. DWA responded to this demand for change with its new slogan *Some for all forever*. The slogan captures three important concepts: *some water*, but maybe not all that is demanded because South Africa does not have an abundance of water; *for all*, rather than for a privileged few; and *forever*, indicating that use of the nation's aquatic ecosystems must be sustainable over a long timeframe. This target would be achieved through a process of negotiated use that would see some aquatic systems minimally used, some moderately used and some heavily used (Management Classes I, II and III respectively). As an over-riding consideration aimed at maintaining the biodiversity of South Africa's inland waters, it was suggested that 20% of them should be maintained at the Class I 'minimally used' level. The allocated Management Classes would guide the setting of an Ecological Reserve and other Resource Quality Objectives for each delineated part of each water resource and, once set, these would be legally binding. Authorisation to use water resources would then follow through a process of compulsory licensing, and monitoring would ensure compliance. The plan could be revisited every five years and adjusted if necessary to accommodate changed circumstances.

8.3 The reality

The atmosphere for change in the 1990s has given way to an atmosphere of increased urgency for service delivery in terms of water supply and sanitation (Chapter 1). Some see protection and sustainable use of water resources as unnecessary or not a priority. The link between the Resource Directed Measures and sustainable service delivery to poor (or indeed to any) people has not registered at many levels of government and society, and instead the measures are seen by some as impeding development and the delivery of services.

In retrospect, changing the legislation and developing the RDM activities were the easy part. The changes now required – to perceptions, values and the hands-on management of water – are far more complex from every perspective: administrative, technical, social and political. We have failed to adequately demonstrate that we are using and managing our water resources in an unsustainable way and that the situation is worsening. Outbreaks of cholera and other water-borne illnesses provide a timely warning that we are over-stressing our water resources. Conflict between water users demonstrates that the move to create an environment in which decisions are taken with long-term sustainability in mind is still in its infancy.

We should be proud of our major achievements:

- a world-renowned water law
- a widespread awareness among the country's water professionals of the need to manage and use inland waters in a sustainable way, and good cooperation between them
- development of an array of RDM technical methods and models to aid this
- a growing number of specialists working competently in the field of IWRM
- an impressive body of activity linked to teaching and presenting the relevant concepts and techniques
- early and growing evidence of cohesion within DWA regarding the incorporation of RDM into the planning and water-use authorisation processes
- increasing international recognition of our work and use of it.

Now we need to bring together – to re-align – the considerable energy and willingness to collaborate of our water professionals, and the drive of our politicians for service delivery and for strong participatory governance that will equitably share the benefits provided by aquatic ecosystems. We have the skills and knowledge to achieve the vision, but at present the effort is scattered, uncoordinated, sometimes contradictory, and often misunderstood or mis-used. How should we move forward? The following sections identify some important actions that would help bring the vision closer to reality.

8.4 Water resource classification

Water resource classification has two ultimate goals: to allow the nation's water resources to be used as efficiently as possible, within acceptable limits, for the good of society and economic prosperity; and to protect aquatic ecosystems at or above those acceptable limits, to ensure long term sustainable use. The acceptable limits are set in discussion with stakeholders and will differ from catchment to catchment.

It is extremely urgent that countrywide classification of water bodies proceeds with all speed as this is the only measure we have for achieving a negotiated and equitable distribution of water; of finding the right balance between resource protection and resource use; and of providing a firm foundation for compulsory licencing and compliance monitoring. Classification is done at the basin scale and, if done in a collaborative and transparent way, it will represent true IWRM. It should bring together up-to-date information on a catchment's water balance; the Management Classes that have been decided upon through a consultative process with stakeholders; and the Reserve and other RQOs for each part of the catchment including the main river, tributaries, estuary, wetlands and aquifers. This information will be at an appropriate scale for use when considering individual water-use licence applications and will obviate the need for endless *ad hoc* Reserve determinations.

DWA, at all levels of government, and the community of water scientists, need be brought together in an urgent national plan to streamline where, how and in what priority order classification is done and, working with stakeholders, to see it through to completion for the whole country. This is no time for individual academic exploration or protecting of turf; rather, we need to combine resources and use the very adequate skills and knowledge that we already have to put such a plan in place, with independent scientists validating the assumptions and indices employed. This plan should use an agreed mix of present methods, applied consistently across the country. Research-backed refinement of the approach as it is applied should be done, but in a controlled fashion at set intervals with general country-wide acceptance.

The classification exercises will reveal in a structured way the catchments where over-use is already occurring, allowing potential new users to understand the situation and not apply for licences where they patently cannot be issued, or to search for other negotiated ways of achieving their needs, such as water trading. Until classification is finalised for a catchment, planning and authorisations for water resource use will inevitably be somewhat *ad hoc* and vulnerable to bad decisions, misunderstanding and conflict.

Action needed:

1. DWA and the community of water scientists should be brought together to create an urgent national plan to streamline where, how and in what priority order classification is done and to then see it through to completion for the whole country. A considerable amount of money is being invested in large Comprehensive Reserve determinations that may no longer be delivering value for money. A few small experienced teams could probably fast-track the classification process, but this needs careful planning guided by a technical advisory group (see Section 8.10).

8.5 Biodiversity overlay

As all-encompassing as water resource classification is intended to be, it still has to integrate with wider issues, such as national and global biodiversity planning initiatives.

The proposed National Freshwater Ecosystems Protected Areas (NFEPAs), defined in a process led by the South African National Biodiversity Institute (SANBI) [1], should have a structured presence and status in the classification exercises. Unless they do, the danger exists that most water resources could be classified for maximum use (Management Class III) with immense negative implications for biodiversity. Additionally, the CMAs must make it clear how they intend to protect FEPAs and designated Reserves under their control so that these cannot be sacrificed for short-term financial gain.

Action needed:

1. Clarify the relationship between DWA and the Department of Environment Affairs in terms of the protection of water resources and biodiversity.

2. Embed conservation planning into the national planning agenda, so that this filter is one through which all developments are processed.

3. Reach formal national agreement on how NFEPAs will be included in the water resource classification exercise.

4. Ensure that CMAs take into account the protection of FEPAs and designated Reserves in their financial models.

8.6 Compulsory licensing

With the NFEPAs included and the classification exercise completed for a catchment, compulsory licensing can proceed. This licensing process replaces the riparian rights in the Water Act of 1956 with a system of *re-allocation* of water use based on the types and amounts of uses agreed during classification. It will consider:

- the natural and current availability of water from all sources (the catchment water balance)

- the present and future requirements of users in respect of both abstraction and effluent discharge

- the Management Classes, Reserve and RQOs set for all parts of the catchment

- equity issues.

These will together inform water managers on how much water is available for potential users (Figure 7.1) and new licenses can then be issued with conditions of use that provide the basic information for compliance monitoring.

The Letsema Project and the general revised RDM and WULA approaches mentioned in Chapter 7, though a step in the right direction, are not without problems and a more pro-active, coherent and streamlined approach is needed.

Action needed:

1. The Chief Directorates of IWRP, RDM and Water Use, together with the DWA Regional Offices, should develop a plan to work in closer coordination when decisions on water-use authorisations are made, whether this be for licences, general authorisations or Schedule 1 use. The order of consideration in the decision making should be RDM, then planning, then water-resource use.

8.7 RDM compliance monitoring and enforcement

There is widespread agreement among aquatic scientists that the country's aquatic ecosystems have significantly deteriorated in condition in the 12 years since the NWA came into effect. This fact is evident in the reports of the River Health Programme and in some early classification work (e.g. Box 7.1). Determined intervention is needed to halt their decline before the point is reached where they can no longer deliver sustainable ecosystem services and to rehabilitate those systems already past that point.

The reasons for their continuing degradation include the widespread failure to operationalise most Reserves as they are signed off and, where they are in place, the widespread failure to monitor compliance and enforce them, with a few notable exceptions (e.g. Boxes 7.2-7.5). Without enforcement, local authorities may tap into the few Reserves that are in place if demand exceeds supply, because they lack the understanding and help they need to do otherwise and perhaps also because they lack the time or willingness to learn. Some upstream water users continue to use water resources to the detriment of their downstream neighbours because of poor enforcement of licensing conditions. The cumulative impact of a number of authorised small-scale users is not being taken into consideration in a structured way by the DWA Regional Offices before authorisation, nor monitored adequately (if at all) afterwards. The registered information on these small-scale water resource users is not being used in an adequate way by DWA Head Office.

Monitoring can inform the wider body of stakeholders on the state of the nation's water resources and provide the basis for understanding the adequacy, or otherwise, of water management. There are substantial national monitoring activities already taking place for flow, water-quality and biological river health but these now need to be augmented with structured RDM monitoring. Ideally, all DWA monitoring programmes should be harmonised for efficiency, and results brought together, analysed and acted upon by one over-arching body within DWA. Early moves in this direction are the possibility that the National Aquatic Ecosystems Health Monitoring Programme and the RDM monitoring programme could be integrated into an Ecological Water Resources Monitoring Programme, but this needs taking a step further to dovetail with the present hydrological and water quality[a] monitoring programmes. Only then can the complete picture of the status of the country's water resources be more fully understood.

In terms of enforcement, DWA recognises that unlawful water use, in terms of abstraction of water from water resources and discharge of wastewater into them, is a significant problem in many parts of the country. It has engaged with prosecutors and magistrates, as well as the police services, to enforce forestry legislation, and a similar initiative should be mounted in respect of water law with a view to fostering an understanding of the requirements of the legislation and the consequences of non-compliance. To aid this work, all monitoring results should be made available immediately on DWA's website, together with the RDM targets, so that stakeholders can also track progress in their catchment.

[a] *Water chemistry and ecotoxicology*

Action needed:

1. Mount an initiative to foster an understanding among water managers and the public of the requirements of the NWA and the consequences of non-compliance.

2. Develop a cost effective hydrological system as part of RDM monitoring based on calibrated cross-sections and cellular communications technology. Use this to monitor the flow of both mainstem and tributary sites.

3. Harmonise all DWA monitoring programmes, with one umbrella body that oversees all results and initiates actions based on them where necessary.

4. Set up the Regional Offices and later the CMAs to be able to adequately carry out RDM monitoring, with DWA Head Office in an oversight/audit role.

5. Create a national database and website that provide up-to-date monitoring data and RDM targets

8.8 Increasing the knowledge capital

The information provided for Reserve determinations to date is based on a mix of data, expert opinion and local wisdom. This is the 'capital' that is being used and it is expanding extremely slowly because it takes years to develop a better understanding of how complex social-ecological systems function. As a result much the same reasoning goes into every Reserve determination, with poor feedback of how accurate this is. It could be, for instance, that the Reserves recommended by scientists and approved by DWA are in fact too low to maintain the health of the aquatic systems and that is one reason why they are still degrading.

It is time to shift focus and aim to expand the 'capital'. This can be done by refocusing the emphasis of the research and energy spent on method development to research on the aquatic ecosystems where Reserves are in place. We need first-hand information on the following:

- if the approved Reserves are being delivered
- if the other RQOs are being met
- if the Reserves and RQOs are achieving the agreed ecological status
- where any of the above are negative, the reasons for this, based on scientific studies.

The learning through such a nation-wide programme could feed directly into future Reserve determinations or water resource classification exercises.

Action needed:

1. Develop a research programme to assess the efficacy of existing Reserves and RQOs based on appropriate monitoring programmes.

8.9 Cohesion and capacity building within DWA

The success of RDM rests not only on its own Chief Directorate operating efficiently, but also on coordination and cooperation between and among all the various units within DWA that are linked in some way to operationalising water resource protection measures; that is, almost all of them. The restructuring in DWA that took place in 2002 was intended to foster inter-unit integration in accordance with the NWA's basic principles, but to a large extent this has not happened and most units are proceeding with business as usual pursuing what is felt to be right for them. The essence of developing good policies to manage water resources is to get all of them mostly right, and not to get a few absolutely perfect while others are neglected. In the same way, implementing the policies requires that they are all brought to bear simultaneously in a particular area, so that the inter-related aspects requiring attention are addressed in an integrated manner. Ultimately, successful IWRM will depend on the ability of DWA to do this – to leverage internal cooperation, which is weak at present.

The situation is exacerbated by DWA being chronically under-staffed, having a history of high staff turnover – more so since 1994 –, not having sufficient numbers of technically qualified personnel to develop all the regulatory instruments required by the NWA, and having a leadership and senior management that has experienced so many changes in the last few years that continuity is weak and departmental memory and cohesion poor. There are also:

- too few dedicated RDM staff, if any, at DWA Regional Offices (Section 7.9.2)
- a massive under-investment in hands-on RDM training at DWA Regional Offices
- difficulties in converting the Reserve and RQO specifications into actions.

It is not surprising that under these conditions DWA has moved forward slowly with the exceedingly complex task of operationalising aquatic ecosystem protection measures and converting former riparian rights regarding water into administrative authorisations *via* compulsory licensing.

This is not to say that everything has to be done at one time, but everything should be closely coordinated within a schedule of priorities into which all relevant units have had input, and to which they all subscribe. It is beyond the scope of this document to suggest how DWA should proceed with more successful integration, but CD:RDM – a key player, albeit not the only one – can contribute toward this by moving to improve some areas linked to its brief, as suggested below.

Action needed:

1. Ensure that dedicated RDM staff are appointed at all DWA Regional Offices, to develop a growing core capability within the regions as well as an RDM point of liaison for other Regional staff involved in linked activities such as licensing.

2. Develop appropriate training for regional RDM staff. This should be hands-on, long-term training where skilled water professionals work through the actual RDM work load with individual DWA personnel or small groups, advising and mentoring them. Regional staff members feel that DWA National Office does not understand the practical challenges they face with RDM operationalisation and that they need to be involved in identifying their own training needs.

3. Address the perceived gap between the RDM information given to regional water managers and the information they actually need in order to manage their water use and water protection activities. Revise the RDM information provided to the regional managers in consultation with them and appropriate technical advisors; improve the capacity of the managers to use the information; and ensure that they have direct contact with the technical advisors instead of only with RDM staff.

4. Arrange for RDM staff in the Regional Offices across the country to network, meet in workshops and mentor newer members, to help reduce their existing feelings of isolation and helplessness. Include the CMAs in this so that they develop the same capability.

8.10 The science-management interface

Some feel that the science behind the RDM process is too costly and complex. The fact that we are not undertaking proper and adequate audits of the status of our water resources is creating, or strengthening, the perception that the three Resource Directed Measures are difficult to determine and expensive to operationalise.

Others are adamant that the science is already as simple as it can be in order to adequately address the considerable complexities of managing a nation's water resources in a sustainable way.

Rather than attempting any further simplification of the science in order to cater for a low level of understanding[b], a more useful approach would be to focus on enhancing the understanding of those responsible for operationalisation and on simplifying the science-management interface.

How, whilst the scientists continue with their work, can we help water managers to better understand this work, the need for sustainability and what to do to operationalise RDM?

Action needed:

1. Build capacity within CD:RDM to *manage* the complex RDM operationalisation that is beginning to unfold. Use a national technical advisory group to *advise* CD:RDM on technical matters, rather than aiming to have DWA staff who understand all the intricacies of the technology used – an impossible goal due to their many other responsibilities and the number of disciplines involved.

2. Finalise the RDM procedures in terms of work flow and methods for operationalisation as a matter of urgency in discussion with the end-user managers, guided and supported by the technical advisory group.

3. Create a plan to coordinate technical assistance to DWA Regional Offices and emerging CMAs as they develop catchment management strategies, guided and supported by the technical advisory group.

[b] *"Everything should be made as simple as possible, but not simpler" Albert Einstein*

8.11 Communication, changing perceptions and water resource audits

Past problems of over-allocation of water are being exacerbated by growing demands for water, bringing protests that the Reserve is inappropriate when people are under financial and other pressures. Some stakeholders, including some within DWA and the government, erroneously perceive the Ecological Reserve as being there to 'protect bugs', in direct competition with the needs of humans [2]. It is seen as hindering development and acting as a constraint to licensing. Outside of water professionals and some relevant NGOs, it is probable that most people in the country remain unaware of, or unconcerned about, maintenance of the ecosystem services provided by the country's inland waters.

There is a poor understanding that the Reserve is an expression of the NWA in terms of the maintenance of these services: flood attenuation, maintenance of biodiversity, carbon sequestration, purification of polluted water, reliable supplies of water in the dry season, and much more. Within the water resource planning process, the results of Reserve determinations are often inserted into the plans at a very late stage, creating the impression that the Reserve is taking water away from people rather than being a means to ensure its sustainable delivery. The real issue – that a planning process needs adjustment – is lost under the misdirected issue of 'humans versus the Reserve'.

In essence, there has been a failure to demonstrate to all stakeholders that water resources are being used and managed in an unsustainable way and that the situation is getting worse. The reality that ecosystems are service-delivery agents for humans is still not well understood in the entire decision-making process, causing difficulties in IWRM at every level from political to end user.There are many possible reasons for this lack of understanding, including the confusion over what sustainable development really means, the newness of the concept of ecosystem services and their value, and the difficulty of relating intangible benefits to peoples' every-day lives, especially for those struggling in poverty. While awareness-raising campaigns have a role to play, more will be gained by engaging with stakeholders to develop both a shared understanding of the use and protection of water resources and a process for making shared decisions on their use. This is what the newly promulgated water resource classification process is intended to achieve.

Action needed:

1. Run a comprehensive awareness campaign for stakeholders on the water resource classification process and its role in sustained service delivery and IWRM.

2. Fast-track the establishment of public private partnerships, installing co-operative governance structures with strong leadership and multi-scale feedbacks to enable a shared responsibility in terms of water resource protection and use of the nation's water resources.

3. Produce brochures, posters, maps and other similar information on the results of Reserve determinations or classification exercise for a catchment so that stakeholders can see what has been done and what the goals are for their area.

4. Feed this information into a national GIS-based database on DWA's website that is open to the public and which – post classification and recognizing that it is an ambitious programme – provides as much as possible of the following information on a daily basis for each river monitoring point across a catchment (incorporates Action 5 under Section 8.7):

- the RDM targets (Management Class, Reserve and RQOs)
- flow volume on that day
- how much of the flow represents the Reserve
- how much of the flow represents what is currently allocated downstream
- how much is thus still available for allocation at that point
- the same information pertaining to water quality and licences for effluents
- the latest River Health results.

5. Create similar databases for wetlands, estuaries and groundwater (Section 8.13) systems.

6. Upgrade the DWA website to make it easier to negotiate and find information.

8.12. The Basic Human Needs Reserve

Because of the weakness in the current approach for setting the BHNR (Chapter 5), the methods currently in use need to be reviewed to produce a consistent approach and formal guidelines.

Action needed:

1. The guidelines should include the volume of the BHNR for each person and the circumstances under which this could differ from catchment to catchment.

2. The Chief Directorates within DWA with the mandate for the BHNR and Free Basic Water should resolve how the two can be linked and aligned in order to ensure that there is not duplication or confusion over allocations. Early indications are that the BHNR will move from CD:RDM to be managed by the Chief Directorate: Water Services, but this needs to be formalised.

8.13 The groundwater component of the Reserve

It will take years to collect the statistically meaningful data required for a comprehensive Groundwater RDM determination but it would be irresponsible to delay the work due to a lack of data. A tool is available within the GRDM software that uses existing data to provide a low confidence GRDM determination in a fairly short period of time, which can then be used when considering license applications. Such a use would have to adhere strongly to the precautionary principle and allow for a large margin of error in the current recharge values.

Recognising the low confidence upon which licenses would be issued, the requirement for users of groundwater systems to monitor groundwater level and rate of abstraction should be part of the licensing conditions. This information should be incorporated into DWA's Groundwater Database with a view to reviewing the licence conditions and adjusting the allocable portion if justified. This could be a win-win situation as the water user would get access to the resource fairly quickly and DWA would acquire more reliable data in a way that is not a financial burden to it.

Action needed:

1. Develop and implement a process for including the requirement in licences for users of groundwater to regularly supply water use and water level data to a central DWA database.

2. Formally use this database in IWRM planning decisions, and in the Integrated Development Plans used by local government.

8.14 Conclusion

It will be important for DWA not to fall prey to frustration and impatience. This could well lead to injudicious amendments to the NWA, which is internationally acknowledged to be among the best of its kind, simply to make its implementation more achievable in the short term. Water resource classification and compulsory licensing are central requirements of the NWA and, although they are technically and administratively onerous, they are vital for achieving the long-term objectives of the NWA, which are equitable, sustainable and efficient use of water, and which accord entirely with the objectives of government policy in general. The work that is done to achieve these objectives could provide learning and guidance to other developing countries contemplating a similar path.

The NWA requires that setting the three Resource Directed Measures be done 'as soon as reasonably practicable'[c]. Twelve years after the NWA became law it is legitimate to ask how long it will be before RDM moves past the approval of Reserves (which is moving along apace), to full operationalisation across the landscape, where progress with RDM monitoring and enforcement, in particular, is negligible.

South Africa has shown many times in many ways that its people can work together to resolve intractable problems. Sustainable use of the country's water resources needs such an endeavour, with all key sector role-players and society at large working together to bring about responsible and equitable use of this limited resource in a system of effective cooperative governance. Prof. Mike Muller, one of DWA's former Directors-General, captured the essence of such an approach to water management when he added two more words to the DWA slogan:

ENSURING some for all for ever, TOGETHER.

[c] *NWA sections 13 and 16.*

References

1. Driver, A., Nel, J.L., Snaddon, K., Murray, K., Roux, D.J., Hill, L., Swartz, E.R., Manuel, J. and Funke, N. 2011. Implementation Manual for Freshwater Ecosystem Priority Areas. WRC Report No. 1801/1/11. Water Research Commission, Pretoria.

2. Van Wyk E., C. M. Breen, D. J. Roux, K. H. Rogers, T. Sherwill and B. W. van Wilgen 2006. The Ecological Reserve: toward a common understanding for river management in South Africa. Water SA 32(3): 403-409.

Appendices

Appendix 2.1 Fundamental principles and objectives for a new water law in South Africa

Appendix 4.1 Terms and acronyms

Appendix 4.2 RDM tools and procedures

Appendix 4.3 Example of completed Reserve template

Appendix 6.1 Knowledge and skills development

Appendix 7.1 Water Use Licence Application (WULA) procedure

Appendix 7.2 Reserve processing procedure

Appendix 7.3 Revised and simplified RDM process

On the WRC website (www.wrc.org.za) click on Knowledge Hub, enter the report number (TT 491) in the search block and enter and scroll down for the report and all appendices.

In 1994 South Africa emerged from political isolation and installed its first democratic government. The country's river scientists emerged from scientific isolation to make a major global contribution to a new science aimed at helping resuscitate the world's dying rivers and bring a more caring balance into the management of those still in good condition. As the incoming government prepared its new water law, the water scientists were ready with their knowledge and vision for sustainability, and so the two strands of history intertwined again and again in ways not imaginable even a few years earlier. This is an account of those times and what came next from some of those who took part.

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