Groundwater Strategy 2010

GROUNDWATER STRATEGY 2010

water affairs

Department:
Water Affairs
REPUBLIC OF SOUTH AFRICA

Foreword

It is now generally understood that the world's freshwater resources are finite, that they cannot continue indefinitely to sustain the ever-increasing demands we make on them, and that access to water, for life and livelihoods, is one of the key factors with potential to limit equitable and sustainable social and economic development.

For a range of reasons, some of which relate to the system of water management introduced in the early 19th century, South Africa's groundwater resources have not received the same level of attention, either from managers or users, as surface water.

As a result it is an underutilised resource, but it has the potential to make a much greater contribution to meeting the country's water needs than is currently the case. One of the principal aims of the strategy is to address this imbalance by, among many other things, clearly stating how much groundwater is reliably available, and where it occurs.

The predominantly fragmented and scattered nature of groundwater occurrence in South Africa has presented considerable difficulties in quantifying its availability with any certainty, and it is of enormous significance that the strategy presents, arguably for the first time, authoritative figures for the volumes of groundwater that can be sustainably extracted for use, not only for the country as a whole, but also for each of the 19 water management areas.

The strategy is not, however, just a technical document. It recognises the critical role played by the institutions that manage the development and use of groundwater, particularly in the many local municipalities that rely on groundwater for a significant proportion of their water requirements.

Targeted education and training programmes are proposed to address the present lack of capacity in the groundwater sector, a communication strategy is put forward to create awareness among water managers and users of the merits of groundwater, and the need for continuing groundwater research is emphasised, to improve our knowledge and understanding of groundwater, especially about the linkages with surface water.

The Groundwater Strategy addresses every aspect of groundwater in a number of carefully thought-out Chapters, and lays a firm foundation for the management of this valuable resource into the foreseeable future.

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Summary of Key Focus Areas

The Groundwater Strategy is the outcome of a three-year consultative process. The process entailed a series of detailed studies, a list of which are given in the References at the end of the Strategy. It is designed to ensure that groundwater is recognised, utilized and protected as an integral part of South Africa's water resource. The Strategy is divided into a series of themes or Chapters, each of which has a number of recommended actions which address the challenges raised in the theme.

The Strategy is designed to be implemented through the Strategic Plan of the Department.

The most important actions from each Chapter are presented below:

Policy, Legislation and Regulation:
- All groundwater water use license applications must be resolved within six months.
- All larger groundwater users must be registered and possess water use licenses.
- Existing groundwater use must be verified within a reasonable time period.
- Borehole drillers must be registered with the Department, and must submit drilling and test pumping data to the Department from all boreholes drilled.

Water Resources Planning:
- Conduct groundwater resource assessments to a level comparable with other water resource assessments (e.g. assessment of surface water potential).
- Implement groundwater development programmes for domestic and productive water use to support national imperatives.
- Update figures on groundwater availability and use as new data becomes available.
- Establish guidelines for the groundwater content of Internal Strategic Perspectives and emerging catchment management strategies.
- Develop and implement best practise guidelines on groundwater management and protection for the municipal, agricultural, energy and forestry sectors.

Human Capacity:
- Develop adequate capacity to fulfil the groundwater functions.
- Develop and implement a national capacity building strategy.
- Mobilise private sector support where necessary to capacitate Regional Offices.
- Implement practical, in-service training courses on priority aspects (e.g. licensing process, the Reserve, groundwater monitoring, etc.) for staff.

Sustainable Groundwater Management:
- Ensure the implementation of existing strategies, regulations and guidelines on groundwater management such as the Artificial Recharge strategy and others.
- Establish a Groundwater Resource Governance Section, which will ensure support to water services institutions in the operation, maintenance and management of groundwater supply schemes. Functions must include the evaluation of artificial recharge potential and conjunctive use schemes.

Institutional Capacity:
- Capacitate and provide adequate resources to the Regional Offices to fulfil their mandatory water resource management functions.
- Improve cooperation and coordination within the Department, and between government departments and the private sector to leverage available capacity and resources.
- Incorporate the recommendations from the Reconciliation Strategies into the Integrated Development Plans (IDPs) and Water Services Development Plans (WSDPs).
- Provide strategic support to water services institutions to develop business plans (i.e. WSDPs) for groundwater development, management and monitoring as well as for the operation and maintenance of groundwater infrastructure.
- The roles and responsibilities for groundwater development and management, including monitoring of groundwater level abstraction and quality, as well as the maintenance and operation of groundwater infrastructure across sectors should be improved and streamlined, and responsibilities clearly defined.

Information Management:
- Announce the National Groundwater Archive (NGA) to the Public Domain, including Catchment Management Agencies (CMAs), water resources and other external stakeholders, as well

as finalize the adoption of measures to incorporate privately held datasets, including the registration of drillers.

- Develop and implement an integrated groundwater information system to support water services provision at municipal level.
- Develop and implement a Groundwater Monitoring Strategy to address the monitoring challenges at national and regional level.

Groundwater Research:

- The Department and the Water Research Commission (WRC) must continue to support groundwater research capacity at tertiary institutions, and prioritise research projects which directly address strategic national objectives, including issues identified as bottlenecks in groundwater management or delivery.
- Dissemination and implementation of research products must be improved.
- Water Research Commission (WRC) should regularly assess the impact of research investment in groundwater.
- Emphasis should be placed on the strategic leveraging of resources between the WRC, DWA, National Research Foundation (NRF) and the alignment of strategic objectives for groundwater management between the WRC and DWA, e.g. the development and roll-out of strategies supported by implementation programmes.

Communication and Awareness:

- Develop a professional marketing and communication plan focussing on promoting successful groundwater use and management.

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List of Abbreviations

A

ADE	Aquifer Dependent Ecosystem
AFD	Agence Française de Développement
AGSA	Auditor-General of South Africa
AGWNet	African Groundwater Network
AMCOW	African Ministers Council on Water
AMD	Acid Mine Drainage
AquiMon	Software for Groundwater Management

B

Burdon Network	Professional network linked to the International Association of Hydrogeologists working on groundwater in the developing world

C

CAPNet	Capacity Building Network
CGS	Council For Geoscience
CMA	Catchment Management Agency
CMS	Catchment Management Strategy
CPD	Continued Professional Development
CSIR	South African Council for Scientific and Industrial Research

D

DANIDA	Danish International Development Agency
DBSA	Development Bank of Southern Africa
DEA	Department of Environmental Affairs
DFID	United Kingdom Department for International Development
DMC	Disaster Management Centre
DMR	Department of Mineral Resources
DWA	Department of Water Affairs
DWAF	Department of Water Affairs and Forestry

E

EIA	Environmental Impact Assessment
EMP	Environmental Management Plan
EU	European Union

F

FETWater	Partnerships and networks for promoting groundwater in SADC

G

GDAS	Hydrogeological Data Access System
GEOSS	Mapping and groundwater consultancy in South Africa
GH	Geohydrology (synonymous with hydrogeology)
GMI	Groundwater Management Institute
GRA	Groundwater Resource Assessment
GRIP	Groundwater Resources Information Project
GS	Groundwater Strategy
GSSA	Geological Society of South Africa
GW	Groundwater
GWDSA	Groundwater Division of the Geological Society of South Africa
GWLS	Global Water License Services

I

IAH	International Association of Hydrogeologists
ICRAF	World Agroforestry Centre
IDC	International Development Co-operation
IDP	Integrated Development Plan
IGARF II	Impact of groundwater abstractions on river flows: Phase 2
ISARM	Internationally Shared Aquifer Resources Management
ISP	Internal Strategic Perspective
IWRM	Integrated Water Resource Management

K

KZN	KwaZulu-Natal

M

MAR	Mean Annual Runoff
MDG	Millennium Development Goals
MPRDA	Minerals and Petroleum Resources Development Act

N

NEMA	National Environmental Management Act
NGA	National Groundwater Archive
NGOs	Non-Governmental Organisations
NGDB	National Groundwater Database, hosted at DWANGOs
NORAD	Norwegian Agency for Development Cooperation
NRF	National Research Foundation
NWA	National Water Act (Act 36 of 1998)
NWRS	National Water Resource Strategy

O

ODA	Overseas Development Assistance
O&M	Operation and Maintenance
ORASECOM	Orange-Senqu River Commission

P

PGDP	Provincial Growth and Development Plan
PSDP	Provincial Spatial Development Plan
PSP	Provincial Spatial Plan

R

RO	Regional Offices
RSA	Republic of South Africa

S

SA	South Africa
SACNSP	South African Council for Natural Scientific Professions
SADC	Southern African Development Community
SALGA	South African Local Government Association
SGWCA	Subterranean Government Water Control Area
SusIT	Sustainability Indexing Tool
SW	Surface water
SW-GW	Surface water – groundwater

T

TBA	transboundary aquifers
TCTA	Trans-Caledon Tunnel Authority

U

UGEP	Utilisable Groundwater Exploitation Potential
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational Scientific and Cultural Organisation
URV	Unit Reference Value

W

WARMS	Water Use Authorisation Registration Management System
WaterNet	Partnerships and networks for promoting groundwater in SADC
WC/DM	Water conservation / demand management
WFGD	Water for Growth and Development
WISA	Water Institute of Southern Africa
WMA	Water Management Areas
WRC	Water Research Commission
WRM	Water Resource Management
WRP	Water Resource Planning
WRSM2000	Water Resources Simulation Model 2000
WSA	Water Service Authority
WSDP	Water Services Development Plan
WSP	Water Service Provider
WTE	Water Trading Entity
WUA	Water User Associations
WULA	Water Use License Application

Symbols

Cl	Chloride
kℓ	Kilo Litre
kWh/m^3	Kilowatt hours per cubic metre
ℓ/s	Litres Per Second
m^3/a	Cubic Meters Per Annum
m^3/hr	Cubic Meters Per Hour
m^3	Cubic Meters
mg/ℓ	Milligrams per litre
million ℓ/day	Million Litres Per Day
ML/day	Megalitres per day
m/s	Meters Per Second
mS/m	MilliSiemens Per Meter
€	Euros

1. Introduction

1.1 The Department of Water Affairs' Strategic Plan 2010/11 – 2012/13

As part of its current Strategic Plan, the Department of Water Affairs has identified six Priority Areas which will allow it to effectively manage the nation's water resources in alignment with agreed government-wide priorities. As an essential component of South Africa's total water resource, groundwater is important today in sectors ranging from agriculture to domestic water supplies. Groundwater will make proportionately greater contributions to the nation's water supplies in future as surface water reaches the limits of its exploitable availability.

1.1.1 **Priority Area 1:** Contribution to economic growth and social development

Many people are not aware that groundwater provides reliable, safe drinking water supplies to rural areas and many towns in South Africa. Even large cities such as the Tshwane Metropolitan Municipality are dependent partly on groundwater. Many farms, mines and industries rely on groundwater for their water supply. Groundwater infrastructure will therefore form part of the Department's spending plans and backlog eradication, and contribute to security of essential economic infrastructure. Chapters 2, 3 and 9 of this document cover this Priority Area.

1.1.2 **Priority Area 2:** Ensuring equitable and sustainable water resources management

The national water reconciliation strategies which are designed to be used to improve water resource sustainability include groundwater. Better use of groundwater will help to solve problems of current water shortages and ensure that water is also available to meet future increases in demand. Improved groundwater use may also help to avoid more expensive alternative and less sustainable water supply options. This is a broad or cross-cutting Priority Area, and relevant actions are discussed in Chapters 2, 5, 6, 7 and 8 of this document.

1.1.3 **Priority Area 3:** Promoting rural development

Groundwater is already a major source of water in rural areas, and better groundwater use and management will help to improve the lives of the most marginalised. Water supply is also crucial to food security, and to land reform. The section on "groundwater and service delivery" in Chapter 3 of this document is particularly relevant to this Priority Area.

1.1.4 **Priority Area 4:** Effective support to local government

Groundwater in South Africa is a local resource, and is usually best managed at local level. The support which the Department provides to local government therefore contains a component of groundwater assessment and management.

Chapter 6 of this document (Institutional Capacity) describes the groundwater capacity that is needed at local level to ensure service delivery, whilst Chapters 4 and 5 are also relevant to this Priority Area.

1.1.5 **Priority Area 5:** Contribution to global relations

The Department is committed to strengthening engagement with South African Development Community (SADC) member states, and to promote dialogue with the African Ministers' Council on Water (AMCOW), currently chaired by the South African Minister of Water and Environmental Affairs.

The section on groundwater and climate change in Chapter 3 of this document, and the section on international cooperation in groundwater research in Chapter 8, refer to this priority. South Africa's skills in groundwater development and management promise to contribute to poverty alleviation in SADC in the coming years.

1.1.6 **Priority Area 6:** Improving the Department's capacity to deliver services

Scarcity of skills in hydrogeology is an area which the Department of Water Affairs is committed to improving. Chapter 4 of this document (Human Capacity) discusses this in more detail. Service delivery, especially in rural areas, often relies on groundwater.

1.2 Aims of the Groundwater Strategy

The aims of the Groundwater Strategy were decided on

Box 1-1:
International Drivers for Change and Groundwater

Recent international agreements support the principles of the South African National Water Act and its implications for groundwater access, assessment and management. In September 2000 the United Nations General Assembly adopted General Assembly Resolution 55/2, or the 'Millennium Declaration', in which member countries endorsed a series of values and principles designed to advance global development and reduce poverty.

One of the resulting Millennium Development Goals (MDGs) commits countries to halving, by 2015, the proportion of people worldwide without access to safe drinking water compared to 1990 levels. The World Summit on Sustainable Development, held in Johannesburg in 2002, emphasised initiatives towards regional and trans boundary cooperation in water resource management, and expressed support for the principles of integrated water resource management (IWRM).

Furthermore, the target of halving the proportion of people worldwide without access to sanitation by 2015 was added to existing MDG agreements. It is recognized that the provision of clean water and adequate sanitation are "cross cutting" issues which assist in meeting many other developmental challenges. Since groundwater is the only affordable and accessible source of clean, safe water across much of the developing world – particularly in rural areas where poverty is most dire – groundwater exploitation and management is vitally important to poverty alleviation and development.

following a detailed consultation process, which ended in 2007. **They are as follows:**

- Groundwater is recognised as an important strategic water resource in South Africa, within an integrated water resource management approach.
- The knowledge and use of groundwater is increased along with the capacity to ensure sustainable management.
- Better groundwater management programmes are developed and implemented at required water resource management levels, tailored to local quantity and quality requirements.

1.3 Groundwater Strategy vision

The Vision of the Groundwater Strategy is as follows:
Groundwater is recognised, utilized and protected as an integral part of South Africa's water resource.

1.4 Structure of this document

The strategy is presented in ten Chapters *(See Table of Contents)*. Each Chapter deals with a particular aspect or theme of groundwater (e.g. Policy, Legislation and Regulation). These Chapters were decided on following a lengthy process of consultation with public and private sector stakeholders. Within each Chapter, there is a background section describing the theme, followed by a problem statement summarising the present situation.

This is followed by a strategy statement, broadly describing what needs to change and how this can happen. Finally a list of concrete, implementable actions relating to the theme is presented. Attached as an appendix is an implementation framework that lists the actions according to the DWA Strategic Plan's six Priority Areas.

1.4.1 Background to the Groundwater Strategy Process

This document is one of the outcomes of a three-year process led by the Department and involving many public sector experts, and consultants.

This process followed the initial groundwater strategy completed as part of the Danish International Development Agency (DANIDA) Programme entitled 'Strategies for Inclusion of Groundwater in the National Water Resource Strategy (NWRS)' and the 2007 publication of a document called "A Framework for a National Groundwater Strategy", which provided direction and support.

This strategy document distils the main outcomes of this process, but in the interests of brevity does not cover all the work in detail. The Framework was an internal DWA directive, the Groundwater Strategy will be the main groundwater input to the second edition NWRS. The National Water Act (Act 36 of 1998) and the National Water Resource Strategy (NWRS) of 2004, which have grown out of the National Water Policy of 1997, provide for groundwater as part of an integrated water resource.

The fundamental principles and objectives of South Africa's water law with implications for groundwater are that:

- All water resources are common to all, and are subject to national control.
- All water has a consistent status in law, irrespective of where (and where in the water cycle) it occurs.
- Groundwater is an integral part of the water resource and must be managed as such.

Also see box 1-1 on International Drivers for Change and Groundwater.

...END

2. Policy, Legislation and Regulation

2.1 Background

2.1.1 Past water laws in South Africa

The law concerning groundwater in South Africa has changed fundamentally in the last fifteen years or so. Earlier groundwater legislation was based on the "riparian" system, founded partly on the principles of Roman-Dutch law. Under this system, the owner of the overlying property held the rights to the groundwater below. In 1912 the Irrigation and Conservation of Waters Act, dealing mainly with irrigation, gave priority to agricultural activities. The Water Act of 1956 entrenched the idea of most groundwater (as well as "private" surface water such as streams) as a private resource, and there was no obligation to share resources equitably.

Since land ownership was in many cases restricted to a small minority of the population, control of water was strongly biased towards a minority of South Africans. The state had little control over private groundwater, except where groundwater had been declared part of a "subterranean government water control area (SGWCA)", a category applied to relatively few locations *(See figure 2-1 indicating the SGWCAs in RSA)*. Taken together, these measures greatly complicated regional groundwater assessment and management, since it had the effect of defining groundwater as a local and "private" resource in law if not in reality.

2.1.2 Modern South African water legislation

Today, South Africa's groundwater is recognised as a common asset whose trusteeship is vested in the state. The National Water Act (Act 36 of 1998)(NWA) recognised groundwater as public water, and abolished the riparian principle. Groundwater is now seen as part of the water cycle, and therefore as connected to other water resources.

Furthermore, the National Environmental Management Act (Act of 1998) and the Minerals and Petroleum Resources Development Act (Act of 2002) lay out new obligations for the mining and other industries in terms of the monitoring and remediation of pollution of water resources.

2.1.3 The National Water Resource Strategy

The National Water Act (Act of 1998)(NWA) stipulates the development of a National Water Resource Strategy (NWRS), whose purpose is to "…provide the framework for the protection, use, development, conservation, management and control of water resources for the country as a whole" (Sections 5 to 7).

The first edition of the NWRS was published in 2004. The NWA states that the NWRS "must be reviewed at intervals of not more than five years", in consultation with civil society. It is currently being reviewed and a second edition is due to be completed in 2011.

The NWRS is a legal document and is binding on all authorities and institutions exercising powers or performing duties under the NWA. It is also the over-arching strategy document governing long-term water resources policy, planning and allocation. It is the document most likely to be seen and read by planners or officials outside of the water field, international funding partners and others.

2.1.4 Water for Growth and Development Framework

The Department is currently finalising its Water for Growth and Development Framework (WfGD), a key document designed to guide water development and management in South Africa. The WfGD considers water in all its competing uses, and acknowledges the major role of water supply in economic growth and development.

It highlights the risk in water management and recommends measures to be taken to ensure water security. The WfGD has been developed in close collaboration with a range of stakeholders in the water sector, and can be considered as one of the main inputs into this Groundwater Strategy. The ongoing revision of the NWRS is also informed by the WfGD.

2.1.5 Integrated Water Resources Management (IWRM)

According to the NWRS, Integrated Water Resources Management (IWRM) can be defined as a process that promotes the coordinated development and management of water, land and related resources in

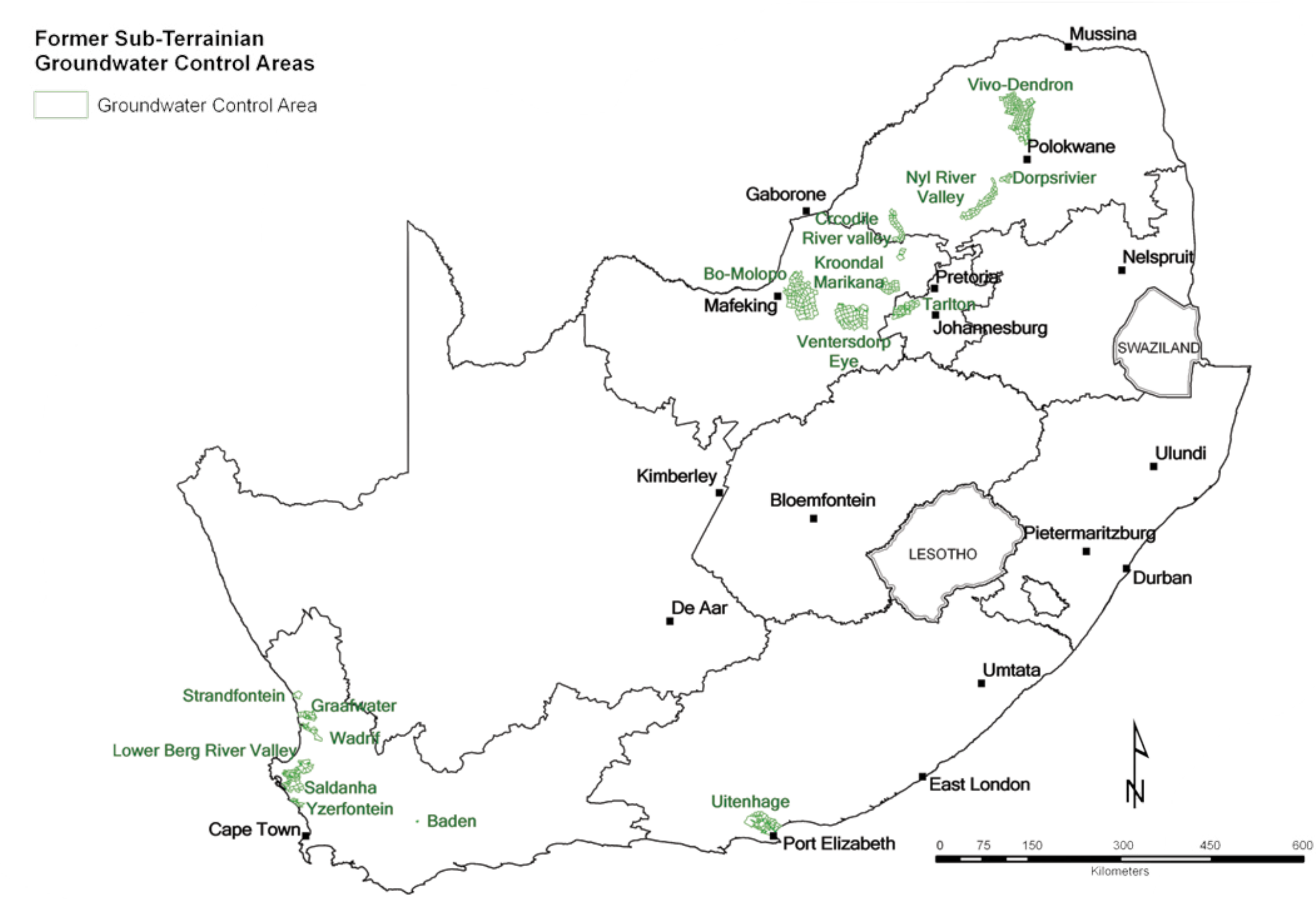


Figure 2-1 Subterranean Groundwater Control Areas

> **Box 2-1:**
> General authorizations and licensing
>
> **The National Water Act makes provision for the regulation of water use through:**
>
> - The registration of water use, and
> - Different types of authorisations.
>
> **Different types of water use authorisations include:**
>
> - **Schedule 1 Water Use** – permissible, small quantities of water use that do not require registration or a licence. Schedule 1 water use applies to all river catchments and aquifers throughout the country.
> - **General Authorisations** - General permission for slightly larger water uses from less-stressed sources allowing a user to use water without a licence provided that the water use is within set limits and conditions to protect the water resource. A general authorisation is only applicable to specific catchments or aquifer systems and is not generally applicable throughout the country. The strength of General Authorisations is thus that it can be applied to specific areas and with specific conditions attached.
> - **Water Use Licences** - A user must apply for a licence for any new water use that exceeds the limits outlined in Schedule 1 and allowed for under general authorisations.
> - **Existing Lawful Use -** Any lawful water use prior to 1998.

order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems. Economic and sectoral water needs should be balanced with the needs of marginalized sectors and the environment. Water cannot be considered separately from the people who use and manage it and a balanced mix of technological and social approaches are required.

The National Water Act supports the principles of IWRM - groundwater can no longer be considered in isolation from other water resources, from ecosystem needs, or from the requirements of the greater user community. The position regarding the licensing of groundwater is often unclear to both users and planners.

Assessment and approval of groundwater use license applications is a slow process with some applications turned down and referred to the tribunal. The wider application of the General Authorisation is seen as a possible solution, with proper management and monitoring. The Department is in the process of updating General Authorisations for groundwater abstractions. This latter process resulted in revised general authorisations for groundwater abstractions per quaternary catchment. The revised general authorisations for groundwater abstractions are the result of a process of extensive deliberations by staff at Regional Offices.

2.2 Problem Statement

South Africa is often acknowledged to have some of the most modern and progressive legislation governing the use and management of water resources (including groundwater) in the world. The problem is one of implementation.

The backlog in issuing groundwater licenses means that water use is taking place without proper regulation. There are also challenges in dealing with illegal water use, and the possible penalties are not widely understood. Although all users are required to register existing lawful use, and most have done so, only about 20% of this use has thus far been verified. The lack of verification makes it more difficult to effectively regulate this use. Limited capacity exists within the Department to carry out this task effectively.

Consequently the enforcement of water use licensing conditions is weak. The waste discharge charge system, based on the polluter pays principle, has also not yet been implemented, and there are several examples of groundwater pollution in South Africa (most prominently acid mine drainage) which are not being addressed effectively. Control of groundwater pollution is further hampered by a limited (and in some cases deteriorating) groundwater monitoring network.

Currently, the Department owns and manages water resource infrastructure itself, with an asset value of approximately R100 billion. Regulatory oversight in the form of standards setting, monitoring of performance, setting of prices, etc of the groundwater component of this infrastructure requires improvement. Local government is a groundwater user in terms of both abstraction from aquifers and the discharge of wastewater.

The principle tool of regulation is the water use licence (either separate licences for water abstraction and water discharge, or a single integrated licence for both abstraction and discharge). The enforcement of water use conditions poses some challenges in the case of local government and in the context of the principle of cooperative governance. The approach to regulating local government as a water user needs to be clarified.

Incidences of groundwater pollution need to be addressed as soon as they are detected. It is cheaper and easier to prevent pollution or address it in the early stages, than to attempt to "clean up" an aquifer afterwards.

In particular, a comprehensive water policy framework within the Department is required to deal with water (particularly groundwater) issues at abandoned and derelict mines. The mine closure strategies currently being developed elsewhere in government should continue to cooperate closely with the Department. Acid mine drainage[(1)] poses a serious threat to both groundwater and surface water.

2.3 Strategy

The sustainable management of groundwater resources in South Africa is dependent on effective regulation, and the National Water Act provides a powerful set of regulatory tools with which to regulate groundwater use, including discharge and other activities which impact on the groundwater resource.

Licenses require clear disclosure of water use (both abstractions and discharge) and can be used to create strong incentives for improvements in water use efficiency through licence conditions.

In general, procedures should be implemented to speed up and simplify licensing procedures - effective licensing of water use and enforcement of licensing conditions are essential. At the same time, the water use verification process needs to be speeded up.

Water quality aspects should be included in both procedures. Where unlawful use or pollution of groundwater takes place, offenders should be prosecuted.

2.4 Actions

- Groundwater must be adequately addressed in revisions of the NWRS, the WfGD Framework, Catchment Management Strategies (CMS), Water Services Development Plans (WSDPs) and other strategy documents.
- Review and continue to implement the policy on 'Groundwater Quality Management in South Africa'.
- Finalise the policy and strategy on the rehabilitation of abandoned mines, ensuring that relevant groundwater aspects are addressed.
- Groundwater contributions to the ecological Reserve needs to be determined where possible in all the water management areas.
- Resolve groundwater licenses within reasonable time frames (suggested period of 6 months).
- Ensure that all groundwater users are registered with up-to-date water use licenses.
- Verify water use within a reasonable time frame and implement programmes to enforce compliance with respect to water use license conditions. Implement

(1) Acid mine drainage (AMD) – the uncontrolled flow of polluted water from derelict or abandoned mines – has a large groundwater component, because it is normally groundwater which flows into mines, becoming polluted in the process. AMD is recognized internationally as one of the most serious and long-term water-related environmental threats. South Africa's AMD problems are amongst the most serious in the world, both in terms of polluted water quality and volumes of decanting water. Unfortunately it is still sometimes heard that "the problem may go away by itself" once a new equilibrium state is established.

stricter regulations regarding noncompliance with respect to water use license conditions.

- Develop regulations for groundwater users and drilling and test pumping companies to provide groundwater data to Regional Offices.
- Render the final granting of licenses to water users dependent on the submission of groundwater and drilling data to the Department.
- Implement Resource Quality Objectives where Water Resource Classification has been determined for groundwater.

...END

3. Water Resources Planning

3.1 Background

3.1.1 How much groundwater does South Africa have?

One of the most important questions that is frequently asked is "how much groundwater do we have in South Africa?" This question is more complex than it might first seem, because using groundwater in a sustainable way for water supplies, without harming the environment, depends on sufficient data and on factors including recharge (i.e. what proportion of rainfall percolates into the ground to become groundwater), the quality of the groundwater, and the properties of the aquifer (i.e. an aquifer that supports only very low yielding bore holes may contain a lot of groundwater, but still not be very useful for water supply). The most recent scientific estimates place groundwater in South Africa in the same league, volumetrically, as our stored surface water resources: The total volume of available, renewable groundwater in South Africa (the Utilisable Groundwater Exploitation Potential, or UGEP) is 10 343 million m³/a (or 7 500 million m³/a under drought conditions)[2]. *(See Table 3-1 below for a breakdown of groundwater availability per Water Management Area.)*

(2) These figures are derived from recent GRA 2 work (see Information Management Chapter). For more detailed information, see Middleton and Bailey (2009) – Water Research Commission report 380/08. For planning purposes the Utilisable Groundwater Exploitation Potential or UGEP is a realistic measure of groundwater availability. "UGEP represents a management restriction on the volumes that may be abstracted based on a defined "maximum" allowable water level draw down. It is likely that, with an adequate and even distribution of managed production boreholes in accessible portions of most catchments or aquifer systems, these volumes of groundwater may be abstracted on a sustainable basis" (Middleton and Bailey, 2009). The Utilisable Groundwater Exploitation Potential takes into account limits imposed by recharge (including its variability due to drought), variations imposed by borehole yield which affect the practicality of abstraction ("exploitation factor"), groundwater contribution to river base flow, and ecological Reserve. It does NOT take into account existing abstractions (including basic human needs), or perceived limitations due to poor groundwater quality (which could be remedied by water treatment, as with surface water).

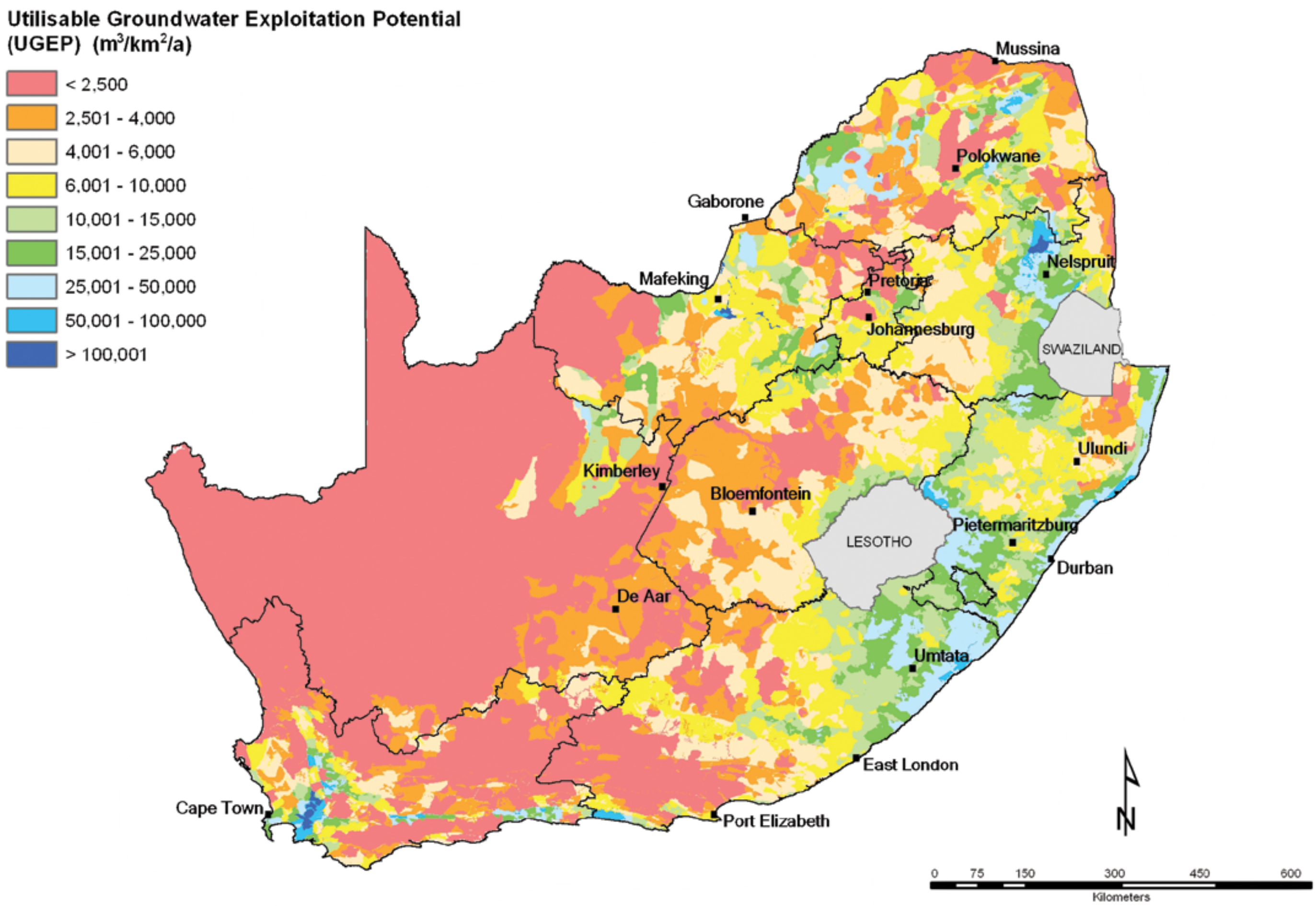


Figure 3-1 Utilisable groundwater exploitation potential for South Africa (GRA 2)

No.	Water Management Area	UGEP (million m³/a)
1	Limpopo	644.3
2	Luvuvhu and Letaba	308.9
3	Crocodile West and Marico	447.8
4	Olifants	619.2
5	Inkomati	667.8
6	Usutu to Mhlatuze (including Swaziland)	862.0
7	Thukela	512.6
8	Upper Vaal	564.0
9	Middle Vaal	398.1
10	Lower Vaal	645.1
11	Mvoti to Umzimkulu	704.9
12	Mzimvubu to Keiskamma	1 385.9
13	Upper Orange (including Lesotho)	673.0
14	Lower Orange	318.0
15	Fish to Tsitsikamma	542.4
16	Gouritz	279.9
17	Olifants/Doring	157.5
18	Breede	362.9
19	Berg	249.0
	TOTAL	10 343.4

Table 3-1 *Groundwater Availability per Water Management Area (WMA)*

Table 3-1 is after Middleton and Bailey (2009) - WRC Report TT380/0

We currently use between 2 000 and 4 000 million m³/a of this groundwater[3]. Therefore there is the potential to considerably increase groundwater supplies in South Africa. In contrast, the assured yield of South Africa's surface water resources is approximately 12 000 million m³/a, but more than 80% of this is already allocated. Although most (but not all) large-volume water users rely on surface water, the majority of small water supplies, which are critical to livelihoods and health, depend on groundwater *(See figure 3-2 for the groundwater use per sector in WMA).*

3.1.2 Groundwater and drought / climate change

Groundwater's resilience to drought is well known – often one of the first responses in times of serious drought is to drill boreholes[4] The southern African region is already prone to droughts, and climate change scientists predict that this may get worse - climate change forecasts for southern Africa anticipate hotter, drier weather, particularly in the west[5]. Rainfall events may be more intense, but less frequent. With surface water resources already stretched in South Africa, groundwater should form a very important part of our climate change adaptation strategy in terms of assuring continuity of water supplies. Much work still needs to be done regarding the effects of climate change on technical issues such as groundwater recharge.

(3) Up-to-date figures for groundwater use in South Africa are hard to obtain. Official figures are based on groundwater licenses, but these can differ greatly from actual use. Hence the wide variation in quoted figures. This highlights the need for better groundwater data collection.

(4) Experience in Zimbabwe has shown that expertly sited boreholes can be "immune" to the harshest drought. See Lovell (2007) for more information.

(5) See Kandji et al (2006) for more information.

However, the seriousness of the issue is not in doubt - as a recent UNEP publication on climate change in southern Africa puts it: "…climate change may bring about a new set of weather patterns and extremes that are well beyond what the local communities in southern Africa are capable of dealing with"[6].

The advantages of groundwater (much lower evaporation/evapotranspiration and slower declines in drought years, because the volumes stored underground are so much higher compared with surface water) mean that it should form a key part of our strategy to adapt to climate change. Groundwater will be less directly and more slowly impacted by climate change, as compared to e.g. rivers (surface water). This is because rivers get replenished more quickly, and droughts and floods are quickly reflected in river water levels. Only after prolonged droughts will groundwater levels show declining trends. Groundwater is also closely linked to the issue of food security through irrigation of crops and maintenance of environmental flows.

The replenishment of groundwater is controlled by long-term climatic conditions. Since rainfall is the main source of recharge to aquifers, climate change may have a considerable impact on groundwater resources. Under predicted climate change conditions, groundwater has to be used and managed in a sustainable way in order to maintain its buffering and contingency supply capabilities, as well as maintain adequate water quality for human consumption.

Land-use planning has to consider groundwater resources as a precious and finite resource, and take all necessary measures to protect groundwater resources and their recharge mechanisms in the long run. Other impacts of climate change on groundwater include possible salinisation of coastal aquifers as sea levels rise, higher annual temperatures increasing rates of evapotranspiration (and therefore reducing recharge), and more intense storm events which can destroy small alluvial aquifers associated with river channels.

Our understanding of the impact of climate changes on groundwater in South Africa is limited and further research need to be conducted on various aspects of groundwater (quality and quantity) to quantify the impact on groundwater and on the communities that are dependent on groundwater.

Recommendations made elsewhere in this document on topics such as artificial recharge, groundwater data collection and groundwater research all form part of our strategy for meeting climate change.

(6) See Kandji et al (2006) for more information.

Box 3-1:
The Comprehensive Rural Development Programme

The Comprehensive Rural Development Programme was launched in August 2009 by the South African government, and is aimed at improving social infrastructure and living conditions in rural parts of the country. The supply of clean, safe drinking water is an important part of the Programme.

The development of our groundwater resources in rural areas can assist the programme to achieve its goals, since it has certain advantages over surface water development, particularly in rural areas. Land reform and support to emerging farmers both have secure water supplies as important components (Water Allocation Reform).

3.1.3 Groundwater and service delivery

Despite major advances in recent years, around six million South Africans lack basic safe water supply and sanitation services[7]. Many of these people live in rural areas, such as parts of the Eastern Cape, KwaZulu- Natal and Limpopo Provinces. In some rural areas the majority of people lack access to a safe water supply, which is a "cross-cutting" requirement for many other development indicators such as health, education and food security.

(7) See the Department's Water for Growth and Development Framework

Rural areas can be difficult to supply with surface water, since the economies of scale found with centralised (surface) water sources in urban areas do not apply.

Groundwater on the other hand is often ideal for rural water supply purposes, for the following reasons:

- Groundwater is a "proximal resource" – it is usually found close to where it is needed, making it ideal for small-scale water supplies in rural areas and for smaller municipalities. Long pipelines from distant surface water sources are not required.
- Groundwater is resistant to the effects of drought, because very large amounts of water are stored underground, and rates of evaporation are low. This means that boreholes can continue to yield water long after rivers and streams have dried up.
- The natural quality of groundwater is usually good, with little or no treatment needed. This means that expensive treatment plants, with associated operation and maintenance implications, are usually not necessary for small-scale supplies. Some treatment of groundwater is often carried out however (e.g. chlorination), and not all groundwater is safe to drink without treatment.
- Groundwater can also be developed "incrementally". Surface water supplies usually require a large initial investment (e.g. dam and treatment plant) but boreholes can be drilled as demand increases and budgets allow.

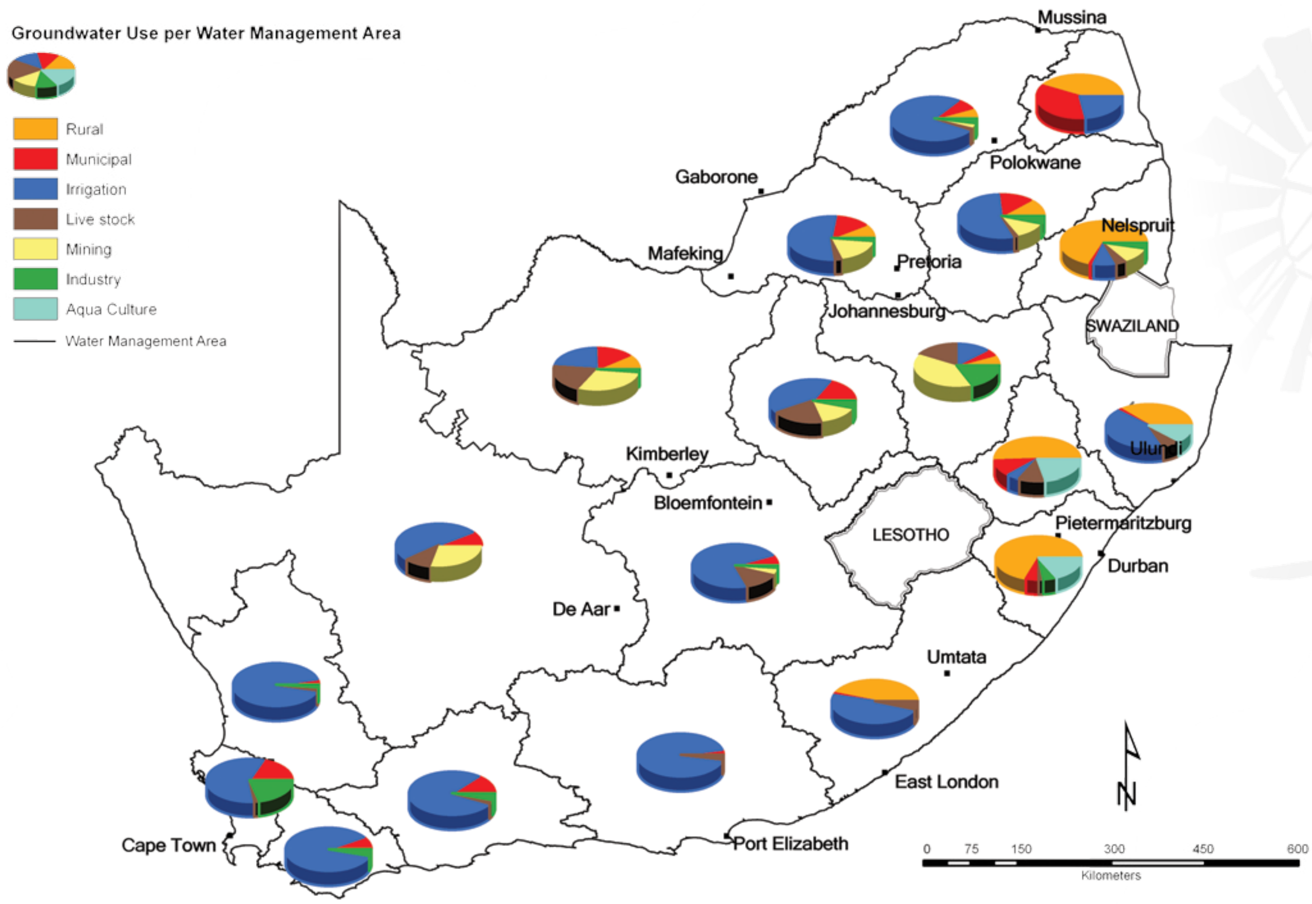


Figure 3-2 *Total groundwater use per sector in WMA*

Even relatively simple, reliable groundwater supply schemes usually cannot be installed and operated without technical assistance. As the Department Water for Growth and Development Framework recognises, "sustainable use of groundwater requires the careful initial siting of boreholes and subsequent monitoring and management to ensure that water use does not exceed supply". The explicit link between groundwater and service delivery in rural areas is not always recognised. *(See box 3-1 on The Comprehensive Rural Development Programme).*

3.1.4 Large-scale groundwater development

Recorded yields from some of the most favourable areas/aquifers indicate that large-scale development of groundwater is possible when appropriate assessment methods are utilised and effective groundwater management is applied. Unfortunately the development of high-yielding aquifers for bulk supplies is proceeding very slowly, and alternatives such as desalination are often proposed instead (e.g. in the southern Cape). In the dolomite aquifers around Gauteng, high-yielding aquifers were once assessed for emergency bulk water supplies, but are today used mainly for irrigation.

3.1.5 Groundwater and power generation

The supply of water to the electricity-generating sector is considered to be a "strategic use" and must be supplied with a high level of assurance (99.5%). Any failure in this water supply will threaten electricity production and hence economic activity.

Coal-fired power stations are usually situated near to coal resources, and not to water sources. Treated effluent and mine waste water, sometimes supplied over long distances, are being considered for supply to new power stations.

Decisions about the extent, timing and location of future nuclear, coal, gas and hydro-electric power plants have significant implications for water resource management, increasing the imperative for integrated planning between these sectors to ensure the timely delivery of water to ensure energy security.

Since surface water supplies are nearly fully allocated, the energy sector represents an indirect driver for increased groundwater development and use. Proposals to rapidly increase the proportion of South Africa's national water supply derived from desalination have considerable energy implications[(8)] *(See section 3.1.6)*

(8) An April 2010 speech by the Minister of Water Affairs stated: "Coastal towns bordered by the sea such as Plettenberg Bay, Knysna, George and Mossel Bay have relied on river water for the past three hundred years or so, notwithstanding their proximity to the sea. But with the prevailing drought, now worse than any in the past one hundred and fifty years, these towns are obliged to introduce purification processes that can utilise seawater as a source for their potable water supplies. Desalination has become the preferred purification option in terms of both the cost benefit and the flexibility of application."

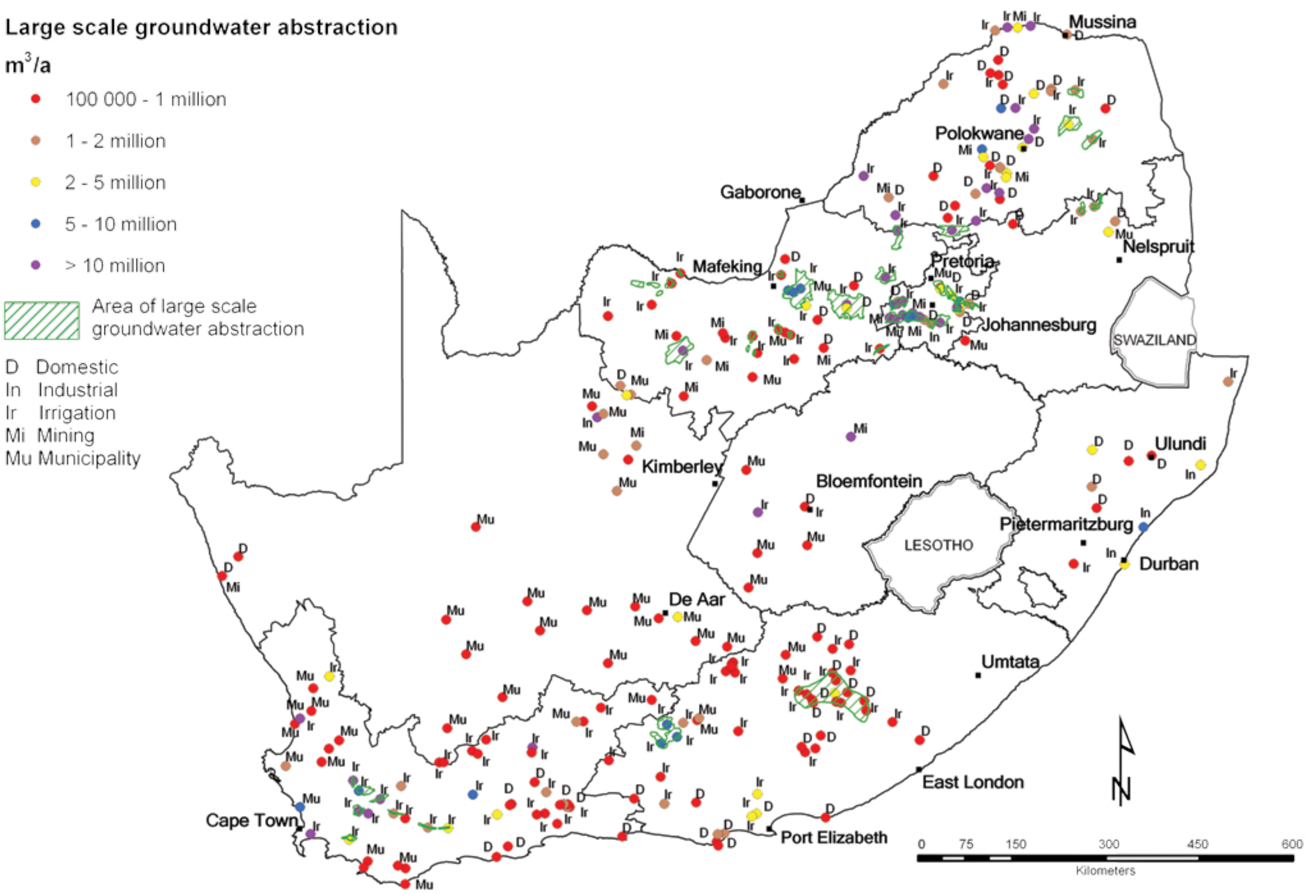


Figure 3-3 Large scale groundwater abstraction areas in RSA

3.1.6 Desalination and groundwater development

Desalination of seawater to produce drinking water costs R4 to R10 per m³, excluding environmental costs (carbon emissions from electricity generation, and brine disposal). Whilst this may be acceptable, the power requirements are very large[9] - Australians have called desalinated water "bottled electricity" due to the power needed!

Large-scale desalination in South Africa has serious energy and carbon implications. It is likely that other measures, such as reducing leaks, controlling demand and developing local groundwater resources will be cheaper and less harmful to the environment. Currently, small desalination plants operate in coastal towns such as Sedgefield in the Western Cape and Cannon Rocks in the Eastern Cape, producing modest quantities of drinking water (less than 15ℓ/s).

These quantities are well within what could be produced by even a small groundwater wellfield. Having said that, desalination can be an effective interim solution (small "containerised" desalination plants can be installed rapidly) while other measures are being taken. Desalination is also used in a few remote areas to treat brackish groundwater where no other water resources exist.

3.2 Problem statement

Whilst senior water resource planners in the Department are well aware of the potential of groundwater, many planners and managers at regional and local level do not incorporate groundwater into their water plans, or else treat it as a last resort, to be used only in emergencies. In some cases very expensive options such as desalination are implemented as short or medium term solutions to lack of water, without groundwater being given early, serious consideration (e.g. at Sedgefield).

Decision makers in the fields of climate change preparedness, rural poverty alleviation, and related fields do not always have adequate information about the ways in which groundwater can assist them, and general (i.e. not specifically water) spatial planning documents rarely consider groundwater, even where groundwater is a potential major factor in continued economic development. There is also still a certain amount of distrust of the GRA 2 figures for groundwater availability, possibly due to fairly minor technical disagreements amongst hydrogeologists about the ways in which the raw data has been interpreted on a national scale.

(9) The Dpartment's Water for Growth and Development Strategy (Version 7) envisages about 7% of national supply provided by desalination by 2040. This is around 2 000 million m³/a, or about 230 000 m³/hr. At an estimated 5 kWh/m³, the energy required would be about 1 150 MW continuously. (This does not include energy needed to get the water from the plant to where it is needed, or transmission losses in the national grid.) This power consumption is the lion's share of a large power station running continuously – for example, the coal-fired Arnot power station near Middleburg has six 350 MW units, and in 2001 produced 1 980 MW, according to the Eskom website.

3.3 Strategy

The potential of groundwater for water supply, poverty alleviation, drought planning, and other vital sectors needs to be made more widely known. Groundwater must be incorporated into all water plans, and towns that need to augment their water supplies should seriously consider groundwater. General planning documents (such as spatial development plans) need to be aware of and incorporate groundwater where relevant. Where groundwater development is being prevented by outstanding license applications, reserve determinations or other procedural delays, these must be resolved as soon as possible.

3.4 Actions

- Consider groundwater to a level of detail that makes it comparable to other options in water resource assessments.
- Conduct groundwater resource assessments and development programmes (including the rehabilitation of existing water supply boreholes) for towns threatened by surface water shortages as water demand increases.
- Implement groundwater development programmes for domestic and productive water use to support national imperatives such as the Comprehensive Rural Development Programme, the Water Allocation Reform process, addressing the Millennium Development Goals, etc.
- Update the GRA 2 figures on groundwater availability and use as new data becomes available.
- Establish guidelines for the groundwater content of Internal Strategic Perspectives (ISPs), emerging Catchment Management Strategies (CMS), and other water resource management guideline documents.
- Implement the Department "Best Practice Guidelines" for the mining sector and develop the same for the municipal, agriculture, energy and forestry sectors to ensure the protection of groundwater resources.
- Develop tools to evaluate the effect of drought and climate change.
- Define groundwater to the same assurance yield of surface water.
- Manage groundwater according to groundwater management areas and units.

...END

4. Human Capacity

4.1 Background

The availability of sufficiently qualified and experienced / specialist hydrogeologists is a vital requirement for the proper implementation of the National Water Act, the National Water Resource Strategy and the Groundwater Strategy. Public sector hydrogeologists assess groundwater resources, guide borehole drilling, devise and monitor groundwater clean-up programmes, review license applications, interpret monitoring data and many other functions.

4.1.1 Decline in experience

There has been a decline in the number of "person-years" of experience in hydrogeology in the state sector. Experienced professionals are leaving public institutions to work in the private sector and in foreign countries due partly to the inability of these institutions to attract and retain such staff *(See figure 4-1)*.

Retired personnel are often not replaced. In addition, the number of vacant posts in the Department for hydrogeologists is around 47% and 53% for geotechnicians and this is compounded by its inability to attract staff. More than 50% of the current groundwater personnel have fewer than 5 years experience and do not have experienced mentors to guide them. Competition for the few scientists who come through universities and other technical institutions is very high.

Historically the Department was the "conveyer belt" for delivering groundwater professionals in South Africa. However, key groundwater planning, development and management functions are being eroded within the Department. Experienced hydrogeologists are also necessary for mentoring younger professionals – without this function it takes longer for new recruits to gain the skills they need, and deprives them of job satisfaction. In the worst cases, a vicious circle of high staff turnover and dwindling institutional memory can occur.

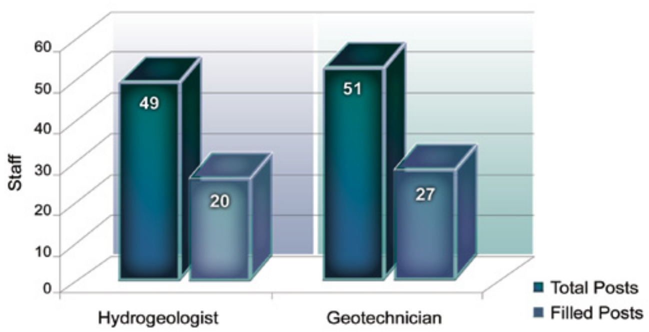


Figure 4-1 *Vacancies at DWA for staff (2008 figures)*

4.1.2 Management of Professional Service Providers (PSPs)

Groundwater assessment and management programmes (i.e. groundwater recharge, geochemical studies, integration with surface water, modelling studies, etc.) require experienced and knowledgeable people in both the public institutions and in private practice.

The Department is able to contract out a considerable proportion of technical groundwater work to the private sector, but there remains a need for technical expertise within the department to evaluate the quality of the work that is being done. This function demands experience as well as technical competence. The state occasionally needs to evaluate the claims of private sector specialists, which may sometimes be contradictory *(See box 4-1)*. Public sector expertise is invaluable in situations where truly independent private sector expertise may not be available.

4.1.3 Groundwater expertise at local level

The alignment of hydrogeological projects and programmes and integration into a water resource management framework aligned to Water Services Development Plans (WSDPs) and associated business plans assumes there is adequate capacity in Water Service Authorities (WSAs) and Water Service Providers (WSPs). It is critical for sufficient internal capacity to be developed within local government.

Staff and technical practitioners with hydrogeological background should be appointed by municipalities to ensure more effective and sustainable groundwater management, particularly as groundwater becomes increasingly relied on for municipal water supply. A "Municipal Hydrogeologist" should be considered in budget negotiations.

Box 4-1:
Low Flows At Maloney's Eye

The Steenkoppies dolomite aquifer compartment near Tarlton falls under the jurisdiction of the Mogale City Local Municipality and the West Rand District Municipality.

Large-scale irrigation using groundwater from the Steenkoppies compartment is thought to have begun in the 1970s and in 1997 it was estimated that lawful abstraction of groundwater in the Steenkoppies compartment amounted to about 19 million m³/a. Groundwater from the compartment drains mainly via the impressive Maloney's Eye spring, which flows at an average rate of about 13 million m³/a (± 472 ℓ/s) and is the origin of the Magalies River. Unlike many other springs, flow records for the Eye are available for the past century.

In recent years the flow at the Eye has declined in comparison to the long-term average, and in early 2007 the Eye reportedly stopped flowing for the first time. Water users downstream of the Eye have complained that the groundwater irrigation starves the Eye of water, in turn causing low flows in the Magalies River. This has been disputed by a group of irrigators in the Steenkoppies Compartment.

The situation has been made worse by disagreements between consultants about the area of aquifer that influences Maloney's Eye and the effect of irrigation on the flows at the Eye. The limited human capacity within the Department of Water Affairs has made it difficult for the state to judge the merits of rival interpretations, and has also contributed to a lack of recent data collection in the area. This is more than "just" an environmental issue – groundwater irrigated agriculture in the greater Tarlton area is worth hundreds of millions of rands and employs thousands of people.

At present the total area under irrigation is about 2600 hectares, but an accurate figure for current groundwater abstraction in the compartment is not yet available. Interested parties are establishing a Water User Association for the area, to be known as the Steenkoppies Aquifer Management Association, which will help to address the issue.

If the situation with regard to groundwater over-abstraction is not managed cooperatively, a future drought could easily lead to great reductions in flow at Maloney's Eye again, to job losses, and even to legal action.

4.1.4 Tertiary training

In recent years there appears to have been a decline in the numbers of experienced university lecturers and mentors in hydrogeology in South Africa[10]. *(See box 4-2 on Hydrogeological Research Capacity Constraints at Universities).*

4.2 Problem Statement

The public sector in South Africa is short of hydrogeologists, hydrogeochemists and groundwater modellers. This shortage affects our ability to develop our groundwater resources in the interests of all, to react to groundwater pollution, monitor the state of our groundwater resources, and many other vital matters.

Even where numbers of people are adequate, the total number of "person-years" of experience is dwindling, and this will worsen in the next five or so years as a further tranche of experienced people retire. There is anecdotal evidence that the Department is seen as a short-term career choice – a stepping-stone on the way to the private sector. Certainly, the retention of public sector hydrogeological staff is a more serious problem today than it was in the past.

This is partly a result of comparatively low salaries, but also due to working conditions[11] and the failure of public sector institutions to maximise the "traditional" benefits of working for the state – such as job security, career support, interesting and varied work, and the chance to contribute to the public good[12].

Public sector career paths for groundwater professionals are currently poorly defined, and little is done to market hydrogeology as a career at undergraduate level or at schools. Currently, South African hydrogeologists can apply to be accredited professionally by the South African

(10) This is related to the numbers of university lecturers in the engineering profession, mentioned in Lawless (2007). There are currently two universities in South Africa (Universities of the Free State and Western Cape) that offer a full-time MSc course in hydrogeology.

(11) Those leaving the public sector sometimes mention convoluted bureaucracy, institutional reorganisation, uncertain career progression, disjointed policy and frequent changes of leadership as being amongst the "push" factors. However, as far as is known there has been no "official" evaluation of staff retention and turnover at the Department – this evidence is only anecdotal.

(12) A survey carried out in 2007 on behalf of the International Association of Hydrogeologists entitled "Hydrogeology in sub-Saharan Africa: Training and employment opportunities" found that hydrogeology as a career is perceived to have a lower status and poorer conditions compared with engineering (for example), that staff turnover from the public to the private sectors is high, and that difficulties with career progression were amongst the reasons for hydrogeologists leaving the profession altogether. Replacement of retiring experienced hydrogeologists was a particular concern in South Africa and Namibia. See IAH (2007).

Box 4-2:
Hydrogeological Research Capacity Constraints at Universities

Eleven universities in the Southern Africa Development Community (SADC) have experienced an increasing number of hydrogeology postgraduate students completing their studies in the past ten years. **However, the sustainability of these programmes and capacity building initiatives is affected by a number of factors which include:**

- Availability of qualified and dedicated trainers
  - Shortage of lecturing staff,
  - Limited number of post-graduate supervisors,
  - Limited time for research due to increasing lecture duties.
- Financial assistance is dwindling to meet the running costs of programmes
  - Decreasing government funding,
  - Lower number of applications – subsidies related to student fees declining,
  - Limited resources for staff training,
  - Huge capital cost associated with laboratory and field equipment,
  - Better job prospects for graduates exist in other disciplines,
  - Limited job opportunities in hydrogeology,
  - No professional recognition of hydrogeology.

The above constraints can be partly addressed through partnerships and networking within WaterNet, Africa Array, CAPNet, AGWNet, and FETWater. Human resource capacity may have to be reliant on skills from across the African continent and beyond and real opportunities in dealing with the capacity gap in South Africa lie in regional, continental and international initiatives. However, a survey of groundwater professionals in sub-Saharan Africa revealed that similar challenges exist(1).

(1) See IAH (2007)

Council for Natural Scientific Professions (SACNSP), but there is not a separate category for hydrogeology. This makes it more difficult to organise a system of Continued Professional Development (CPD), which is a requirement in other countries and in other South African professions. It also hampers the general recognition of hydrogeology as a distinct profession in South Africa. These things in turn make hydrogeology a less attractive career choice compared with (for example) engineering.

4.2.1 Main Reasons for the lack of capacity in the Groundwater Sector

Adequate hydrogeological capacity is required to implement the Groundwater Strategy and to ensure the sustainable use, protection and development of groundwater.

The following reasons have been listed for the lack of capacity in the groundwater sector(13):

- Great difficulty in retaining skilled experienced specialists and technical managers in the public sector. Most of the professional capacity in South Africa is located outside the public sector and will remain so(14). We are seriously missing the public sector as a major player in capacity building.
- While the public sector work is still done through outsourcing, the private sector has not yet taken on a role in national capacity building.
- There is a widespread lack of understanding that capacity building is more than just training(15). While the engineering sector as a whole is starting to address capacity-building strategically, this has not yet happened in the water sector, despite several attempts since 2000.
- The specific lack of groundwater capacity is strongly related to the continued undervaluing of the resource at decision-making level, and thus in a lack of systematic investment in its sustainable utilization.
- The very vulnerable capacity situation in the groundwater academic sector is as a result of a lack of role-player cooperation in groundwater capacity building. All players need to rapidly move forward together with innovative solutions for capacity building in the water sector, before international groups mobilize our skills for initiatives outside of South Africa.

4.3 Strategy

Hydrogeology posts in the public sector need to be filled, and the reasons for high staff turnover must be tackled. More support must be given to existing initiatives within the Department aimed at training groundwater staff.

Continued Professional Development (CPD) programmes should be supported via the DWA Learning Academy, Groundwater Division of South Africa, and tertiary institutions. Mentoring and field work experience for young public sector hydrogeologists could be increased by involving the private sector on a voluntary basis.

Better arrangements at the national office of the Department for supporting regional and local municipalities with groundwater related problems should be considered. Better marketing of hydrogeology as a career at undergraduate level needs to commence.

Attention must be given to the registration of hydrogeologists, and to the issue of Continued Professional Development (CPD) as a requirement of continued registration.

(13) See Braune, Adams and Xu (2009)
(14) See MacKay and Koster (2005)
(15) See MacKay and Koster (2005)

4.4 Actions

- Develop and implement a national capacity building strategy.
- Implement capacity-building milestones in the Department PSP contracts similar to the WRC contract research programmes.
- Implement practical, in-service training courses on priority aspects (e.g. licensing process, the Reserve, groundwater monitoring, etc.) for staff.
  - Roll-out training programmes on groundwater management to staff of water services institutions.
- Mobilise private sector support in developing hydrogeological capacity within regional offices and water services institutions.
- Either establish hydrogeology as a separate professional field of practice via SACNSP, or reach agreement with the Geological Society of South Africa (GSSA) regarding accreditation, to bolster hydrogeology as a defined profession, and to enable an independently monitored Continued Professional Development programme to be implemented as soon as possible.
- Develop adequate capacity to fulfil the groundwater functions.
- Review and improve the working conditions, career development, remuneration packages, etc. for junior and mid-level hydrogeologists within the public sector to assist with staff retention.
- Address the reasons for hydrogeologists leaving the public sector.
- Implement mentoring programmes involving retired professionals.
- Continue with and strengthen the bursary programme.
- All hydrogeologists and technicians must register at SACNSP.

... END

5. Sustainable Groundwater Management

5.1 Background

Good management of groundwater resources is the key to reliable, efficient groundwater supplies. This applies equally to schemes as small as a single borehole and to large wellfields supplying urban areas. Monitoring (borehole water levels, water quality, pumping rates, etc) is probably the single most important component of good groundwater management.

5.1.1 The DWA Generic Guideline

The Department has published clear guidelines called "A Guideline for the Assessment, Planning and Management of Groundwater Resources in South Africa" (the "Generic Guideline"), available free on the DWA website at www.dwa.gov.za/groundwater/documents.aspx. There are also DWA and other documents that outline measures for the protection of groundwater and the prevention of groundwater pollution. Assessment, planning and management of groundwater are related steps, each one of which affects the others in an iterative way.

A lack of effective assessment, planning and management of groundwater resources can result not only in poor service delivery to water users, but also to significant detrimental impacts on the aquifer systems themselves. For example, unmanaged and uncontrolled abstraction and/or dewatering of the aquifers can lead to boreholes, wetlands and springs drying up; and in the case of karst aquifers, sinkhole formation. The Generic Guideline is considered to be consistent with Integrated Water Resources Management (IWRM) principles. The three steps are summarised in Figure 5-1.

5.1.2 Operation and Maintenance of groundwater schemes

Failure of groundwater supply schemes is often blamed on the resource (i.e. the aquifer or the groundwater) rather than on the infrastructure (borehole, pump, pipes, valves etc) used to abstract the groundwater. It is common to hear that "the borehole dried up", or "the groundwater ran out".

Box 5-1:
The NORAD toolkit

This consists of a collection of documents, software and maps aimed at improving the management of groundwater at municipal level in South Africa produced with support from the Norwegian Agency for Development Cooperation (NORAD). The collection is known as the NORAD Toolkit for Water Services. The work was completed in 2003 as part of a collaborative venture between the Department of Water Affairs, the Council for Scientific and Industrial Research, the Council for Geoscience, Mvula Trust and the Geological Survey of Norway. The outputs are aimed at municipalities, water services authorities and providers, national water authorities, NGOs and consumers, and contain much useful and relevant information on groundwater assessment, management, protection and monitoring. All of the NORAD outputs are available on the DWA website at:

- http://www.dwa.gov.za/Groundwater/NORADtoolkit.aspx
- Some municipalities use the NORAD toolkit for managing their groundwater, but uptake needs to be improved.

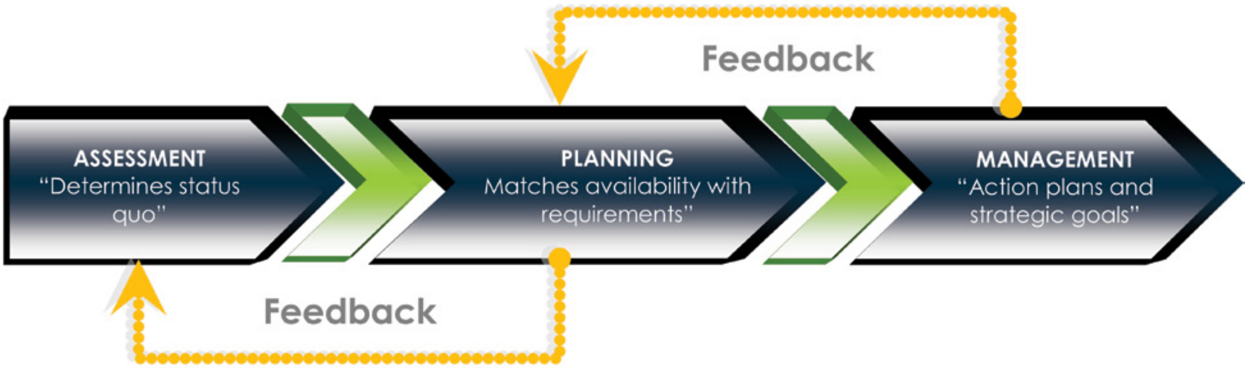


Figure 5-1 Assessment, Planning and Management of groundwater

Box 5-2:
Borehole O&M and supply failure

The picture on the right shows a community water supply borehole in the North West Province of South Africa that became contaminated by hydrocarbons following a leak from the pump's diesel storage tank. Previously, the borehole supplied several hundred people with safe drinking water. This illustrates a failure of O&M – the diesel was not stored properly, no checks were done for slow diesel leaks, nor was the borehole constructed and maintained to guard against such a spillage.

The diesel contamination and cracked concrete block are clearly visible. More that a million rand has been spent to date (April 2010) in trying to replace this source, but a few thousand rand could have prevented the problem.

This is partly because groundwater is out of sight – it seems mysterious to the layperson in comparison with surface water. In fact, failure of groundwater supply schemes is almost always either due to failure of infrastructure (e.g. a blocked borehole screen) or unsuitable pumping regimes (e.g. pumping at very high rates for short periods of time) that are related to a lack of monitoring.

A vital element of groundwater management therefore is day-to-day operation and maintenance (O&M) - the mainly routine tasks that should be carried out in the course of operating a groundwater supply scheme. O&M tasks include maintaining infrastructure (cleaning and de-scaling pipes, replacing worn out components, cleaning of boreholes, checking the operation of switchgear, etc) as well as the monitoring of groundwater levels, groundwater quality, demand, etc.

A specialist contractor may be required for some of the tasks (e.g. cleaning boreholes or replacing pumps). The NORAD toolkit *(See box 5-1)* includes a table of monitoring and management responsibilities in rural groundwater supply schemes, although in general there is a lack of detailed guidelines for routine O&M of groundwater installations in South Africa.

Operation and maintenance of groundwater supply systems is usually seen as the responsibility of the applicable Water Services Authority (WSA) or Water Services Provider (WSP). Frequently the relevant Local Municipality assumes one or both of these roles, but the situation can be considerably more complex.

Critical to successful O&M are more generic municipal or institutional functions and procedures such as budgeting, training and retention of staff, accountability frameworks, succession planning and other features. These have a great bearing on whether services are delivered and routine tasks accomplished including groundwater management. It is likely that poor or nonexistent operation and maintenance of groundwater schemes is the main reason for scheme failure, rather than intrinsic constraints imposed by the groundwater system such as lack of recharge *(See box 5-2)*.

Since groundwater is a "distributed resource", meaning it is generally found locally, the basic skills and personnel for proper operation and maintenance of groundwater systems ideally need to be distributed widely rather than only available at certain key points or large towns. This presents a challenge that is different to O&M of surface water systems, which can often be centralised to a greater degree.

5.1.3 Natural groundwater quality

Groundwater is usually safe to drink without treatment, unlike surface water. This is because harmful microbiological pathogens such as bacteria and viruses usually cannot survive for long in aquifers. However, it is normal for chlorination to be carried out as a precaution for most public groundwater supplies.

Monitoring of the microbiological quality of a groundwater source gives important information about the groundwater system, and early warning of problems.

Groundwater contains dissolved "minerals" such as chloride, sodium, iron and others, in the same way as surface water. The natural dissolved mineral content of groundwater depends on a number of factors, including the aquifer material and the groundwater residence time. Figure 5-2 indicates natural groundwater electrical conductivity (mS/m) in RSA. In some cases, high levels of dissolved minerals cause groundwater to be brackish or

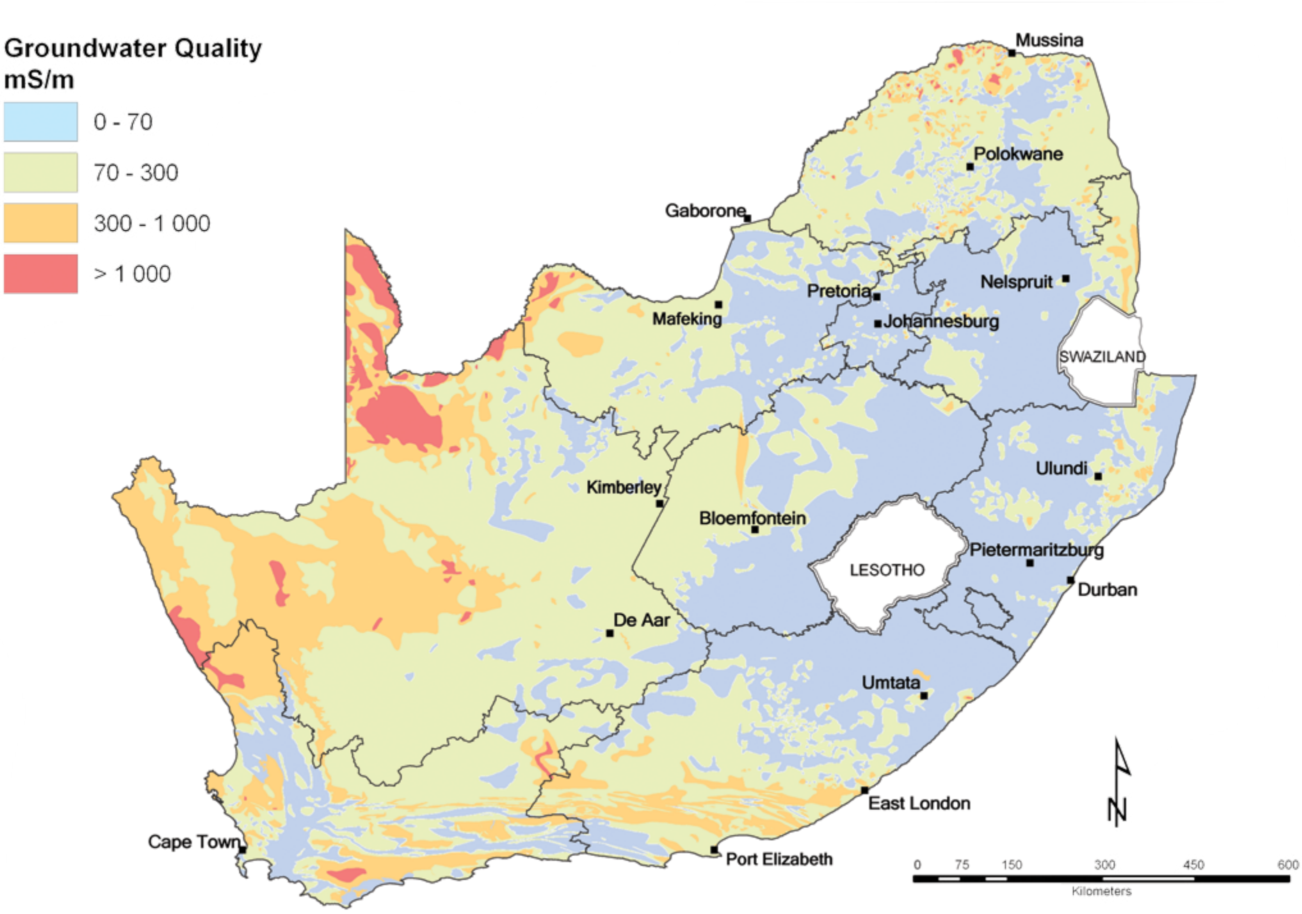


Figure 5-2 *Electrical conductivity map of groundwater in RSA (GRA 1)*

even saline[16]. In some (relatively rare) cases, naturally high levels of dissolved constituents like fluoride, arsenic or nitrate render groundwater unfit to drink, even though it may taste perfectly fresh.

The map in Figure 5-3 shows nitrate concentrations in groundwater across South Africa, based on available data. In areas where nitrate is higher than allowable limits, groundwater will need to be treated or blended. Monitoring is the key to understanding natural groundwater quality variations.

Groundwater is normally less susceptible to pollution compared to surface water, since an overlying unsaturated zone generally protects it. However, once polluted, groundwater is difficult and expensive to clean up. Groundwater pollution can come from a variety of sources, and in the worst cases can make groundwater unsafe to drink and uneconomical to treat.

5.1.4 Protection zone policy in South Africa

A common method that is used world-wide to help protect groundwater quality is to establish areas or "protection zones" around groundwater abstraction points (and sometimes well fields and even whole aquifers) within which activities that may pollute groundwater are controlled. It is also obviously not enough merely to define a protection zone – of equal importance are the restrictions or rules that are made for activities within the protection zone, and the enforcement of these.

Groundwater source protection zones are commonly used in many European countries and in the United States (where they are known as wellhead protection zones) to protect major or vulnerable groundwater sources *(See figure 5-4 for the groundwater levels of RSA).*

There are various documents that cover groundwater protection in South Africa[17] *(See Input Box 5-3),* including protecting single groundwater sources from point-source pollution. The specific legal requirement that will adequately protect groundwater, through protection zoning, is through the recently assented classification of water resources. However, it is usually much easier, quicker and cheaper to protect groundwater from pollution or the effect of over-abstraction than it is to try to reverse the damage at a later date.

Groundwater protection is therefore an economic as well as an environmental imperative, and groundwater protection measures and policy will save money in the long

(16) People may reject groundwater in a particular area because it is more brackish than the local surface water. This can be despite the fact that the dissolved salt content of the groundwater is harmless, and within national guidelines, whilst the "sweeter" tasting surface water may be microbiologically contaminated.

(17) See Xu and Braune (1995), DWAs waste disposal guidelines (DWA, 2008), DWAs sanitation guidelines (DWA 1997 and 2003) and the NORAD guidelines (DWA, 2004b).

term. The cost of dealing with polluted or contaminated groundwater can also involve considerable hardship to people and the environment.

5.1.5 Adaptive management

Natural aquifer systems are complex and difficult to characterise in detail. Good data collection greatly reduces uncertainty, but cannot normally allow the prediction of the long-term effects of groundwater pumping with 100% accuracy. There is always an element – hopefully small – of trial-and-error in aquifer management. A management approach whereby observations are fed back into the management system, and adjustments made if necessary, is called "Adaptive Management".

This approach helps to deal with the uncertainty about the regional status of groundwater resources due to poor monitoring, the limited knowledge of how groundwater parameters change with time and distance, and uncertainties about the impacts of groundwater use on surface water or the ecology. As Seward et al. (2006) put it: "Scenarios and goals are [therefore] regarded as hypotheses and estimates to be tested and challenged as the knowledge base grows". A good groundwater manager is aware of uncertainty and knows that adaptive groundwater management is necessary from the beginning – the manager knows that the soundness of predictions and recommendations will grow as the

Box 5-3:
Policy and Strategy for Groundwater Quality Management in South Africa

DWA published the 'Policy and Strategy for Groundwater Quality Management in South Africa' in 2000.

The mission statement for groundwater quality management is set in the context of the water resources mission and is as follows[i]:

"To manage groundwater quality in an integrated and sustainable manner within the context of the National Water Resource Strategy and thereby to provide an adequate level of protection to groundwater resources and secure the supply of water of acceptable quality". The strategy for groundwater quality management should be executed in the context of the Department's National Water Resource Strategy. As a result, an integrated approach to the management of groundwater and surface water is required in order to provide for adequate protection and efficient management of the total resource.

The functional approaches which the Department adopted in order to achieve its policy goals are[i]:

- A source-directed approach to prevent and minimise, at source, the impact of development on groundwater quality by imposing regulatory controls and by providing incentives.
- A resource-directed approach to groundwater

> > > continues on the next page

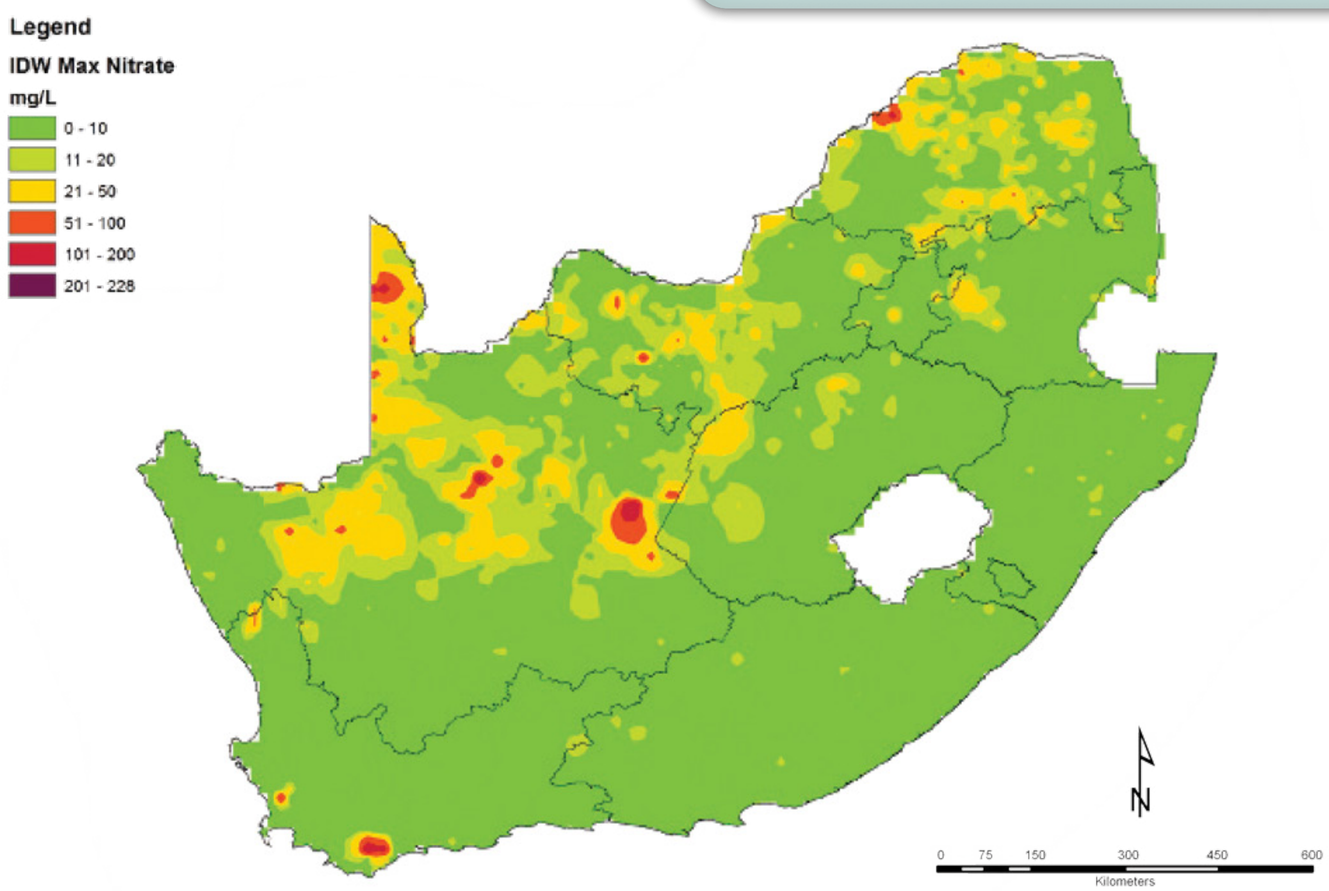


Figure 5-3 Map of nitrate levels in groundwater in South Africa (CSIR)

Box 5-3:
Policy and Strategy for Groundwater Quality Management in South Africa

quality management by implementing resource-directed measures to protect the reserve and ensure suitability for beneficial purposes.

- A site-specific, needs-based approach to the remediation of degraded groundwater.

The value and vulnerability of groundwater represents a strategic component of the water resources of South Africa. Groundwater occurs widely and, geographically, almost two thirds of South Africa's population depends on it for their domestic water needs[1].

Security of groundwater supplies is thus essential and protection of groundwater has become a national priority. **The major reason for poor management of groundwater resources has been a lack of a structured approach to management and a lack of knowledge and information about groundwater.**

- The precautionary principle must therefore be strictly applied when making decisions about groundwater. This approach to protection will be implemented for source-directed, resource-directed and remedial management measures.
- In South Africa's situation of widespread and highly localised groundwater occurrence and use, it will be physically and economically impossible to protect all groundwater resources to the same degree. A differentiated protection approach is necessary, based on the aquifer vulnerability as well as the regional and local importance of aquifers.

(1) **Reference:** DWA (2000). Policy and Strategy for Groundwater Quality Management in South Africa.

knowledge base for groundwater expands with ongoing monitoring.

5.1.6 Artificial recharge

Artificial recharge is a groundwater management technique that is growing in importance in South Africa. Essentially it is the process whereby surplus surface water is transferred underground to be stored in an aquifer. The most common methods used involve injecting water into boreholes and transferring water into spreading basins where it infiltrates the subsurface. Underground water storage is an efficient way to store water because it is not vulnerable to evaporation losses and it is relatively safe from contamination. Internationally, artificial recharge is becoming an increasingly recognised form of water storage and conservation.

South Africa has only one major established artificial recharge scheme *(See box 5-4)*. This technology is under utilised and together with proper groundwater

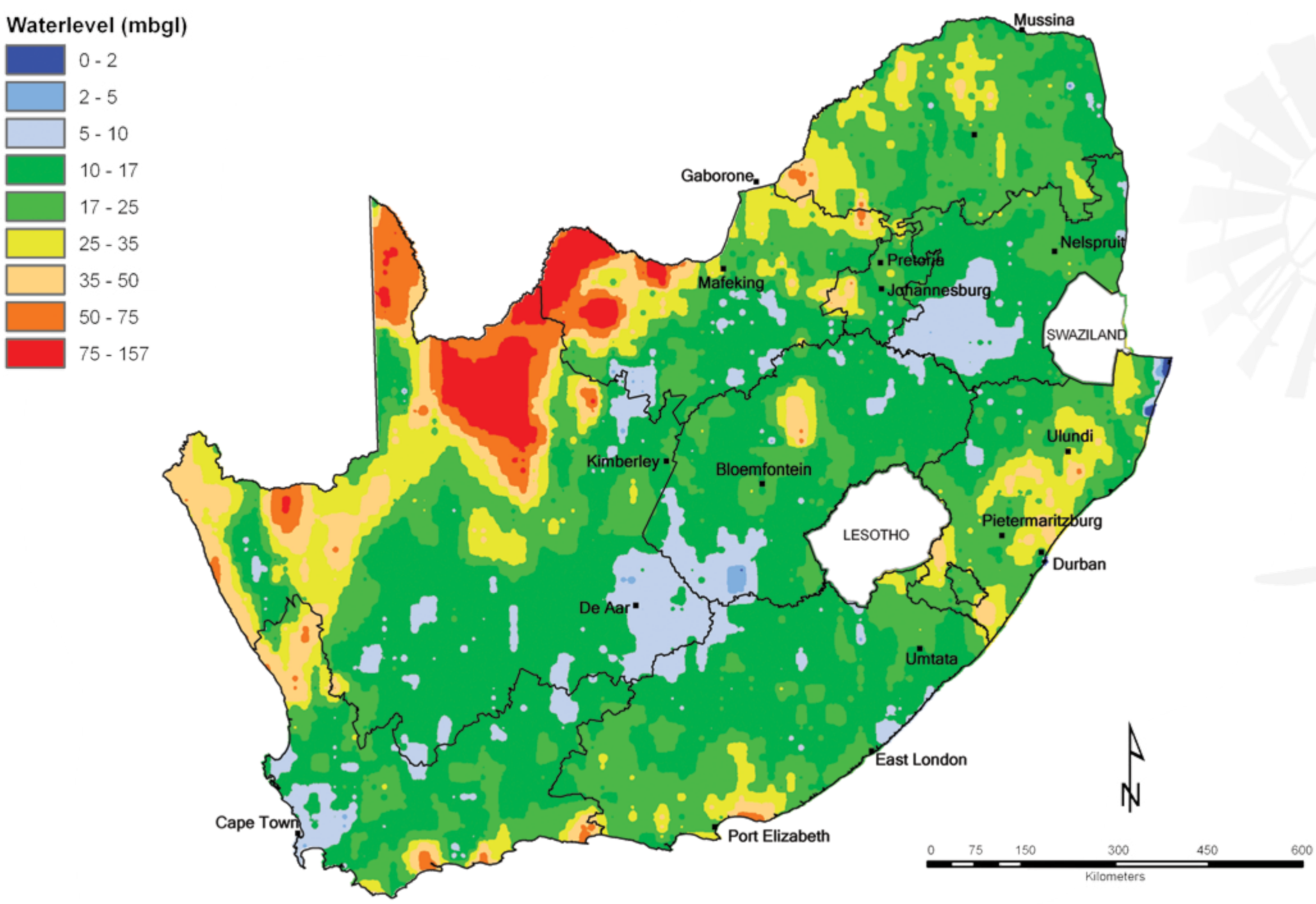


Figure 5-4 Groundwater levels map of RSA

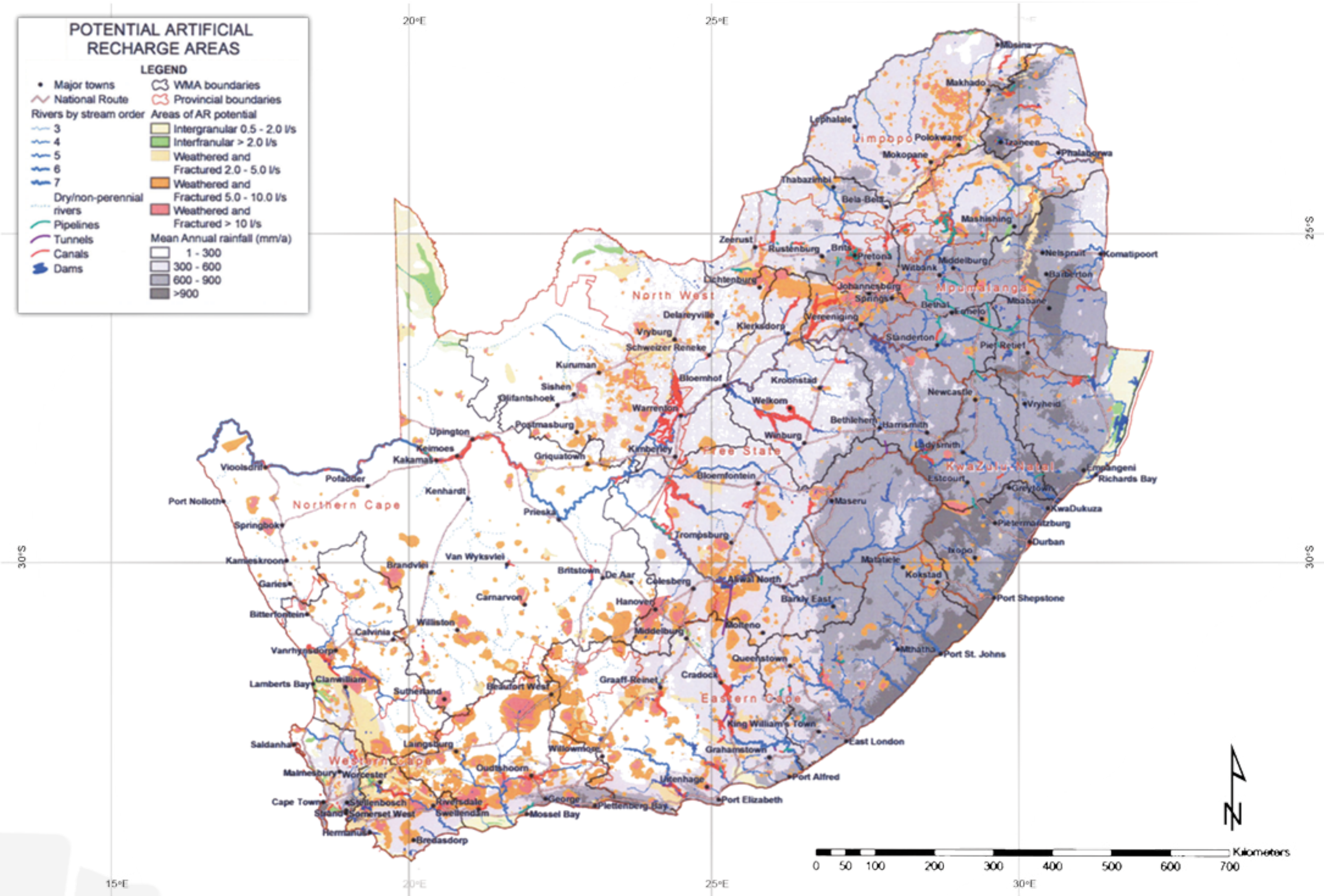


Figure 5-5 *Potential areas for artificial recharge*

management, artificial recharge can contribute significantly towards maximising the use and sustainability of available water resources.

More information on artificial recharge, and the Department's Artificial Recharge Strategy, is available at http://www.dwa.gov.za/groundwater and www.artificialrecharge.co.za.

Although implementing the Artificial Recharge Strategy will be on-going, it was rolled-out between 2007 and 2010 with the prime objectives of informing people about this water storage and conservation measure, and assisting in initiating artificial recharge projects. Key achievements during the recent roll-out period are captured on the artificial recharge website. One of the key achievements was the compilation of the potential artificial recharge area map *(See figure 5-5)*.

5.1.7 Sustainable yield

Some of the reluctance to make greater use of groundwater is due to the suspicion that groundwater use is somehow "unsustainable", or will have increasingly bigger negative effects on the environment and on surface water resources. In fact, with appropriate management, groundwater supplies are sustainable and

Box 5-4:
Artificial recharge of groundwater at Atlantis

The town of Atlantis is situated about 50km north of Cape Town, in the Western Cape Province, and has a population of over 100 000 people. It has no major surface water sources, and annual rainfall is only about 450mm. Atlantis abstracts water supply from boreholes at two wellfields to the west and south-west of the town, supplying 30-40% of the town's water. Groundwater consumption in 2004 was 2.8 million m³ (about 89ℓ/s if pumping continuously)[1].

Artificial recharge of the aquifer, first begun in the early 1980s, is carried out to improve water security during droughts, re-use wastewater and storm run-off, and help to prevent the intrusion of seawater into the aquifer. Treated waste water and storm run-off is diverted to two large recharge basins about 500m up-gradient of one of the wellfields, which are used to infiltrate the good quality water back into the aquifer for later abstraction.

Poorer quality waste water (some of it from the town's industrial area) is infiltrated down-gradient of the wellfields, between the town and the sea, where it is disposed of conveniently and responsibly and also helps to ensure saline water is kept out of the aquifer. Together with some imports of good quality surface water from the Cape Town municipal supply, Atlantis is able to meet its water supply needs using combined groundwater abstraction and artificial recharge. Management by the municipality includes dealing with technical issues such as clogging, pH adjustment and water softening – good management procedures are in place and the system operates reliably.

(1) See Bishop (2006) and Murray (2008) for more details.

Box 5-5: Windmills

Windmills have been used since the nineteenth century as a sustainable way of exploiting groundwater, and thousands are in use in South Africa today. They need little maintenance, and because of low pumping rates do not normally deplete aquifers. The torque provided by the large number of blades means that even quite low winds turn the wheel, which is oriented into the wind by a tail. If the wind speed is too high, a mechanism turns the wheel out of the wind, preventing damage.

Apart from basic annual maintenance windmills need little attention, and can operate for years in harsh conditions. Windmills provide water to farms, homesteads and rural communities across South Africa, but due to low yields are not normally suitable for village or town supplies. Amongst others, the well-known "Climax" brand of windmill is still available in South Africa (via Southern Cross Industries, based in Bloemfontein).

Boreholes pumped by windmills need to yield enough water to ensure that water levels do not drop below safe limits even in periods of constant wind. A small windmill can pump about 4 000 ℓ/day (about 0.05 ℓ/s) assuming average wind speeds of about 4 m/s (Beaufort Scale of 3, or "gentle breeze"). Large windmills can pump 20 times this amount (i.e. about 1 ℓ/s) or higher in the same conditions. Windmills can lift water several tens of metres.

reliable. Sustainability[18], along with equitable access to water, is one of the main principles of the National Water Act. 'Sustainability' implies groundwater use that does not cause long-term deterioration of the overall resource, in terms of quality and quantity *(See figure 5-6 - the yield map of RSA)*.

Aquifers are in a state of natural long-term equilibrium prior to pumping, and in order to maintain this equilibrium groundwater abstractions must be balanced by increased recharge (increase in the quantity of water entering the system) or reduced discharge (reducing the quantity of water leaving the system[19]) over the long-term.

Abstractions from storage imply non-equilibrium conditions. The increase in recharge and decrease in discharge is termed 'capture' and equilibrium is achieved when it balances pumping. Thus, it is only after pumping that the change in recharge will contribute to the determination of a sustainable yield. For sustainable yield, one would need to balance induced recharge or decrease in natural discharge with groundwater abstractions[20].

Due to the high storage in many aquifers, abstractions can at times exceed the recharge – as long as the long-term balance is maintained. In some cases, aquifers recharge mainly following unusually high rainfall events every few years – the rainfall makes up for natural discharges as well as abstractions in the preceding years. In times of drought, when rivers cease flowing, aquifers continue to yield water.

Coastal aquifers generally discharge to the sea, and abstractions from these aquifers should be aimed at capturing the part of this flow of fresh water which is not required to counterbalance salt-water intrusion. Furthermore, over a large area of South Africa, groundwater is not in direct connection with surface water resources. In these areas, groundwater abstractions do not generally deplete surface water.

High storage of aquifers means that, even in areas where aquifers are in contact with surface water, these impacts are buffered and averaged out. The key to determining sustainable yield, and managing impacts of groundwater abstraction, is monitoring.

5.2 Problem statement

Implementation of existing strategies and guideline documents appears to be the main problem, and is linked to the issues of public sector capacity and training. Operation and maintenance (O&M) of groundwater schemes are often given a very low priority, or ignored altogether. Relatively few resources (e.g. the NORAD tools) exist for the management of groundwater at the borehole or small wellfield scale (for example for the municipal manager), and O&M guidelines are particularly lacking. Hydrogeological skills are scarce at local (municipal) level, from where day-to-day O&M is coordinated and funded.

It has been difficult to achieve the implementation of protection zones around important public water supply boreholes, and the majority of such boreholes do not

(18) The meaning of the word 'sustainability' is often contested and can be operationally and conceptually very complex when examined in detail. See Cabezas and Fath (2002), Wright and Xu (2000), Sophocleous (1997), and Kalf and Wooley (1995) for more information.
(19) This includes evapotranspirative losses along zones of discharge, and not just reduced water reporting to surface water systems.
(20) See Seward et al. (2006) and Sophocleous (1997)

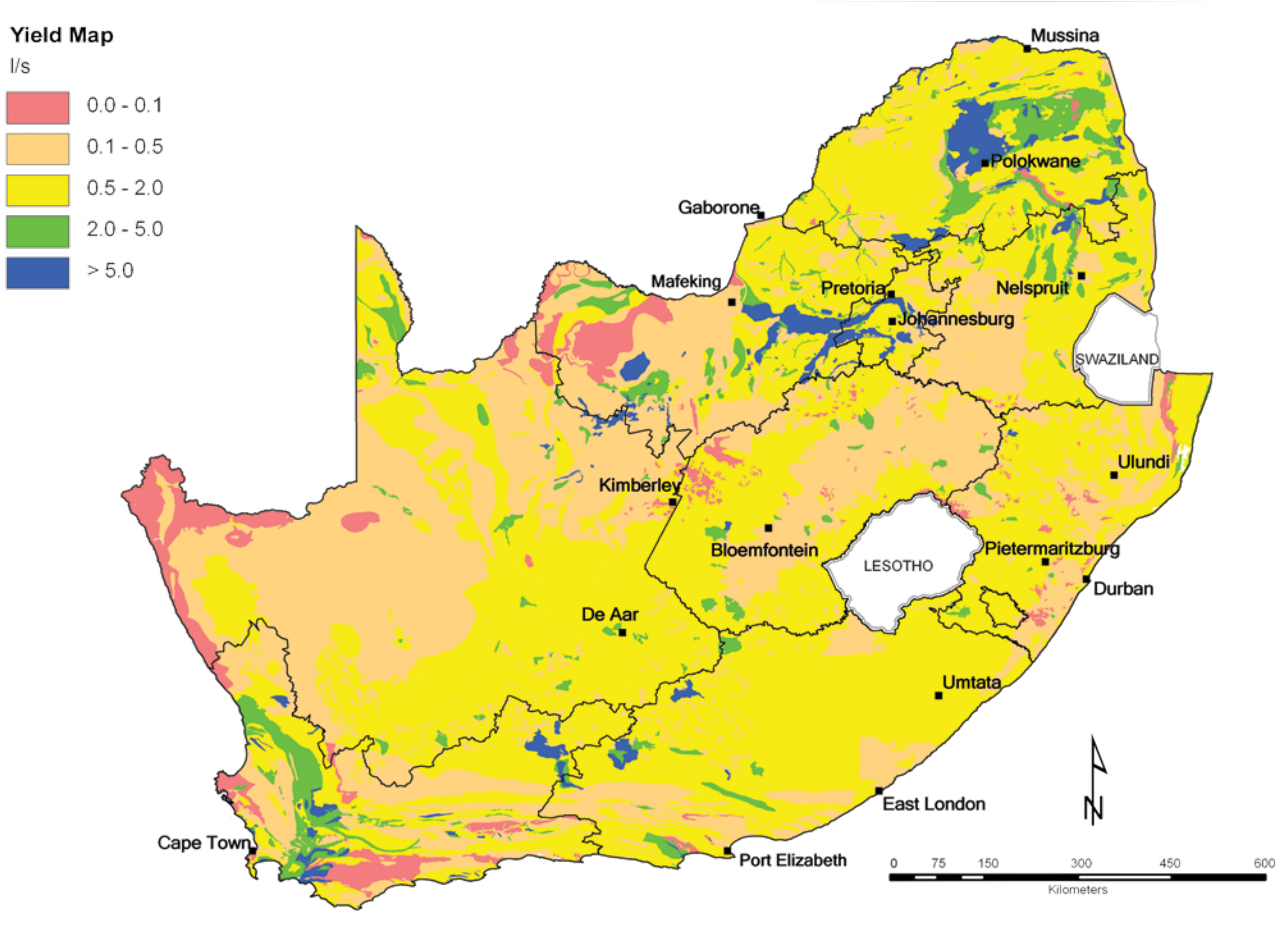


Figure 5-6 *Yield map of RSA (GRA 1)*

have such zones. This is most likely due to a lack of technical capacity as well as the necessary institutional coordination.

Artificial recharge has been implemented successfully in some areas, but technical know-how is still scarce and many municipal managers are still resistant to the idea.

Groundwater pollution and over-abstraction are serious problems in certain parts of South Africa. Poor and deteriorating groundwater quality is widespread and can be attributed to diverse sources in various sectors such as mining, industrial activities, effluent from municipal wastewater treatment works, storm water runoff from urban and especially informal settlements (where adequate sanitation facilities are often lacking), return flows from irrigated areas, effluent discharge from industries, etc.

Measurements and/or observations (i.e. groundwater monitoring systems) are inadequate when used to define the status of, and trends in, groundwater quality and in determining its "fitness to use". Pollution and over-abstraction are dealt with in existing legislation and strategies such as the NWRS, but implementation of such strategies is hampered by a lack of capacity and coordination between different governmental departments and between the different levels of water resource management.

The localized nature of groundwater means that it is generally more effectively managed at the local or catchment level rather than at the national level *(See box 5-6)*. The localized nature of groundwater, and the appropriately localized management of the resource, has its own challenges, driven by the limited hydrogeological human resource capacity in South Africa. *(See box 5-6)*. These practitioners must be spread over a number of institutions to ensure effective management of groundwater. Local management of the resource requires effective deployment of scarce skills.

5.2.1 Groundwater Management in Dolomitic Aquifers

South Africa's dolomite rocks form some of our most prolific aquifers because of their high groundwater potential and good natural water quality. These aquifers are used extensively for irrigation (e.g. in the Delmas and Tarlton areas), public water supply (e.g. Mafikeng, Lydenburg and Tshwane), and are vitally important to natural ecosystems as well as thousands of small-scale groundwater users. However, because of the origin of the karst features, they are not an exploitable aquifer everywhere, groundwater storage being in some cases negligible.

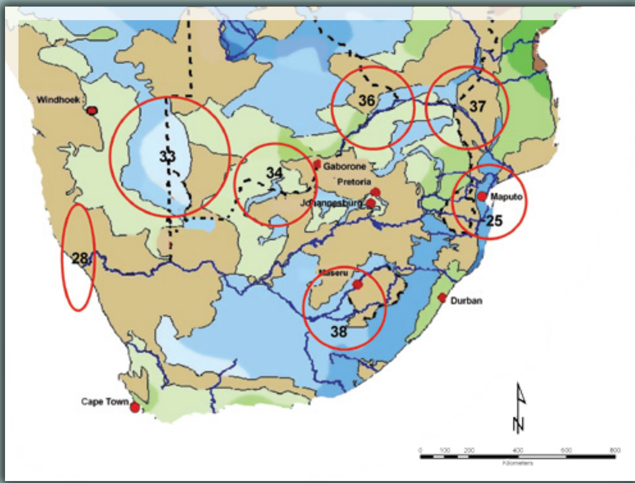
The threat of over-abstraction and pollution in dolomitic areas requires proper groundwater management which takes into consideration the aquifer potential and limitation. Since groundwater becomes surface

Box 5-6: Transboundary Aquifers

South Africa is bordered by six countries (Namibia, Botswana, Zimbabwe, Mozambique, Swaziland and Lesotho) along more than 5000km of border. Aquifers extend across international borders, resulting in a joint responsibility for management of these aquifers. The seven aquifers that have been identified as important transboundary aquifers (TBA) are tabled below[1]. These aquifers consist of all four types of aquifers (Intergranular, Fractured, Combined & Karst). 50% of the border aquifers yield is <0.5 ℓ/s. The median yield of more than half of SAs Transboundary aquifers is <0.5 ℓ/s.

No.	Aquifer Name	Countries
25.	Limpopo Basin	Mozambique, Swaziland, South Africa
28.	Coastal Sedimentary Basin	Namibia, South Africa
33.	SE Kalahari/Karoo Basin	Botswana, Namibia, South Africa
34.	Ramotswa Dolomite Basin	Botswana, South Africa
36.	Tuli Karoo Sub-basin	Botswana, South Africa, Zimbabwe
37.	Medium Zambezi Aquifer	Botswana, Mozambique, South Africa, Zimbabwe
38.	Karoo Sedimentary Aquifer	Lesotho, South Africa

Table 5-1 *Managing shared aquifer resources in Africa. (ISARM - Africa (2000))*



Transboundary Aquifers on the border of RSA

(1) See Appelgren (2004)

water when it emerges from springs, management of karst aquifers requires an integrated approach taking into consideration the close relationship between surface water and groundwater. In addition management of groundwater in South Africa's dolomite rocks must take several special factors into account, which are a result of the geomorphology and hydraulic properties of the aquifers.

Compartmentalisation

South African dolomites are divided into "compartments" by dolerite or syenite dykes. Other features such as brecciated faults and topographic divides may also form compartment boundaries. Groundwater conditions in each compartment may be relatively uniform and the water table surface fairly flat, whilst large differences in water level between compartments may be found. Pumping from one compartment may have only a small effect on an adjacent compartment, depending on the characteristics of the dividing dyke.

Flow does occur between compartments, but usually on a smaller scale compared to flow within a compartment. Compartment boundaries are also often associated with spring lines and seepages, as groundwater is forced to the surface. The groundwater manager working in the dolomites is thus faced with the task of defining compartments, which are then often treated as semi-autonomous units. These compartments are often used as the basis for hydrogeological characterisation and groundwater management.

Vulnerability to pollution

The karstic fissures which contribute to the high transmissivity also allow pollutants to move in the aquifer with relatively little attenuation. There is very little intergranular flow in the dolomites, and as a result relatively little physical filtering of water occurs. Karstic landforms such as sinkholes and dolines together with thin soils also allow surface pollutants rapid access to the aquifer. Together, these characteristics make the dolomites very vulnerable to surface pollution. Once polluted, the dolomites are difficult and expensive to clean up; in common with other aquifers. Protection zoning can used to help protect important boreholes from pollution.

Ground instability

In common with other parts of the world, dolomitic areas in South Africa are vulnerable to sinkhole development. Sinkholes in dolomites occur when sufficient rock is removed by dissolution to cause the collapse of the ground surface. Sinkholes can form naturally, but their formation can be much more rapidly induced by leakage of surface water, or the fluctuation of the water table outside of its natural range.

There is obviously a close link between groundwater (in both the saturated and unsaturated zones) and sinkhole risk, and the groundwater manager in a dolomitic area needs to understand the ground stability issues associated with sinkholes. It is generally very difficult to predict the time and place of sinkhole formation, although several risk assessment methodologies do exist. Gravity surveys may be carried out to determine the integrity of the rock below the ground surface. Piling, rafting or other construction techniques may be required in areas prone to sinkhole formation.

The Department have developed a comprehensive and up-to-date set of procedures for managing groundwater in dolomitic environments. These procedures represent a standardisation of management steps applicable across all dolomites (and with minor modifications, across all of South Africa's aquifers).

Some of the most important management requirements are:

- Delineation of aquifer area, extent of compartmentalisation, boundary conditions and flows.
- Improved understanding of the relationship between rainfall, spring discharge and depth from which groundwater surge occurs.
- Improved monitoring, leading to a better hydrogeological conceptual model, and greater knowledge of pollution threats.
- Preliminary Reserve determination should be conducted.
- The need for, and level of Reserve determination, should be agreed.
- Better and broader public participation, including previously marginalised groups and special interest groups (e.g. the conservation lobby).
- Improved inter-departmental cooperation and cooperation with research centres such as the CSIR and the universities.
- Routine systems of data collation and assessment, enabling informed planning decisions.
- Capacity building in hydrogeological sciences at the Department and elsewhere in government.

5.2.2 Groundwater Management and Mining

Mining operations are expanding (particularly for coal and platinum), but the locations of some of these new mines are in water scarce areas (for example, in the Lephalale and Steelpoort Valley areas) and this will put more pressure on the water resource. The water issues arising from mining operations are both serious and complex, and require agreements between different government departments, affected communities, and the private sector.

The mining footprints undoubtedly impact on water sources whether it is surface or groundwater. Poor and deteriorating groundwater quality is widespread and can be attributed to diverse sources in various sectors such as mining. The discharge or decant of contaminated water and highly saline effluents from mining activities and/or abandoned mines (commonly referred to as acid mine drainage) is a serious environmental threat and social concern. In particular, acid mine drainage from gold mines in the Witwatersrand area and coal mines in Mpumalanga requires urgent attention.

Mining operations also pose other water quality threats, including hexavalent chromium contamination resulting from beneficiation of chrome ore and radionuclide contamination from gold mining operations. Furthermore, acid-mine drainage is rarely recognised as fundamentally a groundwater problem – in most cases only the surface expression of the problem is considered.

The acid rock drainage (ARD) potential, including neutral mine and saline drainage, of mining related residues and exposed surfaces should be assessed and the impacts thereof monitored, according to international best practice, throughout the life-of-mine (i.e. from early planning to post-closure stages) The environmental legislative requirements have been seen by the private sector as an obstacle to the development of new projects and mines.

The Chamber of Mines has criticised the government for introducing laws and regulations blamed for reducing mining investment by as much as R10 billion a year[21].

The Chamber has also argued that the government, especially the Department of Mineral Resources, lacks the capacity and skills to implement the new laws and regulations. This resulted in the slow processing of applications for mining and prospecting permits as well as water licences and the approval of environmental impact assessments[22].

Currently, for mining to take place, the DMR must approve the EMP (under the Minerals and Petroleum Resources and Development Act - MPRDA) while DEA approves the EIA (under the National Environmental Management Act - NEMA). Mining per se is not a listed activity as per NEMA, but mining related land-uses must undergo an EIA process and must be approved by the DEA.

In the awarding of a mining license, the Department of Environmental Affairs acts as a commenting authority and the Department of Water Affairs is responsible for processing Water Use License Applications (WULA), while the DMR is the approving / competent authority.

Mine closure programmes remain a challenge and the Minister of Mineral Resources in consultation with the Minister of Environmental Affairs is to publish strategies to facilitate mine closures. If mining activities cause pollution or are in contravention of environmental authorization

(21) See Brown (2007)
(22) See Brown (2007)

conditions, the Minister may direct the rights holder to investigate mining activities or to take steps as per a directive issued in terms of the MPRDA or NEMA. Should any of the conditions of the environmental authorization be contravened, these can lead to the suspension or cancellation of the mining right, but not the environmental authorization.

5.3 Strategy

Sustainable management of groundwater demands adequate hydrogeological capacity (particularly at local level), along with the availability and/or awareness of existing water resource management guideline documents. Urgent action must be taken in places where serious pollution or over-abstraction threaten the integrity and reputation of the resource (e.g. acid mine drainage near the Cradle of Humankind, over-pumping in the Delmas-Bapsfontein area dolomites).

Groundwater monitoring is the foundation of groundwater management, and this needs to be improved at all levels. Hydrogeological support must be available to municipalities and other local institutions dealing with water provision and resource management. Inter-governmental cooperation (including existing cooperative structures) must be more effective to ensure that decisions with respect to water resource management, the environment and water services are taken timeously, communicated and implemented.

5.4 Actions

- Ensure the implementation of available strategies, regulations, guidelines and tools on groundwater management *(See Chapter 2 and Box 5-7)*, such as:
  - » Existing DWA strategies for groundwater management and protection, as well as guidelines for the operation and maintenance of groundwater infrastructure, etc.
  - » The strategy for artificial recharge,
  - » The waste discharge charge system, intended to enforce the polluter pays principle,
  - » The guidelines for the "Assessment, Planning and Management of Groundwater Resources in South Africa",
  - » Roll out of groundwater tools like CHART, Aquiworx and SAGDT.
- Establish a groundwater advisory service, hosted in regional offices, for water services institutions, for example a Groundwater Call Centre for municipalities
- Establish a Groundwater Resource Governance Section in the Department.
- Support the water services institutions, in order to take up operation and management functions, and ensure the sustainable utilisation of the resource. Community involvement and awareness can help alleviate theft and vandalism.

Box 5-7:
DWA Protocols, Strategies, Guidelines and Standards regarding groundwater management

A few key policy and guideline DWA documents, addressing varied aspects of groundwater management (i.e. development, protection and monitoring), are available on the DWA website. Whilst some of these documents are in regular use (e.g. the NWRS), many are rarely consulted and some have been forgotten. There is a need to evaluate these and similar documents, determine which ones are relevant and useful, and ensure that these are widely and consistently utilised. Those documents that have been superseded should be retired. At local and district level in particular, there is a need for better uptake of current and relevant guidelines and strategies. In some cases, local officials are not aware of the relevant guideline documents.

Policies & Strategies

- Policy and Strategy for Groundwater Quality Management in SA (DWAF, 2000).
- A Groundwater Strategy for the NWRS. The DWAF/ DANIDA groundwater strategy project (DWAF, 2001).
- Towards a strategy for a Waste Discharge Charge System. Water Quality Management Series. Sub-Series No MS 11 (DWAF, 2003).
- National Water Resources Strategy (DWAF, 2004).
- A Framework for a National Groundwater Strategy (NGS)(DWAF, 2007).
- Artificial Recharge Strategy for South Africa (DWAF, 2007).
- Feasibility Study towards the Policy Development for the Protection of Aquifer Dependent Ecosystems in South Africa (DWAF, 2007).

Protocols, Guidelines & Standards

Water Services & Sanitation programmes:

- Minimum Standards and Guidelines for Groundwater Development in Water Services and Sanitation Projects (DWAF, 1997).
- A Protocol to manage the potential of Groundwater Contamination from on-site Sanitation (DWAF, 2003)
- Technical guidelines for the development of water and sanitation infrastructure (DWAF, 2004).
- **NORAD Toolkit for Water Services (DWAF, 2004):**
  - » A Framework for Groundwater Management of Community Water Supply,
  - » AquiMon – Software for Groundwater Management,
  - » Decision Making Framework for Municipalities,
  - » Hydrogeological Data Access System (GDAS),
  - » Groundwater Monitoring for Pump Operators,
  - » Guidelines for Protecting Boreholes and Wells,
  - » Guidelines for Protecting Springs,
  - » Guidelines for Protecting Groundwater from Contamination,
  - » Implementing a Rural Groundwater. Management System,

> > > *continues on the next page*

Box 5-7:
DWA Protocols, Strategies, Guidelines and Standards regarding groundwater management

- » Introductory Guide to Appropriate Solutions for Water and Sanitation,
- » Involving Community Members in a Hydrocensus,
- » Standard Descriptors for Geosites,
- » Sustainability best Practice Guidelines for Rural Water Services,
- » Sustainability Indexing Tool (SusIT).

Comparative Costs for Water Supply Programmes:
- Conceptual Planning and Costing of Community Water Supply Schemes (DWAF, 1998).
- Cost Benchmarks – Typical Unit Costs for Water Services Development Projects (DWAF, 2003).

Water Quality:
Waste Management Series:
- Minimum Requirements for the Handling, Classification and Disposal of Hazardous Waste. 2nd Ed. (DWAF, 1998).
- Minimum Requirements for Waste Disposal by Landfill. 2nd Ed. (DWAF, 1998).
- Minimum Requirements for Water Monitoring at Waste Management Facilities. 2nd Ed. (DWAF, 1998).

Water Quality Management Series:
- Operational Guideline for the DWAF to assist the DME with Environmental Management Programmes in terms of the Minerals Act. Sub-Series No M 5.0 (DWAF, 1998).
- Guideline Document for the Implementation of Regulations on Use of Water for Mining and Related Activities aimed at the Protection of Water Resources. 2nd Ed. Sub-Series No M 6.0 & 6.1 (DWAF, 2000).
- A Conceptual Introduction to the Nature and Content of the Water Quality Management and Assessment Components of a Catchment Management Strategy. Sub-Series No MS 8.1. (DWAF, 2003).
- A Guideline to the Water Quality Management Component of a Catchment Management Strategy. Sub-Series No MS 8.2. (DWAF, 2003).
- A Guide to Conduct Water Quality Catchment Assessment Studies: In Support of the Water Quality Management Component of a Catchment Management Strategy. Sub-Series No MS 8.3. (DWAF, 2003).

Sanitation:
- A Protocol to manage the potential of Groundwater Contamination from on site Sanitation (DWAF, 2003).

National and Regional Groundwater Management Programmes:
- A Guideline for the Assessment, Planning and Management of Groundwater Resources within Dolomitic Areas in South Africa (DWAF, 2006).
- A Guideline for the Assessment, Planning and Management of Groundwater Resources in South Africa (DWAF, 2008).

Database systems
- National Groundwater Archive.

Hydrogeological data , maps and reports
- Hydrogeological information (i.e. data, reports and maps) can be obtained at georequests@dwa.gov.za or alternatively for reports specifically at www.dwa.gov.za

- » Implement the various guidelines of the NORAD Toolkit for Water Services, (or similar guidelines).
- » Develop training programmes *(See Chapter 4)* for municipal officials supporting the implementation of the NORAD Toolkit, for example training courses on the operation and management of boreholes and wellfields.
- Prioritise the conjunctive use of groundwater and surface water resources for municipal water supply schemes.
- Investigate and support the development of large scale groundwater schemes for water services provision where favourable aquifer systems occur.
- Formalise internal coordination processes to facilitate the exchange of groundwater information between different departments.
- Improve and formalise working relations with Department of Education, Department of Health and the Department of Agriculture, Forestry and Fisheries to ensure that hydrogeological capacity is available for drilling programmes implemented by the latter governmental departments.
- The Department, the Department of Environmental Affairs (DEA) and the Department of Mineral Resources (DMR) must adopt and implement the integrated authorization system to improve the regulation of environmental management, water resource management and related activities / land-uses such as mining. The general aim is to facilitate the integration and alignment of regulatory provisions (i.e. with regards to the authorization processes) as contained in the NWA, NEMA and the MPRDA.
- Approach the DMR and review all the regional mine closure strategies.
- Initiate feasibility studies at potential artificial recharge sites.
- Conduct continuous awareness programs of artificial recharge or recharge enhancement as a sustainable management method.

...END

6. Institutional Capacity

6.1 Background

Institutional capacity refers to the way in which water management institutions are structured and mandated, and in the way they collaborate in addressing groundwater management and groundwater problems. It is their ability to deliver. It is closely related to the human capacity issues, which has been discussed extensively in Chapter 4 and is not discussed further here. The arrangements for general and water-related planning in South Africa at national, district and local level are briefly described below, together with the institutions responsible for implementation of water policy and the documents that guide them *(See figure 6-1)*.

6.1.1 National level planning

At national level, the National Water Resource Strategy (NWRS) describes in general terms how South Africa's water resources should be "protected, used, developed, conserved, managed and controlled" in accordance with the National Water Policy and the National Water Act. A progressive decentralization of responsibility from national level to the regions is provided for, and the "equitable and sustainable" use of water is a strong theme.

According to the NWRS, the role of the Department is to provide a "national policy and regulatory framework" for regional and local institutions to conduct the management of water. The Minister of Water and Environmental Affairs remains the custodian of South Africa's water resources. It is envisaged that the national department's role will progressively change, becoming more concerned with national policy, the regulatory framework for water resource management, and monitoring the performance of other institutions.

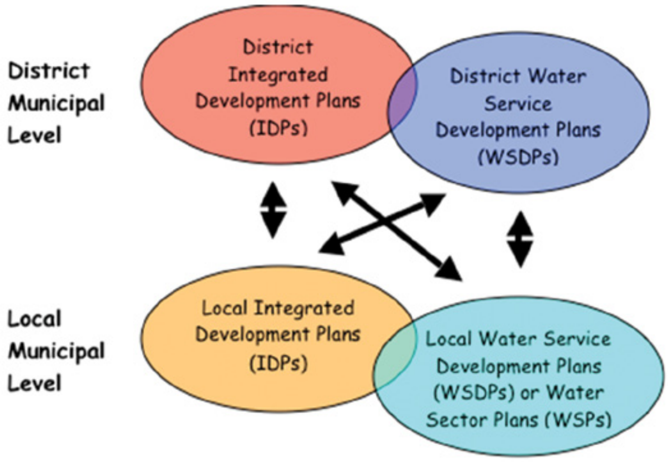


Figure 6-1 District and local level planning

6.1.2 District level planning

The second tier of the water resource management framework is represented by the nineteen water management areas (WMAs), which are based mainly on surface water catchment boundaries and cover the entire country.

In terms of the Water Act, each WMA must be managed by a Catchment Management Agency (CMA), whose functions will include the management of water resources and water-related activities in collaboration with local bodies. Originally, one CMA for each of the nineteen WMAs was envisaged, but this is being reviewed and fewer CMAs may be established[23].

In order to facilitate this task a Catchment Management Strategy (CMS) will be developed for each WMA under the auspices of its governing CMA, which is a document (sensitive to evolving pressures and inputs) designed to guide water management in the WMA. Until such time as the CMAs are operational, water management at WMA level is guided by a series of documents developed by the Department between 2002 and 2004 called Internal Strategic Perspectives (ISPs). (Each WMA has at least one ISP). CMA level water management is informed by, and in turn informs, general planning at provincial level, represented by the Provincial Growth and Development Plan (PGDP) and also the Provincial Spatial Development Plan (PSDP).

Provincial boundaries and CMA boundaries do not coincide, which adds somewhat to the complexity of regional water planning. Water User Associations,

(23) At present two CMAs are operational – the Breede-Overberg CMA, and the Inkomati CMA. There is currently (April 2010) no date for the establishment of the other CMAs, nor has it been decided how many CMAs will eventually be established, since this depends to some extent on available resources and evolving policy.

Advisory Committees, and non-statutory bodies such as Catchment Forums assist with the establishment and direction of the WMA *(See box 6-1)*.

6.1.3 Local level planning

Each municipality in South Africa (both District and Local) is required to develop an Integrated Development Plan (IDP), which lays out the general strategy for all development in the municipal area. Furthermore, municipalities designated as Water Services Authorities must develop a Water Services Development Plan (WSDP) as part of the IDP process that concentrates on increasing access to water services, and must also take into account water supply sustainability. In an iterative process, the WSDP for any municipality takes direction from but also provides information to the IDP.

In summary, there are a variety of levels (from national to local) at which water resources management strategies should be developed. Whilst the various tiers of management are not yet all functional (e.g. the CMAs), and others suffer from a lack of technical capacity, effective management of groundwater resources needs to take account of all the various tiers and stakeholders to ensure wide support, acceptability and sustainability. This is particularly important where aquifer boundaries cross jurisdictional boundaries (such as municipalities or provinces). The final responsibility for national design and coordination of groundwater monitoring programmes remains with the national DWA office[24].

6.1.4 The ISPs

The Internal Strategic Perspectives (ISPs) developed between 2002 and 2004 contain useful recommendations regarding groundwater, and highlight important groundwater-related issues which the CMA must address when it is operational. Most of the ISPs have a separate section on groundwater, although all recommend that management of the total water resource be integrated.

The ISPs were always intended as interim documents, to be used until the relevant CMA became functional, and were also intended to be "live" documents – that is, to be updated annually as new information became available. Updating has not happened in most cases. Some common themes emerge: most of the ISPs place groundwater monitoring, and operation and maintenance of groundwater sources, as priority issues that need to be addressed.

A lack of trained hydrogeological staff is often mentioned. The quality of information on groundwater in each ISP area is generally inadequate, and the ISPs recommend greater efforts in gathering new data, and in consolidating existing data holdings.

(24) See Nomquphu et al (2007)

Box 6-1:
Water User Associations (WUAs)

These are statutory bodies, established by the Minister, comprising of water users with a common purpose. WUAs (a third tier of water management institutions) are thus established for a particular purpose (i.e. undertaking water-related activities at a local level for their mutual benefit) and its operations must be aligned to national policies and strategies such as the NWA, NWRS and CMS. The CMS will guide the establishment of WUAs and their specific functions.

Some of the challenges experienced by WUAs with regard to groundwater management at local scale are:

- **To address a particular local need and priority regarding any form of water use:**
  - Support to emerging as well as resource poor, established farmers. Emerging farmers, in particular, are an important user group and they are often dependent on groundwater but lack the technical and financial resources to operate and maintain groundwater infrastructure, especially in more complex aquifer systems. They also often compete for the groundwater resource with established commercial users (for example large-scale irrigators). Challenges include establishment of monitoring systems and control of abstractions.
  - Control of abstraction for livestock and game use. Groundwater is often the main source of water for livestock and game but there is poor monitoring of groundwater use.
  - Monitoring and control of groundwater use by irrigation boards and municipalities. Irrigation boards are big users of groundwater resources but there is usually poor monitoring of groundwater use and poor control of abstraction resulting in over-abstraction in some cases. Groundwater is also commonly used as a component of supply in many municipalities across South Africa. However, pro-active management and monitoring of groundwater by municipalities is often lacking and coordination with WUAs is rare.
- **To foster effective co-operation in undertaking water-related activities at a local level for mutual benefit.**
  - Subterranean water control boards are established to control groundwater abstraction in stressed (i.e. heavily impacted) aquifer systems and to control threats to sensitive groundwater systems.

WUAs are well placed to:[1]

- Implement and manage conjunctive use of groundwater and surface water resources and the artificial recharge of local aquifer systems.
- Implement water demand and water conservation measures.
- Reduce and/or prevent over-exploration and degradation of the groundwater resources.
- Create awareness on the available local water resources and serve as institutions to promote/establish the sustainable and shared management of available groundwater resources.

(1) See Braune, 2000

As the Fish to Sundays ISP (part of WMA15) puts it, the flow of hydrogeological data is "irregular at best".

6.2 Problem Statement

South Africa currently has a blend of "old" (such as Regional Offices) and "new" (such as the Breede-Overberg CMA) institutions managing groundwater, with some uncertainty about when roles and responsibilities might change. The new institutions and planning processes (e.g. the CMAs) were in part envisaged as vehicles for the implementation of integrated water resource management (IWRM), with its implicit acknowledgement of the importance of groundwater. The delay in establishing these institutions may hamper more effective regional groundwater management. Even where new institutional arrangements have been made (e.g. the Inkomati CMA), the human resources and other capacity elements may not yet be fully developed and some of the groundwater management functions may still rely on capacity at National Office.

For the most effective groundwater management to take place, the various tiers of water planning and management need to cooperate closely, and planning documents need to support each other. This does not always happen, and there appears to be a particular gap between general planning documents (e.g. integrated development plans) and water-specific planning. It may be that the delays in implementing the CMAs (and related delays in releasing updated ISPs and catchment management strategies) means that water issues don't yet carry the weight they need. Although *de jure* arrangements exist (e.g. Regional Offices) for interim water planning, in fact water issues seem to fall between the cracks.

For example, the Mogale City Municipality's general planning documents contain little on groundwater, despite the nearby very serious case of acid mine drainage, and the profitable local agricultural industry that relies on local (and declining) groundwater resources[25]. At local level, the alignment of hydrogeological projects and programmes and integration into a water resource management framework aligned to Water Services Development Plans (WSDPs) and associated business plans assumes there is adequate capacity in WSAs and WSPs, but this is often not the case.

An honest appraisal of bottlenecks in the implementation of groundwater assessment and management functions at the Department offices must be carried out. In some cases relatively minor matters (e.g. difficulties in gaining access to private property to measure water levels, a critical issue in the east rand dolomites) can compromise regional groundwater assessment programmes.

6.3 Strategy

Certainty about the nature and role of institutions needs to be raised, together with better coordination between and within institutions. For example, greater clarity with regard to the status of CMAs needs to be reached, since these bodies will ultimately bear a key responsibility for groundwater management. In the meantime, the building of adequate institutional capacity in Regional Offices with the intention to transfer such capacity to future CMAs when they are established is recommended.

Better alignment of groundwater management objectives between National and Regional Offices must take place. At present, National Office does not receive groundwater data or information from certain Regional Offices[26].

A National Office platform for the communication and coordination of groundwater activities across water management institutions would be useful. This could also incorporate water service functions and the coordination of national water resource planning.

Communication channels between the Regional Offices and regional water services institutions (e.g. district municipalities) should be improved. Communication suffers when there is no groundwater person in the regional office and/or when groundwater is not considered as a water supply option for water services provision. Water resource management functions need to align closely with water services functions at the Regional Office level to optimally employ limited resources and exploit linkages and mechanisms for improving cooperation.

Human capacity is a critical element at all levels and is covered in Chapter 4. Data collection, storage and interrogation are also very important, and are covered in the Information Management Chapter.

6.4 Actions

- Capacitate and provide adequate resources to the Regional Offices to fulfil their mandatory water resource management functions.
- Support and if necessary re-establish Water User Associations to improve the local management of groundwater resources.
- Redefine the roles and responsibilities for groundwater development and management within the constraints of limited capacity across both water resource management and water services institutions. This should include monitoring of groundwater level abstraction and quality as well as the maintenance and operation of groundwater infrastructure across sectors (i.e. water resource management, the environment and water services).

(25) Recent estimates value groundwater-dependent agriculture around Tarlton (Mogale LM) in the hundreds of millions of rands, directly employing thousands of people. Boreholes draw groundwater from the Steenkoppies dolomite compartment, which has shown a long-term decline in average groundwater levels. DWA have in the past threatened to halt or severely limit groundwater abstractions in order to address low flows at the spring draining the compartment, known as Maloney's Eye, which is the source of the Magalies River.

(26) It has been reported that National Office has not received groundwater data from the northwest Regional Office for more than two years. At the same time, the failure of the groundwater supplies to the town of Mafikeng have precipitated a water supply crisis which is currently being addressed by drilling boreholes in an adjacent groundwater compartment. Without monitoring (including submission of this data to the National Office) it is likely that the new compartment supply will in time fail as well.

- Improve and streamline the coordination of water resource management and water services functions across the various institutions.
  - Produce a simple flow-chart showing 'who is responsible for what' groundwater management functions.
  - Establish a platform within Regional Offices for the coordination of groundwater activities.
- Improve cooperation between government departments and the private sector to leverage available capacity and resources.
  - Coordinate with governmental departments such as DEA, para-statals and the private sector to utilize available capacity and resources.
  - Improve the coordination of functions between the directorates of water resource management and water services within the Regional Offices to optimally utilise limited capacity and resources.
  - Provide strategic support to water services institutions to develop business plans (i.e. WSDPs) for groundwater development, management and monitoring as well as for the operation and maintenance of groundwater infrastructure.
  - Formal communication channels between DWA offices and other water management institutions (such as water service providers or water user associations) must be established, or improved where they exist.
  - Consider public – private partnerships to manage major aquifer systems as well as to address significant impacts associated with large-scale abstractions, pollution, mine water decanting and regional mine closure programmes.
- Incorporate the recommendation from the Reconciliation Strategies into the IDPs and WSDPs.
- Strengthen support for collaboration with institutions from other countries, e.g. SADC based IWRM post-graduate training programmes, sector partnerships, bi-lateral aquifer management committees, etc.

...END

7. Information Management: Monitoring, Data and Information

7.1 Background

Groundwater data – water levels, geosite locations, groundwater quality, and other parameters – is the foundation of groundwater management. Without data, managers and users cannot "see" the resource. The Department currently keeps groundwater data in a web-based database called the National Groundwater Archive (NGA) that was released internally to the Department users in October 2008.

The NGA contains data with in excess of 249 000 geosites, of which 242 000 are boreholes *(See figure 7-1 for a chart of growth in data holdings and Figure 7-2 for a map of the borehole spatial distribution on the NGA)*. The NGDB is due to be upgraded to a system called the National Groundwater Archive (NGA) that will have the advantage of allowing users to upload data remotely.

The Water Use Authorisation Registration Management System or WARMS, records volumes of groundwater used. This is based mainly on registered volumes - it is very difficult to verify actual use, since a licensing compliance model is not available. Currently the available groundwater data is easily accessible via an excellent email service offered by the Department (georequest@dwa.gov.za). *(See box 7-1 and 7-2)*

A lack of reliable groundwater data makes it difficult to make accurate assessments of the availability (i.e. quantity and quality) and abstraction (i.e. rates, quantities and drawdown levels) of groundwater. Lack of data on the status of water supply infrastructure (i.e. borehole construction, pumps, etc.) is a major constraint on investment in operation and maintenance activities.

A reliable dataset can only be achieved through approved, standardized, capturing procedures of quality approved data. Quality data can be achieved through continuous monitoring using scientifically proven methods.

Figure 7-3 shows a map of the water level monitoring stations and Figure 7-4 shows the groundwater quality monitoring stations of the Department.

Lack of data combined with lack of skills, results in poor information for decision support and poor management of the resource. Poor management is manifested in over-

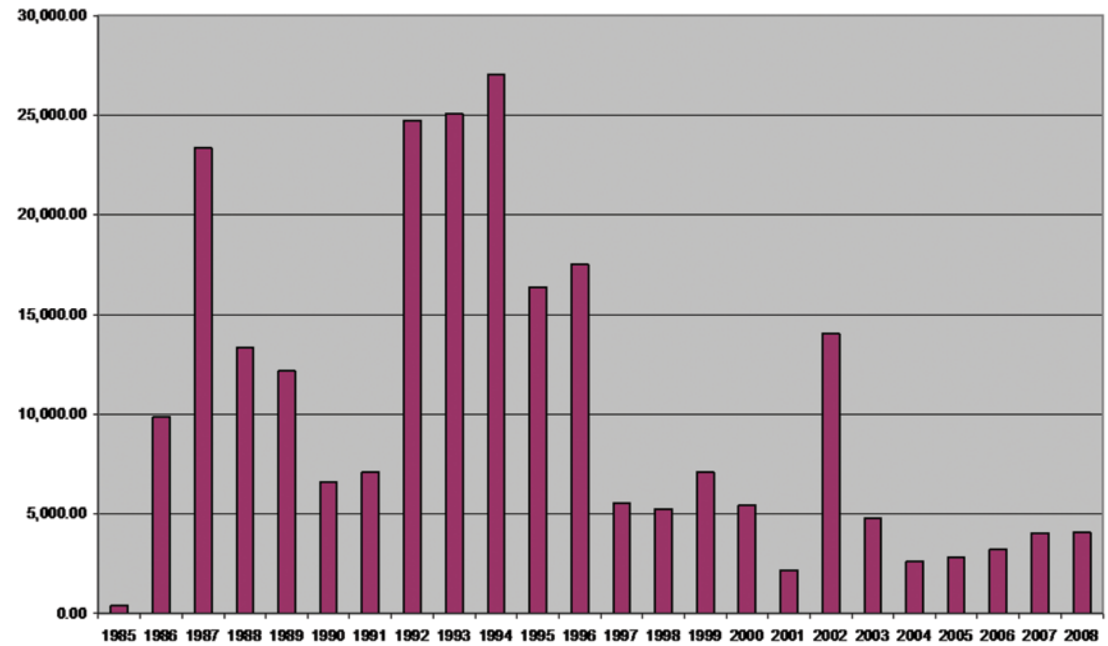


Figure 7-1 *Annual growth in Groundwater records, 1985 to 2008*

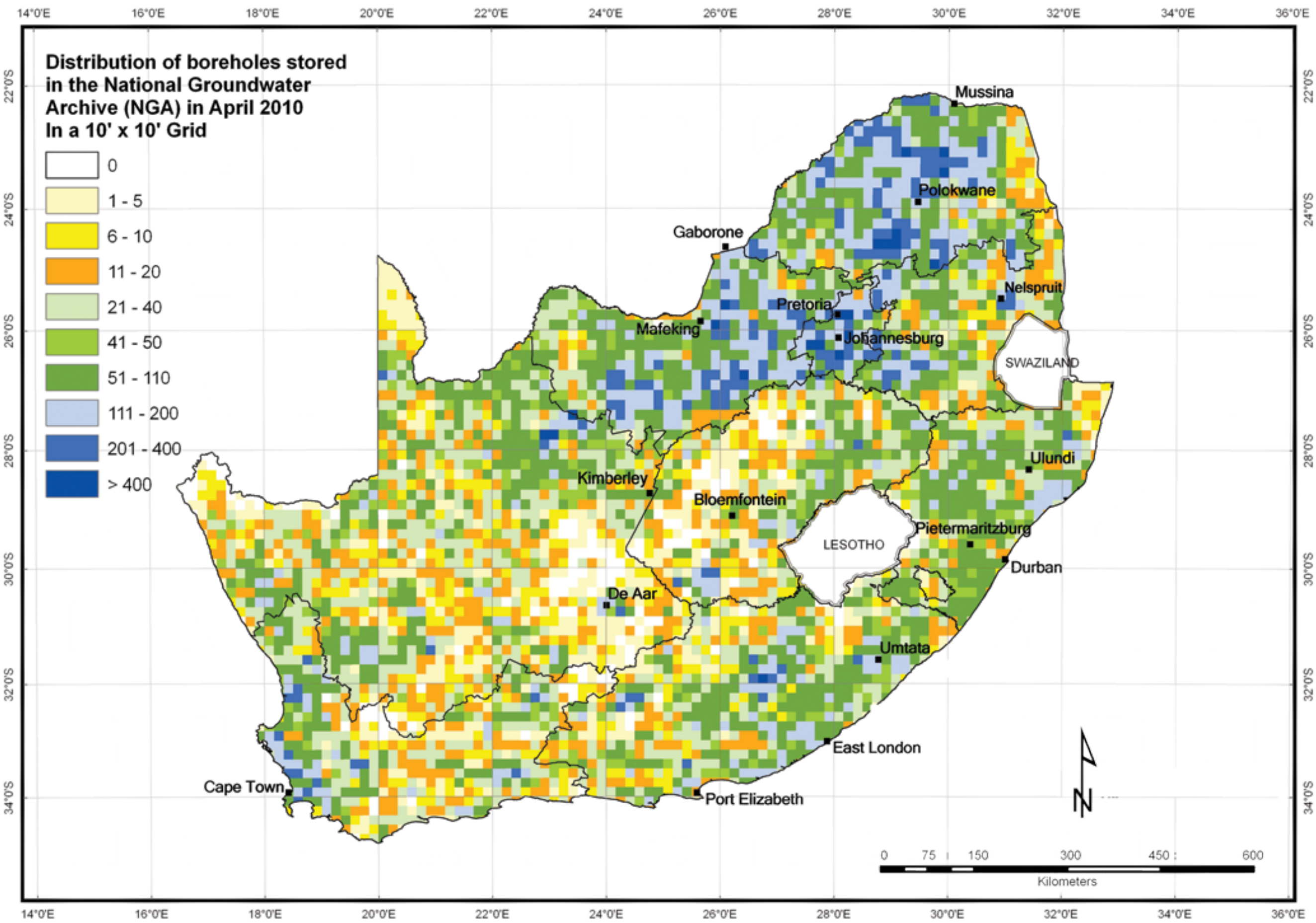


Figure 7-2 *Distribution of borehole records stored in the NGA*

abstraction, pump failures, poor monitoring, groundwater pollution and a lack of policing underpinned by a lack of trained staff. Adequate investment in the maintenance of infrastructure, data collation and interpretation are likely to repay themselves many times over as more effective use of local resources (i.e. limit reliance on distant surface water supplies) and thus more reliable groundwater supply schemes are made possible.

7.1.1 Groundwater Resource Assessment - Phase 2 (GRA 2)

The Groundwater Resource Assessment Phase 2 (GRA 2) project began in 2003, following the national hydrogeological map project, and quantifies South African groundwater at local and regional levels. It provides a rough, desk-top estimate of the status of

Box 7-1:

DWA groundwater website

(http://www.dwa.gov.za/groundwater/)

The website is the window on all the sections in the Department that are involved in groundwater. Some of what the visitor can expect includes the latest news, forms, data, maps, documents, reports, a glossary, products, links, contacts and lots more.

Box 7-2:

Groundwater maps of South Africa

Groundwater data is required for making products such as groundwater maps that are needed to manage water resources, help find borehole drilling sites and avoid areas of poor water quality. The first comprehensive picture of the groundwater resources of South Africa (depth to groundwater, groundwater quality, etc) was only produced in 1995 – the set of seven maps and accompanying report was based on a statistical analysis of data on 120 000 boreholes in the national database.

This was followed in 1998 by a groundwater “harvest potential” map of South Africa, giving the first estimates of how much groundwater could be sustainably abstracted in any given area. In 2003 the first set of regional hydrogeological maps was completed by the Department of Water Affairs, covering the whole country at a scale of 1:500 000 on twenty-one sheets, and broadly following an international standard hydrogeological map legend.

These maps (known as the Hydrogeological Map Series) show type of aquifer (e.g. intergranular or fractured) and median borehole yield, together with geology, rainfall, and other information. They are very useful for planning, but like all maps at that scale cannot replace fieldwork for siting boreholes or for detailed groundwater investigations. The process leading to the production of these maps is called the Groundwater Resource Assessment Phase 1, or GRA 1.

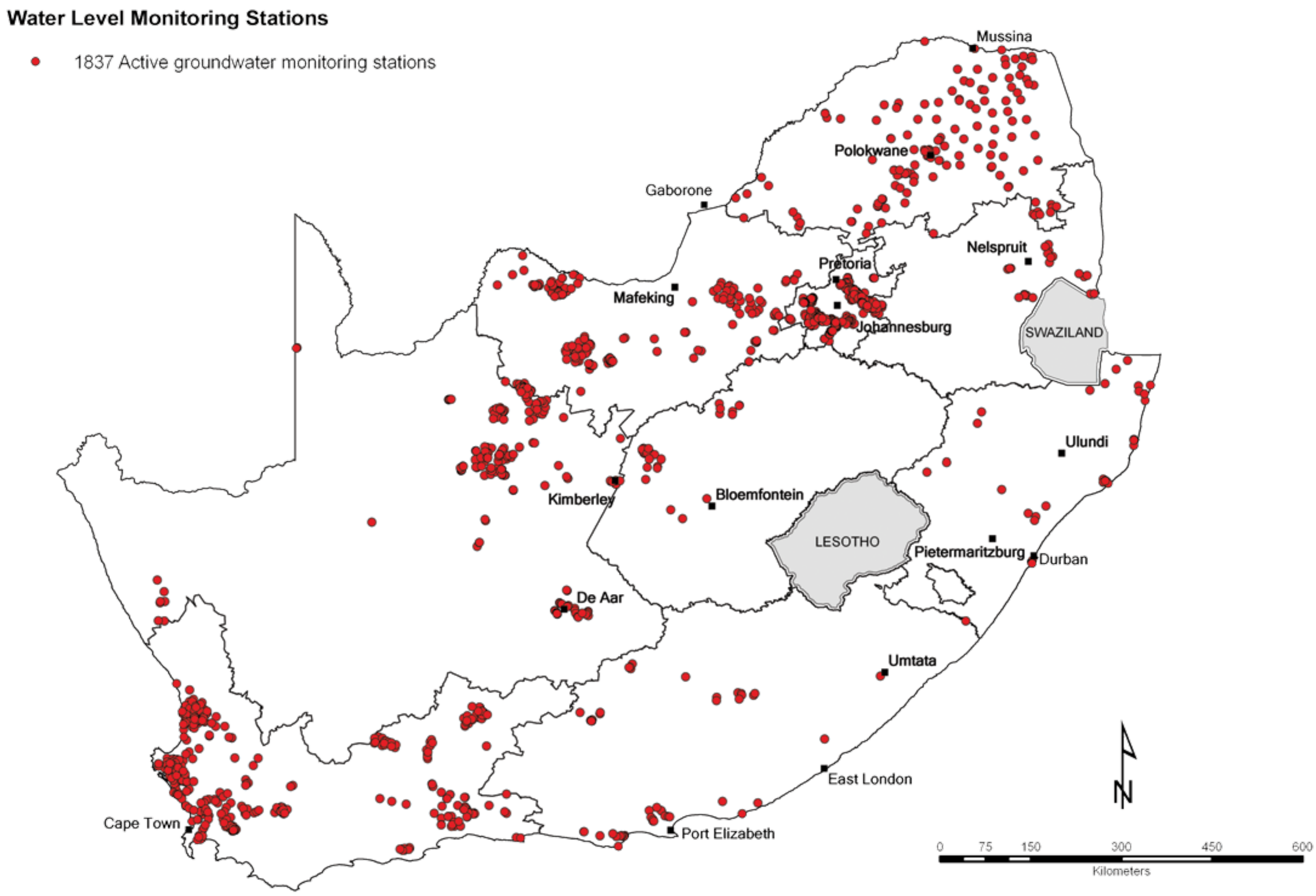


Figure 7-3 *Groundwater monitoring stations: groundwater level*

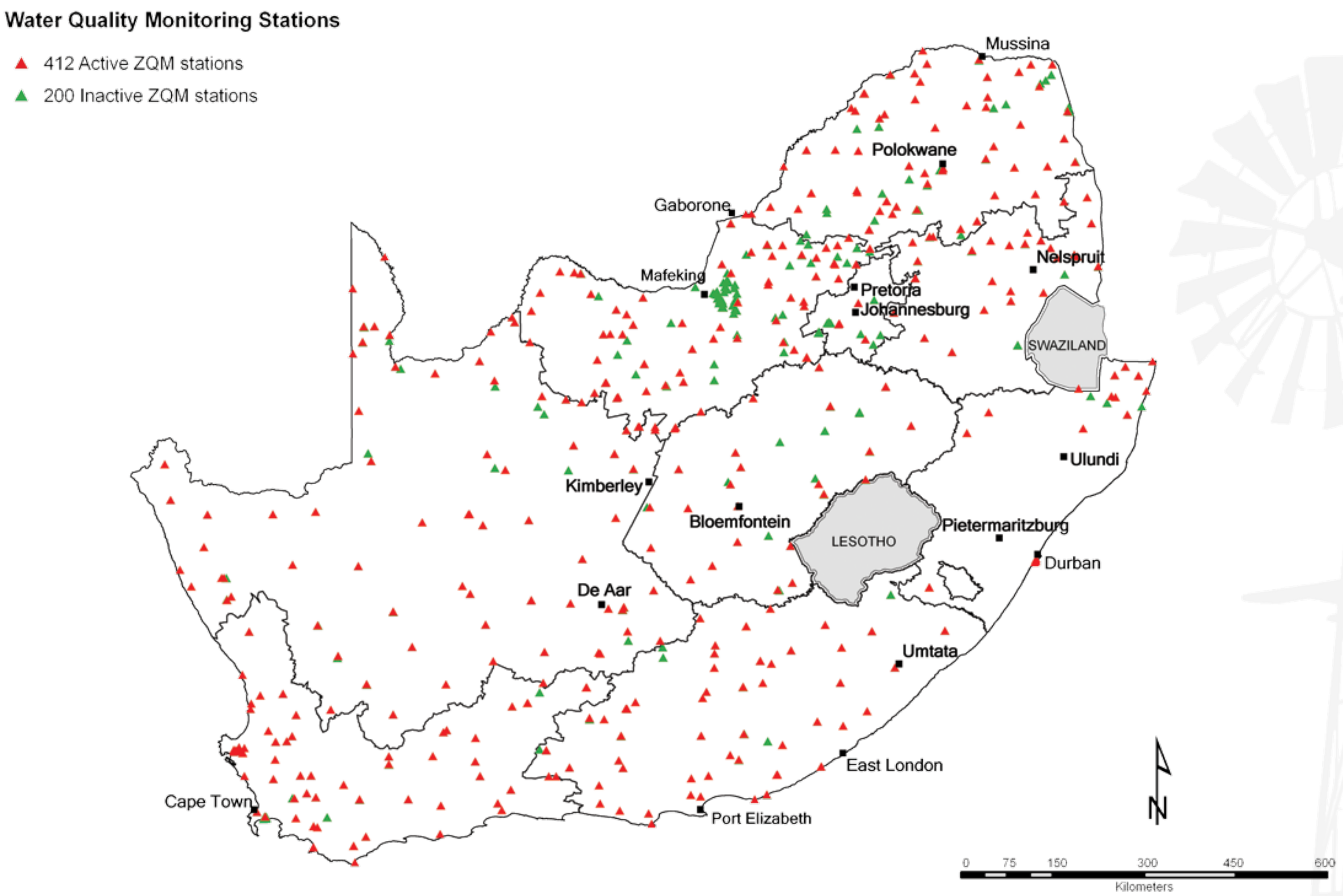


Figure 7-4 *Groundwater monitoring stations: groundwater quality*

the groundwater resource and what volumes might be abstracted without damaging surface aquatic ecosystems over the long-term *(See Chapter 3)*. The GRA 2 dataset is currently being revised to reflect the latest thinking and data. It is worth remembering that any groundwater data product, such as a map or a table

Box 7-3:
The GRIP Project

The Groundwater Resource Information Project (GRIP) is a national Department of Water Affairs project to improve data holdings by accessing unpublished or "private" data as well as "new" groundwater data collected by visiting boreholes in the field – particularly in priority areas.

GRIP will also develop systems and procedures for the collection and verification of unpublished data. GRIP was started in Limpopo Province, and extended to KwaZulu-Natal, the Eastern Cape and Mpumalanga and it is planned to extend it to the Free State. To date, GRIP has been most fully implemented in the Limpopo Province, where it began in 2002 and is still underway. More than 2 500 villages have been visited in Limpopo Province, 15 500 borehole sites have been verified, and 1 500 additional pumping tests have been added to the provincial database.

Limpopo Province now has probably the most extensive and best verified dataset on rural groundwater resources in the country, and enough is known about groundwater in the province to allow it to be much better integrated into general water resource management. The extra data has led to a higher borehole drilling success rate in the province, saving a considerable amount of money. It is planned that all GRIP data be entered into the DWA national WARMS database and NGA, although this has not fully taken place yet. The GRIP projects in the other provinces are not as advanced as those established in Limpopo.

Box 7-4:
DWA Groundwater GH Reports
(http://www.dwa.gov.za/ghreport/)

DWA has more then 3216 internal reports (GH report) and consultant's reports in its library available. Most of the internal reports are downloadable.

The oldest report (GH 3357) is a report on the Zeerust Springs dated 5 November 1906. This report contains spring flow records of various springs, volumes used for irrigation and plans to manage the use. In 1912 a Prof. Schwart wrote a report (GH 1140) for the mayor of Uitenhage on the Uitenhage Springs.

He included sketches in his report and warned the council not to drill any boreholes within several miles of the springs.

Box 7-5:
South Africa's Groundwater Regions

Beginning before the development of the national maps described above, and continuing to the present day, a long-term project recognising the subdivision of the country into a series of "Groundwater Regions" has been underway[1].

These regions are based on the occurrence of groundwater (mainly type of porosity – i.e. primary or secondary) as well as on lithostratigraphical, physiographical and climatic considerations. Groundwater in a region is not necessarily part of the same hydraulic or hydrological unit. It is intended that each region will ultimately have a separate groundwater report and map or maps, explaining and depicting groundwater occurrence and conditions in the region in detail.

A number of groundwater issues including methods for geophysical exploration, recharge, hydrochemistry and the siting of boreholes are included in the reports. A total of 64 Groundwater Regions have been defined, and to date four of the reports have been completed. The completed reports are available from the Water Research Commission (WRC). The Groundwater Regions work is continuing as resources and skills allow, with at least one further region currently in the pipeline. No date for the final completion of all the regions has been set.

(1) See Vegter (2001) and (2006) for more information

of groundwater availability *(See Input Box 7-3),* is only as good as the raw data on which it is based.

Related hydrological and environmental datasets (e.g. rainfall volume, chloride concentrations in rainfall, spring flow measurements, etc) are also key to the better understanding of our groundwater resources. However, these are not always designed with groundwater in mind, and are not aligned with groundwater management strategies.

7.1.2 Data in the private sector

Private contractors in South Africa drill thousands of boreholes annually, yet very little of the data finds its way back to the Department databases. Most groundwater consultants and contractors maintain extensive private databases for their own use, in a variety of formats and standards. There is an urgent need to address this issue, possibly by "registering" drillers and requiring them to submit details of boreholes drilled to the Department for inclusion into the National Groundwater Archive (NGA). This is already provided for in the law[27]. This is likely to cost

(27) The National Water Act states that (Section 141) "The Minister may require in writing that any person must, within a reasonable given time or on a regular basis, provide the Department with any data, information, documents, samples or materials reasonably required for (a) the purposes of any national monitoring network or national information system; or (b) the management and protection of water resources."

very little compared with the value of the data gained. The private sector and the drillers in return would benefit from having access to a much improved and current dataset.

Similarly, there is also evidence that municipalities collect groundwater data but retain it for internal use and are not aware of the requirement for wider distribution.

7.1.3 Database compatibility

Data on groundwater in South Africa exists in various different databases held by a variety of organizations and individuals *(See boxes 7-4 and 7-5)*. Many of these databases are inaccessible (e.g. those held by private companies) or are difficult to access (e.g. groundwater data held at a provincial level). Combining databases would make groundwater planning easier and cheaper.

The process should start by integrating those databases that are already publicly available (in theory), and later address the problem of "private" groundwater data. The National Groundwater Archive (NGA) recognises many of these aims, and endeavours to incorporate obtained groundwater data where feasible. The NGA is designed to encourage the submission of data generated by private work that would normally not be seen by the Department[(28)].

7.2 Problem statement

- There is evidence that groundwater data holdings are declining in parts of the country (e.g. the Tshwane dolomites near Pretoria).
- Inaccessibility of data and fragmentation of databases is also a serious problem.
- Earlier records held in the NGDB have estimated locations based on the cadastral farm name on which the borehole is found – this can lead to inaccuracies in position of several kilometres.
- Modern pumping rates are rarely available.
- Records date from the early part of the last century to the present day; some records are many decades long, others consist of only a single point and date.
- Much groundwater data is held by the private sector, where it is difficult to access, and private sector drillers do not submit borehole data to the Department.
- A lack of standard data capturing formats also hampers the integration of databases.
- A planned updated national database system (the National Groundwater Archive) has not yet been completely rolled out to the public.
- Improved institutional arrangements for data collection are required.

(28) It is likely that this will need to be combined with a legal requirement to submit data, as there is currently little incentive for private companies to submit their data to DWA or to share it – private data confers a short competitive advantage, despite being to the long-run detriment of groundwater management and possibly even to the profession of hydrogeology.

Box 7-6:
National Groundwater Archive

To register for NGA go to: http://www3.dwa.gov.za/nganet.

Now you can Search, View, Capture and Export Groundwater related data directly via the Internet.

If any enquiries email: ngaadm@dwa.gov.za.

- Existing data needs to be verified, and existing databases need to be integrated.
- The backlog of sample processing / analysis at laboratories can also be considered in the problem statement.

7.3 Strategy

- Privately held data needs to be incorporated into national, accessible databases.
- In particular, private drilling contractors need to be "registered" as soon as possible, to allow the data that they collect to be made publicly available.
- Current groundwater databases need more funding and attention, and need to be verified and combined.
- In particular, the future of the new National Groundwater Archive needs to be clarified.
- Data collection by Regional Offices, and submission of the data to head office, needs to be reviewed.
- "Bottlenecks" in data collection (e.g. lack of appropriate equipment or guidelines) must be resolved as soon as possible.
- Data collection is of course also closely related to sufficient human capacity.

7.4 Actions

- Announce the National Groundwater Archive (NGA) to the Public Domain to incorporate the privately held groundwater datasets:
  - » Roll out the National Groundwater Archive to the public to be completed.
  - » Implement the registration of drillers to begin the incorporation of privately collected groundwater data.
  - » Resolve incorporation of privately held groundwater datasets into the NGA, including aspects of accessibility and exchange of data, standardization of data capturing formats for various purposes, reporting of data and information, etc. Include provisions / clauses in all DWA contracts specifying that all data collected as part of the project be submitted to the Department, in a standard the Department format linked to, for example, the NGA. The contract should also ensure that the contractors capture the data on NGA. Implement

the systematic roll-out of regional groundwater data collection and information programmes, and re-start where these have stalled (e.g. GRIP).
    - Verify water use within a reasonable time frame and implement programmes to enforce compliance with respect to water use license conditions. Implement stricter regulations regarding non-compliance with respect to water use license conditions.
- Assess outstanding groundwater data requirements to fulfil the water resource management functions of the National Water Act and structure groundwater monitoring programmes and databases accordingly:
    - Improve and extend groundwater monitoring programmes; for example the national groundwater quality monitoring programme, monitoring programmes for major aquifer systems (i.e. regional), real time monitoring in "hot-spot" (i.e. local) areas, climate change, etc.
    - Implement long-term, representative groundwater level monitoring programmes as well as Cl-measurements in rainfall at local and regional aquifer scales.
    - Improve aspects of accessibility and exchange of data, standardization of data capturing formats for various purposes, reporting of data and information, etc.
    - Support water services institutions in the development and implementation of asset registers on groundwater infrastructure and monitoring of groundwater use and groundwater quality.
    - Support water services institutions in the implementation of groundwater infrastructure, monitoring of groundwater use and groundwater quality regarding the requirements of Water Services Development Plans.
    - Engage with relevant authorities to improve hydrological & environmental monitoring programmes necessary for groundwater management; such as the rainfall monitoring systems maintained by the South African Weather Service.
- Provide an integrated groundwater information system to support water services provision at municipal level. Improve the compatibility (and/or integration) of existing groundwater databases / information systems maintained by different institutions (including water quality databases and municipal groundwater asset registers).
- Support the DMR in the implementation of an integrated information system to record and report on the status of active and abandoned mines - An updated database on mines reflecting accurate, relevant and valid information on environmental and groundwater management information.
- Re-assess the funding required for groundwater monitoring, data capture as well as the operation and maintenance of groundwater infrastructure.
- Develop and disseminate groundwater information products.
- Develop and implement a Groundwater Monitoring Strategy to address the monitoring challenges at national and regional level.

...END

8. Groundwater Research

8.1 Background

South Africa has strong capability in water research, through semi-public institutions such as the CSIR and the CGS, the universities, and the private sector. In some areas (e.g. isotope hydrogeology, or use of geo-electrical applications for groundwater exploration) South Africa has been a world leader.

8.1.1 The Water Research Commission

The Water Research Commission (WRC) is central to the support of water research and the development of capacity in the southern African region *(See box 8-1)*. The WRC's mandate is to support water research and development as well as the building of a sustainable water research capacity in South Africa. Knowledge created through WRC funds strongly supports the Department's overarching objective, i.e. water for economic growth and sustainable development. The WRC continues to support the water sector and all its relevant institutions and partners by providing them with knowledge aimed at informing their decision-making processes, improving their monitoring and assessment tools and making available a new and improved range of technologies related to water resource management and the provision of water and sanitation services.

8.1.2 Public sector research

The public sector (e.g. DWA) also commissions scientific groundwater research programmes, and projects with a research component. This has resulted in improved knowledge of South African groundwater conditions over the years, and has led to the publication of (for example) the 1:500 000 national hydrogeological maps, and the development of the Groundwater Resources Assessment Phase 2 (GRA 2) project.

8.1.3 WaterNet

WaterNet is a network of 52 university departments, research and training institutes specializing in the field of water resources in the SADC region, including Kenya and Uganda. The network aims to build regional institutional and human capacity in Integrated Water Resources Management (IWRM) through training, education, research and outreach by harnessing the complementary strengths of member institutions in the region and elsewhere.

8.1.4 Research cooperation

Given the limited pool of groundwater researchers, cooperation between research institutions is still insufficient. An example is the national programme to address mine closure, with its important groundwater (AMD) component, which has not been adequately coordinated across institutions. The necessity to compete for research funding may contribute to a lack of collaboration and in some cases an unwillingness to share research outcomes and data. In the worst cases, there is

Box 8-1:
The Water Research Commission has published a number of 'status' research reports focussing on major aquifer systems:

(http://www.wrc.org.za/)

- A Synthesis of the Hydrogeology of the Table Mountain Group – Formation of a Research Strategy. WRC Report No. TT 158/01.
- Hydrogeology of the Main Karoo basin: Current Knowledge and Future Research Needs. WRC Report No. TT 179/02.
- Basement Aquifers of Southern Africa. WRC Report No. TT 428/09.

A few specialist research titles include:

- Manual on the Quantitative Estimation of Groundwater Recharge and Aquifer Storativity. WRC Report No. TT 73/95.
- Groundwater Development in South Africa and an Introduction to the Hydrogeology of Groundwater Regions. WRC Report TT 134/00.
- Manual on Pumping Test Analysis in Fractured-Rock Aquifers. WRC Report No. 1116/1/02.
- Groundwater Sampling (Second Edition). WRC Report No. TT 303/07.
- Vulnerability Mapping in Karst Terrains, Exemplified in the wider Cradle of Humankind World Heritage Site. WRC Report No. KV 208/08.

Numerous groundwater and related research reports on a diverse range of specialist topics can be accessed at www.wrc.org.za a "zero-sum" mentality in which gains for one research institution are considered as losses to another.

At times research is inward-looking (considering groundwater conditions to be somehow unique in South Africa), with the attendant danger of "reinventing the wheel – i.e. duplicating research that has already been done elsewhere[29].

The mechanisms for translating pressing national groundwater problems into directed research are not always straightforward, in the very worst cases leading to research institutions allocating research priorities that are only peripheral to the national interest.

For example, much research still needs to be done into the causes and remediation options regarding acid-mine drainage (AMD), or the issue of hydrocarbon contamination. Research institutions are also beset by high turnover of groundwater research staff, lack of funding, and challenges related to ongoing institutional reorganization and change.

8.1.5 International cooperation

It is sometimes stated that South Africa's groundwater (and associated research) is different to that found elsewhere[30]. In fact, most of our pressing issues (e.g. capacity constraints, low yielding aquifers, a semi-arid climate, AMD, fractured rock aquifers) occur elsewhere in the world, and it's probable that this outlook has more to do with scientific isolation prior to the 1990s, than with our hydrogeology.

However, these views can still lead to reluctance to use international literature or international expertise when confronted by hydrogeological problems – for example, our technical response to the AMD problems in Gauteng in the first few years did not follow common approaches adopted elsewhere – even today unconventional ideas are still heard[31]. This situation is slowly changing as international collaboration in South Africa improves, especially with SADC and AMCOW.

8.1.6 International methods of assessing groundwater

A review of groundwater assessment and management

(29) For example, a 2006 consultant's report on the acid mine drainage problem stated "an incident of such a magnitude had never occurred anywhere in the world and that the environmental engineering team . . . were working in completely uncharted territory". The website of a national research organization states that "the complexities of groundwater management are particularly challenging in the southern African region because of its complex geology, fractured rock and a semi-arid climate, which differentiates it from the international norms".

(30) See the Global Acid Rock Drainage Guide (www.gardguide.com) for more information on standard approaches to AMD. There is still – more that a decade after the AMD problem in the Western Basin began – no integrated database of groundwater level and groundwater quality data in the area. Datasets in various formats are held by several different individuals and organisations, and are not easy to access.

(31) For example, in a SAFM radio debate on 16 March 2010 between two South African professors involved with water policy, one stated that our AMD problem might resolve itself in the next few years. See Younger (1997) for a discussion of the longevity of AMD.

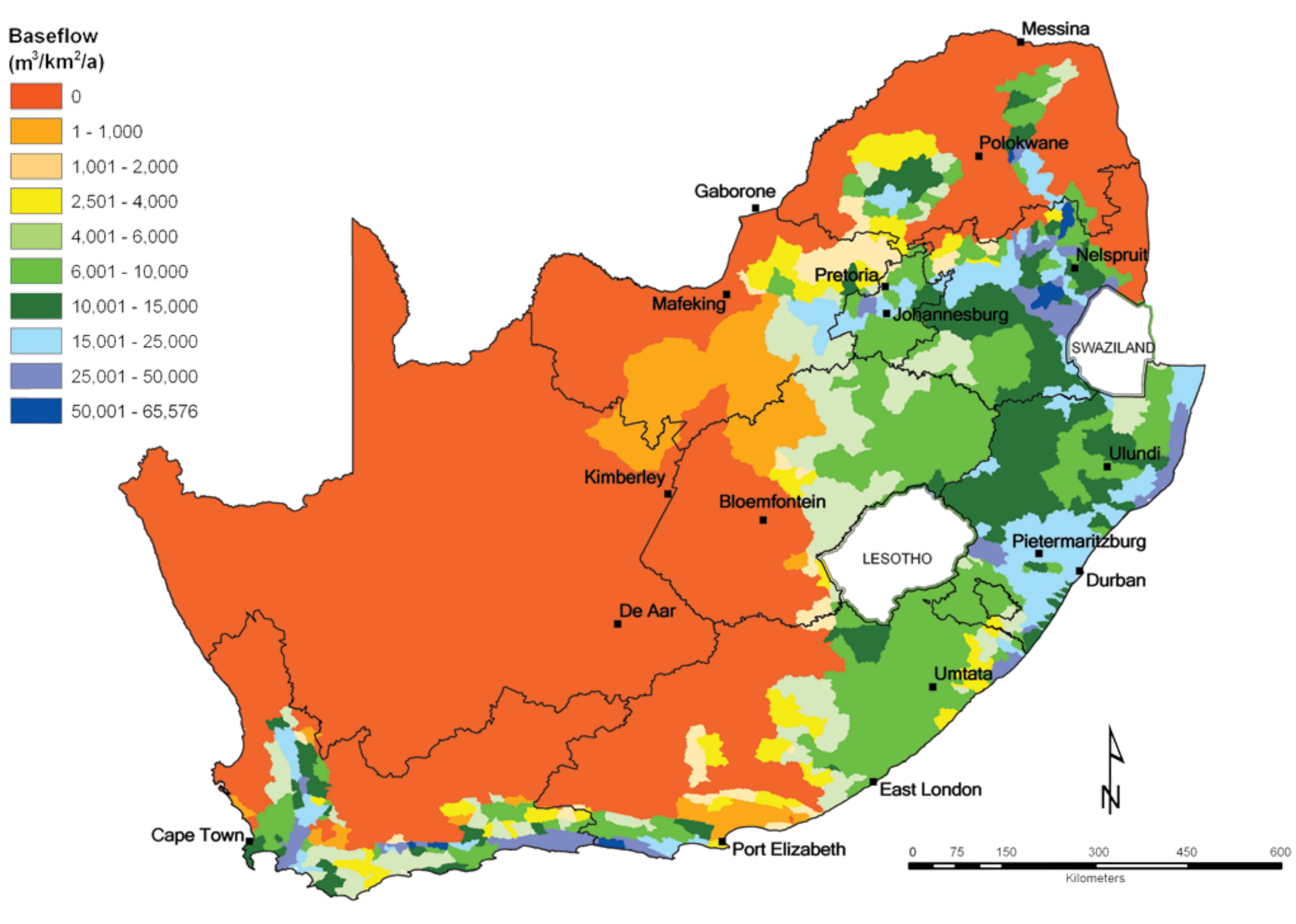


Figure 8-1 Groundwater contribution to baseflow (GRA 2)

in the United Kingdom, Australia and California[32] indicates that numerical techniques (hydrodynamic methods) are increasingly used for estimating local groundwater availability, including the impact of abstractions on adjacent groundwater systems and users. Other methods are also used however, if only to provide first approximations and in the construction of conceptual models.

There is no "one size fits all" groundwater assessment methodology, and methodologies appear to have developed organically against a changing background of data, human resources, legal requirements, growing demand, and water restrictions.

In South Africa, with our historical bias towards surface water, we may naturally want to choose a single groundwater assessment methodology[33] (such as the surface water system currently in use) and adapt data collection, staff deployment and other policies towards that methodology. In fact, the best way of assessing and managing groundwater often depends on local conditions, as recognised in the Department of Water Affairs' Generic Guideline – what is universally important is collecting good quality groundwater data.

All of the international examples show moves towards more data-intensive groundwater assessment methodologies, and this implies that increasing data density and availability in South Africa will become more important[34]. This need not mean collecting new data only – much data that is already generated in South Africa (e.g. by private consultants and drillers) is currently difficult to access *(See Chapter 6)*.

8.1.7 Surface-water groundwater interaction

A better quantitative description of interactions between surface water and groundwater (SW-GW) is needed in South Africa, because they can be mutually dependent. We still don't fully understand the overall contribution of groundwater to surface water yields per aquifer unit at a regional scale.

To complicate matters, no clear guideline for quantifying SW-GW interaction (and related impacts) exists, and different concepts and terminologies are in use. Surface

(32) These three examples were chosen because good data is available for all three, they are all places where major efforts have been made towards better groundwater management, and are all places where scarcity of water increasingly informs water resource planning. As a middle-income country with a relatively sophisticated scientific and administrative infrastructure, South Africa can benefit by leap-frogging many of the early problems that these examples grappled with. We have much to learn from developing countries in many areas, but the technical assessment and management of groundwater resources is only modestly advanced in most of these.

(33) For example, some years ago it was thought that spring flows in some South African dolomite aquifers could be predicted using chemical samples, and routine measurement of some important spring flows was consequently stopped. This turned out to be wrong – but the data that was not collected can of course never be retrieved.

(34) Almost all hydrogeologists would agree that you can't have too much groundwater data!

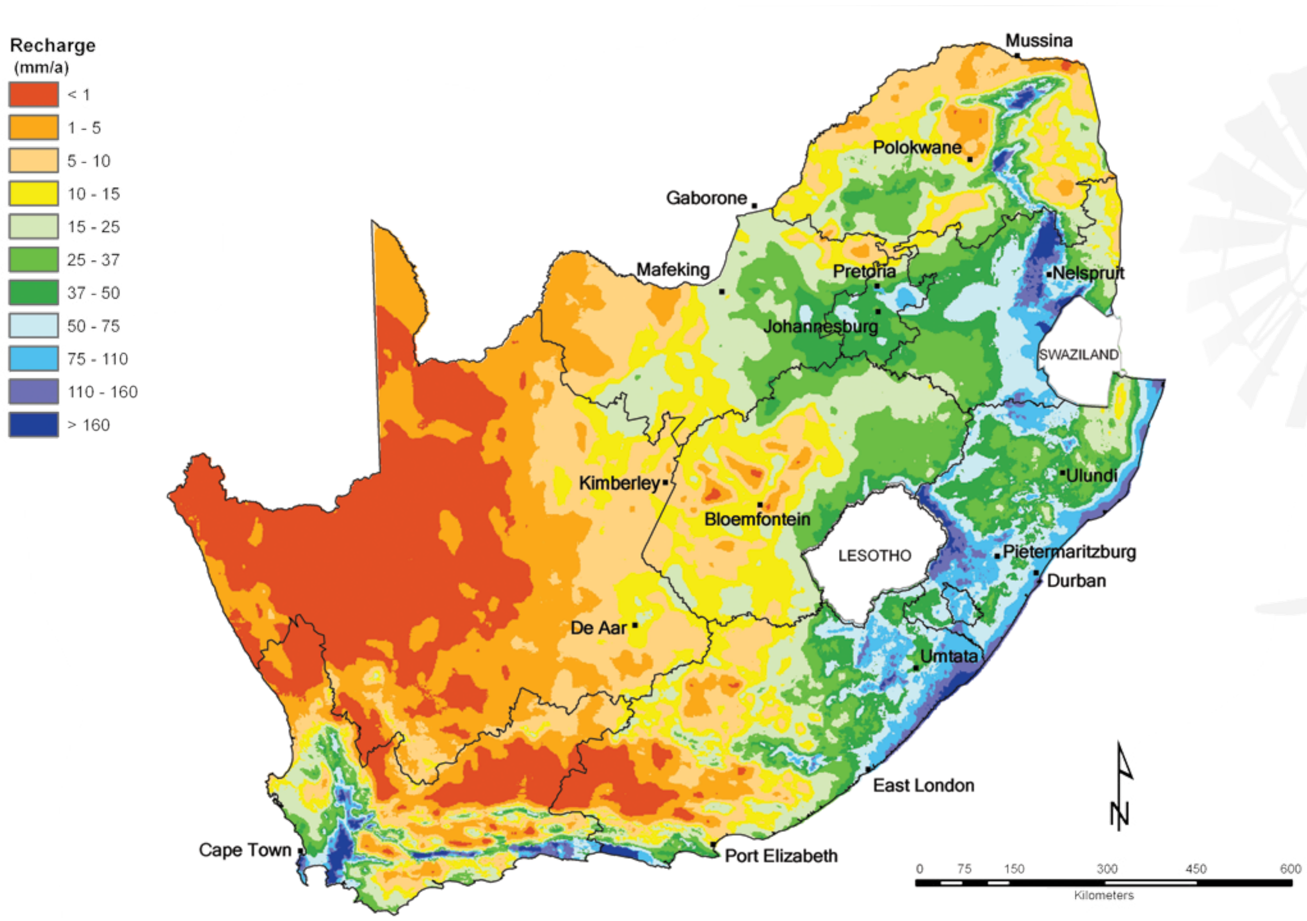


Figure 8-2 Groundwater recharge (GRA 2)

water planners in the Department currently use a surface water model (known as WRSM2000) that includes a SW-GW interaction model, but reviews by hydrogeologists have questioned its applicability on a large scale[35].

A general challenge for the quantification of SW-GW interaction is the different nature of SW and GW resources with regard to residence times (days to weeks versus years to millennia) and spatial distribution (single channel versus three-dimensional aquifer unit).

While the time scale complicates numerical coupling of SW and GW in combined models as well as the impact predictions of GW abstractions due to often long time lags, the spatial scale of aquifers is especially challenging for monitoring and characterisation tasks, not to mention independent forward predictions of groundwater contributions to base flow *(See figure 8-1)*.

8.1.8 Groundwater recharge

Groundwater recharge is the most important factor in the determination of available and sustainably usable groundwater resources in the country. Despite its importance there are currently no reliable national recharge estimates available – although accurate figures are available only in certain local areas.

Recharge figures in the Groundwater Resource Assessment Phase 2 project (GRA 2) are based on a commonly used method known as the chloride mass-balance method, but reliability is hampered by an insufficient national coverage of chloride measurements in rainfall as well as errors inherent in the method *(See figure 8-2)*. Other methods of estimating recharge appropriately are needed.

8.1.9 Aquifer-dependent ecosystems (ADEs)

A classification system for aquifer-dependent ecosystems (ADEs) in South Africa has been proposed[36] based on the aquifer type (e.g. carbonate, alluvial) and on habitat type (e.g. riverine aquatic, spring). Identifying ADEs and assessing the impact on them of groundwater abstraction is not a trivial task.

The system provides information and protocols on how to do this. In some cases ADEs may be the limiting factor on groundwater development potential, and this may be especially true in primary aquifer systems with their

(35) See Dennis (2005) and Sami & Witthüser (2006)

(36) See Colvin et al (2007)

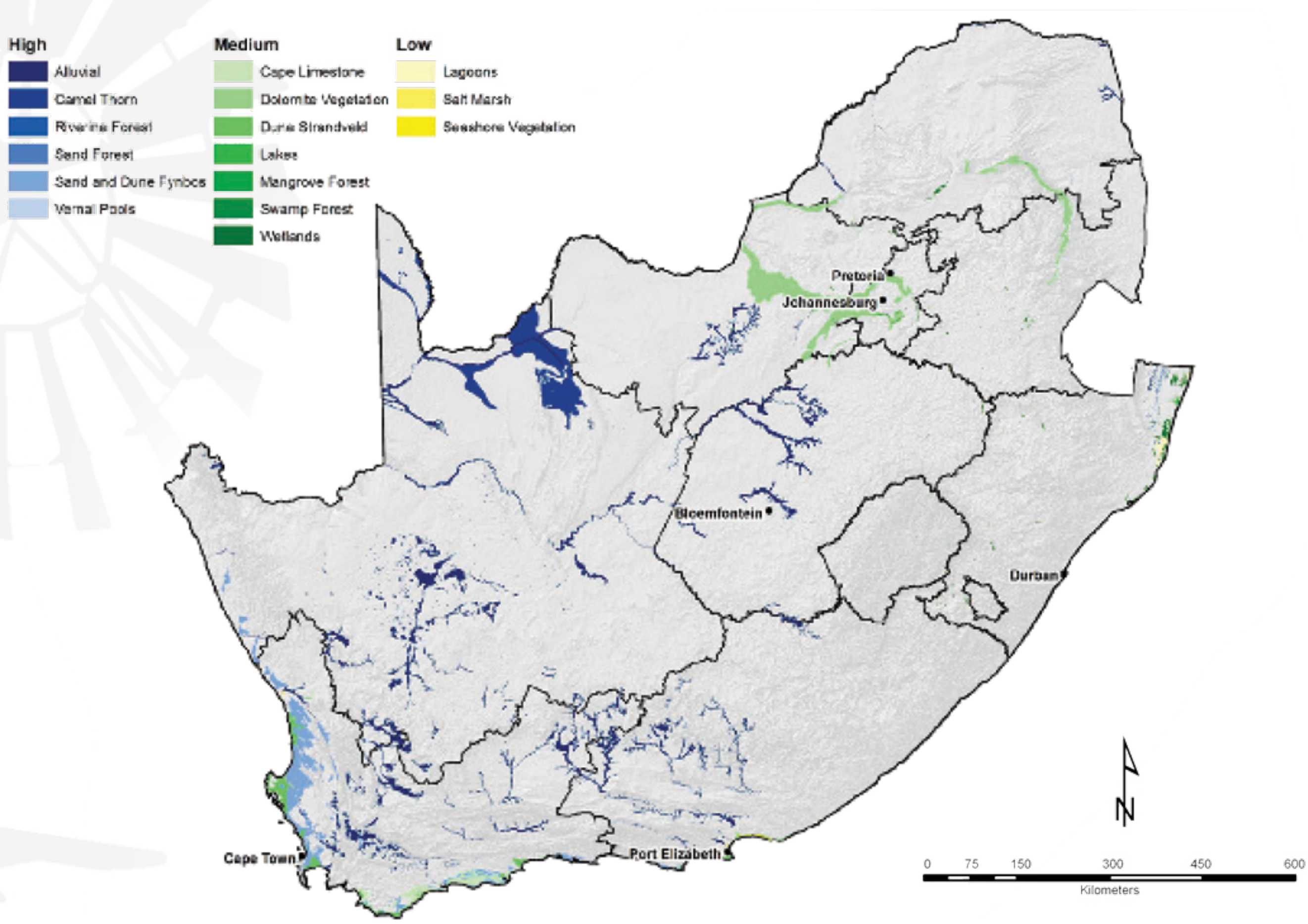


Figure 8-3 Groups of vegetation types showing probability of being aquifer dependent (after Colvin 2007)

shallow water tables and close proximity to surface water resources. The complexity of many ADE / groundwater systems and the relative lack of data means that an adaptive approach is recommended for groundwater development, which has the flexibility to change as resource conditions change and as new data becomes available.

Monitoring is a vital part of achieving an acceptable balance between ADEs and groundwater development. Figure 8-3 shows vegetation groups with a high, medium and low probability of being linked to aquifers.

8.2 Problem Statement

South Africa has a strong groundwater research capacity with a respected international standing. However, research is not always coordinated between institutions to the best advantage, and historically has not always been aimed at the most pressing groundwater related problems (e.g. roll-out and management of rural water supplies to the poorest sections of South African society).

Certain technical issues such as groundwater – surface water interaction and recharge need more research attention at a national scale. There is also still a tendency, in some cases, to "reinvent" solutions to groundwater problems that have been studied for decades elsewhere in the world (e.g. the AMD problem). There is still probably less international cooperation, particularly with neighbouring African countries, than could be the case.

8.3 Strategy

Working conditions and career paths in the research sector should be clarified and improved where possible. Ensure that clearly defined recommendations or actions arise, in particular those that can be easily implemented.

The Water Research Commission should actively coordinate groundwater research by defining national research needs (in consultation with DWA and the water resources sector) and publicizing these on their website (i.e. over and above what they are able to fund).

Improve mechanisms for identifying national research imperatives and communicating this to research institutions. WRC to convene a research forum with senior researchers in South Africa to discuss pressing and emerging groundwater research priorities, and improve inter-agency cooperation and collaboration. Better coordination of groundwater research across institutions – large research projects often need to incorporate more than one institution in order to ensure a "critical mass" of scientists.

The Department (in cooperation with research institutions) should issue clear guidelines regarding the ownership of groundwater data gathered as part of public funded projects, which should submit all data as part of the contract. The WRC should make recommendations for improving international cooperation, and leveraging international expertise, to the benefit of groundwater research. It should support the GWDSA as a forum (via their new website) for discussing and debating research projects and outcomes.

8.4 Actions

- DWA and the WRC must continue to support groundwater research capacity at tertiary institutions. Such capacity can be strengthened through groundwater industry-supported chairs and the promotion of coordinated research programmes involving a number of tertiary institutions. This will assist in retaining and attracting experienced staff, as well as supporting post-graduate programmes to increase the research capacity in South Africa and regionally.
- The WRC, together with DWA, should continue to prioritise groundwater research projects that directly address strategic national objectives. These longer term research projects should be supported by consultative projects. This could include work on issues identified as bottlenecks in groundwater management or delivery, such as improving the methodologies focusing on surface-groundwater interaction.
- The WRC should continue to create a leading knowledge infrastructure to support groundwater research in South Africa.
- Improve the dissemination of research reports and products.
- The WRC should regularly assess the impact of research investment in groundwater. Performance criteria need to be developed and monitored.
- Emphasis should be placed on the strategic leveraging of resources between the WRC/DWA/NRF and the alignment of strategic objectives for groundwater management between the WRC and DWA; e.g. the development and roll-out of strategies supported by implementation programmes.
- South African water research should become more Africa-orientated through support given to regional networks and partnerships.
- The Groundwater Division of the Geological Society of South Africa, supported by the private sector, should play a prominent role in promoting and influencing groundwater research in South Africa through seminars and workshops.

...END

9. Communication and Awareness

9.1 Background

A lack of awareness of groundwater's potential is still one of the main problems faced by the sector, and is a cross-cutting issue that affects all parts of this strategy. Effective communication is needed to state the advantages of groundwater, convey the best practical ways to develop and maintain groundwater supplies, and to dispel some of the many myths that surround groundwater (e.g. it is unreliable, unsafe or backward).

One of the greatest challenges in implementing groundwater development programmes across South Africa remains poor perceptions of the resource. The occurrence, 'use value' and threats to groundwater must be better understood by the public, decision-makers, water resource managers and others in order to achieve Integrated Water Resources Management. The degree to which people understand groundwater and its contributions to water supply, the environment and economic development and other services determines the perceived value of the resource.

Groundwater is already the mainstay of water supply to several towns in South Africa, such as Atlantis, Prince Albert, De Aar, Beaufort West, and Vryburg, and serves as a sustainable and reliable supply to augment surface water supplies to numerous towns in all provinces across South Africa *(See figure 9-1 and Boxes 9-1 and 9-2).*

In other areas (such as the North West dolomites and parts of the Eastern Cape) groundwater has great potential to meet service backlogs, but is poorly managed and the

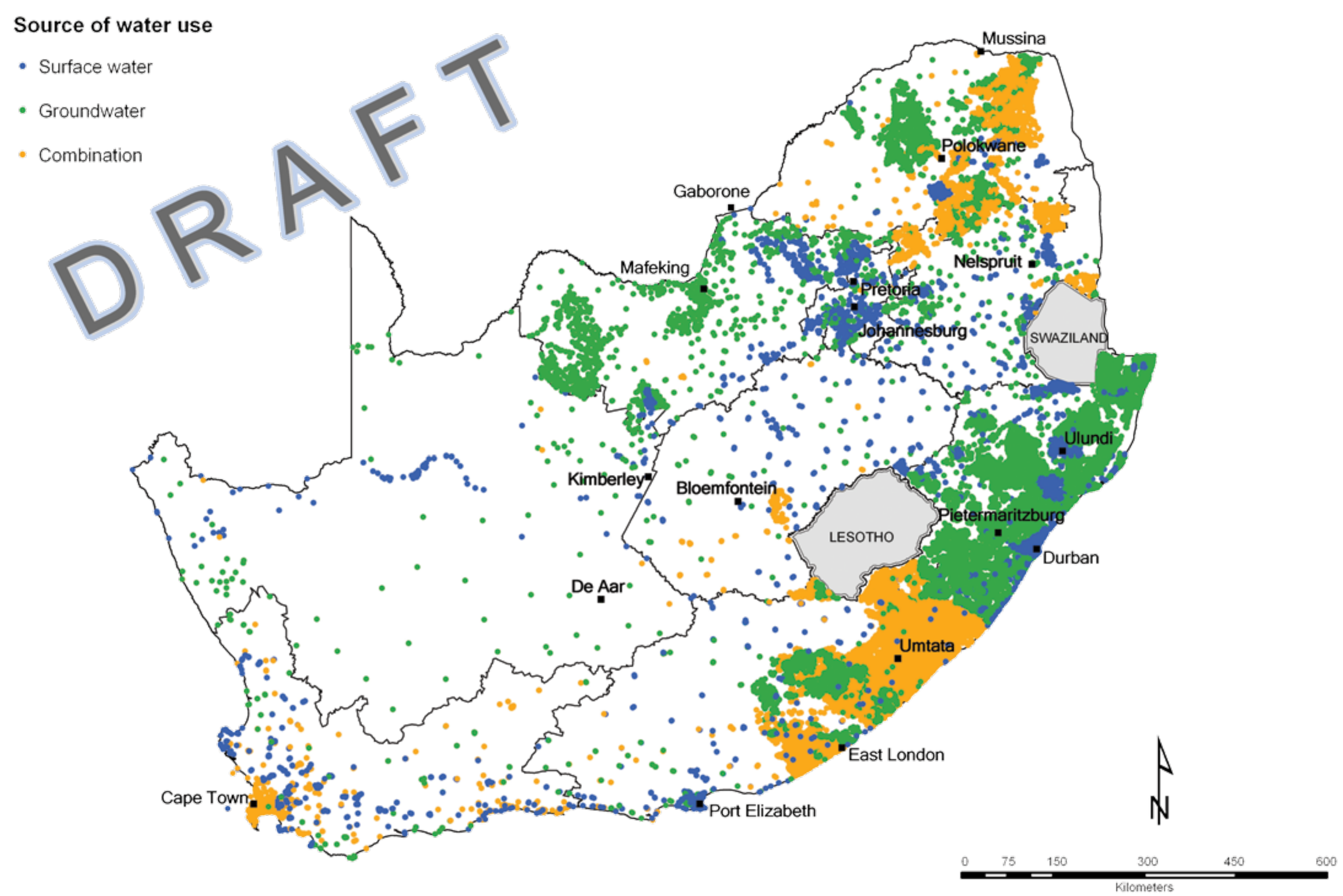
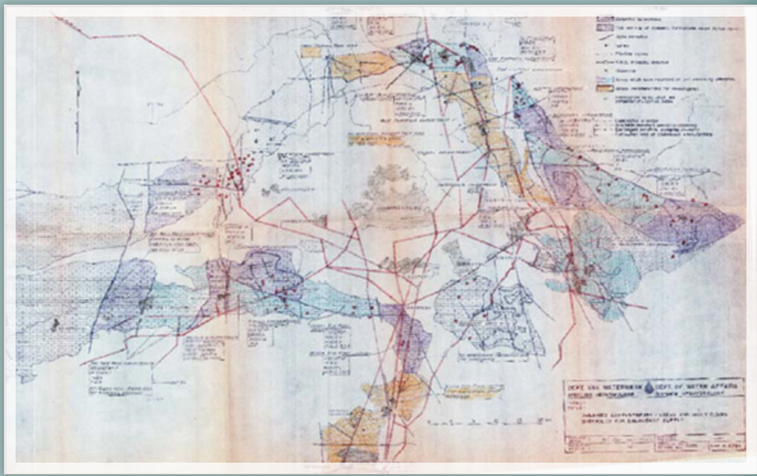


Figure 9-1 Water sources of towns

Box 9-1:

The Groundwater supply to Tshwane Metropolitan Municipality



Few know that Pretoria has depended on groundwater since the town was founded – indeed, the copious "Fountains" springs to the south of the city centre may well be a primary reason for Pretoria's location. In 1905, a geological publication had the following to say: "It has been stated and not without reason, that the water supply of the Capital is unsurpassed by that of any other town in South Africa, and it undoubtedly constitutes one of the most valuable assets of the Municipality"[1]. To this day a proportion of the water supply to the Tshwane metropolitan area is derived from springs and boreholes in the dolomite compartments south of the city and which includes the Fountains. In total, groundwater supplies about 60 million ℓ/day (about 690 ℓ/s) to Tshwane[2], mainly to the central business district area, but suburbs to the east and west of the centre also receive some groundwater. Groundwater is cheaper per unit volume than obtaining water from Rand Water – it is chlorinated as a precautionary measure, but otherwise needs no treatment. One of the first maps of the dolomite groundwater resources intended to inform public water supply in what is today the Gauteng area was completed as late as 1986 (see below).

Table 9-1 Groundwater contribution to Pretoria's water supply in the mid 1980s

Source	m^3/annum	ℓ/second	million ℓ/day
Rietvlei springs	3 700 000	117.3	10.1
Pretoria Fountains springs	7 800 000	247.3	21.4
Sterkfontein spring	2 300 000	72.9	6.3
Erasmia spring	1 100 000	34.9	3.0
TOTALS	**14 900 000**	**472.5**	**40.8**

(1) Hall (1905)

(2) It is also not widely known that Johannesburg uses about 11 ML/day of groundwater, pumped from the Zuurbekom dolomite compartment to the south west of the metropolitan area, and after treatment with ozone is blended into the city's supply. This is one of the city's oldest water sources.

situation may even be deteriorating. Resources need to be directed to;

1. raising awareness of good examples of groundwater use and management, and
2. investigating those cases where groundwater is not being well managed, and taking corrective action (deriving valuable lessons which can inform turn-around actions).
3. Target audiences for the communication and awareness campaign vary from the general public to public sector employees at municipal level to senior decision-makers in water resource management. Each "audience" requires a slightly different approach.

9.2 Problem statement

Outside of the relatively small groundwater community, too few people know about the potential of groundwater and the contribution groundwater makes every day to agriculture, industry and town water supplies. Myths abound, and it is still common to hear that groundwater is unreliable or unsafe. There is evidence that many rural communities consider it to be backward, at best an interim solution before a "proper" surface water supply can be installed. Groundwater does not generally appear in strategic planning documents, and is even neglected in some water plans.

Towns situated near major aquifers (e.g. Plettenberg Bay, Knysna and George) give serious consideration to desalination and to expensive new surface water schemes, before a groundwater assessment has been done. As an example it costs about R75 million for a Reverse Osmosis plant yielding 10 million litres per day as suppose to R10 million for a Groundwater development yielding 3 million litres per day.

9.3 Strategy

Greatly improve the awareness of and knowledge on both the importance of and potential for groundwater resources in South Africa. Such an awareness campaign must target the general public and staff of both water resource management and water services institutions.

Box 9-2:
Beaufort West's groundwater supply

The Karoo town of Beaufort West is situated in a dry part of the Western Cape, distant from surface water, and the town relies mainly on groundwater for its water supplies.

The small Gamka Dam supplies about a quarter of the town's water supply, but most domestic water comes from boreholes and springs. Borehole yields in the generally low-yielding Karoo rocks are modest (less than 5 ℓ/s, although higher yields have been recorded), but taken together the town's boreholes supply about 1.6 million m^3/a, or the equivalent of about 50 ℓ/s pumping continuously[1].

Outstanding knowledge gaps about the local groundwater system are being resolved, with help from the Water Research Commission and the Department of Water Affairs. For example, a deep and a shallow aquifer have been identified, and the groundwater is believed to be divided into discrete compartments by dolerite dykes – although some leakage is expected between compartments. Recent research into available groundwater supply options has led to the definition of three main "groundwater response units", based on groundwater chemistry and piezometric response, and progress towards more efficient and sustainable management of the full groundwater resources available to the town.

(1) See GEOSS (2005) and (2007)

Finalise and implement a marketing and communication plan, including a survey of perceptions on groundwater (main target "audiences": rural communities, local municipalities, National Office, national decision-makers). This should include carefully researched best-practice examples (e.g. Hex River Valley irrigation, Atlantis and De Aar, Vryburg, etc. municipal supplies).

It is recommended that the assistance of an experienced, professional marketing or public relations organization be central to the marketing plan, since the potential benefits and cost-savings are likely to be considerable. Parts of this plan will include elements discussed in the Human Resource Capacity section. A sub-section of the plan, aimed at schools, could include the career orientation programmes such as the Grahamstown science week, special educational materials, a groundwater prize, and similar initiatives.

Early identification and rectification of groundwater supply problems, which if left unresolved do immense, long-term harm to the reputation of the resource (e.g. Delmas). This is closely linked to the Sustainable Management theme. The outcomes of the current reconciliation studies (i.e. the 'All Towns' project) with recommendations on groundwater availability and supply potential should be made widely accessible. The DWA "call centre" for municipalities *(See Sustainable Management section)* in particular should have access to all of this information.

9.4 Actions

- Develop a marketing and communication plan focussing on success cases for groundwater use and management
  - Wider marketing and publication of DWA groundwater use, management and monitoring products / toolkits and WRC research products.
  - Produce regular communiqués on successful groundwater use and management schemes, and investigate ways of bringing these to a wider audience.
  - Dedicate part of DWA Water Week to groundwater, including the award of a groundwater prize for towns excelling in groundwater management, a prize for a student excelling in groundwater studies, etc.
- Continue with bi-annual groundwater conferences and expand the seminar series for professionals.
- Greater participation of groundwater professionals in conferences hosted by WISA, the municipal, agricultural, mining and energy sectors.
- Strengthen partnerships and networks for promoting groundwater in SADC, for example WaterNet, FETWater, African Groundwater Network, Burdon Network.
- Improve groundwater awareness campaigns such as:
  - Information hosted in libraries at schools.
  - Information to inform students at tertiary institutions during orientation week.
  - Science and career orientation festivals (i.e. Grahamstown), 20/20 campaign, WET, etc.
  - Focussed 1-day campaigns for local politicians, SALGA, municipal officials and parliament.

…END

10. Financial Implications Of The Groundwater Strategy

10.1 Introduction

The Groundwater Strategy (GS) has been distilled into eight separate strategies (Policy, Legislation and Regulation; Water Resources Planning; Human Capacity; Sustainable Groundwater Management; Institutional Capacity, Information Management; Groundwater Research; and Communication and Awareness).

A list of proposed actions has been developed for each of these. Some of the actions have already been included in the Department's (or the WRC's) Strategic Plan and incorporated into Key Performance Areas and budgets. Some of the actions have been adopted in principle, but have not yet been budgeted for (or not sufficiently budgeted for). Other actions still require adoption – either in the short or medium term.

This Chapter looks at three financial implications of the strategy:

1. The additional costs to be imposed on the Department when the strategy is adopted (as well as consideration of the costs imposed on other state institutions and the private sector);
2. the potential source of funding for these additional costs (as well as an assessment of the risks linked to these funding streams); and
3. an estimate of the costs associated with not implementing the strategy.

10.2 Cost of Implementation

To determine the cost of implementation, one first needs to identify those activities that have already been budgeted for, or which are expected to commence regardless of whether the Groundwater Strategy is adopted or not. These activities should not be included in the cost of implementation, since they will be incurred even if the Groundwater Strategy is not adopted.

The cost of the remaining activities should then be split into capital and operating costs, with a further distinction being made under operating costs between establishment (or commissioning) costs and routine (ongoing) costs. A detailed breakdown of the proposed actions, with notes relating to their potential cost, is available as a separate document. The information presented below summarises the financial implications.

10.2.1 Existing activities

DWA's Strategic Plan for 2010 to 2013 lists six core priorities:

1. Contribution to economic growth and social development
2. Ensuring sustainable and equitable water resources management
3. Promoting rural development
4. Effective support to local government
5. Contribution to global relations
6. Improving the Department's capacity to deliver services

Many of the actions support the priorities above and have already been provided for in current performance plans and budgets.

Existing activities that support the Groundwater Strategy actions include the work on groundwater that forms part of the All Towns Reconciliation Strategy Study, the continued development of a national groundwater information system (and the National Groundwater Archive), the work on reserve determinations, verification of water use, the development of regulations for groundwater users and drillers, the development of technical guidelines, work on artificial recharge, support to institutions such as ORASECOM and the Groundwater Management Institute (GMI), support to groundwater research, and the hosting of groundwater conferences.

A number of actions, such as the verification of water use, are not specific to groundwater. Where appropriate, a proportion of the cost has been attributed to groundwater (and to the implementation of the Groundwater Strategy).

10.2.2 Capital costs

There are significant capital costs associated with groundwater development. However, the primary responsibility for these capital costs rests with local government and other users of the groundwater. Whilst certain Regional Offices invest in exploratory drilling activities, the Groundwater Strategy does not call for the expansion of these activities.

Instead the primary capital outlay linked to the Groundwater Strategy relates to extension of the monitoring networks. An estimated R26m is required to extend the monitoring network in all regions, monitoring water quality and quantity. These costs are for drilling and logging equipment for an additional 1300 boreholes.

There may be minor capital costs associated with the establishment of a Groundwater Management Unit within the Department and increasing the capacity of the Regional Office (office furniture, computers, etc.) but the Strategy does not call for the purchase of drilling equipment and other high value items.

10.2.3 Operating Costs

Operating costs can be split between establishment (or commissioning) costs and routine (ongoing) costs. Many of the proposed actions require both – for example the issuing of licences requires a once-off cost to address the backlog, with an ongoing cost to assess new applications and renewals.

10.2.3.1 Establishment costs

Total establishment costs associated with the Groundwater Strategy are estimated to be in the region of R61m over the next five years, excluding the costs of completing the Groundwater Resource Information Project (GRIP). Completing the GRIP is a major exercise which has been partially funded from various budgets but which still requires another R212m over the next five years. The Groundwater Strategy calls for the completion of GRIP and this cost has therefore been added to the cost implications. The establishment costs associated with each of the eight sub-strategies is summarised below.

10.2.3.1.a Policy, Legislation and Regulation

Commissioning costs of R11.1m over two years are associated with the implementation of the Groundwater Strategy actions related to policy and regulation. The primary cost (R10m) is to supplement the budget for reserve determination, with R1m provided for finalising the strategy on the rehabilitation of abandoned mines.

10.2.3.1.b Water Resource Planning

R10.5m could be spent on commissioning activities related to WRP over the next two years. R7.5m of this relates to the development and dissemination of best practice guidelines with respect to WRM (and groundwater in particular) whilst R3m relates to improvement of the GRA 2 methodology and setting up the appropriate monitoring network.

10.2.3.1.c Human Capacity

Most of the costs under human capacity are ongoing. However a budget of R4.2m is provided for the establishment costs related to recruiting the full complement of groundwater staff required for each Regional Office. An additional R500,000 may be needed to complete a formal review of working conditions, career development, etc.

10.2.3.1.d Sustainable Groundwater Management

A number of the actions listed in this section impose costs on other institutions – such as the requirement to investigate and develop favourable aquifer systems – a cost to local government. Other costs are for the department as a whole – such as the implementation of the waste discharge charge system.

Establishment costs of R2.1m have been associated with this sub-strategy – mainly relating to collaborating with the DMR and the DEA on the establishment of an integrated authorisation system and supporting the DMR in the improvement and implementation of regional mine closure strategies.

10.2.3.1.e Institutional Capacity

Many of the costs associated with the Institutional Capacity actions are already being incurred by the Department, or are the responsibility of other institutions. For example, the bulk of costs associated with the establishment of Water User Associations are typically borne by the Associations themselves.

A number of actions associated with strengthening institutional capacity are also resolved by implementation of the actions related to human capacity – such as ensuring adequate staffing of the Regional Office. establishment costs associated with the Institutional Capacity actions are expected to amount to R1.25m, with R1m of this to support the establishment of the SADC Groundwater Management Institute (GMI).

10.2.3.1.f Information Management

The bulk of the establishment costs associated with the Groundwater Strategy can be attributed to this sub-strategy – a total of R243m. The completion of GRIP, on its own, will potentially require funding of R212m over the next five years.

Another R23m over three to five years is provided for the completion of the NGA (completion of modules, transfer of data, and training of data capturers in Local Government (LG) and private drilling companies).

Completion of the groundwater monitoring strategy could require another R3m, although implementation thereof has not been provided for (but could be in excess of R20m).

Developing an integrated groundwater information system and ensuring compatibility or integration between databases could cost R4m over two years.

10.2.3.1.g Groundwater Research

There are very few establishment costs associated with the Groundwater research actions. R200,000 has been provided to conduct a once-off review to assess the impact of research investment in groundwater.

10.2.3.1.h Communication and Awareness

Many of the costs associated with communication and awareness are already provided for, or are on-going. A budget of R300,000 has been provided for the design of brochures to be used in groundwater awareness campaigns.

10.2.3.2 Routine costs

Routine costs imposed as a result of the Groundwater Strategy could amount to an additional R66m per annum being spent by the Department. A significant proportion of these costs relate to increasing the groundwater capacity within the Regional Office, with the second major contributor being the maintenance of an extended monitoring network.

The costs associated with each of the 8 sub-strategies is summarised below:

10.2.3.2.a Policy, Legislation and Regulation

There are no routine costs associated with the actions under this sub-strategy. The actions either require a once-off response, or would be addressed by an appropriately capacitated Department.

10.2.3.2.b Water Resource Planning

There are very few routine costs associated with the WRP actions, apart from R500,000 provided for the additional monitoring costs associated with an extended GRA 2 monitoring network.

10.2.3.2.c Human Capacity

Routine costs for this sub-strategy amount to R29.3m. A review of the groundwater capacity in the Regional Office reveals significant shortages in the required staff. In some cases the positions are budgeted for but vacant. The estimated cost here is for recommended Regional Office positions that have not been budgeted for. The required additional budget for all Regional Offices is estimated to be R22.4m.

This excludes the additional budget requirements of those Regional Offices that have traditionally executed additional functions – such as exploratory drilling. Other routine costs associated with the Human Capacity actions include the premium payable on contracts, to ensure that capacity building elements are built in (R3.7m); the cost to subsidise the attendance of WSA officials at external groundwater training courses (R1.7m); and a bursary programme to support an additional 10 geo-hydrologists per annum (R1.5m).

10.2.3.2.d Sustainable Groundwater Management

Most of the costs associated with these actions are once-off, or are expected to be undertaken by existing capacity. The exception is the establishment of a Groundwater Resource Governance Section within

Table 10-1 Summary of commissioning and routine cost implications of Groundwater Strategy implementation

	COMMISSIONING	ROUTINE
Policy, Legislation and Regulation	R11,100,000	R0
Water Resource Planning	R10,500,000	R500,000
Human Capacity	R 4,700,000	R29,300,000
Sustainable Groundwater Management	R2,100,000	R10,000,000
Institutional Capacity	R1,250,000	R950,000
Information Management	R31,000,000	R20,000,000
- GRIP completion (Regional Offices)	R212,000,000	R0
Groundwater Research	R200,000	R2,550,000
Communication and Awareness	R300,000	R2,600,000
COMBINED SUMMARY OF COSTS	**R273,450,000**	**R65,900,000**

the Department, which is expected to cost in the region of R10m per annum.

10.2.3.2.e Institutional Capacity

Most of the costs associated with these actions relate to better utilisation of existing resources. A total of R950,000 is expected to be added to the annual costs of the Department through implementation of the Groundwater Strategy. R700,000 would be for support to the SADC Groundwater Management Institute and R250,000 to contribute to ongoing support for the weaker WUAs.

10.2.3.2.f Information Management

Additional annual expenditure is expected to amount to R20m – to maintain fully functioning monitoring networks at a national level and at regional level. This cost estimate is over and above the current budgets allocated to network maintenance, and is meant to cover networks that monitor chemical analysis, water quality and quantity.

10.2.3.2.g Groundwater Research

Most of the actions required under this sub-strategy do not have specific cost implications. Additional routine expenditure is expected to amount to R2.55m per annum, with the primary cost being a provision of R2m to support one or more academic chairs focussing on groundwater.

10.2.3.2.h Communication and Awareness

R2.6m has been provided for additional communication and awareness costs. R1m is for ongoing marketing and awareness raising; R700,000 is for the printing and dissemination of brochures, with another R500,000 provided for the expansion of conferences and seminars.

10.2.3.3 Summary of operational expenditure

A detailed review of the actions listed by the Groundwater Strategy reveal that implementation of the strategy could result in additional (once off) expenditure of R273m over the next five years (with the bulk of this – R212m – reserved for the completion of GRIP across all regions). Additional annual expenditure could amount to R66m. The cost estimates are summarised in table 10-1 on the next page.

10.3 Sources of Funding

At present the Department's water resources management activities are mainly funded from two sources: revenue from Water Resource Management (WRM) charges collected by the Water Trading Entity (WTE), and allocations from the government's Exchequer Account. The Department also benefits from some international donor funding.

10.3.1 Revenues from WRM charges

The Department is empowered to charge for water use in terms of s56(1) of the National Water Act. The latest Pricing Strategy (March 2007) confirms four principal objectives: social equity, ecological sustainability, financial sustainability and economic efficiency. The resulting charges for water resource management are meant to cover activities required to 'protect, allocate, conserve, manage and control the water resources and manage water quality' in South Africa.

No distinction is made between surface water and groundwater – the WRM charge is meant to cover all water resources, regardless of source. Many WRM costs apply equally to both sources. In theory one could attempt to make an allocation of the remaining funding between surface water expenditure and groundwater expenditure – based on the volume of water requiring management (both passive and active).

For example, passive management relates to the 10 343 million m³/a of Utilisable Groundwater Exploitation Potential, relative to the 12 000 million m³/a of surface water (roughly a 46:54 split), whilst active management would be more of a 20:80 split based on current annual use of groundwater relative to surface water. Whilst this exercise may be largely academic, there are some clear indicators that a disproportionate share of the WRM revenue is devoted to surface water activities. For example, the lack of groundwater personnel in the Regional Office is an area that could be addressed through a more appropriate allocation of budget, funded by the WRM charge.

Notwithstanding the pricing strategy objective of financial sustainability, the WTE losses for the past three years, including all income and grants and all expenses including depreciation, have been in the region of R1.5 billion per annum – which is similar to the annual depreciation cost. This indicates that the WTE has received sufficient income to meet its operating costs, but has not been able to make any provision for the rehabilitation or refurbishment of existing assets.

A significant proportion of the WTEs income is from the agricultural sector, which has traditionally enjoyed price caps that have kept their charges well above the rates required for cost recovery and provision for replacement. Removing these caps will require support from a number of different sectors

10.3.2 Exchequer account

In the absence of significant increases in water use charges, the WTE will continue to operate at a loss. The increased funding required by the Groundwater Strategy will therefore need to be funded by the Department's parliamentary appropriation from the Exchequer Account.

10.3.3 Donor funding

Donations – whether in cash or in kind – make up a very small percentage of funds utilised in the water sector. A major concern with donations is that a well-intentioned donation may create responsibilities, obligations or other consequences that the recipient had not considered. For example, the donation of an asset may give rise to operating and maintenance costs that are not sustainable. In order to prevent these scenarios, National Treasury formed an International Development Co-operation (IDC) directorate which was responsible for the establishment of a policy framework and management system for Official Development Assistance (ODA).

ODA is regarded by National Treasury as an official resource flow which is supplementary to the budget and is not viewed as replacement funding for normal revenue. **ODA may take the form of:**

- grants – as actual non-repayable funds,
- technical cooperation in the form of expertise and
- financial co-operation as loans or credit guarantees.

The Department receives ODA through its Directorate for International Relations. The directorate manages international relations with donors who approach the directorate directly. The bulk of ODA received by the Department, are grants from the European Commission, Ireland, Flanders and DFID. Ewing & Guliwe[37] state that some the Department programmes would not exist in the absence of external funding and cite the Masibambane Water Programme as an example of an initiative where ODA funding from EU, DFID and Flanders has been crucial.

Treasury's Development Cooperation Information System reveals a number of funded projects in the water sector. Not all of this is funded via the Department. For example, a number of long-term loans from the European Investment Bank to the DBSA, for the purposes of 'Water Supply and Sanitation Capacity Building', are listed as ODA.

Johannesburg Water is also listed as having received assistance from the Agence Française de Développement (AFD) in the form of a credit line of €40m for the upgrading of water and sanitation services in Soweto. This loan, worth R340m according to the ODA listing, is presumably a 'soft loan' or guarantee to enable Johannesburg Water to obtain a better credit rating and hence a lower interest rate on its debt.

The ODA listing, run for all donations to the Water and Sanitation sector, covering a period ranging from 1996 and stretching into the future to as far as 2026 for some of the loans, reveals total committed funds of R5.8bn (with expected matched funds of R2.6bn). Given the time frame, this represents a fairly inconsequential source of funds for the water sector. However, as stated above, they may be supporting projects which would not otherwise have happened.

A review of commitments specifically catering for Water Resource Management reveal grants amounting to R275m and a loan of R800m (€100m). The commitments range from SADC level to regional level. The loan commitment was made by the European Investment Bank to the TCTA, to improve the water quality of the Berg.

What these commitments indicate is that ODA is a potential source of funds, and could be targeted for use on specific projects – such as the eradication of backlogs in the licensing process, and completion of groundwater resource assessments.

10.4 The cost of not implementing the Groundwater Strategy

An important aspect of the financial analysis of the Groundwater Strategy is estimating the cost of not implementing the Groundwater Strategy. This can then be compared to the cost of implementation, to develop a cursory sense of the cost and benefit of the Groundwater Strategy.

Two key assumptions in assessing the cost of not implementing the Groundwater Strategy are:

1. **All benefit derived from sound groundwater development and management is attributed to the Groundwater Strategy.** This assumption is built on the centrality of the Groundwater Strategy in groundwater development and management in South Africa - as the Groundwater Strategy is central to the development and management of groundwater in South Africa, it is arbitrary to separate out those groundwater management actions that occur as a result of the Groundwater Strategy from those that would have taken place in any event. While this assumption might not be entirely accurate, it is appropriate for this exercise.
2. **The Value of the Groundwater Strategy to South Africa (the South African economy) is calculated.** While the costs of the Groundwater Strategy to the Department have been computed above,

(37) Deborah Ewing and Thulani Guliwe. The State of Social Giving in South Africa Report Series. University of Kwazulu Natal, 2006. Available: http://www.ukzn.ac.za. Accessed: March 2009

distinguishing the value of the Groundwater Strategy to the Department from its value to South Africa as a whole is arbitrary and not useful in the context of the Department's mandate as custodian of water resources in South Africa. While this assumption means that comparing the cost of the Groundwater Strategy to the Department with the costs of not implementing the Groundwater Strategy to South Africa as a whole is not an equal, direct comparison, it is appropriate in the context of the Department's mandate as custodian of national water resources.

Box 10-1:

Assessing the marginal cost of alternative water sources compared to groundwater

It is stated that groundwater resources in South Africa total approximately 10 billion m^3 per annum. Of this, some 2 – 4 billion m^3 are used, with a remainder of circa 6 billion m^3 per annum. Based on a high-level analysis of where this groundwater is located and existing groundwater quality, it is conservatively assumed here that 25% of the 6 billion m^3 are available[1] for utilisation. This implies that annually 1.5 billion m^3 of groundwater is available for development.

In addition to groundwater, the common sources of water are:

- Water conservation and water demand management,
- Augmentation of surface water supplies through impoundment and transfers,
- Recycling and reuse of effluent; and
- Desalination.

Based on URV values, it is recognised that WC/DM is almost always the most cost-effective mechanism to meet supply and demand. Accordingly, it is excluded here from the marginal cost analysis. Ranges of URV values for the remaining sources have been extracted from the literature and through interviews with key experts, and reflect the costs in areas where groundwater is available.

- Groundwater: R 3 – 5 / kℓ
- Surface water augmentation: R 3 – 7 / kℓ
- Effluent reuse: R 7 – 10 / kℓ
- Desalination[2]: R 7 – 15 / kℓ

Based on an assessment of where groundwater is available and what the alternative sources of water are in those areas, the following split is applied to the marginal cost analysis:

- Surface water augmentation: 40%
- Effluent reuse: 20%
- Desalination: 40%

Using these figures, a marginal cost range of R2 – 11 billion is computed, with the probable figure of R4 billion per annum.

(1) available here means that it is (1) located close to where it is required, (2) readily accessible and (3) of adequate quality for its determined purpose
(2) incorporating the escalation of energy prices

Five areas are considered here for the valuation of the Groundwater Strategy:

i. Utilisation of groundwater as a cost-effective alternative to other water sources;
ii. Prevention of groundwater contamination;
iii. Avoided cost of inappropriate development;
iv. Avoided environmental impacts of poor groundwater management, and
v. Knowledge or technology benefits arising from groundwater research.

High-level quantitative valuation of (i) – (iii) was possible, building on assumptions that enable national aggregation of benefits. Valuation of (iv) and (v) is qualitative only, but remains significant as such.

10.4.1 Valuing the utilisation of groundwater as an alternative to more expensive water sources

Elsewhere in the Groundwater Strategy, it is noted that groundwater resources often represent a cheaper sustainable source of water than other surface water related sources. However, due to a number of factors including poor information, limited knowledge and perception, groundwater resources are often not developed with the more expensive alternative water sources pursued in preference. This introduces a marginal cost to South Africa. Avoiding that additional marginal cost is a distinct benefit of the Groundwater Strategy and is valued here.

Estimates from various locations in South Africa have been combined here, to develop a cost differential between developing and managing groundwater resources versus the next best alternative. That alternative is often investing in water conservation and demand management, developing a new surface water source (dam and/ or pipeline), treatment and re-use of effluent, or desalination (on the coast). Some high-level assumptions were included in the comparison, to develop nationally representative numbers, and it is recognised here that significant variation exists in the cost of developing groundwater and the cost of the alternative surface water sources. Utilising those assumptions, a figure of R4 billion per annum has been computed *(See box 10-1)*.

10.4.2 Preventing groundwater contamination

Groundwater contamination is a significant problem globally and introduces marked costs to the economy. Contamination typically occurs through poor management practices, either in the extraction of groundwater or in the management of surface water effluent that communicates with an aquifer. Improved management as a result of the Groundwater Strategy, therefore, prevents the costs of groundwater contamination from being incurred.

Box 10-2:
Assessing the cost of groundwater contamination

1. Cost of poor quality water

A recent study by the Department[1] projected the cost of increased salinity in groundwater on households and in the agricultural industry, building on work undertaken by the Department on the costs of salinity in surface water. The report concluded that nationally, the costs of a salinity increase of 200 mg/ℓ on rural households was R176 million per annum, while the costs of reduced yields from irrigation from groundwater was R30 million per annum. This implies an annual cost of R2 – 20 million, assuming that 1 – 10% of groundwater use nationally is affected by a 200 mg/ℓ salinity increase through pollution.

2. Cost of moving the borehole

This cost is difficult to quantify, as it depends on a number of highly variable factors, principally the distance to non-polluted aspects of the aquifer and the aquifer characteristics and mobility of the pollutant plume. Assuming a cost of R250,000 per borehole and the need to move 25 boreholes per annum due to pollution of the aquifer provides a total annual cost of circa R6 million.

3. Cost of moving to an alternative water source

The valuation of this cost has been discussed in detail in Box 10-1. It was not possible to gain an estimation of the proportion of annual groundwater usage that needs to be replaced by an alternative surface water source as a result of groundwater pollution. If that figure is 10 million kℓ per year (i.e. 0.25% of annual groundwater usage), then the range of costs incurred as a result of groundwater pollution are R30 – 150 million.

4. Cost of aquifer treatment

Data on the costs of treatment of aquifers is not available in South Africa. However, this practice has been deployed for some time in the United States, Australia and Europe, and costs are available from those locations. Costs vary dramatically, depending on the nature of pollution, the characteristics of the aquifer and the desired water quality improvements. However, by and large, the costs of treatment are very high indeed, often in the order of R50 / kℓ water treated. Assuming an aquifer of 10 million m³, this amounts to a full treatment cost of R500 million.

(1) Determining the monetary and strategic value of national water monitoring programmes, Department of Water Affairs and Forestry, 2008.

There are various ways in which these costs are incurred:

- Cost of using poor quality water;
- Cost of moving the groundwater source to an alternative aquifer/unpolluted part of the same aquifer;
- Cost of moving to an alternative water source (surface water augmentation, effluent re-use or desalination); and
- Cost of treatment of the groundwater aquifer to re-mediate pollution.

Box 10-3:
Assessing the cost of inappropriate groundwater development

Inappropriate groundwater development occurs through poor placement of boreholes (dry boreholes or reduced flows) and through over-equipping of boreholes following overestimation of yields.

Assuming approximately 50 000 new boreholes are drilled in South Africa every year, at an average cost of R75,000 per borehole, and assuming that 30% of boreholes are dry of which 50% are as a result of poor information or knowledge; this equates to a cost of circa R500 million per annum in costs incurred through poor placement of boreholes.

Assuming that 30% of boreholes in South Africa are over-equipped through over-estimations of the yield of the borehole, that 75% of overestimations are due to lack of capacity and knowledge, and that over-equipping is by approximately 25% of total equipping cost (R50,000 per borehole); this equates to a total cost of over-equipping of circa R500 million per annum.

Box 10-2 describes some of these costs, noting that assessing the real costs of groundwater pollution are difficult in the absence of good information on groundwater pollution and the impact thereof. Nevertheless, Box 10-2 demonstrates that the costs are likely to be significant, possibly in the order of tens or even hundreds of millions per annum.

When one considers the cost of treating aquifers, following widespread contamination of an aquifer (e.g. mine drainage, hydrocarbon, heavy metals), then costs could escalate to hundreds of millions or even billions.

10.4.3 Avoided cost of inappropriate development

Interviews with groundwater practitioners have revealed that much groundwater is inappropriately developed, primarily due to a lack of information and knowledge in the sector. Inappropriate development refers to both borehole placement that yields no or reduced flows, and over-equipping of boreholes.

This reflects two key elements that the Groundwater Strategy seeks to address – technical capacity in the groundwater sector in South Africa and improved general understanding of groundwater by current and potential water users through improved information products and dispelling of misconceptions.

As Box 10-3 describes, the collective cost of this inappropriate development to the South African groundwater sector may be in excess of R50 million per annum.

10.4.4 Avoided environmental impacts and other externalities through poor groundwater management

Much attention has been given in recent years to the connectivity of groundwater and surface water systems, and the role that groundwater plays in maintaining base flow volumes and low-flow water quality. Similarly, groundwater-dependent ecosystems, including sensitive wetland systems that are primarily groundwater fed, are gaining significance.

Whilst it is not possible here to develop a national value for groundwater from an environmental perspective, nor the externalities cost of poor management of groundwater, it is assumed here that this cost is significant *(See box 10-4 on the next page)*.

The Groundwater Strategy addresses this issue through improved management of groundwater, which reduces the cost of externalities in three ways:

- Reduced over abstraction resulting in reduced base flow volumes;
- Reduced groundwater pollution resulting in reduced water quality impacts through groundwater discharge (particularly significant in the mining environment – Acid Mine Drainage); and
- Improved understanding of groundwater-dependent ecosystems and the groundwater reserve.

10.4.5 Knowledge and technology benefits arising from groundwater research

This category of benefits is very difficult to value, as the generation of information products and knowledge results in downstream benefits in such a wide variety of ways that quantification and attribution are difficult and in many cases arbitrary. In addition, unknown benefits may be generated into the future from past, current or future research that cannot be quantified now.

Much of the research generates applied knowledge products that result in benefits through a range of applications (e.g. artificial recharge, geohydrology, geophysics and groundwater exploration, environmental impacts and groundwater dependent ecosystems, pollution abatement particularly in the mining sector, etc). Attempts at quantifying these benefits are outlined in the various sections above (avoided cost of alternatives, groundwater pollution, environmental costs, etc).

It is estimated that groundwater research through the academic institutions in South Africa costs about R25 million per annum. While the returns on this expenditure cannot be quantified here, it is anticipated that the benefits are well in excess of these costs, based on the analyses contained above.

Box 10-4:

Costs of not managing groundwater: Wheal Jane in Cornwall, UK[1]

Wheal Jane was an important tin mine in the Carnon Valley in Cornwall, United Kingdom. The mine had been worked for tin and other metals from the mid 1700s, resulting in a complex system of shafts and adits. The modern mine workings were very wet and the groundwater in the mine was of very poor quality as a result of the oxidation of pyrite and arsenopyrite ores (Acid Mine Drainage).

When the mine was operational, water levels were managed by pumping, with the discharge of this water into the Carnon River after partial treatment. Following the withdrawal of a government grant which supported the mine dewatering and associated closure of the mine in 1991, water levels rose and quality deteriorated further. On the 13th January 1992, a massive spill of acidic water (ph <3) with very high concentrations of toxic heavy metals emerged from the mine, contaminating the Carnon River and Falmouth Bay.

The highly visible disaster and concerns regarding environmental impacts and the effect on tourism resulted in expensive treatment systems deployed at Wheal Jane. These treatment systems where still in operation over a decade later (2002), with treatment cost over the 10 years in excess of R300 million. While the environmental (and economic) cost of the Wheal Jane accident was not definitively quantified, the resultant cost of treatment gives an indication of the contingent value of the environmental impacts associated with the 1992 disaster.

(1) Younger, P.L. Mine water pollution from Kernow to Kwazulu-Natal: geochemical remedial options and their selection in practice. Geoscience in south-west England, 10, 2002.

10.4.6 Summary of impact of not implementing the Groundwater Strategy

Without having to resort to detailed economic valuations of groundwater in South Africa, to accurately quantify the value of groundwater and groundwater management in South Africa, two conclusions are clear from the above discussions:

1. Groundwater and its management is an integral aspect of effectively managing the water resources in South Africa, and costs are incurred in a multitude of ways through injudicious or inadequate management of our groundwater resources.
2. These costs are significant, and are certainly more than one order of magnitude (i.e. 10 times more) and possibly two orders of magnitude (i.e. 100 times more) greater than the cost of implementing the Groundwater Strategy.

... END

11. Actions Table

PRIORITY AREA 1: CONTRIBUTION TO ECONOMIC GROWTH AND SOCIAL DEVELOPMENT	
CHAPTER	**ACTION**
2	• Finalise the policy and strategy on the rehabilitation of abandoned mines, ensuring that relevant groundwater aspects are addressed.
2	• Groundwater must be adequately addressed in revisions of the NWRS, the WfGD Framework, Catchment Management Strategies (CMS), Water Services Development Plans (WSDPs) and other strategy documents.
3	• Water resource assessments should consider groundwater to a level of detail that makes it comparable to other options.
3	• Establish guidelines for the groundwater content of Internal Strategic Perspectives (ISPs), emerging Catchment Management Strategies (CMS), and other water resource management guideline documents.
3	• Implement the Department's "Best Practice Guidelines" for the mining sector and develop the same for the municipal, agriculture, energy and forestry sectors to ensure the protection of groundwater resources.
7	• Reassess the funding required by the Department for groundwater monitoring, data capture as well as the operation and maintenance of groundwater infrastructure.

PRIORITY AREA 2: ENSURING EQUITABLE AND SUSTAINABLE WATER RESOURCES MANAGMENT	
CHAPTER	**ACTION**
2	• Review and continue to implement the policy on 'Groundwater Quality Management in South Africa'.
2	• Groundwater contributions to the reserve determinations are to be completed as soon as possible in all water management areas.
2	• Resolve groundwater licenses within reasonable timeframes (suggested period of 6 months).
2	• Ensure that all groundwater users are registered with up-to-date water use licenses.
2	• Verify water use within a reasonable time frame and implement programmes to enforce compliance with respect to water use license conditions. Implement stricter regulations regarding noncompliance with respect to water use license conditions.
2	• Develop regulations for groundwater users and drilling and test pumping companies to provide groundwater data to Regional Offices.
2	• Implement Resource Quality Objectives where Water Resource Classification has been determined for groundwater.
2	• Develop and implement a Groundwater Monitoring Strategy to address the monitoring challenges at national and regional level.
3	• As new data becomes available, update the GRA 2 figures on groundwater availability and use.
3	• Develop tools to evaluate the effect of drought and climate change.
3	• Define groundwater to the same assurance yield of surface water.
5	• Establish a Groundwater Resource Governance Section in the Department.
5	• Investigate and support the development of large scale groundwater schemes for water services provision where favourable aquifer systems occur.
5	• Improve and formalise working relations with Department of Education, Department of Health and the Department of Agriculture, Forestry and Fisheries to ensure that hydrogeological capacity is available for drilling programmes implemented by the latter governmental departments.
5	• DWA, the Department of Environmental Affairs (DEA) and the Department of Mineral Resources (DMR) must adopt and implement the integrated authorization system to improve the regulation of environmental management, water resource management and related activities / land-uses such as mining. • The general aim is to facilitate the integration and alignment of regulatory provisions (i.e. with regards to the authorization processes) as contained in the NWA, NEMA and the MPRDA.
5	• Approach the DMR and review all the regional mine closure strategies.
5	• Feasibility Studies must be initiated at potential artificial recharge sites.
5	• Continuous awareness of artificial recharge or recharge enhancement must be done as a sustainable management method.

6	• The roles and responsibilities for groundwater development and management, including monitoring of groundwater abstraction and quality, as well as the maintenance and operation of groundwater infrastructure across sectors (i.e. water resource management, the environment and water services) must be redefined within the constraints of limited capacity within both water resource management and water services institutions.
6	• Improve cooperation between government departments and the private sector to leverage available capacity and resources.
6	• Incorporate the recommendations from the Reconciliation Strategies into the Integrated Development Plans (IDPs) and Water Services Development Plans (WSDPs).
7	• Finalize the National Groundwater Archive (NGA) as well as the incorporation of privately held groundwater datasets.
7	• Implement the systematic roll-out of regional groundwater data collection and information programmes, and restart where these have stalled (e.g. GRIP).
7	• Assess outstanding groundwater data requirements to fulfil the water resource management functions of the National Water Act and structure groundwater monitoring programmes and databases accordingly.
7	• Support the DMR in the implementation of an integrated information system to record and report on the status of active and abandoned mines - An updated database on mines reflecting accurate, relevant and valid information on environmental and groundwater management information.
7	• Render the final granting of licenses to water users dependent on the submission of groundwater and drilling data to the Department.
7	• Develop and implement a Groundwater Monitoring Strategy to address the monitoring challenges at national and regional level.
8	• The WRC, together with DWA, should continue to prioritise groundwater research projects that directly address strategic national objectives. Such longer term research projects should be supported by consultative projects. • This could include work on issues identified as bottlenecks in groundwater management or delivery, such as improving the methodologies focusing on surface-groundwater interaction.
8	• The WRC should continue to create a leading knowledge infrastructure to support groundwater research in South Africa.
8	• Improve the dissemination of research reports and products.
8	• The WRC should regularly assess the impact of research investment in groundwater.
8	• Emphasis should be placed on the strategic leveraging of resources between the WRC/DWA/NRF and the alignment of strategic objectives for groundwater management between the WRC and DWA; e.g. the development and roll-out of strategies supported by implementation programmes.

PRIORITY AREA 3: PROMOTING RURAL DEVELOPMENT	
CHAPTER	**ACTION**
3	• Conduct groundwater resource assessments and development programmes (including the rehabilitation of existing water supply boreholes) for towns threatened by surface water shortages as water demand increases.
3	• Implement groundwater development programmes for domestic and productive water use to support national imperatives such as the Comprehensive Rural Development Programme, the Water Allocation Reform process, addressing the Millennium Development Goals, etc.

PRIORITY AREA 4: EFFECTIVE SUPPORT TO LOCAL GOVERNMENT	
CHAPTER	**ACTION**
4	• Mobilise private sector support in developing hydrogeological capacity within regional offices and water services institutions.
5	• Ensure the implementation of available strategies, regulations, guidelines and tools on groundwater management (See Chapter 2 and Box 5-7).
5	• Establish a groundwater advisory service, hosted in regional offices, for water services institutions, for example a Groundwater Call Centre for municipalities.
5	• Support the water services institutions to take up operation and management functions, to ensure the sustainable utilisation of the resource.
5	• Prioritise the conjunctive use of groundwater and surface water resources for municipal water supply schemes.
6	• Capacitate and provide adequate resources to the Regional Offices to fulfil their mandatory water resource management functions.
6	• Support and if necessary re-establish Water User Associations to improve the local management of groundwater resources.
7	• Develop and implement an integrated groundwater information system to support water services provision at municipal level. Improve the compatibility (and/or integration) of existing groundwater databases / information systems maintained by different institutions (including water quality databases and municipal groundwater asset registers).
7	• Disseminate groundwater information products.

PRIORITY AREA 5: CONTRIBUTION TO GLOBAL RELATIONS	
CHAPTER	**ACTION**
6	• Strengthen support for collaboration with institutions from other countries, e.g. SADC based IWRM post-graduate training programmes, sector partnerships, bilateral aquifer management committees, etc.
8	• DWA and the WRC must continue to support groundwater research capacity at tertiary institutions. • Such capacity can be strengthened through groundwater industry-supported chairs and the promotion of coordinated research programmes involving a number of tertiary institutions. • This will assist in retaining and attracting experienced staff, as well as supporting post-graduate programmes to increase the research capacity in South Africa and regionally.
8	• South African water research should become more Africa-orientated through support given to regional networks and partnerships.
8	• The Groundwater Division of the Geological Society of South Africa, supported by the private sector, should play a prominent role in promoting and influencing groundwater research in South Africa through seminars and workshops.
9	• Continue with bi-annual groundwater conferences and expand the seminar series for professionals.
9	• Greater participation of groundwater professionals in conferences hosted by WISA, the municipal, agricultural, mining and energy sectors.
9	• Strengthen partnerships and networks for promoting groundwater in SADC, for example WaterNet, FETWater, African Groundwater Network, Burdon Network. • Improve groundwater awareness campaigns.

PRIORITY AREA 6: IMPROVING THE DEPARTMENT'S CAPACITY TO DELIVER SERVICES	
CHAPTER	**ACTION**
4	• Develop and implement a national capacity building strategy.
4	• Implement capacity-building milestones in DWA PSP contracts similar to the WRC contract research programmes.
4	• Implement practical, in-service training courses on priority aspects (e.g. licensing process, the Reserve, groundwater monitoring, etc.) for staff.
4	• Develop adequate capacity to fulfil the groundwater functions.
4	• Either establish hydrogeology as a separate professional field of practice via SACNSP, or reach agreement with the Geological Society of South Africa (GSSA) regarding accreditation, to bolster hydrogeology as a defined profession, and to enable an independently monitored Continued Professional Development (CPD) programme to be implemented as soon as possible.
4	• Review and improve the working conditions, career development, remuneration packages, etc. for junior and mid-level hydrogeologists within the public sector to assist with staff retention.
4	• Address the reasons for hydrogeologists leaving the public sector.
4	• Implement mentoring programmes involving retired professionals.
4	• Continue with and strengthen the bursary programme.
4	• All hydrogeologists and technicians must register at SACNSP.
5	• Formalise internal coordination processes to facilitate the exchange of groundwater information between different departments.
9	• Develop a marketing and communication plan focussing on success cases for groundwater use and management.

12. References

Groundwater Strategy: Supporting Reports

Groundwater Strategy: Supporting Reports	№ of Pages
Literature Review: GRA1, GRA2 and International Groundwater Assessment Methods	55
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Case Studies of Groundwater Use in South Africa: Groundwater Success Stories	28
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