20 Years of Groundwater

Research, Development & Implementation in South Africa

1994 - 2014

SP 78/14

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Department:
Water and Sanitation
REPUBLIC OF SOUTH AFRICA

20 YEARS OF FREEDOM
south africa 1994 - 2014

UNIVERSITY of the WESTERN CAPE

WATER RESEARCH COMMISSION

20 Years of Groundwater Research, Development and Implementation in South Africa 1994-2014

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Where the abbreviations DWA and DWAF are used in this book, the former official names of the current Department Water and Sanitation is implied.

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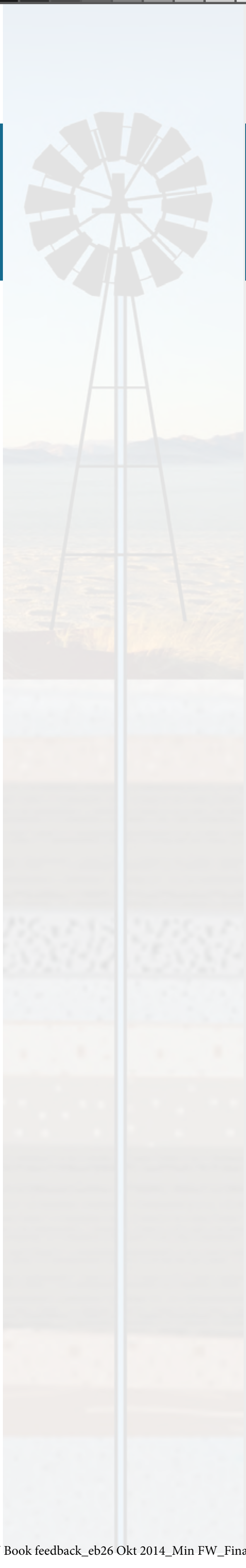

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Foreword

Wells and springs have been nurturing South African communities long before the promulgation of the National Water Act in 1998 recognised the value of groundwater as a public resource.

Following the end of apartheid this resource became even more important as South Africa's first democratically-elected government inherited huge services backlogs with respect to access to water supply and sanitation. It was only through the development of resources such as groundwater that this backlog could be reduced. Today, close to 60% of our towns either use groundwater as a sole source or in conjunction with surface water.

Foreword by the Honourable Minister of Water and Sanitation, Nomvula Mokonyane

As we strive to reach the last 5% of the population without access to safe drinking water, most of whom are located in far-flung rural spaces, there is no doubt that groundwater will continue to play a major role in water supply in South Africa.

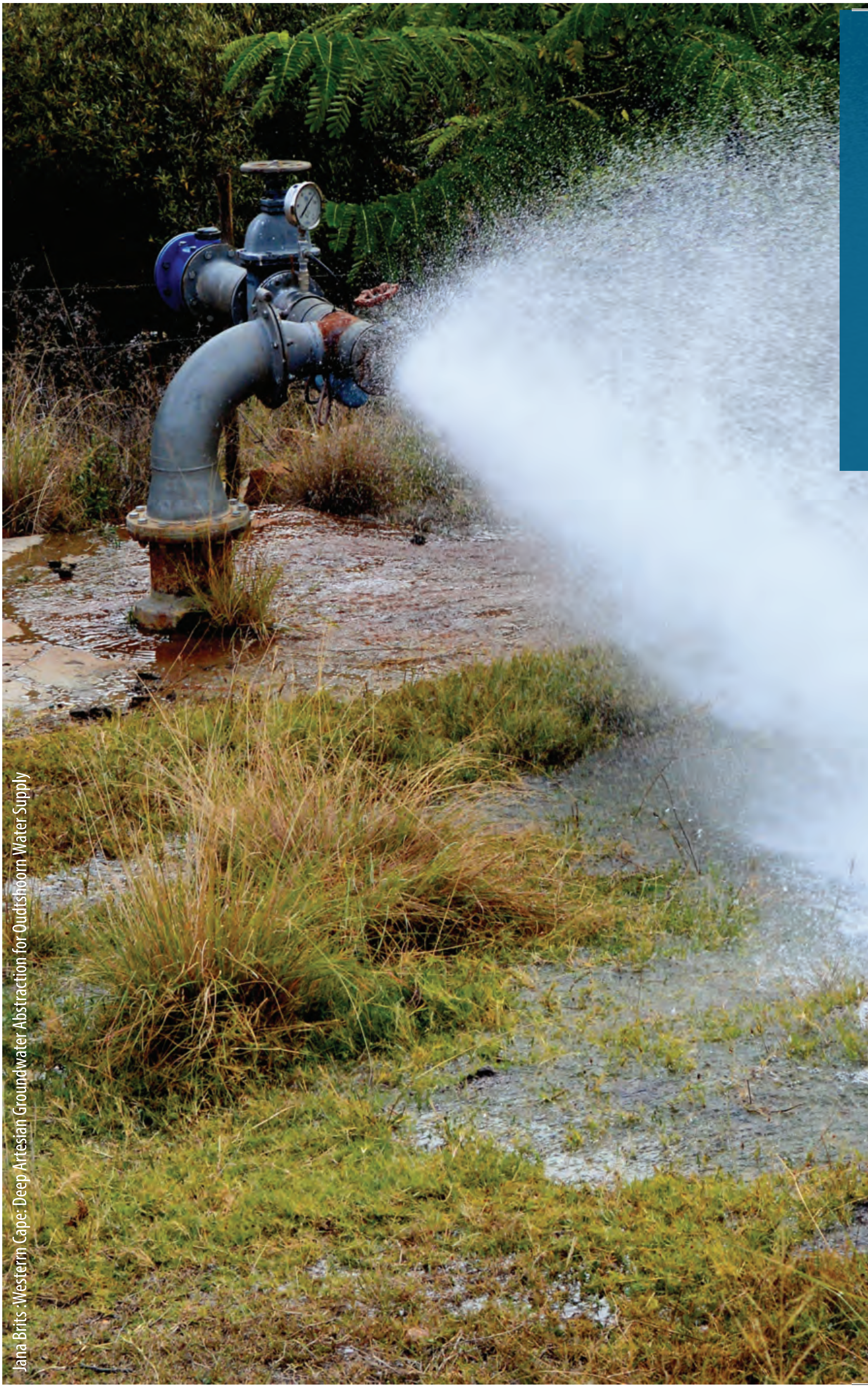
With the improved knowledge gained from years of exploring the riches of our underground resources, groundwater has now taken its rightful place in the planning, development and management of water resources in South Africa. With the majority of our potential underground resources remaining unutilised, groundwater has been put forward as an augmentation option for several regions in the various water reconciliation studies commissioned by the Department of Water and Sanitation looking at the potential future water supply needs of South Africa.

While our aquifers have faithfully supplied us with water for hundreds of years, we have not always appreciated their value. It is now vital that groundwater protection and management features strongly in national and regional policy, planning and management agendas to overcome its past neglect and lay a foundation for its increasingly important role in ensuring national water security.

Although small in number, our groundwater specialists have proven themselves to be among the best in the world. As a community they have to continue to strive together towards optimum sharing of best practices to ensure the sustainable management of this precious resource. New ideas and innovations informed by research and development will be welcomed so that we can continue to improve our decision-making informed by science and technology.

Continued capacity building in the sector as well as improving education and awareness among South Africa's people will be crucial in ensuring the sustainability of the country's groundwater resources. All of South Africa's citizens have a role to play in ensuring the legacy of our underground treasure remains for generations to come.

Minister
Department: Water and Sanitation



Jana Brits: Western Cape: Deep Artesian Groundwater Abstraction for Oudtshoorn Water Supply

Preface

South Africa is celebrating 20 years of democracy. Every sector of our society has been touched and transformed by the creative energy released following the watershed elections of 1994. The basic water and sanitation backlog that the water sector had to address as immediate priority was massive and presented both grassroots and national scale challenges that the sector and national department had never experienced before. By 1997, in a parallel and widely consulted process, a National Water Policy White Paper was ready to chart the integrated water resources management way forward. The ultimate achievement, however, was to bring basic water infrastructure coverage to over 95% of the population in less than two decades. Millions of people who had spent their life carrying water for kilometres every day now had a secure supply a tap away.....

It is good to realize that even the Cinderella of water resources, the hidden and often neglected underground water resource, was strongly impacted by the political transformation of the country. One can celebrate that this so called "private water" in terms of the previous Act, became the resource that enabled a basic water service to be provided to more than 60% of communities that had never been served before. It was the resource that had previously been important only to rural towns, for private irrigation farmers who capitalized on every new strong groundwater strike, and remote mines that could have no other source. Within two decades it had become a source of living water to communities in every corner of our country.

This publication would like to provide a glimpse of recent advances made in both assessment and management of the resource. The Groundwater Strategy, prepared as input into the National Water Resource Strategy 2013, speaks in its vision of the new challenges:

"Groundwater is recognised, utilised and protected as an integral part of South Africa's water resources."

The most visible change has been from the past focus on resource exploration to country-wide quantification of groundwater resources. Research focus has shifted to resource protection and understanding groundwater as part of the overall hydrological system and ecosystem. The actual management on the ground of hundreds of small groundwater schemes supplying dispersed communities has emerged as a major new challenge which is just starting to be addressed. The recent joining of the water and sanitation functions and the strong focus on regional implementation and support can greatly help to address this challenge in a holistic way from national to grassroots level.

The way forward will have to be tackled strategically, with a strong national groundwater champion role coming from the Department and a continuing science leadership role from the WRC. Jointly these two should harness the capacity of the private and academic sector and build new capacity into local level groundwater management institutions.

The many persons from all sectors, identified in the appendix, who contributed their valuable time and knowledge to the development of this publication, are especially acknowledged here.

In this way, we will see the forgotten resource, groundwater, becoming one of our most valued assets.

Chief Executive Officer
Water Research Commission

Groundwater's Role
Globally and in Africa

"What makes the desert beautiful is that somewhere it hides a well."
- Antoine de Saint-Exupery –

"When you drink the water, remember the spring."
- Chinese Proverb –

Distribution of the earth's water

Water not only covers three quarters of the earth's surface – it is also present almost everywhere below ground surface, down to considerable depths. This groundwater represents by far the biggest portion of all liquid (not frozen) freshwater on earth – about 96% (See figure below). In comparison, the global volume of freshwater in lakes is less than 1% of the total fresh groundwater volume.

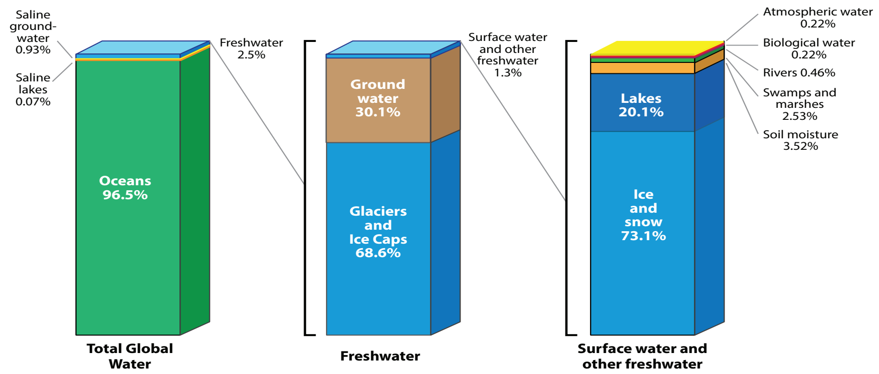
Poorly understood resource

Despite having been the source of life-giving water for individuals, families and communities throughout the ages, groundwater still receives comparatively little attention. Few recognize that today about half of the world's population drinks groundwater every day. Few recognize that it contributes to more than half of the world's production of irrigated crops; that it sustains wetlands and rivers, provides stability to the soil and prevents seawater intrusion. Few also recognize the increasing pressures on groundwater resources from population growth, climate change and human activities with a widespread impact in terms of groundwater depletion and pollution.

Global groundwater use

During the twentieth century, groundwater abstraction across the world increased explosively, largely as a result of numerous individual decisions by farmers and without centralized planning or coordination. This development has been called the silent revolution. It was driven by population growth, technological and scientific progress, economic development and the need for food and income.

The groundwater portion of the earth's freshwater
Source: Igor Shiklomanov's chapter "World fresh water resources" in Peter H. Gleick (editor), 1993. Water in Crisis: A Guide to the World's Fresh Water Resources.



Present (2010) abstraction of groundwater in different parts of the globe. (Margat and Van der Gun, 2013)

CONTINENT	GROUNDWATER ABSTRACTION **					COMPARED TO TOTAL WATER ABSTRACTION	
	Irrigation km³/yr	Domestic km³/yr	Industrial km³/yr	Total km³/yr	%	Total water abstraction** km³/yr	Share of groundwater %
NORTH AMERICA	99	26	18	143	15	524	27
CENTRAL AMERICA AND THE CARRIBBIAN	5	7	2	14	1	149	9
SOUTH AMERICA	12	8	6	26	3	182	14
EUROPE (INCLUDING RUSSIAN FEDERATION)	23	37	16	76	8	497	15
AFRICA	27	15	2	44	4	196	23
ASIA	497	116	63	676	68	2267	30
OCEANIA	4	2	1	7	1	26	25
WORLD	666	212	108	986	100	3831	26

The present abstraction of groundwater in different parts of the globe and for a variety of uses is summarized in the table above.

Global challenges

Despite these developments, the present use only represents a small fraction of the overall groundwater resources on our earth. To unlock groundwater's full potential in a sustainable way does not only require our best scientific and technical skills, but social and institutional dimensions which have not even started to be brought to bear on the challenge. Key to sustainable development of the resource is a much higher valuation by society of the different services of groundwater systems, like those mentioned in the table above, and in particular groundwater's natural reservoir function, which has to be built at great cost in the case of surface water systems.

Furthermore, there is a growing recognition that management of this open-access resource is likely to be successful only if stakeholders are cooperating fully. This is because the majority of groundwater management measures aim to influence or change people's behaviour. The groundwater science and technology community has a crucial role in supporting both water managers and local stakeholders in this endeavour.

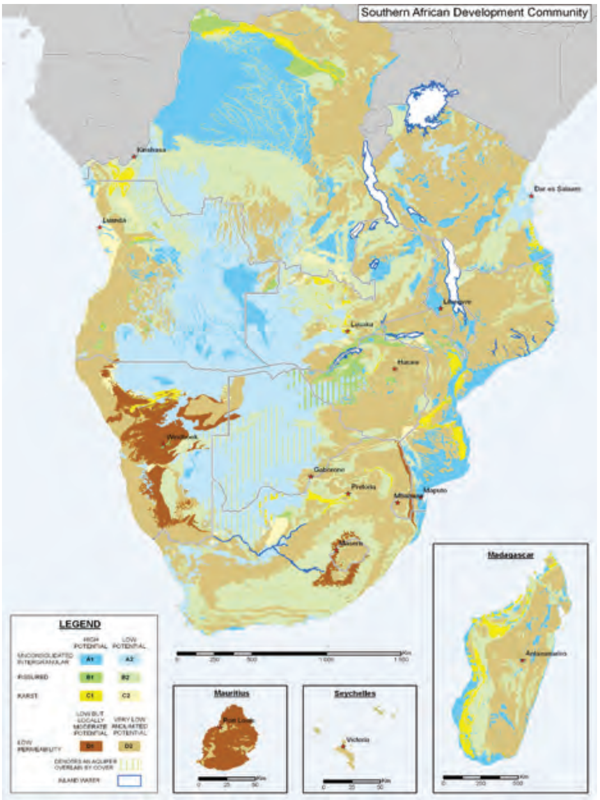
Role and challenges in Africa

Water is a key factor in Africa's development. Nonetheless, the African continent has to date used only a small proportion (5%) of its available water resources. Key is the large spatial and temporal variability of resource availability, going with the more arid climate prevalent in about 60% of the African continent and the lack of human and financial resources to deal with this major challenge.

There is thus a growing perception that local groundwater resources will have to play an increasingly strategic role in Africa, in particular for the most vulnerable and most neglected rural communities (AMCOW, 2008). Crucial in this regard is that, in sub-Saharan Africa, more than 300 million people still have no access to safe water supplies – approximately 80% of these live in rural areas (UN, 2012).

In the Southern African Development Community (SADC) this realisation has led to the production in 2010 of a **first SADC-Hydrogeological Map** as a joint venture by all its member states. Furthermore, SADC responded to the issues and challenges facing groundwater and its management in the sub-region through the establishment in 2011 of a regional Groundwater Management Institute (GMI), hosted by the University of the Free State in South Africa.

Explosive groundwater development has been called the silent revolution: driven by population growth, technological and scientific progress, economic development and the need for food and income.



A thumbnail of the SADC Hydrogeological Map (SADC, 2010)

Handpump in an African village

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Principles of Good Groundwater Governance

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.

The 'water crisis a governance crisis'

These are challenging objectives, especially in the light of the key message coming from the 2012 Marseille World Water Forum – The 'water crisis' the world community faces today is largely a governance crisis. Securing water for all, especially for vulnerable populations, is often not only a question of hydrology (water quantity, quality, supply, demand) and financing, but equally a matter of good governance. Managing water scarcity and water-related risks (floods, natural disasters, etc.) requires resilience, institutions, collaborative efforts and sound capacity at all levels (WWF 2012:5 in Harris et al., 2013).

Governance has recently been defined by the UNDP as:

'the exercise of political, economic and administrative authority in the management of a nation's affairs at all levels — and thus comprises the mechanisms, processes and institutions through which the citizens of the nation articulate their interests, mediate their differences and fulfil their legal rights and obligations."

This was also the definition taken on board by the Africa Development Bank in their assessment of water governance in Africa. Typical criteria for assessing governance in a particular context might include the degree of legitimacy, representativeness, popular accountability and efficiency with which public affairs are conducted. (Governance Working Group of the International Institute of Administrative Sciences, 1996).

Challenges for groundwater governance

In probably one of the most insightful groundwater resource management books entitled: *'Groundwater and Society – Resources, Tensions and Opportunities'*, Burke and Moench (2000) make a plea for the development of effective governance approaches for groundwater, a very complex common pool (open access) resource. Because of its ubiquitous nature and relative ease of local access, there are widely distributed and generally dispersed abstraction points and many stakeholders, who are involved in its development, use, as well as misuse. This complicates the traditional national approaches to resource regulation and requires a very high degree of **participative management**. It also requires novel approaches to the systematic planning, financing and implementation of hundreds and even thousands of small, locally dispersed groundwater schemes (Braune et al., 2008 and Burke and Moench, 2000).

Top-down facilitation of local actions

A number of major issues will have to be addressed from the beginning to encourage stakeholders to be more willing to contribute to the management efforts, in particular (Burke and Moench, 2000):

- Proper valuation of groundwater: stakeholders respond to economic factors
- Scientific understanding and data: without understanding, people are often unwilling to act
- Education and social ethics: broad-based education is often central to building social support for management.

These need to work in concert with legal and regulatory frameworks that both enable local populations to develop management approaches suited to regional conditions, and provide avenues for higher level interventions to address the actions of large individual consumers or polluters.

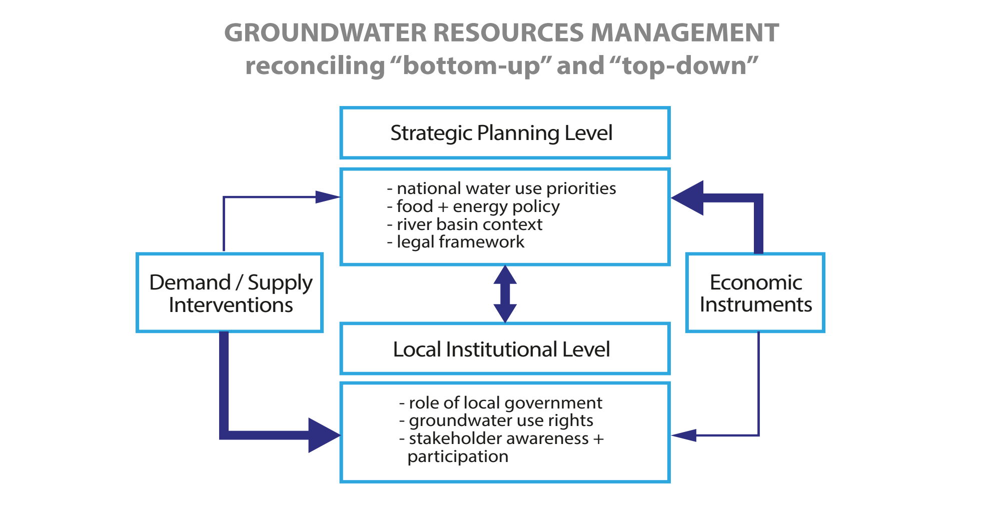
The management approach advocated under these unique circumstances has been coined as 'top-down facilitation of local actions' (Foster, 2006). As shown in the figure below, this brings out the importance of the stakeholder-driven local level management for groundwater as well as the need for an appropriate enabling environment.

South Africa has been able to engage in the presently ongoing global process that seeks improved governance approaches for the underground resource. The fascinating findings for the African continent are summarized in a Water Research Commission Report (Braune and Adams, 2013). The Commission is also starting to engage South African scientists to grapple with the local challenges of groundwater resource valuation (Pearce et al., 2013) and governance (Seward and Xu, 2013).

A framework for groundwater governance

A very useful analytical framework for groundwater governance (Wijnen et al., 2012) was included in the Africa Consultation for the global 'Groundwater Governance' initiative. It is shown on the next page, slightly abbreviated.

Groundwater resource governance (Foster, 2006)



The presentation in this booklet of the 'twenty years of groundwater research, development and implementation in South Africa' will broadly follow the structure of this framework.

Strategic Framework for Groundwater Governance

"Governance is the operation of rules, instruments and organisations that can align stakeholder behaviour and actual outcomes with policy objectives."

Enabling Environment / Policy level

Processes by which a nation establishes its objectives for groundwater, integrates those policies with water, land and environmental policies, and aligns and harmonises them with other related policies affecting groundwater.

Strategic / National level

Institutions and instruments designed by a nation to align stakeholder behaviour and actual outcomes with policy objectives. These include planning, regulation, economic instruments, institutional development and information management.

Local level

Organisations and institutions that control actual outcomes on the ground and respond (in varying degrees) to the rules and incentives from strategic level governance. This level includes the individual groundwater users, local collective management institutions and relevant public agencies.

Wijnen et al. (2012)

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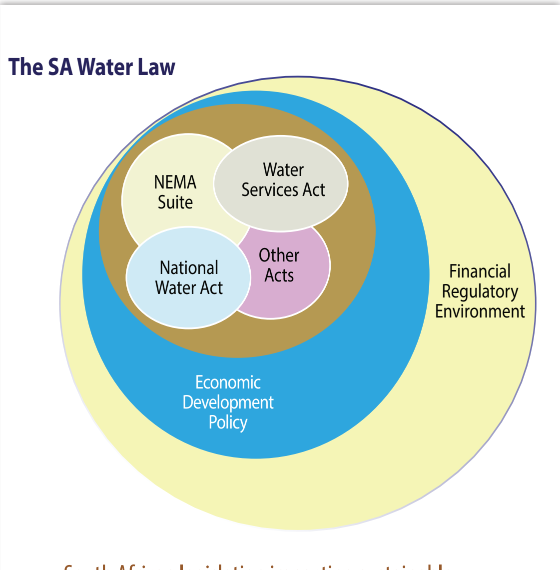
Water Resources
Management Environment in South Africa

South Africa is the 30th driest country in the world and has less water per person than countries widely considered to be much drier, such as Namibia and Botswana. Many parts of the country are fast approaching the point at which all of the easily accessible freshwater resources are fully utilised. Increasing urbanisation and industrialisation place enormous pressure on our scarce water resource in terms of management and allocation. Ensuring a sustainable water balance requires a multitude of strategies, including water conservation and water demand management, further utilisation of groundwater, desalination, water re-use, rain water harvesting and treated acid mine drainage (Department of Water Affairs, 2013a).

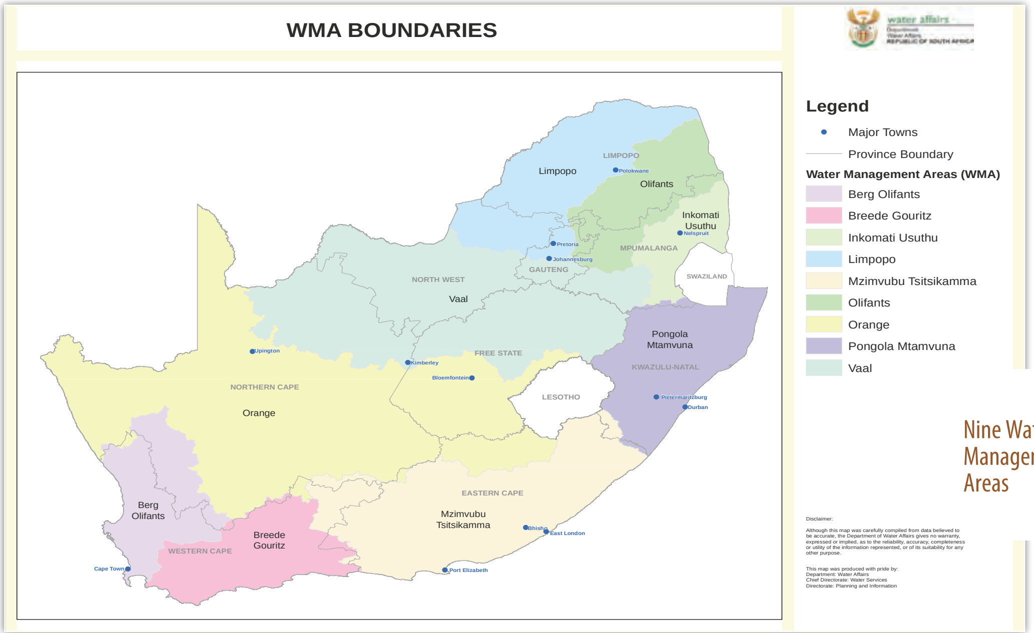


South African legislation impacting sustainable groundwater utilization.

South Africa entered a new phase in its history with the election of its first non-racial democratic government in 1994. Policy reform in the recent years of South Africa's new democracy has, for obvious reasons of history, been focused upon the promotion of basic human rights and the democratic values of human dignity, equality and freedom throughout the society.

Responsibilities for various functions were allocated between the three autonomous spheres of government at local, provincial and national level. The governance of water was defined as the competence of government at a national level while the function of providing water services was the primary competence of local government, with national government's role being one of regulation and support. In these circumstances, cooperative governance between the Department of Water Affairs, the Local Government, and other line agencies, in close consultation with communities, is especially important to achieve sustainable development.

The National Water Act was aimed at fundamentally reforming the previous Water Act of 1956 which was not only racially discriminatory in how water was allocated, but was based on the legislation of water-rich Europe which was not appropriate for a water-scarce country such as South Africa. The Act is premised on balancing the three legs of social benefit, economic efficiency and environmental sustainability. With its promulgation, groundwater lost its previous status of private water and became public water. It states that water is an indivisible national resource



Nine Water Management Areas

(rivers, streams, dams, and groundwater) for which national government is the custodian. It contains rules about the way the water resource is protected, used, developed, conserved, managed and controlled in an integrated manner.

Important for the management of local groundwater resources are the subsidiarity approaches. The 1997 Water Policy White Paper (DWAF, 1997) stipulates that responsibility for the "development, apportionment and management of available water resources" should be delegated to a "catchment or regional level in such a manner as to enable interested parties to participate." The present generalised lack of technical and managerial expertise led to the decision in 2012 to reduce the number of Catchment Management Agencies to nine from the original proposal of 19 CMAs. Up to now eight of the original nineteen CMAs have been gazetted of which two are operational. Regional level water management is still carried out by the offices of the national department.

Also, based on a framework of developmental water management adopted in the National Water Resource Management Strategy and on experience of the last fifteen years, a decision has been taken to bring the National Water Act and the Water Services Act into one, seamless piece of legislation governing the entire water value chain (Department of Water Affairs, 2013b). One consequence of this will be a multiple water use approach, which incorporates all water uses in an area, to be followed in planning and implementation of water schemes.

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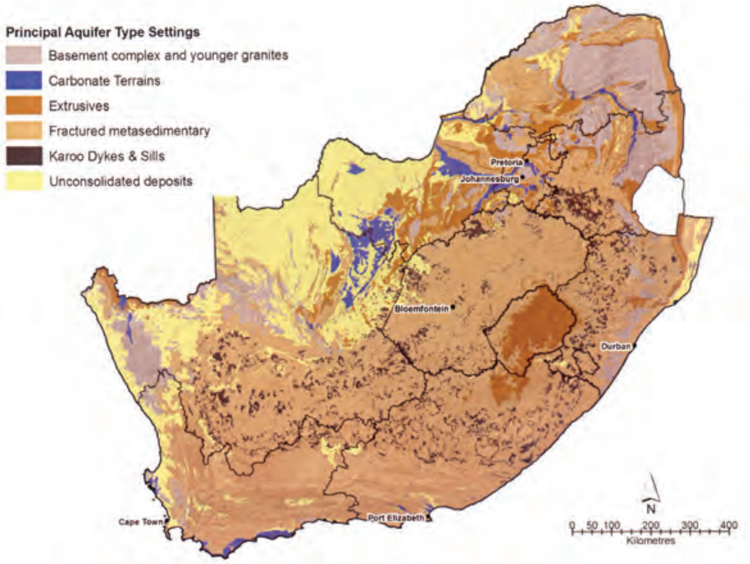
South Africa's
Groundwater Resources



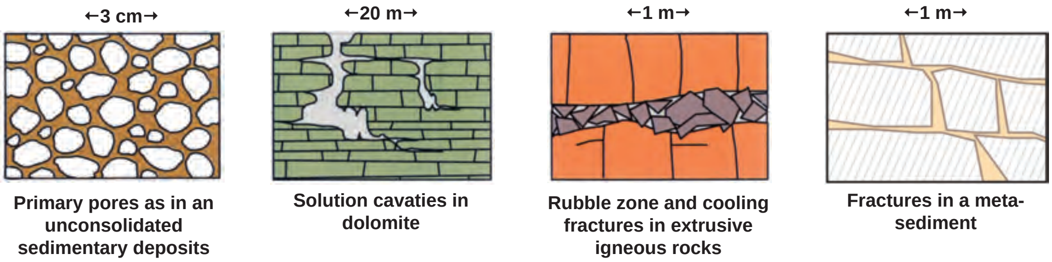
Map of main aquifer types based on primary lithology
(Source data – Council for Geoscience 1: 1000 000 lithology) (Colvin, 2007)

South Africa's aquifer systems have received their water-bearing properties, in particular the permeability, through the region's geological and hydrological history and as a result of the physical and chemical composition of the different rock types.

The figure below illustrates the main types of permeability found in different rock types. Permeability is termed primary if it is formed as the rock is formed (intergranular) and secondary if it is formed in the rock itself (fissures and caverns, fractures, joints and faults).

The simplified geology map enables a national scale view of the main aquifer types in South Africa based on the aquifer properties of the main lithology (rock type) of the different rock strata.

A very pragmatic aquifer system management classification was already developed in 1995 to support the regulatory system developed by



Different aquifer permeability types (Colvin,2007)

Some of the landscapes going with the different aquifer types are shown below, just to illustrate the variety and complexity. (from Colvin et al., 2007)

Coastal aquifer (primary)

Alluvial aquifer (primary)

Karoo aquifer (secondary)

Dolomite aquifer (secondary)

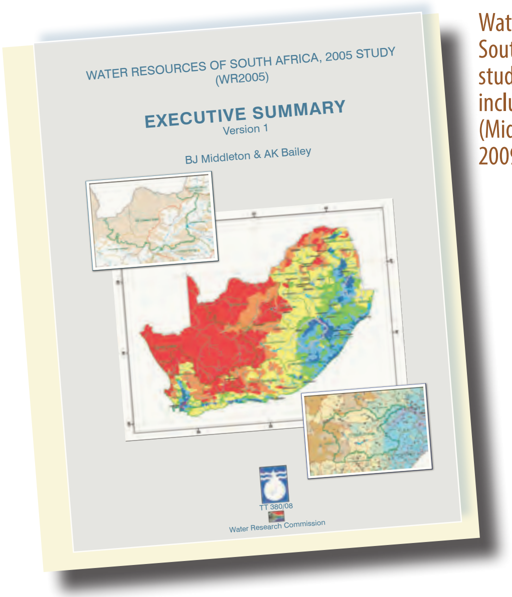
DWAF (Parsons, 1995). It comprised major, minor and poor aquifer systems as well as sole source and special aquifers. Their role and relative coverage of the country is shown in the table below.

Aquifer Systems in South Africa (after Parsons, 1995)

AQUIFER SYSTEM CLASSIFICATION	COVER-AGE OF COUN-TRY (%)	GENERAL LOCATION
MAJOR AQUIFERS	18	Primary aquifer systems along the coast; Dolomitic systems in parts of Gauteng, Mpumalanga, the Northern Cape and North West Province; Rocks of the Table Mountain Group bordering the Cape coast; Parts of the Karoo Supergroup; Cities and towns receiving water from major aquifer systems are Pretoria, Mmabatho, Atlantis, St. Francis Bay and Beaufort West.
MINOR AQUIFERS	67	Minor aquifers occur widely across South Africa with variable borehole yield and water quality. They supply many smaller settlements, e.g. Nylstroom, Williston, Carnarvon and Richmond.
POOR AQUIFERS	15	Poor aquifers occur mainly in the dry northern and western parts of the country. The generally low borehole yields of poorer quality are, however, still of critical importance to small rural communities.

The further class of sole source aquifer can occur anywhere in the country, and is strategic because it supports 50% or more of a domestic water supply, for which there are no reasonable alternative sources.

Geologists and geomorphologists, like the renowned Alex du Toit and Lester King respectively, have described the shaping of our landscape over millions of years (Du Toit, 1926 and King, 1963). Converting this geological understanding to an expression of groundwater resources has been the endeavour of early hydrogeologists like Dr. J.F. Enslin of the then Geological Survey of South Africa (Enslin, 1963). The systematic country-wide quantification of our groundwater resources as we have it today, followed out of a



Water Resources of South Africa, 2005 study (for the first time includes groundwater) (Middleton and Bailey, 2009).

national groundwater mapping programme of the Department of Water Affairs and Forestry, launched in 1992, jointly with the Water Research Commission. Its first output, largely based on the life-long work of Dr. J.R. Vegter, was a series of national maps and explanatory document published by the Water Research Commission in 1995 (Vegter, 1995). In parallel, over the period 1995-2003, the Department published a set of 21 hydrogeological maps covering the country at a scale of 1:500 000, with accompanying explanatory booklets.

Because of the immediate demand of this type of information by the Department's water resources planners, a further phase of national assessment and quantification of groundwater resources at quaternary catchment level followed (2003-2005), aided by a consortium of consultants and culminating in the Groundwater Resource Assessment Phase 2.

Importantly, the fourth iteration of the Surface Water Resources of South Africa (2004-2007) for the first time included groundwater, drawing largely on the database and outputs from the GRA 2 project (Middleton and Bailey, 2009).

Some key findings from the above studies, also summarised in the Department's Groundwater Strategy (DWAF, 2010), are shown below:

The total volume of available, renewable groundwater in South Africa (the Utilisable Groundwater Exploitation Potential) is 10 300 million m^3/a (or 7 500 million m^3/a under drought conditions). We currently use between 2 000 and 4 000 million m^3/a of this groundwater. 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 m^3/a, but more than 80% of this is already allocated.

As the National Water Act had indicated in 1998, groundwater is indeed a "significant resource".

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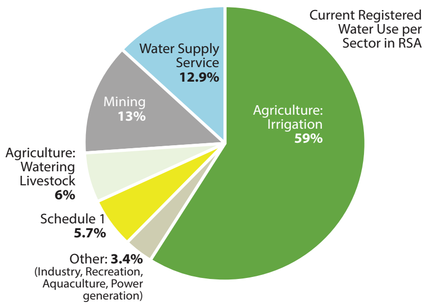
Main Users of Groundwater

Overall use

A major advance towards improved development and management of the country's groundwater resources has been that groundwater was registered for the first time in terms of the provisions in the National Water Act, 1998. This information is available on the Departmental WARMS database from which the figure of current registered water use per sector has been developed.

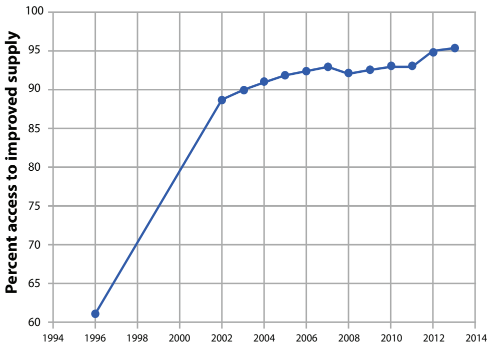
Status of groundwater use per economic sector in South Africa



This information is still far from perfect, especially the irrigation data, because verification, which is also required by the Act, has so far only taken place in a few catchments. It is known that many farmers have been reluctant to register their irrigation water use because they continue to see the water underneath their farm as their private property. (in line with the classification of groundwater in terms of the previous Act).

Community water supply

The Reconstruction and Development Programme (RDP) and subsequent plans and strategies have enabled major progress in supplying our citizens with an improved water source since 1994. According to the 2010 Millennium Development Goal (MDG) Report (UNDP, 2010) in 1996 only 61.1% of the national population was using an improved drinking water source. In 2013 that figure stands at 95.2% (DWA, 2013), meaning that South Africa has easily achieved this MDG obligation.



Water Supply Improvements in South Africa since 1996

Source: UNDP (2010) and DWA (2011, 2012 and 2013) (Cobbing, 2013)

In a number of provinces this achievement would not have been possible without groundwater becoming an important source (see next page). It should also be noted that, in general, the groundwater information, except for Limpopo Province, is still very incomplete, because individual boreholes are not linked to settlements or schemes (in Limpopo the information is available through the GRIP programme).

PROVINCE	NUMBER OF SETTLEMENTS	GROUNDWATER USE (%)
EASTERN CAPE	9023	55
FREE STATE	305	42
GAUTENG	3863	16
KWAZULU-NATAL	9465	49
LIMPOPO	2664	84
MPUMALANGA	719	39
NORTH WEST	1320	68
NORTHERN CAPE	468	69
WESTERN CAPE	1648	21
TOTAL	29475	

This has been the most dramatic change for groundwater services in South Africa.

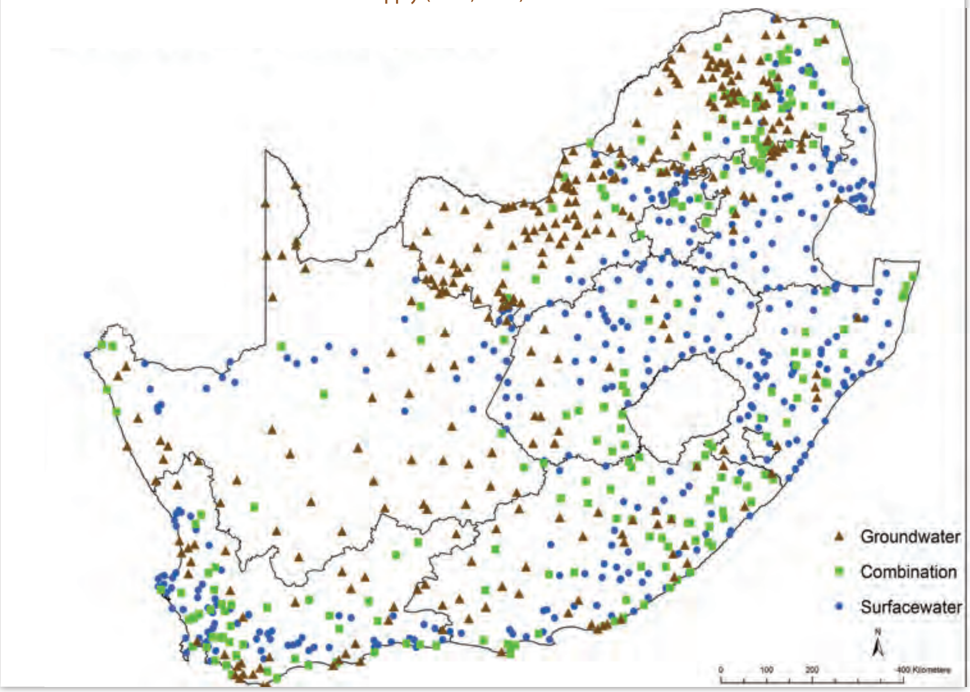
In terms of volumes, it represents a very small portion of the overall water supplied, but in terms of the national objective of development and the elimination of poverty and inequality, it represents major progress. In general, these local groundwater sources would also be adequate for village subsistence level cropping, critical to the improvement of food security at local scale, for stock watering, and other local productive needs, should there be a policy priority to step up basic water services.

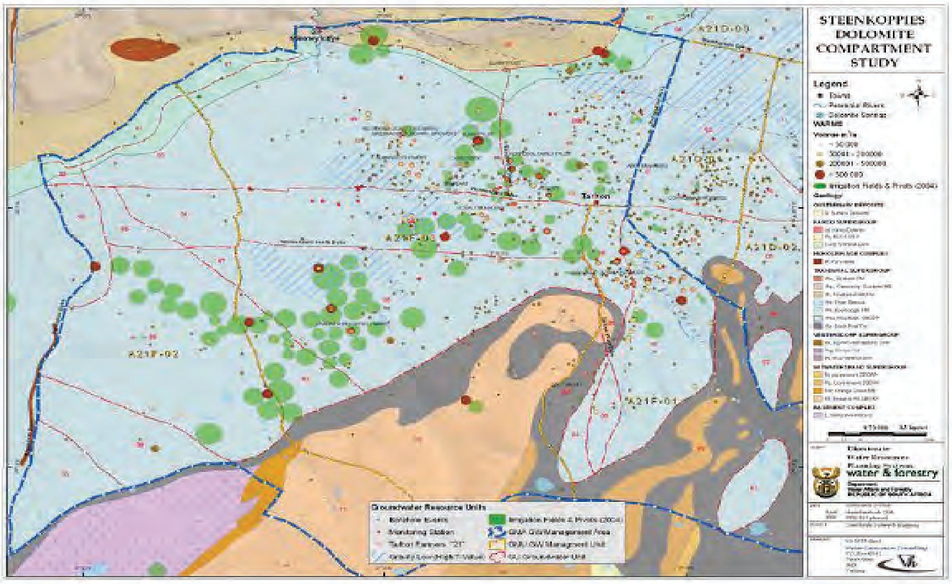
Urban water supply

Groundwater is becoming increasingly important for urban water supply. 22% of towns use groundwater as sole source and another 34% in combination with surface water. Water sources of domestic water supply (urban & rural) are shown in the map below.

The National Water Resources Strategy 2 (DWA, 2013) stresses government's vision for urban development and Reconciliation Strategies and other water infrastructure planning will

Water sources of domestic water supply (DWA, 2012)





Location of irrigation fields and pivots in the Steenkoppies Dolomite Compartment (DWA, 2009)

ensure that there is sufficient water supply for the future development of South Africa's cities and towns. A key recommendation in most reconciliation studies, undertaken by the Department of Water Affairs since 2008, is that, following water conservation and demand management measures, ***groundwater should be the first supply option.***

The growing country-wide importance of groundwater can be illustrated through the example of the Olifants Catchment (Water Management Area 4 on the WMA map) where there are no more feasible surface water schemes and thus 70 million/m^3 are sought from groundwater – a massive challenge.

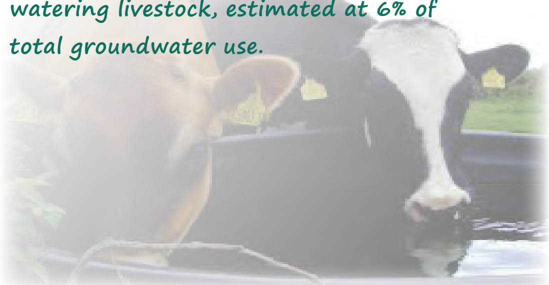
This national guidance regarding groundwater is, however, to a large extent not yet heeded at local level, is not incorporated into local water plans, or else treated as a last resort, to be used only in emergencies. In some cases very expensive options such as desalination are implemented as short or medium term solutions to a water crisis, without groundwater being given early, serious consideration (e.g. at Sedgefield and Plettenberg Bay). As a result, the development of high-yielding aquifers for bulk supplies is proceeding much too slow.

Agricultural water supply

Irrigation presents by far the largest use of groundwater in South Africa. Like in many other parts of the world, it has mainly happened as a result of private development. The intensity of use when high-yielding aquifers are discovered, often through exploration activities of the Department, can be seen in the map above of the Steenkoppies Dolomite Compartment (DWA, 2009).

In many instances this intensive use has led to overuse and depletion of aquifers, e.g. Tosca, Dendron, Delmas and Tarlton.

Another significant groundwater use is for watering livestock, estimated at 6% of total groundwater use.



Mining and industrial water supply

Mines are often in remote areas and provision of an adequate water supply is one of the key challenges of the whole operation. Groundwater sources have always played an important role here, estimated at 13% of total groundwater use. Important challenges here are various water conservation and demand management measures in the mining operation to prevent overuse and contamination of the scarce local resource.

A recent success story in this regard has been the Vaal Gamagara pipeline from the Vaal River in the Northern Cape. The pipeline was reaching the end of its design life, while mining demand had doubled. Exploration and inclusion of 20 Mm^3/a groundwater sources along the pipeline route brought down the cost for a new pipeline from R 7 Billion to R 5 Billion. The groundwater exploration costs in this venture amounted to R 31 Million. Normally nobody would have been prepared to pay this amount for groundwater exploration, whereas it only represented a fraction of the savings that resulted.


Photo: DWA


Photo: Independant media


Photo: DWA


Photo: DWA

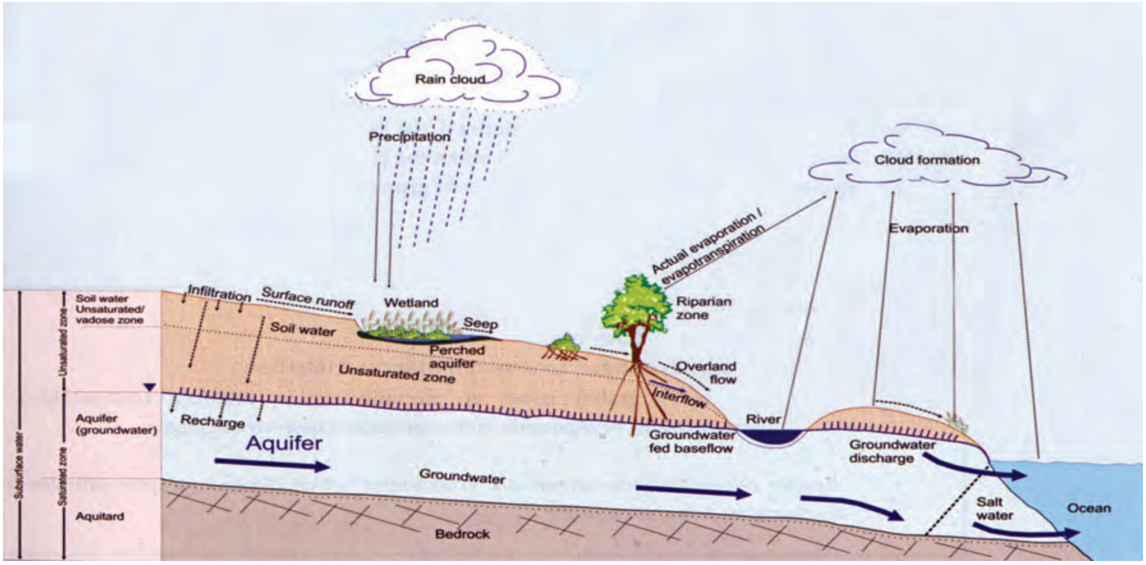
Groundwater and ecosystems

Aquifer Dependent Ecosystems (ADEs) occur throughout the South African landscape in areas where aquifer flows and discharge influence ecological patterns and processes. Their identification is often difficult but a type-setting and identification has been undertaken to guide groundwater management and allocation (Colvin et al., 2007). Examples of known South African Aquifer Dependent Ecosystems include:

- in-aquifer ecosystems in the dolomites (North West Province);
- springs and seeps in the TMG sandstone (Western Cape);
- terrestrial keystone species such as Acacia erioloba in the Kalahari;
- lakes and punctuated estuaries on the shallow sand aquifers of the east coast in KwaZulu-Natal;
- riparian zones in the seasonal alluvial systems of the Limpopo;
- seeps on the Karoo dolerite sills.

Like for surface water, the water requirements of these ecosystems are to be secured through the Resource Directed Measures of the National Water Act. Successful protection of ADEs will require cooperative governance of land, water and the environment (Colvin et al., 2007).

Subsurface and surface flows of water in the environment (Colvin et al., 2007)



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Enabling Environment

Policies & Strategies

The law concerning groundwater in South Africa has undergone a momentous shift since democratisation of the country in 1994. Earlier groundwater legislation was based on the "riparian" system, founded partly on the principles of Roman-Dutch law. Under this system, the rights to groundwater were held by the owner of the overlying property, who could essentially abstract groundwater with little or no control. Today, in terms of the National Water Act, 1998, South Africa's groundwater is recognised as a common asset, whose ownership is vested in the state and which is subject to all the stipulations of the Act.

Prof. Kader Asmal, who took over as Minister of Water Affairs in 1994, became the first champion of the forgotten resource.

Under Prof. Asmal, special attention was given to groundwater in the Water Act drafting committee. A young environmental lawyer from the University of the Witwatersrand was seconded to the Department's Directorate: Geohydrology for six months to give special attention in law to the unique characteristics and role of groundwater. A separate chapter on groundwater was initially foreseen for the Act, but this was not pursued to maintain the focus on integrated water resource management in the intended framework legislation. The work was published by the Water Research Commission (Lazerus, 1997) and needs to be revived in support of urgently required groundwater regulation.

In 2000, the International Association of Hydrogeologists for the first time held their conference in South Africa and the then Minister of Water Affairs, Ronnie Kasrils, gave the opening address. Only a few years later, he then had the honour to be invited to address the Groundwater Opening Ceremony at the 3rd World Water Forum in Kyoto in 2003. Within a short time, South Africa's groundwater had found its way on the international map.

The value of groundwater

"Those of us who have never been thirsty, truly thirsty, struggle to empathize with those of whom real thirst is a daily torment. Nor do those of us who have not had to carry heavy containers of water, day in and day out, for long distances over rough terrain, really understand the real value of having water – safe water – "on tap".

Asmal in DWAF (2004)

"I experienced this exciting period personally from the groundwater side. Groundwater, the forgotten resource, was regarded as of little value in terms of the past priority of commercial agriculture and urban-industrial development and was classified as "private water" in the old Act, meaning that government had basically no interest in its development and protection. It had remained the domain of the hydrogeologist and the driller and it still took years before it became part of the armoury of water resources planners.

Not so for the new minister. He soon defined surface water as the "masculine resource", the resource of engineers, concrete, dams and pipelines, whereas groundwater he saw as the "feminine resource", the resource of women with their daily water-bearing burden and of children desperately in need of a daily life-giving supply of water. And that is what groundwater became in a matter of years, now serving 60-90 per cent of communities with domestic water in the different provinces".

Asmal (2011)

It is now vital that groundwater protection and management features strongly in national and regional policy, strategy, planning and management agendas to overcome its past neglect and lay a foundation for its increasingly important role in ensuring national water security. Some developments in this regard can be highlighted here:

- High level government strategy documents are unequivocal in stating that South Africa

- must diversify its water mix to maintain national water security.
- The key message in the second National Water Resources Strategy (DWA, 2013) is that 'groundwater is important, currently under-valued and under-used'.
- A groundwater performance indicator was included in one of the twelve Presidential Outcomes announced in 2009 and incorporated in the Minister's performance agreement, signed in 2010: the target was to achieve a growth in the percentage of groundwater use of all water used in South Africa from 8% to 10% by 2014. Based on the most recent figures this percentage has already been exceeded and now stands at 16%.
- In a budget speech to Parliament in April 2011, the Water and Environmental Affairs Minister, Edna Molewa made some of the most groundwater-positive inputs to parliament to date. They followed the release of the new national groundwater strategy, published as Groundwater Strategy 2010.
- In the new water infrastructure development phase under the National Infrastructure Plan of 2012, groundwater is unlikely to attract high profile champions in the construction industry, because developments are generally modest when compared to surface water impoundments and long-distance pipelines. Nonetheless, there is scope to emphasize significant job creation opportunities to support and manage local groundwater abstraction better.

However, the growing incidence of water interruptions, not just in small rural settlements but in a growing number of urban centres, point to a gap between the intent of policy and strategy, and the available capabilities and systems to give effect to them. This is particularly evident in relation to groundwater and is giving groundwater a bad name.

The 2009 Water for Growth and Development Strategy noted that:

At present, the country lacks the depth in skills and leadership in hydrogeology to drive the understanding and acceptance of groundwater from national down to local management level. Steps must be taken to strengthen geohydrological skills and build technical training capacity at institutions across the country.

This situation has resulted in a wide-spread call, inside and outside the Department, for a well-capacitated groundwater champion in DWS – a groundwater governance unit, which can guide and direct the oversight. DWS has now taken the decision that a groundwater unit will be created to oversee local management (Mochotlhi, 2014).

Recommendations

DWS Groundwater Strategy urgently needs to be updated with sector input, rolled-out and implemented. To do this strategically, it still needs to become a national strategy with an agreed implementation plan, closely linked to the NWRS II;

The intended Groundwater Governance Unit in DWS should be carefully planned in the light of the overall groundwater governance and local management situation;

Improved management of local groundwater resources urgently requires regulation, which was already foreseen with the drafting of the National Water Act. The original work by Lazerus can serve as a starting point.

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Groundwater
Strategy

The Groundwater Strategy of the Department was the outcome of a three-year consultative process. The Strategy is designed to ensure that:

"Groundwater is recognised, utilized and protected as an integral part of South Africa's water resource."

The aims of the Groundwater Strategy were decided on, following a detailed consultation process with public and private sector stakeholders:

- 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.

Areas on which the Strategy makes recommendations include:

Policy, Legislation and Regulation; Water Resources Planning;
Sustainable Groundwater Management;

The Groundwater Strategy published in 2010.

Human Capacity; Institutional Capacity; Information Management, Monitoring, Data and Information; Groundwater Research; Communication and Awareness; Financial Implications of the Groundwater Strategy.

An important aspect of the financial analysis of the Groundwater Strategy was estimating the cost of not implementing the Groundwater Strategy. It was found that the costs of opting for more expensive water sources as alternative to groundwater, of inappropriate development and of incurring groundwater contamination and other environmental impacts were 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.

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Valuation
of Groundwater Resources

Findings made in a recent SADC study related to proper valuation of groundwater resources, appear to hold for South Africa to (Braune et al., 2008):

- Growing awareness at decision-making levels about the importance of groundwater is not adequately reflected in policies and practices.
- Investment in groundwater, relative to its potential to address national objectives, is limited and this is still offset by pollution and ineffective maintenance.

In 2009, Statistics South Africa (StatsSA) published a draft Water Resource Account for South Africa which estimated the size of the groundwater economy in South Africa at approximately R620 million per year (expressed in terms of contribution to Gross Domestic Product (GDP)). **This turned out to be a gross underestimation, largely because national GDP type data do not have the ability to adequately capture the asset value of aquifers.**

Since then the Water Research Commission has put the spotlight on this important issue (Pearce et al., 2013). It is clear that aquifers are natural assets. They form part of the ecological infrastructure of a country. And the values of these assets theoretically appear on a country's natural resources balance sheet. Natural assets of this kind are characterized by complex inter-temporal and inter-ecosystem service characteristics.

The project introduced Comparative Risk Assessment (CRA) methodology as a structured way for experts to interact with stakeholders in order to demonstrate the systemic connections between aquifers and ecosystem services and describe how a change might impact on an ecosystem service. This was undertaken for three case study sites, covering a variety of aquifer types under diverse economic, social and environmental conditions (Pearce et al., 2013). Groundwater valuation has already been introduced into a new Groundwater Management Framework, an umbrella guideline supporting municipal groundwater management (Riemann, 2011).

Recommendations

Work on groundwater valuation should continue until it has become standard practice in groundwater resource planning and implementation at all levels.

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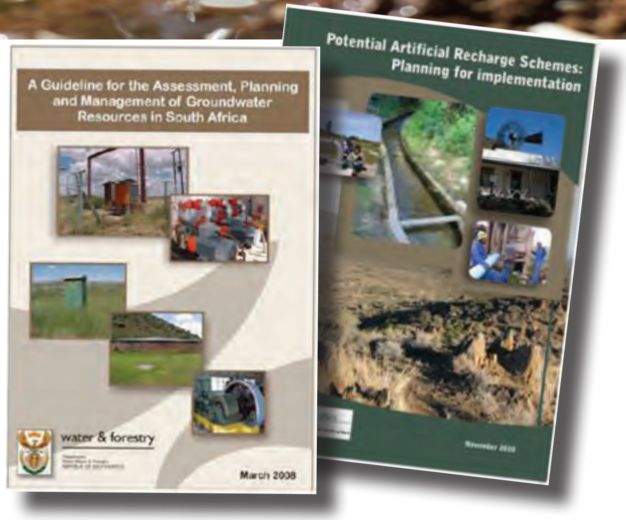
Water Resources Planning

The vision of the National Water Act, 1998 is Integrated Water Resources Management. It was therefore crucial that, with the major restructuring of the Department in 2003, groundwater was integrated into the water resources planning functions. Groundwater is now fully part of the planning basket, with two groundwater specialists in the national and regional planning team. This has had tremendous benefits for groundwater resource development and management:

- At the national level it led to development of a Departmental Groundwater Strategy and the extensive inclusion into the second edition of the National Water Resources Strategy;
- Groundwater became part of the nationwide programme to develop water reconciliation strategies for Water Management Areas, Metros, all towns, villages and clusters of villages across the country started in 2008. These studies provided the groundwater potential for each municipality at a local scale and identified possible target aquifers in the vicinity of the towns, where this appears to be feasible (e.g. DWA, 2011);
- Groundwater staff had the opportunity to comment on major municipal projects to be undertaken with government grant funding, e.g. the Municipal Infrastructure Grant (MIG);
- With support from the Water Research Commission, departmental guidelines could be prepared, addressing various aspects of sustainable development and management of groundwater resources (e.g. DWA, 2008 and Murray and Ravenscroft, 2010).



Greater use of groundwater sources does indeed hold enormous promise for accelerating sustainable access to improved water services and augmenting supply in many parts of the country. The lead times for developing groundwater resources are far shorter than are typically found in big surface water development projects, which allows for delivery of the benefits far sooner. There is also scope for substantial cost savings in

Successful introduction of groundwater sources	
LUSIKISIKI	Wanted to build just a dam, but were able to develop local groundwater for a conjunctive use option
MIDDELBURG AND HOFMEYR	Groundwater was provided at a quarter of the cost
OUDTSHOORN	Groundwater from a deep Table Mountain Group aquifer will augment the existing surface water storage and the groundwater from the Klein Karoo Rural Water Supply Scheme, thus providing additional assurance of supply
SISHEN MINE	Considerable cost reduction through development of groundwater along the pipeline from the Vaal River
BITTERFONTEIN	Desalination of local brackish groundwater the most cost-effective option
HERTZOGVILLE (example of opportunity lost)	Groundwater is available: just needed drilling of production boreholes – in last moment municipality applied for a surface water scheme

developing local decentralised groundwater-based schemes, instead of big regional surface water schemes with major pipelines conveying water from distant impoundments.

Despite this raised profile on paper, experience on the ground indicates that many municipalities only turn to groundwater as a last resort. Groundwater is perceived as an unreliable and difficult source to manage. According to the Department of Water Affairs, 'more than 70% of WSAs do not want localised solutions and prefer regional schemes.' One reason is that water boards generally operate and manage the big regional schemes, and the municipalities can buy bulk potable water rather than having to abstract and treat it themselves (Eales and Cobbing, 2013). **Financing via the Regional Bulk Infrastructure Grant (RBIG) presents one the biggest problems. It gives municipalities large financing in their own control with which they will aim for the biggest scheme possible, often with complete neglect of local groundwater sources.**

A move away from this trend appears to be the use of a new Municipal Water Infrastructure Grant (MWIG) introduced in March 2013 to address the remaining water services backlog in rural settlements within 24 District Municipalities. Allocations for 2013/14 (figure below) indicate that municipalities have in fact allocated a relatively high proportion of MWIG to groundwater-based service improvements (Eales and Cobbing, 2013).

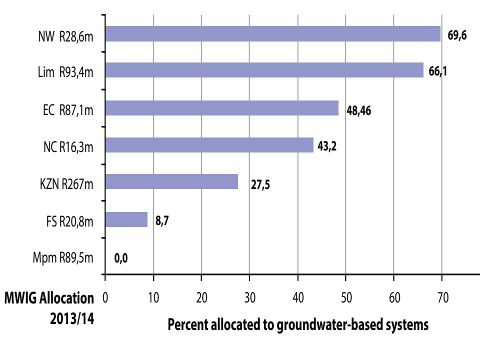
In general, municipal water supply from groundwater remains a major problem. The problem has been recognised as such, since at least 2004, when the Dinokana groundwater supply in North West Province failed without any prior warning and a number of villages were left without water. World-wide it is accepted that drinking water supply to communities requires the highest standards of planning, implementation, operation and maintenance. Local government in South Africa, at this stage, does not have the groundwater technical capacity to undertake this function responsibly. Policy, regulation and comprehensive support is required for a more sustainable way forward. This is further discussed under 'Local level management.'

Recommendations

Planning should not only address water resource reconciliation issues, but also the human and institutional capacity requirements for a successful implementation and sustainable utilisation of local water resources;

Standards should be urgently developed as input to possible regulations for the supply of drinking water from groundwater.

Percentage of MWIG allocated to groundwater-based systems, 2013/14 (from Eales and Cobbing, 2013)



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Conjunctive Use

Both groundwater professionals and water resource planners stressed in discussion, the importance of not going for either a groundwater or a surface water solution, but seeking conjunctive use solutions. This has to do with both water security and with resource sustainability.

"Conjunctive use of surface and groundwater consists of harmoniously combining the use of both sources of water in order to minimize the undesirable physical, environmental and economical effects of each separate solution and to optimize the efficient use of total water resources."

The natural storage (water buffer) available in aquifers makes conjunctive use particularly attractive. The different approaches of managing the water buffer to achieve water security have featured strongly at recent World Water Forums.

Operating our natural reserve bank

"By storing surface water in aquifers, a 'water bank' can be created through the combination of three elements:

recharge, retention and reuse (3Rs).

Excess water from surface reservoirs is stored in the aquifer, thus creating a bridge between years with high rainfall (when there is surplus to be stored) and drought years,

making the water supply system resilient to climate variability and, in the long term, climate change.

Van Steenbergen et al. (2009)

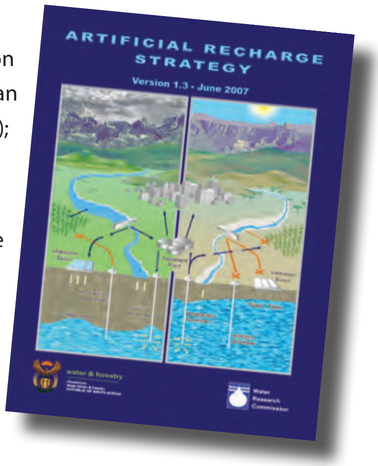
In South Africa, artificial recharge has recently been given a welcome push, by devoting a government strategy to it (DWAF, 2007).

Artificial recharge, also called Managed Aquifer Recharge, as included in the Departmental planning options, has many purposes:

- Store and conserve water in the subsurface for later use (through infiltration basins or by injecting water via boreholes);
- Prevent sea water intruding into coastal aquifers by creating hydraulic barriers at the coastline;
- Use aquifer media for water treatment, like a large-scale sand filter.
- Maintain the Reserve, whereby surplus water (fresh or waste) would feed areas where the Reserve is considered to be under threat due to large-scale groundwater or surface water abstraction.

Some recent initiatives include:

- conducting feasibility studies for the towns of Plettenberg Bay and Prince Albert;
- transferring groundwater from one aquifer to another in Williston (western Karoo);
- conducting trial borehole injection tests in Langebaan (Cape west coast);
- substantially increasing the artificial recharge and abstraction capacity in Windhoek by drilling new injection boreholes and deep abstraction boreholes.



City of Windhoek (Namibia) – a major urban conjunctive use application

"The Namibian capital Windhoek has around 300 000 inhabitants, with current water use ~21 Mm^3 /annum, most of which comes from three dams, the furthest 200 km distant. The remainder is sourced from groundwater sources (50 boreholes around the city) and reclaimed water.

To improve water assurance and to supply virtually the entire city during a drought emergency, the city opted for artificial recharge over other options because it represented a significant cost saving.

The so-called Windhoek Aquifer consists of highly fractured quartzites. The amount of water stored in this buffer is 35 Mm^3 – less than capacity because of overdrafts in the past. By injecting treated surface water from the abovementioned dams during times of surplus, the amount could increase to 66 Mm^3. The groundwater could then be used during drought periods to bring about a secure water supply system.

The water bank project of the Windhoek Aquifer started in 2004 and full implementation of the programme will take 15 years.

Current artificial recharge capacity: 2.8 Mm^3 /annum (5 injection boreholes).

Target artificial recharge capacity: 8 Mm^3 /annum (8 new injection boreholes have been drilled).

In the long term, treated surface water will be blended at a ratio of 3:1 with reclaimed waste water from the Goreangab Water Reclamation Plant, using advanced treatment techniques.

Braune et al., (2011); DWAF (2010)

Guided and supported by the Water Research Commission, the Department has made a major effort to promote the technology and guide its country-wide implementation. DWA's artificial recharge website provides access to all the resources below (www.artificialrecharge.co.za):

- Artificial Recharge Strategy (2007)
- Potential Artificial Recharge Areas in South Africa (2009)
- A check-list for implementing successful artificial recharge projects (2009)
- Lecture notes on artificial recharge (2009)
- Artificial Groundwater Recharge: Recent initiatives in Southern Africa (2010)
- The Atlantis Water Resource Management Scheme: 30 years of Artificial Groundwater Recharge (2010)
- Artificial Recharge Strategy, Version 2 (2010)
- Potential Artificial Recharge Schemes: Planning for Implementation (2010)
- Planning and Authorising Artificial Recharge Schemes (2010)

Recommendations

The Artificial Recharge Strategy needs to be anchored still more strongly into national, regional and local government strategies to achieve systematic roll-out.

The hydrology / hydrogeology (water science) component in support of national water resources planning needs to be strengthened to oversee the implementation of this and other strategies towards sustainable development of scarce water resources.

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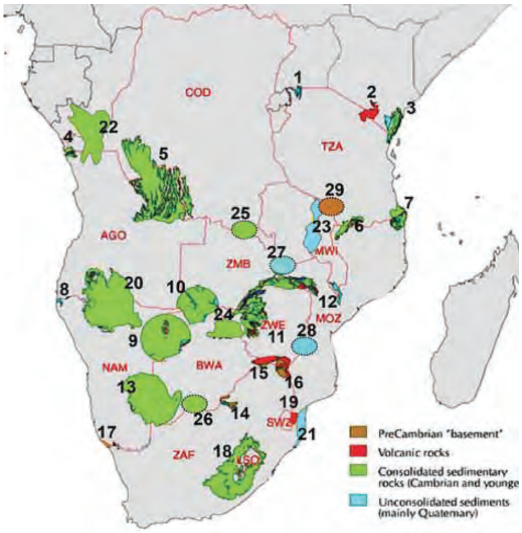
Transboundary
Aquifer Management

A large proportion of South Africa's water resources fall into transboundary basins. The National Water Act, 1998, recognises the need for the joint management of such shared resources. In the SADC region, formal regional cooperation was already established in 2000 through a protocol, the Revised Protocol on Shared Watercourses in the Southern Africa Development Community.

An important groundwater milestone in the region has been the resolution in 2007 by the African Ministers Council on Water (AMCOW, 2008), as part of its Africa Groundwater Initiative, to 'promote the institutionalisation of groundwater management by river basin organisations to ensure regional ownership of the initiative'. SADC endorsed the AMCOW policy direction and the Orange-Senqu River Commission (ORASECOM) became the first river basin commission in SADC to establish a Groundwater Technical Committee.

International guidance for such joint management is for the first time available through the Draft Articles on The Law of Transboundary Aquifers prepared by the UN International Law Commission (UNESCO, 2009). In the region, the ISARM (Internationally Shared Aquifer Resources Management) initiative of UNESCO had started to help with the mapping of transboundary aquifers (see figure). International funding has recently been approved (SDC, 2012) for a pilot study in Southern Africa (Botswana, Namibia, South Africa) in the Kalahari-Karoo aquifer system (basin No. 13 in the figure) within the Orange-Senqu River Basin to test transboundary aquifer management principles in the region.



Transboundary Aquifers in the SADC Region (Braune and Xu, 2013)

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Recommendations

International cooperation can give the widely neglected resource, groundwater, a major boost. It is therefore crucial that transboundary aquifer management is supported strategically by key stakeholders and synergies are created, nationally, regionally and internationally to take it forward rapidly and systematically.

Regulatory Measures

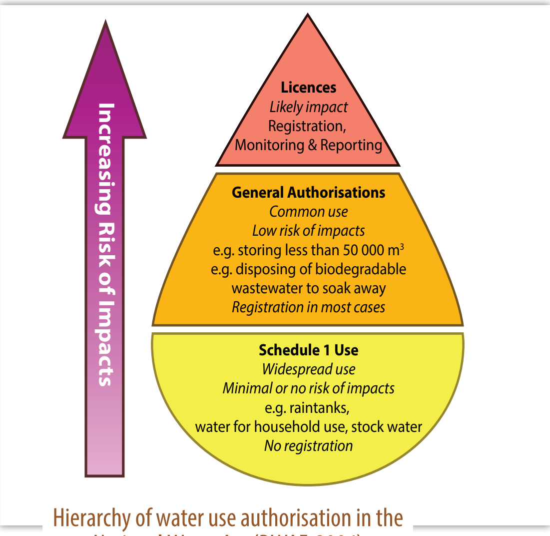
Regulation of water use

The foundation of water management in the National Water Act, 1998, is the regulation of water use.

Water use in the Act is defined very broadly and includes:

- Taking and storing of water
- Activities which reduce streamflow
- Waste discharge and disposal
- Activities which impact detrimentally on water resources and which can be declared controlled activities.

General authorisations are intended to alleviate the burden of issuing licenses for common, but low impact water uses and form part of the migration to full implementation of the National Water Act, particularly for those water use categories that have never been controlled or regulated before. The authorisation hierarchy obtained through these different instruments is illustrated in the figure below.



Hierarchy of water use authorisation in the National Water Act (DWAF, 2004)

The NWA sets out rules to use water wisely. These rules say that the bigger the risk of potential negative impact on the water resource, the more stringent the rules will be for using that water (DWAF, 2004).

Groundwater use registered for the first time

A water use registration drive, which took considerably longer than the initially intended 2 years, provided the first overall assessment of water use in South Africa. For groundwater the registration requirement was set for uses of 10 m^3/day and more. Over 20 000 users were registered with a total registered volume of 2.4 billion m^3/a (DWS WARMS database, 2014).

Registered groundwater users (DWS WARMS database, 2014)

USE SECTOR	% OF REGISTERED USERS
AGRICULTURE	79.5
WATER SERVICES	8.3
INDUSTRY	5.2
OTHER (MAINLY SCHEDULE 1)	4.2
MINING	2.6
URBAN	0.2
TOTAL: **20 269 USERS**	**100.0**

Need for verification

This groundwater registration must be seen as a major accomplishment towards bringing groundwater, from its past "private" water classification, into an integrated water resource management in South Africa. We are still missing information. Domestic use and stock-watering fall under Schedule 1 use, which did not need to be registered. Also there was over-registration to achieve a higher "existing lawful use". Others drilled new boreholes and expanded irrigation significantly during the period between the announcement of registration and when actual registration took place. And then there were those who did not register their use at all – illegal use in terms of the Act.

The bottom line is that we will only know the true state of affairs when verification of use, part of the water use regulation processes, has taken place. Verification has been progressing slowly, but there have been pressures on the Minister in the last three years to speed it up. In the case of groundwater, successful verification of use has taken place in the Van Rhynsdorp area. Other advances have been:

- Stopping of illegal irrigation at Tosca (Northern Cape) and Maloneys eye (Gauteng)
- Advancement with compulsory licensing in Upper Vaal Catchment

Groundwater abstraction licences

A general concern is that the issuing of groundwater abstraction licences takes prohibitively long (5-6 years in the case of Hermanus) and is one of the reasons why municipalities shy away from groundwater. This has partly to do with the scientific processes underlying resource protection which are largely surface water based, and the lack of groundwater specialist capacity in the regulatory arm of DWS. Furthermore, DWS is still lacking the capacity to monitor whether there is compliance to set licence conditions. Such information is already coming in from users to the various Regional Offices, but cannot be attended to because of lack of capacity.

Registration of drilling contractors

The Department of Water and Sanitation recently embarked on a project to investigate the mechanisms for successful registration of drilling contractors as well as possible training and controlling mechanisms. A particular objective is to get the data from the thousands of boreholes drilled annually onto a national database for the benefit of the country as a whole. This had already been proposed at the time of writing the National Water Act, 1998, but it was then felt that registration of water use was a major task and immediate priority, whereas the more detailed aspect of borehole registration should follow later.

South Africa is fortunate that the drilling industry in South Africa through the Borehole Water Association of Southern Africa (BWA)) already many years ago embarked on a process of self-regulation. They started with the publishing of general guidelines or a code of practice for its members – *'A Minimum Code of Practice for Borehole Construction and Pump Installation'*. In 1996, they followed this up with a project to have SABS Standards for borehole construction, based on their guideline (SABS, 2003).

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Recommendations

Urgent attention now needs to be paid to groundwater-specific regulation requirements, in particular the regulation of the drilling industry and the provision of borehole data. Whilst maintaining a hydrological systems approach in regulation, a much greater focus on geology, which is governing the functioning of groundwater systems, will be required;

Verification of registered groundwater use as well as licence compliance monitoring should start without delay in the most vulnerable groundwater resource areas;

(Compliance monitoring will become a strategic focus area of DWS– a new Chief Directorate is intended).

Resource Protection

Groundwater quality protection strategy

The Department's groundwater quality protection strategy of 2000 states (DWAF, 2000):

"As the country's people start depending more and more on groundwater, so the need grows to provide for the security of its supply. Protection of groundwater has, therefore, now become a national priority."

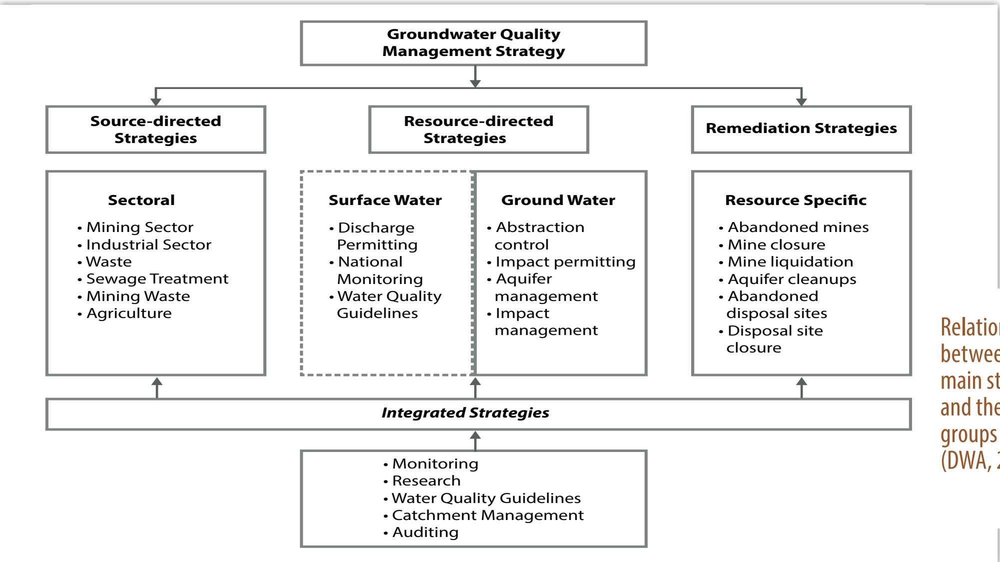
Resource degradation through pollution of underlying groundwater is wide-spread in Africa in both urban and rural areas (Xu and Usher, 2006). This is because of its invisible nature – it takes a long time to notice when it has become polluted and, unlike surface water, it has limited ability to purify itself. In South Africa our knowledge of groundwater pollution is only incidental, because monitoring information is only available at a national / basin level, whereas compliance monitoring is not yet functional.

The groundwater quality protection strategy foresaw three main functional groupings and a fourth group to integrate and support the work of the three shown in the figure.

Resource directed measures

Resource directed measures (RDM) focus on the water resource as an ecosystem rather than simply on water itself as a commodity. They include a national classification system for water resources, a "Reserve," which includes the basic human needs reserve (water for drinking, food preparation and personal hygiene) and the ecological reserve, which must be determined for all or part of any significant water resource, including groundwater.

These measures have been the Departmental protection focus to date, and in particular the requirement of a Reserve determination as part of any water use license application. While more than a thousand Groundwater Reserves have been determined and weighty reports



Relationship between the three main strategies and the functional groups around each (DWA, 2000)

produced, these have served little purpose for groundwater protection itself. Firstly, in large parts of the country, where there is no baseflow, no ecological Reserve based on groundwater can be determined. Secondly, in the parts where the groundwater system does interact with the river system, our scientific understanding of the interaction is still imperfect. Also, we have to rely on regional information from the Groundwater Resource Assessment to try to make local predictions and groundwater use information, an important input, is still very scanty (Seward, et al, 2006; Riemann, 2013).

Resource classification and the setting of Resource Quality Objectives, which is seen as the foundation for systematic groundwater resource protection, has only just started, e.g. in the Olifants/Doring and Komati Catchments. Unfortunately, the tools that hydrogeologists have been developing since the nineties, e.g. Parsons (1995), could not yet be matched up with the ecosystem-focused approaches for RDM.

Groundwater scientists who are dealing with these challenges daily, experience the long licence delays as a major damper on groundwater development. Because of the resilience available in groundwater systems, they suggest an adaptive management approach in which a conditional abstraction license is granted, based on best understanding and a model of the aquifer, which will be reviewed after a specified time of monitoring.

Source-directed measures

Source-directed measures in order to prevent or minimise the impacts of pollution sources are often prescribed by legislation other than the National Water Act. The National Environmental Management Act, 1998 (NEMA) is a crucial instrument for preventing or minimizing various forms of high impact on groundwater. The Department will have to develop best practice guidelines and will classify groundwater resources, and these conditions will become part of the control measures of other authorities. Some of these are illustrated below.

A protocol to manage the potential of groundwater contamination from on-site sanitation

This protocol has been written into the implementation requirements of all on-site sanitation projects and was based on a first protocol developed in 1997 by the National Sanitation Programme, jointly with the Directorate Geohydrology.

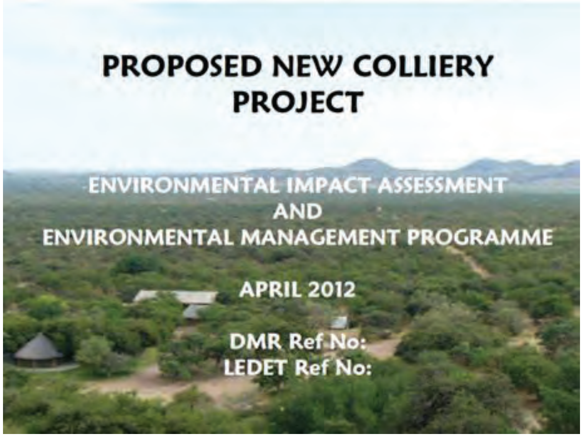
The measure of protection is based on the vulnerability of aquifers to contamination. The vulnerability to contamination from sanitation systems and other pollution sources is high in areas of high rainfall and shallow water tables. The vulnerability is also high for fractured aquifers and other permeable environments such as sandy or gravel soils. This is mainly because of high flow rates and less time and distances available for filtration, die-off and adsorption processes to take place.

One of the measures in the protocol addresses pit toilets.

Pit latrines may be adapted in three main ways. These are:

- increasing the depth of the unsaturated zone by reducing the depth of the pit;
- sealing the pit, but with a water drain close to the surface;
- converting the sanitation system so that the pit only contains dry solids.

Department of Water Affairs (2003)



Hydrogeological inputs to an EIA for a new colliery (Carel Haupt)

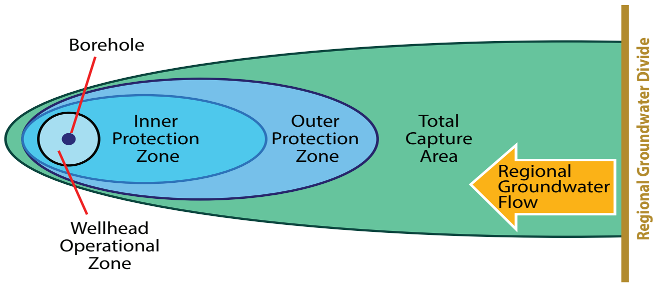
Hydrogeological investigation for a Truck Stop (Carel Haupt)

Protecting sources of drinking water

While one can, in the above examples, see the beginning of the different functional approaches of the groundwater quality protection strategy, an important part is still missing, namely 'a programme of special protection of vulnerable groundwater sources supplying domestic water to communities'. This measure is particularly important for groundwater and is standard practice in many parts of the world. Even though the constitution of South Africa recognizes the right to a living environment that is not harmful, South Africa still has no policy to protect sources of drinking water for its citizens. Polluted groundwater reached national news with an outbreak of gastro-intestinal disease claiming 5 lives in Delmas in August 2005.

Besides the scientific challenge of determining protection zones which strike a balance between the need to control pollution and to support development (see figure below), local level communities and government need to be convinced of the merits of this approach, because zoning of land for different purposes is a function of local government. The approach was first proposed in South Africa in the nineties (Jolly and Reynders, 1993), followed by unique work to develop appropriate zoning methodology for South Africa's predominantly hard rock aquifers with tracer experiments at the Campus Test Site in Bloemfontein (Xu, 1998). A draft policy in this regard (DWAF, 2008) still needs to be tested and implemented.

Common protection areas delinated around drinking water supplies



Groundwater quality research

The groundwater science community participated over a number of years in developing the Department's groundwater quality protection strategy of 2000. In this period the Water Research Commission launched a series of projects (see table) to assess the impact of mining, agricultural activities and urban development, all to assist those responsible for groundwater policy formulation.

The Department intends to increase its emphasis on source-directed controls and a unit will be established for this purpose shortly.

Groundwater quality research through the Water Research Commission	
Protocols for assessing groundwater pollution impacts	1999
Assessment of agricultural practices on the quality of groundwater resources in south Africa	1999
The assessment of current and future water pollution risks due to gold mining in dolomitic areas	2000
Handbook of groundwater quality protection for farmers	2001
Guidelines to set resource quality objectives for groundwater	2001
The quantitive evaluation of the modal distribution of minerals in coal deposits in the highveld area and the associated impact on the generation of acid and neutral mine drainage	2001
The development of a strategy to monitor groundwater quality on a national scale	2001
Groundwater protection in urban catchments (a) identification (b) guidelines (c) determining standards of pollution in Southern Africa	2002
Microbial groundwater monitoring protocols refinement	2004
Field investigations to study the fate and transport of dense-aqueous liquids (DNAPLs) in groundwater	2004

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Recommendations

Groundwater-specific regulation needs to be developed to address the unique protection requirements for groundwater. These should be seen alongside the integrated protection requirements through Resource Directed Measures, which must continue and become more effective;

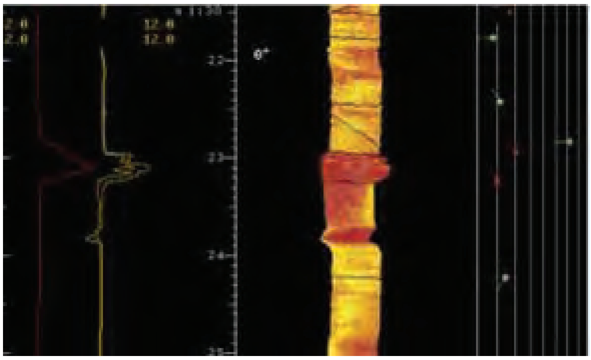
Groundwater sources for domestic use should receive the highest protection priority and an appropriate protection zoning approach should be introduced for this purpose.

Water Resources
Information Management

Two eras of groundwater resource focus

The National Water Act, 1998 for the first time explicitly requires the establishment of a water resources information system and regular monitoring and assessment of resources. A review written in 1998 (Braune and Reynders, 1998), clearly saw two eras of groundwater resources focus:

> Past achievements have been mainly on the groundwater exploration side and more recently a much bigger resource assessment focus. A unique feature of South Africa's groundwater occurrence is the predominantly fractured rock environment. Through systematic and more and more integrated work, largely financed and coordinated by the Water Research Commission, at the micro, meso and regional scales, these systems are now well understood in terms of modes of emplacement, fracture development and hydraulic behaviour.



Acoustic scanner image of borehole U05 on the Campus Test Site (Van Tonder et al., 1998) (The position of the fracture zone (red) and other smaller fractures are clearly visible on this picture)

This knowledge is now also finding wider distribution through a systematic hydrogeological mapping programme at national and 1:500 000 scales. Work on a new generation National Groundwater Information System is already underway. It will be GIS-based and with stand-alone capability in each of the nine Regions. The foundation for this work was laid through the establishment with the help of the Water Research Commission of the National Groundwater Database in 1986 at the Department of Water Affairs.

Groundwater mapping programme

The mission and aim of the Department's groundwater mapping strategy reflects the changed focus (DWAF, 1992).

The Department of Water Affairs and Forestry completed their Phase 1 Groundwater Resources Assessment in 2003 after the publication of a series of 21 hydrogeological maps.

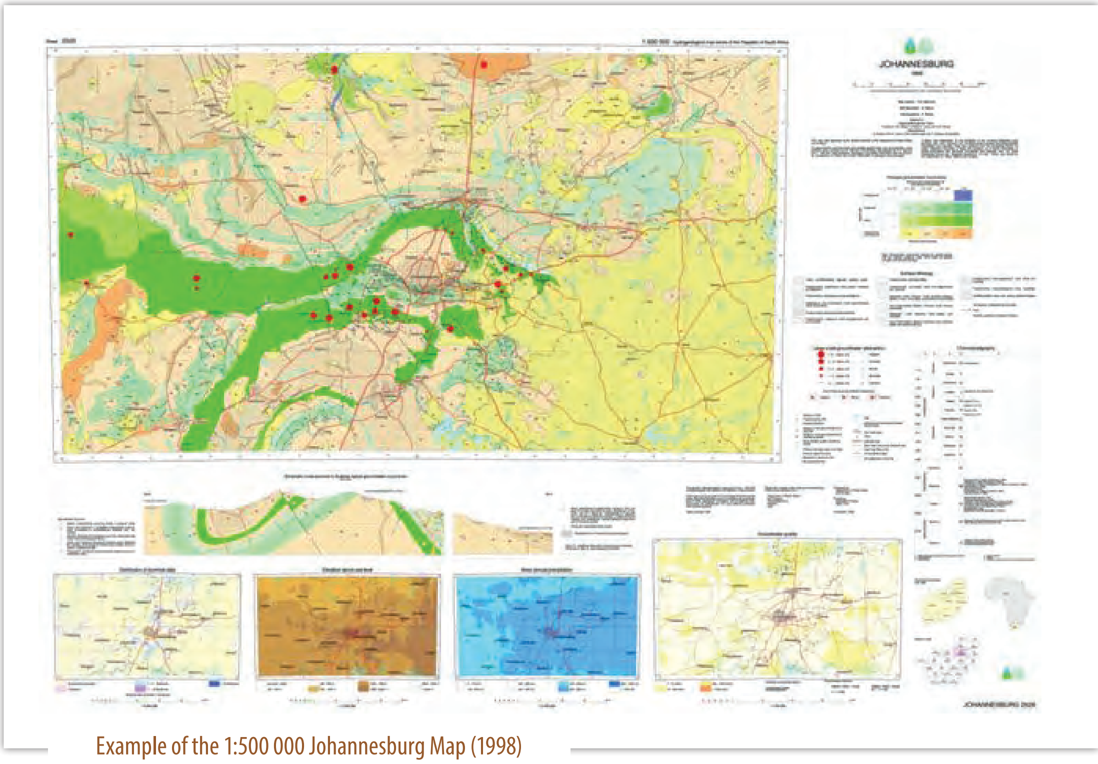
A Groundwater Mapping Strategy for South Africa, 1992

Mission Statement

To achieve confidence in the use of groundwater and for groundwater to be an integral and correctly managed part of the water resources of the country.

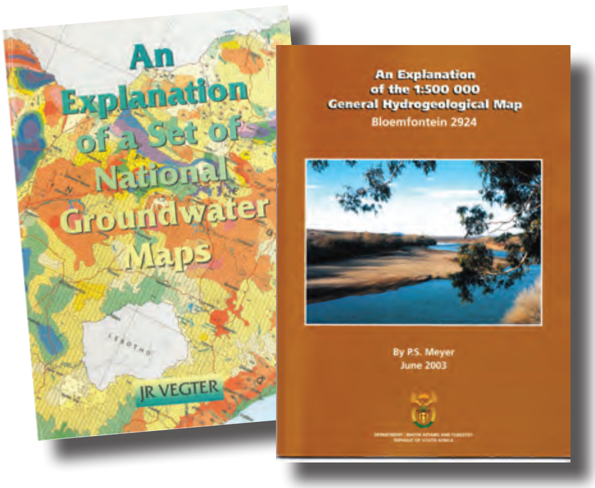
Overall Aim

To develop a series of hydrogeological maps and the associated dynamic data base by the year 2000 which will form an integral part of the socio-economic development of South Africa.



Example of the 1:500 000 Johannesburg Map (1998)

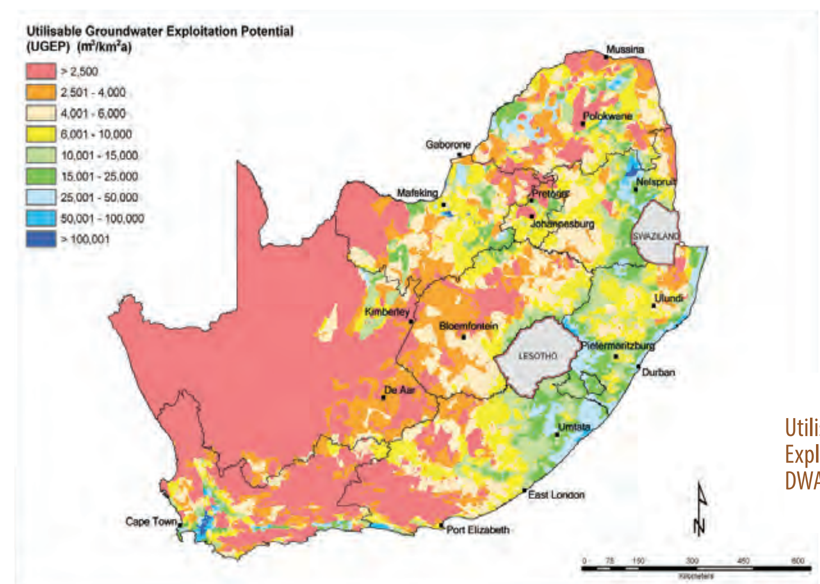
The brochures going with each map proved to be very educational, because they focused on the groundwater environment on people's doorstep. The last ten brochures have unfortunately not been published yet, even though they have been print-ready for a number of years already.



Groundwater resource assessment

In 1995, in parallel, and in many ways foundational to the hydrogeological mapping, the Groundwater Resources of South Africa (consisting of a report and accompanying set of groundwater maps) was published by the WRC (Vegter, 1995). The maps were based on a statistical analysis of data from approximately 70 000 boreholes held mainly by the Department of Water Affairs and Forestry. The seven national scale maps on two A0 sheets were a first attempt at a visual representation of South Africa's groundwater resources, and are as follows:

- Borehole prospects
- Saturated interstices
- Depth of groundwater level
- Mean annual groundwater recharge
- Groundwater component of river flow
- Groundwater quality
- Hydrochemical types



Utilisable Groundwater Exploitation Project – DWAF GRA II Project, 2005

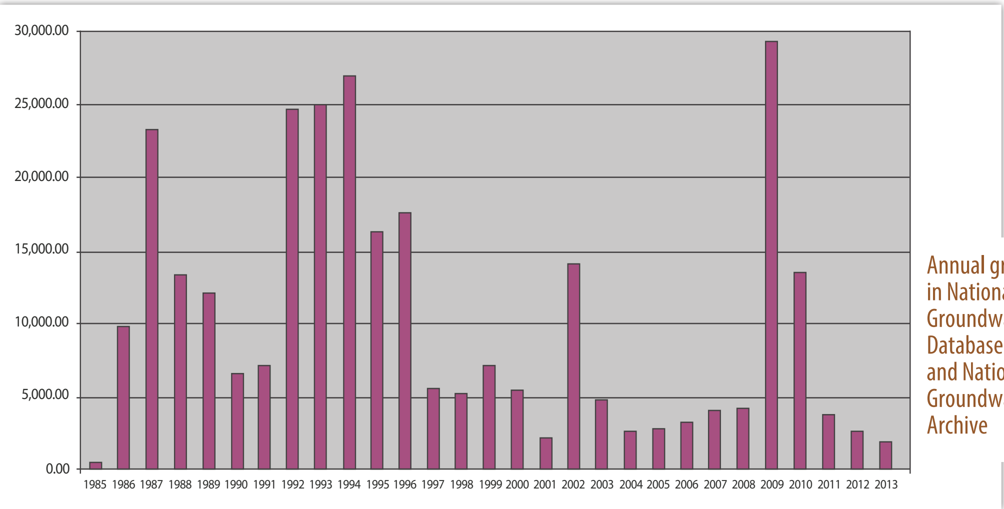
The vast experience of Dr. Vegter is still benefitting the country long after his retitrement. Beginning before the development of the national maps described above, and continuing to the present day, a long-term project recognising the subdivision of the country into a series of "Groundwater Regions" has been underway (Vegter, 2001) (see example on p. 41). It is intended that each of the 64 regions will ultimately have a separate groundwater report, including issues such as methods for geophysical exploration, recharge, hydrochemistry and the siting of boreholes are included in the reports. Five reports have been completed so far and are available from the Water Research Commission (WRC).

Groundwater part of water resources of South Africa

A major step forward was the inclusion of groundwater into a major revision of the water resources of South Africa study (WR2005). The 1990 Surface Water Resources of South Africa Study (WR90) and its predecessors have played a major role in providing key hydrological information to water resource managers, planners, designers, researchers and decision-makers throughout South Africa since the late sixties and had never included groundwater. This had only been possible through the preceding groundwater mapping and assessment programme and a follow-on assessment phase, Groundwater Resources Assessment (GRA2) by the Department of Water Affairs and Forestry, completed in 2005.

A national groundwater data base

The foundation for all groundwater resource assessment and mapping is the the National Groundwater Database (NGDB), presently containing about 250 000 borehole records. Concern has been expressed about the decline of borehole data capture as illustrated in the figure below (Witthueser et al., 2009). The rise in acquisitions between 1992 and 1996 (see figure on next page) reflects the efforts made during the production of the hydrogeological maps and in 2009/10 when data ownership was introduced with the change-over to the



Annual growth in National Groundwater Database and National Groundwater Archive

National Groundwater Archive and some of DWA regions migrated their data to the national facility. A further concern, already recognised with the writing of the National Water Act, was that information from private drilling (approximately 100 000 boreholes are drilled in South Africa per year) is not ending up on the National Groundwater Archive (see above).

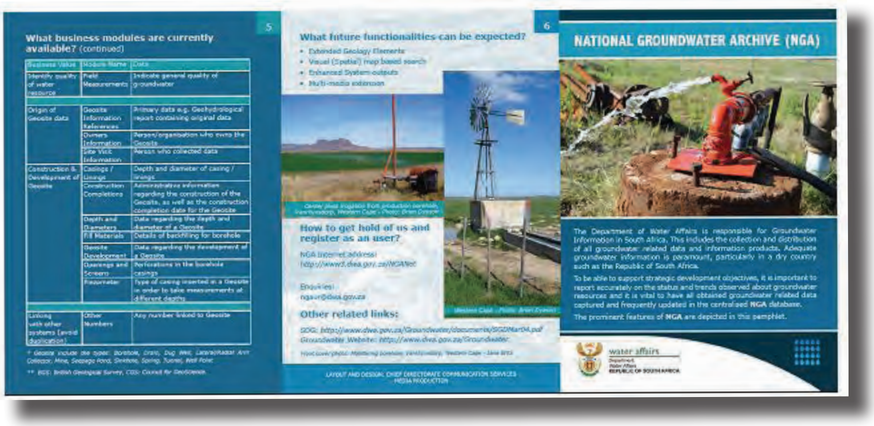
The National Groundwater Archive, the successor of the National Groundwater Database, has become a lot more user-friendly and accessible to users in recent years. Importantly, users can now upload and control their own data.

All of the international examples show a move towards more data-intensive groundwater assessment methodologies. In South Africa this need not entail only the collection of new data – much data that is already generated in South Africa (e.g. by private consultants and drillers) is currently difficult to access. It is likely that a process to centralize "private" data would be a very cost effective and rapid way of expanding national groundwater data archives.

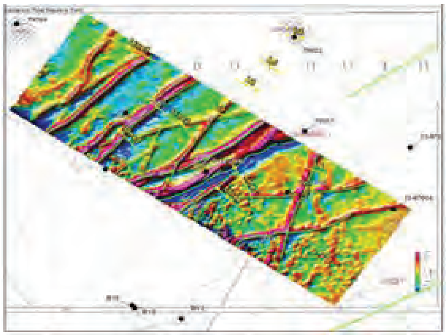
Continuation of groundwater resource assessment

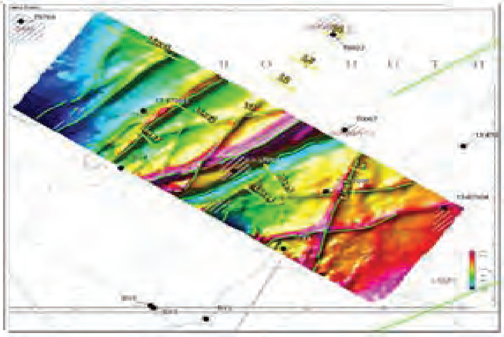
Assessment of groundwater resources at all scales will have to continue and even intensify. Some of the issues for the near future are the potential impact of shale gas development and deep groundwater exploration, e.g. dolomitic groundwater under Kalahari in much of the north west of the country (see Emerging Issues).

While there is a lot of expertise in the private



Contours from dual airborne magnetic survey (C. Monokofala and F.E. Wiegmans, 2013)





sector (example above) which can be mobilised through the Water Research Commission, the Department will have to remain a lead partner.

Information management a strategic requirement

To transform water management in South Africa from a highly centralized to a strongly devolved and participative approach, information management will need to become a strategic requirement. This is particularly important for groundwater governance – 'national facilitation of local actions'. A rapidly increasing number of stakeholders at all levels will have to provide groundwater data and will need information support. A groundwater information system must lead and maintain this whole process, created and sustained by vision and commitment and anchored in legislation. Some critical success factors will be:

- Dynamic system (continuously updated and adapted)
- Participative and client-driven development
- Appropriate technology to achieve participation and effectiveness
- Central direction, coordination and maintenance
- Openness to all

Recommendations

Groundwater data requirements have increased dramatically in South Africa. Much data that is already generated (e.g. by private consultants and drillers) is currently difficult to access. A process to centralize "private" data is seen as a very cost effective and rapid way of expanding national groundwater data archives. Regulations should be developed in this regard in consultation with the groundwater industry;

A research project could be considered in which the expected flow of data and information from and to different stakeholders and levels is analysed to arrive at a streamlined flow of information and appropriate processes/systems to manage it;

A vast amount of groundwater information is available and needs to be appropriately publicized. The brochures accompanying the 21 general hydrogeological maps of the country are particularly useful in this regard. The remaining ten brochures need to be printed without delay.

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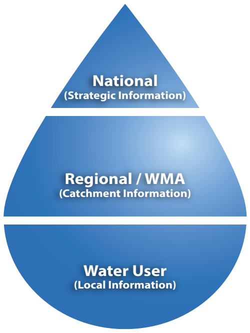
Groundwater Resources Monitoring

Monitoring at a number of levels

Ongoing monitoring is essential to be aware of the state of a system and its response to external impacts and management interventions. Monitoring takes place at a number of levels in support of management at these different levels. Besides establishing national monitoring programmes, the Act also requires the Minister to establish mechanisms to coordinate the monitoring at the different levels.



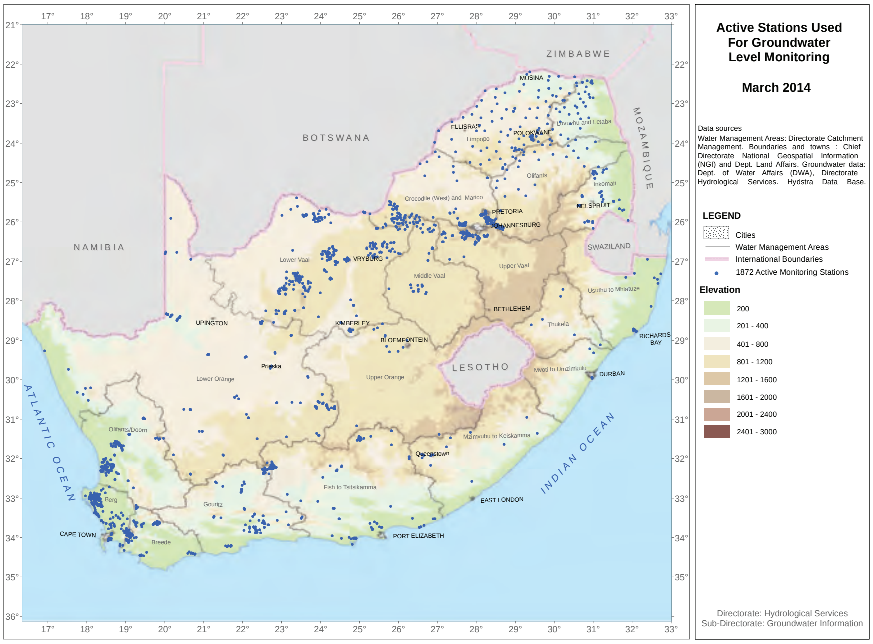
Hierarchy of information requirements for management of water resources

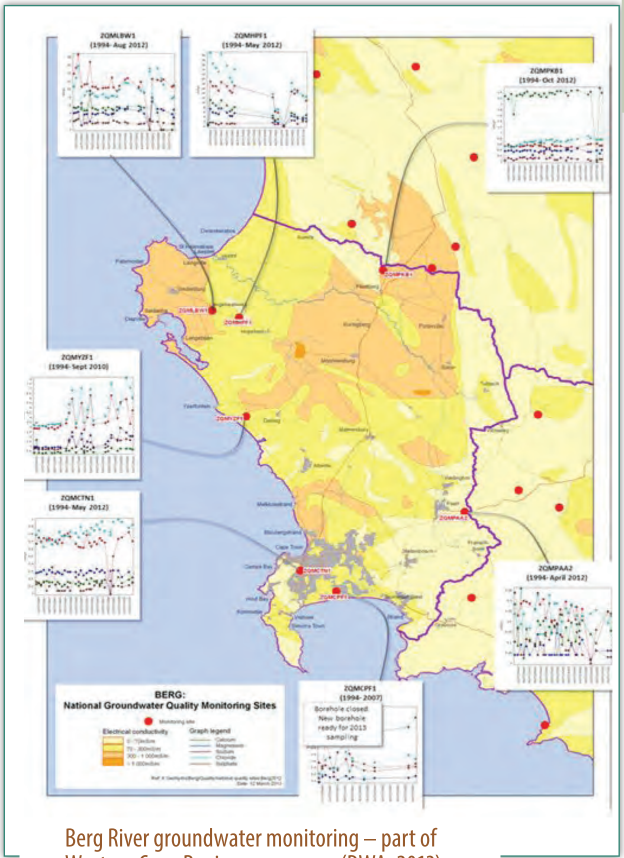
While monitoring of our rivers and dams has started around a hundred years ago, only a few groundwater level records are longer than fourty years. The map of national groundwater level monitoring stations (see below), still shows large blank areas and investment into groundwater monitoring is about 15% of that for the surface water network (DWAF, 2004).

The regional level monitoring, presently undertaken by the DWA Regions, depends completely on individual regions' priority and capacity.

Stakeholders are starting to realise the importance of monitoring. In the Limpopo Region, for example, the Premier regularly requests the quarterly monitoring reports and in the Western Cape Region the information is made widely available to stakeholders.

National groundwater level monitoring stations (DWA, 2014)





Berg River groundwater monitoring – part of Western Cape Region progamme (DWA, 2013)

Example of findings from the Western Cape groundwater monitoring

In the Berg WMA the normal seasonal groundwater level fluctuations are evident.

In the West Coast and Cape Flats area there is an overall long term general decline since 2001. Water levels declined abnormally steeply since October 2010, in the absence of the normal recharge during the winter rainfall season of 2011. The decline may be the combined result of abnormally low rainfall in the area, together with increased abstraction due to the lack of rainfall. The better rainfall in the 2012 winter season did not do much to reverse the downward trend.

No groundwater water quality deterioration trend is observed.

The establishment of new boreholes is planned in areas where there are no representative boreholes for groundwater level monitoring at this stage (e.g. Diep River and Berg Baseline monitoring routes).

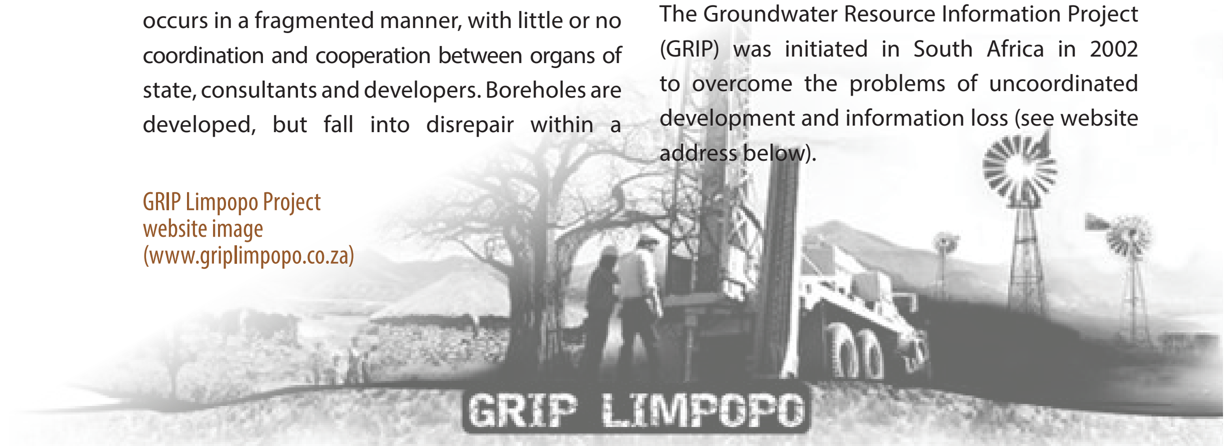
DWA (2013)

Groundwater use and infrastructure information

A critical aspect which is not monitored at all at this stage is groundwater use and groundwater infrastructure. Looking behind the scenes, one often finds a shocking wastage of investment. Groundwater development occurs in a fragmented manner, with little or no coordination and cooperation between organs of state, consultants and developers. Boreholes are developed, but fall into disrepair within a very short time — nobody wants to take responsibility.

Information about such development is very quickly lost and new drilling very often takes place within a few years. Water resource planners widely see these failures as unsustainability of groundwater sources.

The Groundwater Resource Information Project (GRIP) was initiated in South Africa in 2002 to overcome the problems of uncoordinated development and information loss (see website address below).



GRIP Limpopo Project website image (www.griplimpopo.co.za)

GRIP is a systematic approach to gather, verify, upload and use field data on boreholes and equipment to provide planners with appropriate site-specific as well as area-wide information on already developed groundwater infrastructure. A GRIP survey of Capricorn District in Limpopo (five local municipalities, 60-100% reliant on groundwater) illustrates the situation. Only 25% of the existing boreholes are in use, 22% are destroyed and the status of 53% of them is not verifiable (Cobbing et al., 2013).

A statement on the website illustrates the role and importance of the approach.

"If the GRIP data had been available during the drought of 1992 to 1996, 70% of the water crisis could have been solved without having to spend any money."

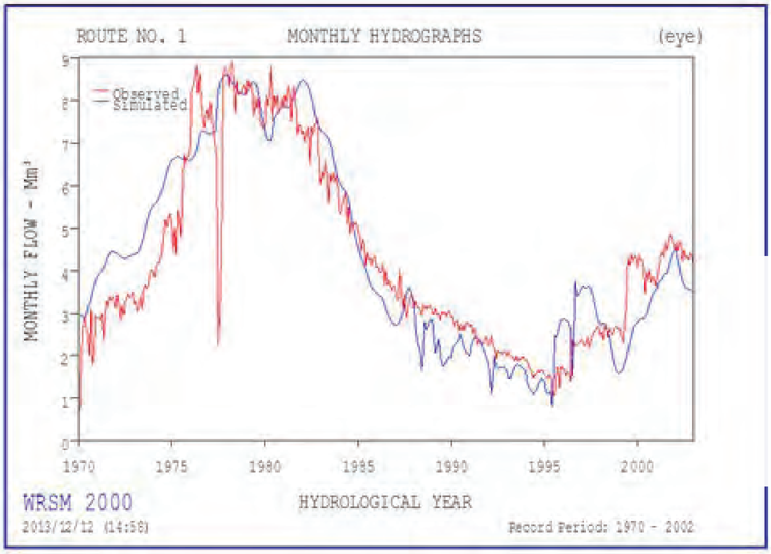
The uniqueness of this initiative is that it is funded from the water supply budget rather than the hydrogeological service budget (Botha, 2005). Despite the proven benefits of GRIP in Limpopo province, adequate budget has not yet been found in the other provinces to fully roll out a similar initiative there.

Integrated monitoring

With the National Water Act, 1998 came the recognition in law that water occurs in many different forms which are all part of a unitary, inter-dependent cycle and which require an integrated approach to its management. The immediate consequence was that the new instruments for resource allocation and protection in the Act all required dynamic groundwater information, compatible with the widely available surface water flow measurement time series and hydrological model simulations.

With the revision of the 'Water Resources of South Africa' as part of the WR 2005 project in 2005 the bold decision was taken to include groundwater in the same way as surface water in the assessment and address the interaction between these two components of the hydrological cycle.

The only way this could be achieved within the project time period was to develop and include a groundwater module into the well-known Pitman hydrological model, which had served surface water resource assessment in South Africa for the last 40 years.



Calibration of the Schoonspruit Eye Catchment with the revised Pitman Model (WRC, 2014)

The model could be verified by comparing simulated flow against measured flow in 105 quarternary catchments across a broad range of rock types and climatic zones. On the previous page is a typical verification of the model in the Schoonspruit eye catchment (WRC, 2014).

The model makes provision for very practical and often required interactions and is starting to be used in a variety of regulatory instruments, e.g. the setting of Resource Quality Objectives (Sami, 2014):

- Baseflow discharged from regional aquifers to river channels;
- Interflow occurring from saturated zones and high lying springs above the regional aquifers;
- Transmission losses from surface water in situations where the aquifer water table is in contact with the river;
- Groundwater baseflow reduction and induced recharge caused by pumping of aquifer systems in the vicinity of rivers.

To improve the above essential groundwater tools, it is crucial that groundwater abstraction monitoring and groundwater level monitoring becomes much more widespread, and that groundwater and surface water monitoring becomes more integrated. Remote sensing will have to play a major role here to achieve region-wide coverage. This will provide the basis for much improved modelling of the groundwater part at the same level as has been possible for surface water for 40 years already.

Recommendations

A critically important DWS project is presently underway to review and plan all monitoring together with key partners like the WRC and the South African Environmental Observation Network (SAEON). This opportunity should be utilized to address the lack of systematic groundwater resources and abstraction monitoring in large parts of the country and achieve a more integrated monitoring with surface water;

Greater integration of groundwater resource and groundwater use information is essential;

Ways of extending and financing the GRIP programme in all DWA regions to gather information on existing groundwater infrastructure need to be found;

Only through the registration of drillers and systematic record keeping of boreholes can this wastage of groundwater infrastructure ultimately be stopped.

Regular monitoring of groundwater levels (Smart, 2013)

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Groundwater Research

The WRC operates in terms of the Water Research Act (Act 34 of 1971) and its mandate is to support water research and development as well as the building of a sustainable water research capacity in South Africa. The WRC serves as the country's water-centred knowledge 'hub', leading the creation, dissemination and application of water-centred knowledge, focusing on water resource management, water-linked ecosystems, water use and waste management and water utilisation in agriculture

First WRC groundwater research

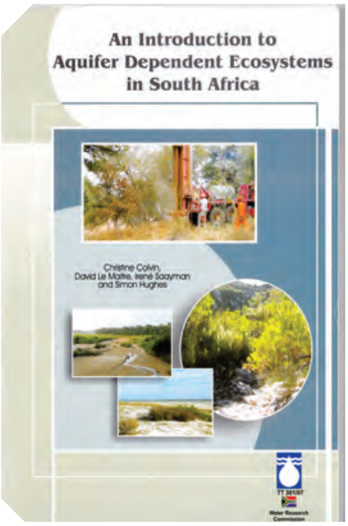
The first WRC groundwater-related research project, initiated in 1974, dealt with the recharging of stormwater into the Cape Flats aquifer. The initial research focus was on resource characterisation and groundwater technology. The investment from the WRC in these areas over the years has undoubtedly led to a greater understanding of South Africa's complex aquifer systems, and finding ways to effectively manage them.

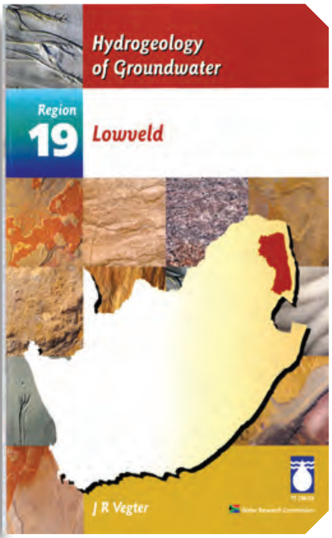
Since 2000 a greater resource management focus within an integrated water resource management framework was added to the WRC research portfolio. This progression of research focus reflects the progression of groundwater attention nationally, before and after the promulgation of the National Water Act in 1998.

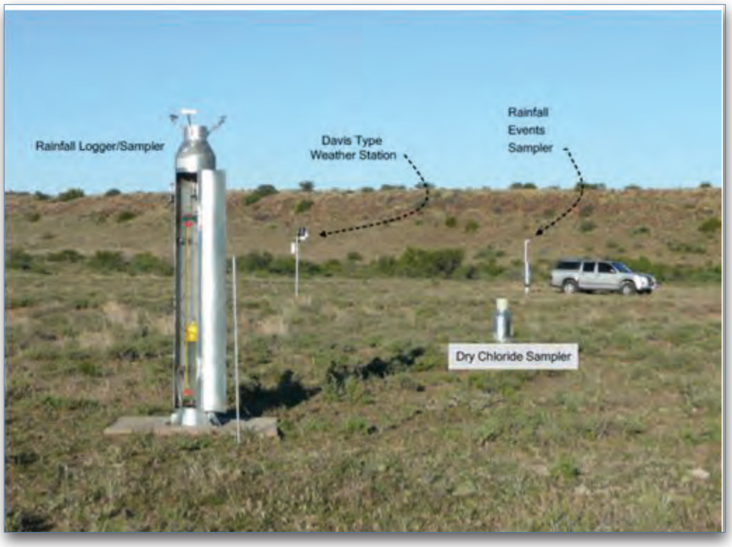
Funding

Funding for groundwater projects has varied between 6% and 16% of the Commission's annual research spending. In 2012, more than R5m was invested in groundwater projects, with another R2.8million in 2013. The current areas of focus include groundwater-surface interactions and improving understanding of South Africa's vast fractured rock aquifers in terms of hydraulic behaviour and chemical characteristics. Another focus is around building, understanding and developing the necessary tools for groundwater management at the local (i.e. municipal) level (Adams, 2013).

Projects are also intended to build research capacity in certain areas. A case in point is the present research into the use of isotope







A special purpose network configuration for monitoring the hydrological state variables required for estimating groundwater recharge – De Hoop Poort monitoring site (Van Wyk, 2011)

hydrology to characterise and assess water resources, in particular the linkages between different systems. This important research field requires very specialised knowledge and laboratory infrastructure, which was slowly being eroded and needed to be revived.

Research findings are widely publicised in attractive research reports and publications like Water Wheel and Water SA and are easily accessible through the WRC Knowledge Hub (WRC, 2013).

Research partnerships

Partnerships with research clients like the Department Water and Sanitation, in research planning and implementation are crucial, from focusing the research to facilitating its roll-out. Many projects cannot do without the infrastructure of government, like drilling rigs, monitoring equipment and laboratories. Most of all, human capacity development for the sustainable development and management of our water resources, requires projects which can lead to a Masters or PhD DWS employee.

The Institute for Groundwater Studies in Bloemfontein, as example of a partnership cooperation, was able to bring understanding to groundwater recharge processes in arid environments, which would not have been possible without years of sophisticated observation across a vast area (van Wyk, 2011).

All this indicates that government needs its own water resources research capacity. It was for this reason that the Department established its Hydrological Research Institute in the 1970s. Areas of expertise included water quality monitoring and remote sensing of catchment processes. Most important, however, was the Institute's close linkage, on behalf of the Department, to the external research establishment.

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Local Level Management

Community water supply

The introductory section on groundwater governance has highlighted the need for a very high degree of participative management required in the case of groundwater resources. This was certainly the intention of the National Water Act, 1998 – devolution of management as far down as possible, so that everyone can participate. On the other hand, the discussion in this publication so far has largely focused on the national level of groundwater resources management. This illustrates where the focus in South Africa has been to date.

Appropriate local action has, however, become crucially important, because the most strategically important groundwater service, that of domestic water supply, is being very poorly managed at the local level at this point in time.

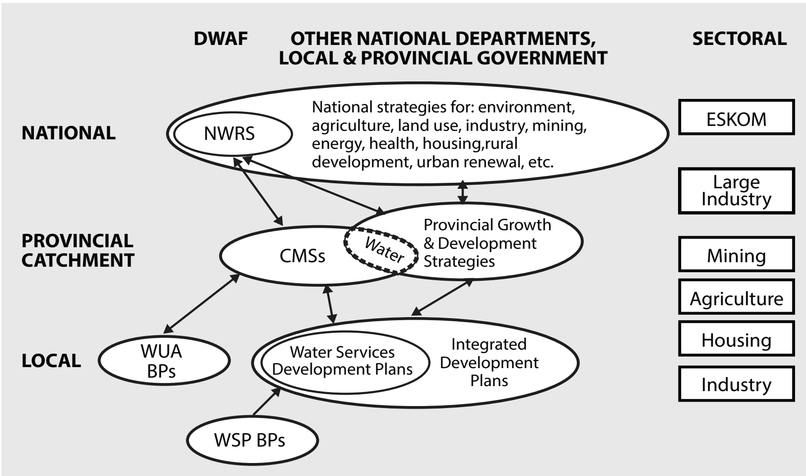
A key reason for this problem is that the intended devolution of water resources management to Catchment Management Agencies (CMAs) and supporting management institutions, in particular Water User Associations (has not yet taken place in any significant way, see figure below). Inexperienced and non-capacitated municipalities, already struggling with their supply function, also have to develop and manage their local groundwater resources, without adequate support.

In the following sections the focus will be on the challenges of sustainable groundwater development and management at local level and the 'national facilitation' requirements to make it happen. This is clearly a national priority at this point in time and cannot wait for the roll-out and empowerment of CMAs.

Progress since 1994

South Africa has made tremendous progress in providing safe drinking water to its citizens since 1994. The White Paper on Water and Sanitation, released in November 1994, had emphasized the political importance of a speedy delivery of water and sanitation services, ensuring that all

Water-related cooperation in a National Planning Framework (DWAF, 2004a)



South Africans can have access to basic water supply and sanitation services – defined as a standpipe supplying 25 litres per capita per day within 200 m of the household and with a minimum flow of 10 litres per second (DWAF, 2004b).

In line with the interim Constitution, the White Paper confirmed that the long-term goal was to have democratic local government take responsibility for both providing and sustaining water services. Various interim measures were undertaken until local government came in place after the elections of 2000. These included (DWAF, 2004b):

- Extending the mandate of the water boards in order to enable them to provide water services directly to end consumers
- Using Mvula Trust, an NGO, established before 1994, to promote the delivery of water and sanitation services on the principle of community-led development.
- Introducing an arrangement with private sector partners to Build, Operate, Train and Transfer (BoTT) schemes under contract to speed up service delivery since 1997.

Local government in a new role

The emergence of wall-to-wall local government required the development of a sector-wide approach to water services that would build a partnership between all the institutions concerned. Water Services Authorities were "responsible for ensuring access to water services" and as such have a governance function and Water Services Providers could be appointed for a delivery function. The Masibambane programme (Zulu for "let us work together"), assisted by strong international donor support and a single-window funding arrangement, introduced the partnership approach.

Shortly after the 2000 local government elections, government decided to consolidate the various parallel programmes for municipal infrastructure funding into a single Municipal Infrastructure Grant. This would be channelled directly to municipalities according to an allocation formula.

Whereas the 1994 White Paper focused on the interim role of DWAF in the direct delivery of basic services to people living in rural areas, the Strategic Framework for Water Services established in 2003, mapped out a vision for how the water sector as a whole will work

from The Mvula Trust Website (www.mvula.co.za/)

in providing water services. DWAF would no longer normally be directly involved in operating any water services infrastructure or funding any new infrastructure. It will, however, continue to set the policy frameworks and oversee and regulate the activities of all water service institutions.

The passing of the Municipal Systems Act (Act 32 of 2000) had confirmed that Water Services Development Plans were an integral component of the municipalities' Integrated Development Plans, and as a result a more systematic culture of planning was developed in municipalities during this period. For its continued support role, DWAF developed Water Services Development Plan Guidelines and a national Water Services Development Plan reporting system (DWAF, 2004a).

International context

It is interesting to view the institutionalisation of community water supply in South Africa in an international context. Internationally, for many years, community-based management has been advocated, particularly where state institutions are unable to operate or manage rural water supplies. There is now acknowledgement that communities either cannot or do not manage rural water supply systems in isolation, but do need support. Lockwood and Smits (2011:12) state that

"A tipping point may now have been reached with more and more national governments and development partners beginning to recognise the scale of the problems associated with poor sustainability and the real threat this presents to achieving the WASH Millennium Development Goals." "Moving from an unimproved to an engineered water supply actually increases dependence on external organisations to provide support. If the support does not follow, then systems fail."

In a recent conference paper, Parsons discusses a small-town groundwater supply in South Africa and notes: *"To harness the benefits of groundwater, groundwater schemes have to be based on proper exploration, good management and monitoring."* (Parsons, 2013:6). In general, a greater role for formal organisations (often local or regional government) is being recognised in the search for sustainable rural water supplies.

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Local Government

as Water Service Provider / Authority

Municipal government

From 2000, with the advent of wall-to-wall municipal government and the introduction of local government in the former 'homelands' for the first time, responsibility for managing thousands of groundwater schemes was transferred from DWAF and community management structures to new municipal administrations. In essence there was a decentralization of management responsibility from DWA 'down' to local government, and centralization of operational responsibility 'up' from community management structures to local government.

Wide-spread failure of groundwater schemes

Since then there have been many reports of scheme failure, starting with the much publicized Dinokana in 2004 and Delmas in 2005. We do not have an overall figure of performance of groundwater schemes, because there is not yet enough attention to compliance monitoring. Most smaller groundwater supplies are not covered by the Blue Drop reporting system.

The available evidence suggests that the reasons for failure have less to do with hydrogeology and aquifer yields than with the operational requirements of sound groundwater management. Operational management requirements are comparatively straightforward, but they do require attention to logistical detail, and this requirement exposes vulnerabilities in the institutional capacity of many water services providers; the large number of dysfunctional village boreholes in Limpopo and elsewhere is a case in point. A high yielding aquifer is necessary, but not sufficient; what matters more is the capacity of the available human resources to operate and maintain potentially hundreds of boreholes and localized supply schemes dispersed across a wide area within a municipality, and to attend to the logistics of delivering fuel, spares and maintenance personnel timeously.

Failure of groundwater supply 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 or on other causes such as electrical supply failure. It is common to hear that "the borehole dried up", or "the groundwater ran out". 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. 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. Unsuitable pumping regimes can cause infrastructure failure in several different ways. *For example*, a pumping regime which draws groundwater levels down excessively for short periods can introduce air into the aquifer and cause bacterial growth which leads to blockage (biofouling) of borehole screens. Precipitation of iron or manganese can also occur. High flow rates can mobilize silt or sand, leading to rapid pump wear, and pumps can also overheat and burn out if water levels drop below their intake shrouds. The "failure" of the groundwater resource at Prince Albert in the Western Cape Province to meet the town's summer demand was quickly traced to inappropriate management actions, including a lack of monitoring and unsuitable pumping regimes. Once these were fixed, the groundwater supply scheme was able to meet the demand.

The Water Wheel, 2011

Groundwater-based systems are typically used in small scattered settlements – which are precisely the areas where the institutional resources capable of supporting reliable delivery of fuel and spares, quick dispatch of spares and ready access to skilled maintenance personnel are least likely to be found.

A typical groundwater supply setup

The town of Mahikeng is the provincial capital of North West Province, and is the seat of both Ngaka Modiri Molema District Municipality (NMMDM) and Mafikeng Local Municipality. The town itself has a population of about 70 000 people, and the peri-urban villages surrounding Mahikeng have a total population of about 230 000 people. Roughly 75% of the town's supply is from groundwater, whilst if the peri-urban areas are taken into account, roughly 90% of the population of NMMDM is reliant on groundwater.

The yield of the Grootfontein wellfield supplying the town has declined considerably due to other abstractions in the compartment (leading to falling water levels) and other factors such as pipeline breaks. Botshelo Water operates and maintains a large number of the rural and peri-urban single-sources, including 358 boreholes in 30 villages in the NMMDM area and 97 boreholes in 46 villages in the Kagisano Molopo Local Municipality area and maintains the following infrastructure on behalf of the municipalities:

- 95 Diesel Engines
- 56 Electric Pumps
- 88 Hand Pumps
- 119 Wind Pumps

Groundwater contamination

Most geohydrological assessments of groundwater quality focus on physico-chemical parameters; chemical indicators are comparatively stable and do not require frequent monitoring. Many municipalities make little effort to monitor, manage or protect the quality of abstracted groundwater, in part because it is widely believed that groundwater is free of microbial contamination because of underground filtration. But there is growing evidence that the quality of water from many boreholes is poor – mainly as a result of human and animal faecal contamination – and warrants disinfection. This adds an important dimension to groundwater sustainability challenges: in a context where a significant proportion of the population is immune-compromised, good water quality management is imperative. Yet monitoring water quality regularly across numerous sites requires commitment and attention to logistical detail; the same applies to disinfection. Protocols are available for establishing on-site sanitation and for siting of boreholes to minimise contamination from pit-latrines, but there is no information on how regularly and effectively such guidelines are used.

Perceptions of groundwater

There is widespread wariness of groundwater as a source of municipal water in South Africa.

Despite the raised profile at a national planning level, experience on the ground indicates that many municipalities only turn to groundwater as a last resort. During recent droughts in the Southern Cape, for example, around 100 boreholes were drilled to relieve critical water shortages in towns such as Plettenberg Bay, George, Mossel Bay, Sedgefield and Knysna. In all instances, the target expected from groundwater source development were met or exceeded. However, only Sedgefield and Plettenberg Bay made use of this water during their greatest time of need (particularly between 2008 and 2009) and as far has been ascertained none of the boreholes have been brought into permanent production. Instead other alternatives schemes have been undertaken, such as desalination plants (Water Wheel, 2011).

Groundwater perceptions

Overall, groundwater is perceived by many (if not most) municipal role-players and communities as an unreliable and difficult source to manage, and they have a marked preference for surface water sources – ideally with bulk potable water supplied by a water board.

• Schemes with a high ratio of initial capital cost to ongoing operation and maintenance cost may be preferred by contractors and consultants, which will favour bulk (often surface) water schemes. This may be because bulk schemes are better understood, but may also be due to a simple profit motive.

• Operation and maintenance budgets at municipal level come under pressure from other budgetary demands throughout the financial year, and planning O&M under such circumstances is difficult.

• There is a lack of skilled technicians and other O&M specialists, particularly in small towns and remote areas where many groundwater schemes are found. Such people must be able to repair a variety of problems and have skills in various areas – in other words, a "Jack of all trades" – and such people are particularly rare.

• The licensing process has been a clear hindrance to groundwater development country-wide. It is a complicated process and can take 3-4 years for a license decision (e.g. Hopefield, Hermanus). This is also why consulting engineers with water supply contracts, shy away from groundwater sources, despite the DWS Planning strategy prioritizing local groundwater sources.

Adapted from (Cobbing et al., 2013 Del. 2)

An important contributing factor to this situation is that there are few remaining groundwater champions at high level in the Department Water and Sanitation (let alone in government more widely) to drive the sectoral debate and promote awareness of the contribution groundwater can make to safeguarding national water security and addressing service backlogs.

Operation and maintenance

There is very high agreement that carrying out O&M on groundwater sources results in lower costs and higher reliability overall.

Benefits of O&M

A recent cost-benefit study of groundwater supplies for rural areas in developing countries found that:

• Almost 40 times more benefit, than cost, is provided with a properly constructed, operated and maintained well system.

• A 3- to 5-fold increase in net value is realized with the implementation of an operation and maintenance (O&M) program.

• Neglecting O&M results in much more substantial loss of overall value than most people realise. As Taljaard (2008:42) states, "Basic first-line maintenance is an absolute necessity for sustainable operation of any borehole and plant and should be conducted conscientiously."

At present capital costs tend to be considered in far more detail than recurrent costs. Groundwater sources in South Africa today are attended to only when they fail, and indications are that this is a more costly approach than providing for on-going O&M.

Cobbing, et al. (2013 Del. 3.)

Compared with the guidelines and technical products for borehole drilling and siting, there is little in the public domain on either the recommended or "best practice" ways to operate and maintain groundwater sources, or on the best mechanisms for establishing operation and maintenance procedures and organisations. Little is available on either the true costs of borehole O&M or on the recommended spending on borehole O&M as a proportion of capital costs.

Hermanus success story

Hermanus is a rapidly expanding town on the Cape south coast. Since 2002 the town has employed professional groundwater expertise (Cape Town-based Umvoto Africa) when it became clear that surface water resources would no longer meet the needs. Since then three wellfields have been developed, with the potential of supplementing the annual municipal allocation from De Bos Dam of 2.8 million m^3 by a maximum of 3.2 million m^3 of groundwater per year.

An adaptive groundwater management process is followed based on ongoing monitoring and evaluation of the groundwater sources (Water Wheel, 2013 and Riemann, 2014):

- All production boreholes equipped with flow meters that automatically record pumped flow every 30 minutes;
- All wellfields equipped with continuous groundwater level monitoring boreholes
- Far-field monitoring boreholes in which groundwater levels are measured every three months;
- In the wellfield close to the sea, electric conductivity as measure of salinity is recorded every 30 minutes and pumps will shut down automatically at pre-determined water level or water quality levels;
- Comprehensive water quality monitoring of all boreholes takes place every three months;
- Umvoto Geohydrologists look after the monitoring network and keep an eye on the well fields;
- A hydrogeological model of the groundwater system has been developed and is periodically updated and refined with the knowledge gained from the ongoing data collection;
- Remote sensing images are analysed regularly at selected sites for detecting possible impacts of abstraction on vegetation, wetlands and other special habitats;
- All the data collected in the monitoring programmes are used by Umvoto to compile a comprehensive annual report as well as an interim report in mid-year. These are presented to monitoring committees made up of representatives from the Overstrand Municipality, Breede-Overberg Catchment Management Agency, conservation agencies and NGOs, ratepayers associations, local landowners and other interested parties.

The three Hermanus wellfields and associated monitoring sites.

A production borehole in the Volmoed Wellfield overlooks the lower Hemel en Aarde Valley.

The thorough and transparent approach followed has paid dividends in terms of allaying fears amongst Hermanus residents that the 'hidden treasure' of groundwater will be plundered. It will no doubt also help increase confidence in other municipalities that aquifers can provide a viable and cost-effective alternative to surface water supplies. This will require that hydrologists will stay involved in the management of wellfields they have developed to ensure that they are properly operated, and that recommendations for sustainable pumping are followed.

Recommendations

Supply of safe drinking water is the most important water service from groundwater world-wide. Given the serious problems in this service experienced in recent years, it is essential that specific capacity building is targeted at municipalities in cooperation with the whole sector, in particular the Department of Cooperative Governance and Traditional Affairs, the Local Government SETA, the South African Local Government Association (SALGA) and the Institute of Municipal Engineers of Southern Africa (IMIESA);

As basis for capacity development and support, an analysis is required of the relevant vocational and professional inputs into groundwater management, and the relationship between these in terms of planning/oversight/analysis/direction/operation rules;

A champion needs to be found within municipalities who is respected and understands/speaks the local government language and sees groundwater management issues and solutions within the municipal environment. It is crucial to collect and tell the success stories of community water supply from groundwater to counter the growing perceptions that groundwater is an unreliable source;

Practical guidelines on all aspects of groundwater scheme O&M and institutional arrangements in this regard need to be developed urgently.

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Rural Water Supply

Rural water supply

Rural backlog

The remaining 5% of households not served yet with a basic water supply tend to be in the rural former "homeland" areas of the Eastern Cape, KwaZulu-Natal and Limpopo Provinces. Groundwater has the potential to supply dispersed rural communities where surface water schemes may become prohibitively expensive or technically difficult. This is despite the reluctance to use groundwater by Water Services Authorities (WSAs) and the variety of incentives which seem to favour more centralised surface water options.

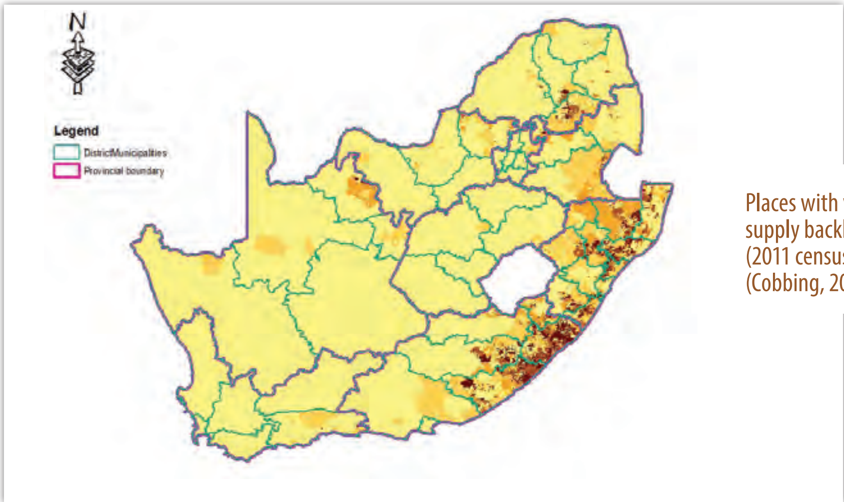
However, it must be noted that the very issues that led to a groundwater supply being chosen in the first place such as scattered rural communities, logistical and infrastructural difficulties and limited maintenance capacity are often the very issues that also mitigate against the long-term reliability of the groundwater supply.

Community-based operation

Experience has shown that these deep rural areas cannot be served sustainably without some form of community involvement. In South Africa, for various reasons, this has not been the approach, except where Mvula Trust had been involved in the initial years. It can be expected that in the challenging remaining backlog areas, a balanced approach will probably be the answer, going for community involvement strongly supported by local government and facilitated by national government.

Based on experience in the Eastern Cape and wider, Gibson (2010) highlighted some advantages of community-based operation:

- Local work done best by local people
- Immediate source of information for operational reports
- Customer relations
- Reduction in vandalism
- Efficiency of operations (and ability to respond immediately to breakdowns)
- Increased job opportunities at a local level
- Relatively easy and quick to mobilise



Places with water supply backlogs (2011 census) (Cobbing, 2013)

At the time when District Municipalities inherited the responsibility for many rural schemes from the Department of Water Affairs and Local Municipalities, the Alfred Nzo DM in the Eastern Cape in 2001, implemented a pilot project to investigate requirements for the successful implementation of a Community Based Organisation (CBO) service delivery approach for rural water services. The Chris Hani DM recognised the successes achieved in ANDM and implemented a similar programme in 2004. The challenge of the operation can be seen from the attached table below.

Areas served with CBO approach (Gibson, 2010)

	Villages served	Households served
Alfred Nzo District Municipality (2002-2005)	144	27 154
Chris Hani District Municipality (2004-2009)	285	40 283

Elements of a community-based approach

A community committee

Data collection by committee

Key data set: tap days (tick forms for each tap each day – working / not working)

Individual monthly report produced out of this

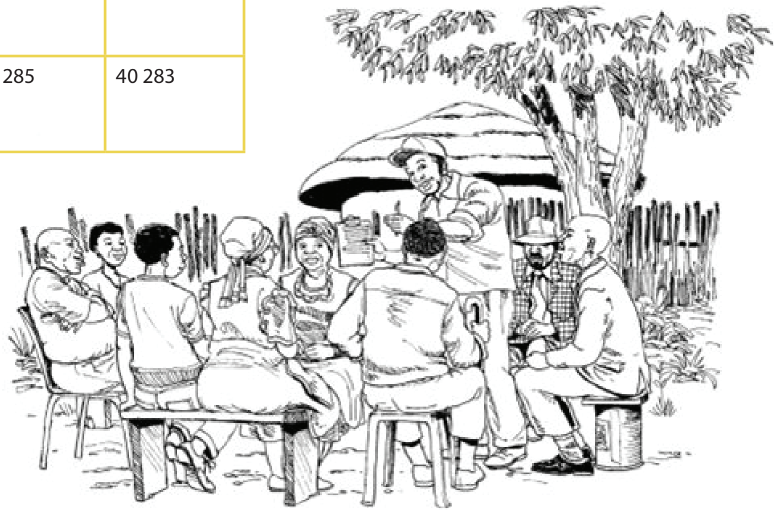
Problem reporting by phone (this makes a 1 day response time possible)

Response by maintenance team (drivers licence and basic plumbing skills required)

Emergency team for more serious problems (electromechanical artisans)

Monthly support/control visits with cash payment based on satisfactory monthly report

Gibson (2014), Personal communication



Involving Communities in Hydrocensus DWAF (2004) NORAD-assisted Programme

A cost analysis of rural schemes showed that O&M costs can be remarkably stable month-on-month, that they are made up mainly of salaries and travel expenses, that borehole sources cost a similar amount to maintain compared with gravity (spring) sources, and that the cost per kilolitre of water supplied can be reasonable even in remote areas. These things all hinge on a successful O&M strategy, however (Gibson, 2010).

To enhance reliability and reduce the maintenance costs of rural water supply schemes, the concept of repair-ability must be given adequate consideration in project design – even the repair of hand pumps, e.g. welding, may be beyond the capability of the localised maintenance team.

The fact that many of the recently constructed small rural water supply schemes have failed

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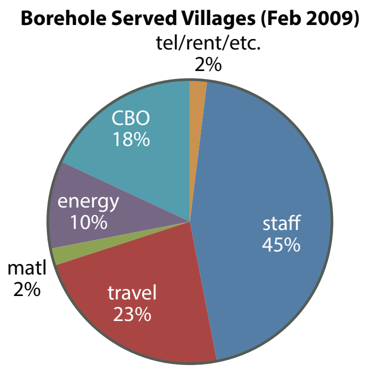
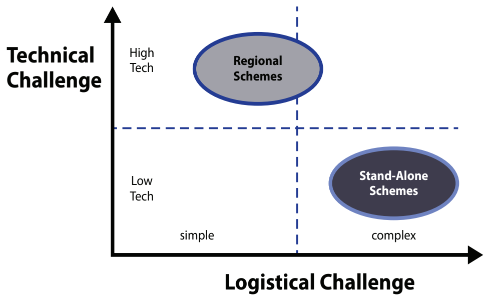


O&M Cost breakdown for borehole served villages (Gibson, 2010)



The Operational Challenge in Rural Water Supply (Gibson, 2011)

to deliver a reliable service in South Africa is influencing planners and managers to recommend that small stand-alone schemes be abandoned and that large regional schemes be constructed. This sentiment is being driven by the complex challenge that water services organisations must address to adequately service numerous remote schemes. However, such a decision results in the exchange of the logistical challenge of many small schemes for a technical challenge associated with 'connected infrastructure'. Experience has shown that the technical challenge tends to be under-estimated resulting in inadequate skills and funding being allocated (Gibson, 2011).

Government is committed to wipe out the remaining backlog and recognises the support requirement challenges.

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Recommendations

A more professional approach to groundwater development in the logistically challenging backlog areas will pay big dividends in terms of scheme longevity and security of water supply;

Groundwater schemes will have to be planned and installed with advice from a qualified hydrogeologist, even at the feasibility stage;

A plan for the on-going operation and maintenance of an installed groundwater scheme must be developed, also with professional groundwater advice;

There is a need for better O&M resources and more standardisation of groundwater abstraction equipment and procedures to make groundwater supplies more robust.

Local Collective
Management Institutions

Some form of regulation and organisation of local groundwater users is generally seen as essential for the sustainable development of the resource. Working cooperatively is new for groundwater users for whom the resource had been their ‘private water’ before the new water legislation. The Act now provides for local level organization through the institution of a Water User Association (WUA). WUAs are defined in the NWA as water management institutions whose members voluntarily agree to undertake water related activities for their mutual benefit. Principal functions of the Association are concerned with management of the water resource or infrastructure. Typical examples (surface water-related) in this category are preventing water wastage or unlawful use, regulating flow of the watercourse, protection of the water resource and monitoring flow quantity and quality. The Minister of Water and Sanitation must establish a WUA, once he or she is satisfied that it is in the public interest and that wide public consultation has taken place.

The case information below from across the country makes it clear that such cooperation is essential, but also illustrates the many remaining challenges:

DENDRON

The Dendron irrigation farming community in Limpopo Province had completely over-exploited their major aquifer system of deeply weathered granite rock. In 1992 the Department of Water Affairs and Forestry was requested by financial institutions and the provincial government to intervene, because of the impact of declining water supplies on the regional economy. After several years of intensive awareness-and capacity-building, local farmers have introduced major groundwater monitoring and conservation measures, which have already turned the system decline around. The initaitive was then serving as example to the water user association establishment process under the new legislation and even to neighboring countries (Bertram, 2002). However, the enthusiasm was broken after long years of unsuccessful application to become a WUA (transformation from an irrigation board) and lack of continuing communication and support from DWAF. Monitoring and participatory management has ceased. Also pollution with elevated nitrates from feritilizer application and high concentration of pit latrines is widespread (Pietersen, 2011).

TOSCA / VERGELEGEN

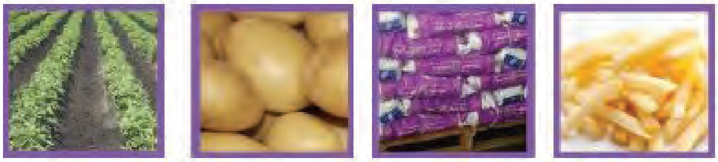
The Tosca/Molopo Water User Association, concentrating on irrigation in the Tosca / Vergelee area to the north of Mahikeng near the Botswana border, was established in 2004 by the Minister of Water Affairs, following the establishment of a pilot committee in January 2001 (Van Dyk, 2005). Control of excessive irrigation volumes is critical in this arid area and was a significant issue in the early stages of the WUA, with DWA taking action against non-compliant users (Van Dyk, 2005). **The current situation with respect to over-abstraction in that area is not known.**

STEENKOPPIES

The Steenkoppies dolomitic compartment near Krugersdorp hosts one of the most valuable resources of groundwater in the country, key to an irrigated agricultural industry worth three quarters of a billion rand and employing thousands of people. Since the 90s the Department has been trying to control over-abstraction, which finally in 2007 led to a crisis downstream in the Magalies River, when eight of the nine springs constituting the compartment’s outflow in the Maloney’s Eye stopped flowing. Control has been hampered by a lack of an adequate assessment of the aquifer potential and of a verified groundwater use from the compartment. Since 2007 the irrigation farmers of the compartment have been trying to establish a Water User Association. It appears that to date the applications have been rejected, because the proposed WUA’s governing board is not yet sufficiently representative of the area, and will need to be revised before final approval is granted. The responsible District Municipality, has up to now shown little attention to this economically important resource in its area, probably due to a lack of understanding of the issues (Holland et al., 2009; DWA, 2010).

SANDVELD

The Sandveld is a very sensitive coastal aquifer system along the Cape West Coast. It has competing users, namely high value irrigated agriculture (seed potatoes), five towns virtually dependent on groundwater and sensitive groundwater-dependent ecosystems. Whatever management there is, is through foresight of Potatoes SA, an association serving the potato farmers. Potatoes SA employs a hydrogeologist to undertake monitoring and make annual management / operational recommendations. The hydrogeologist got involved in area in 1995 through a WRC project – 'impact of agriculture on groundwater'. Monitoring showed seriously declining water levels and a shocked meeting of 300 farmers decided on the employment of the hydrogeologist. Through the active support of the then Department of Water Affairs (drilling and monitoring), a much better monitoring network was achieved. The appointed hydrogeologist now combines all monitoring points including private boreholes and provides water level and water quality information. The big drawback is that Cederberg municipality draws from the same aquifer and has stopped all monitoring – this despite data loggers that were installed in 2005. Reasons for this are not clear – probably new managers and no budgets (Conrad, 2014).



This requires sustainable groundwater systems (www.potatoes.co.za/)

There has been some work on guidelines for the establishment of water user associations, using the dolomites of the North West province as test case. For the five different user associations considered for this aquifer system, the most urgent need expressed was for DWS to intervene and assist with the establishment of the WUAs. Of particular concern to representatives from WUAs are (Stephens and Bredenkamp, 2002):

- defining the optimal boundaries of the WUAs
- the organisational capacity to begin the process of establishing the WUA
- the need for accurate information on water supply and allocations to effectively manage the resources.

A key stumbling block to the establishment of WUAs appears to be the issue of adequate representativity of the whole spectrum of water users, in which the commercial farmer has dominated up to now. On the one hand this issue needs to be addressed, so as not to entrench present inequalities. On the other hand, vulnerable water resource systems, most already beyond the sustainability threshold, could suffer further and irreparable damage, if local participation is not urgently initiated;

Local user participation and cooperation needs long-term support in terms of the institutional processes of WUA establishment, the proper assessment of the resource in terms of boundaries and potential and the establishment of monitoring and information systems for ongoing management. (See

Groundwater abstraction and water quality monitoring by private irrigators (Conrad, 2014)

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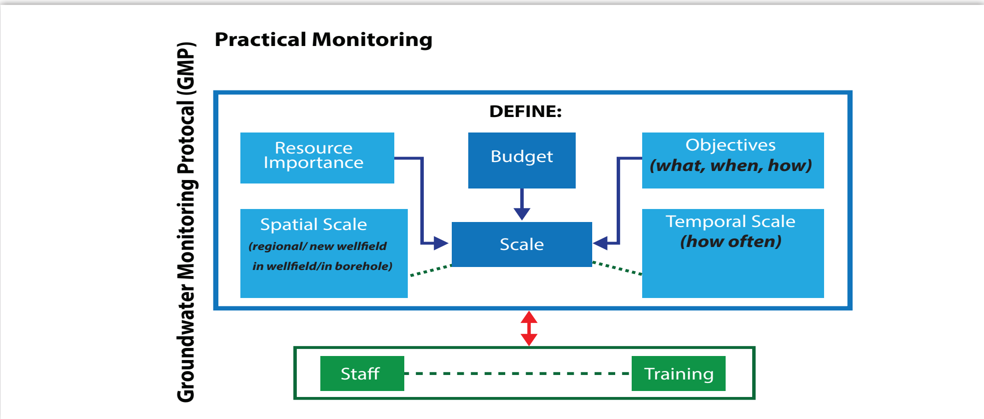
Groundwater Monitoring Protocol example below). DWS its regional offices and geohydrological functionaries have not been able to sustain this support in most instances.

It appears that the Catchment Management Agency as first line of support is a critical missing element. The CMA would introduce the institutional requirements for WUA establishment into its Catchment Management Strategy and would then have to prioritise and resource the implementation as necessary. In this situation, players with capacity, in particular municipalities, organised agriculture and the groundwater consulting fraternity, need to take the lead, under the guidance of the Department of Water and Sanitation and its strengthened groundwater component.



Assistance with the development for a groundwater monitoring network (Conrad, 2014)

Recommendations

Establishment of new local user associations which are essential for sustainable groundwater resource utilization, will require long-term hydrogeological support, in particular with the assessment of the resource and with the establishment of monitoring networks and information management systems. This technical support has to go hand in hand with support towards the institutional processes of WUA establishment and effective water use regulation.

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Groundwater
Management Framework

Based on a literature review and case studies, the Water Reseach Commission has helped to design a Groundwater Management Framework to guide and improve management of groundwater resources at local level of responsibilities, i.e. WSA, WSP, WUA (Riemann et al., 2011). It is to become an overarching guideline for the many existing excellent guidelines already available for specific aspects of the task. Groundwater management includes one or more of the following:

- Aquifer protection
- Groundwater quality management
- Groundwater remediation
- Groundwater assessment
- Groundwater monitoring
- Wellfield planning and design
- Wellfield operation and maintenance.

The different aspects of groundwater management relate to two main categories, viz.

- Aquifer protection, and
- Aquifer utilisation.

Monitoring and data management is a critical part of all aspects of groundwater management and has an overarching role that requires standardisation of the process.

The Framework (refer to the overall structure on the next page) describes for each category separately the different aspects, associated tasks and assigned responsibilities of the relevant institutions. Importantly, the Framework also identifies the different role players, who are, or should be, responsible for some of the above aspects of groundwater management at different levels.

The proper valuation of the groundwater resource is foundational to its sustainable management. Therefore it makes up a special part of the framework and feeds into all aspects of the task into both categories and their sub-categories.

Virtually for all areas of groundwater management, guidelines already exist and can be activated through the Framework (see table).

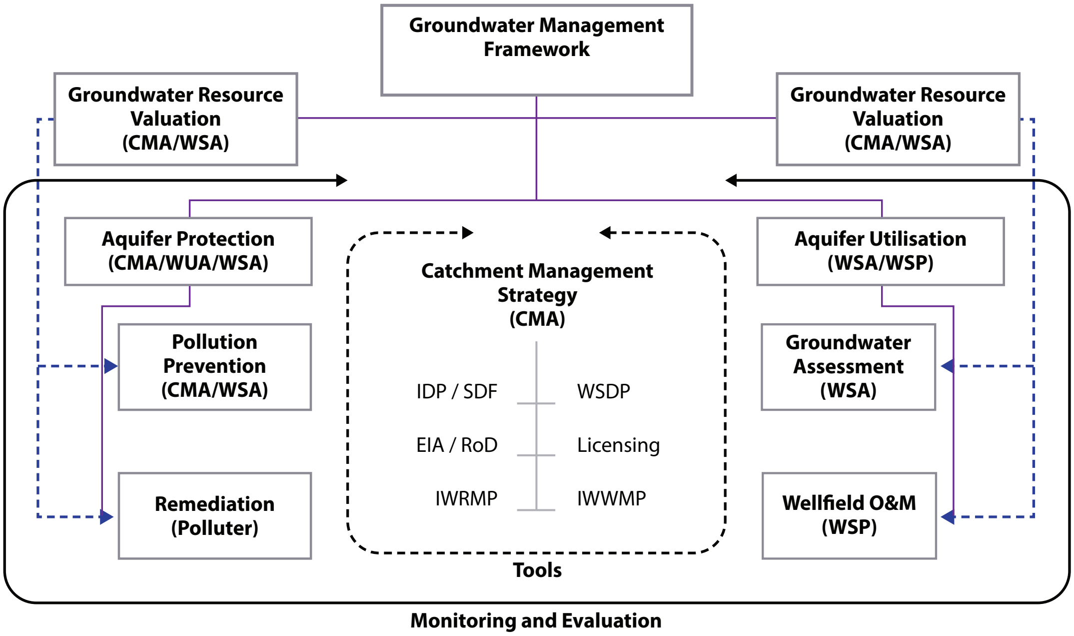
A drive to improved groundwater resources management should also include monitoring the performance according to certain criteria (benchmarking) and advertising the result. The Department calls this Incentive-based Regulation and has two programmes: the Blue Drop Certification Programme for Drinking Water Quality Management Regulation; and the Green Drop Certification Programme for Wastewater Quality Management Regulation (DWA, 2012).

Definition of Incentive-based regulation

"The conscious use of rewards as well as penalties to encourage performance excellence and continuous improvement, based upon an innovative performance rating system."

Participation in Blue and Green Drop Assessments is mandatory.

(Section 62 of Water Services Act, 1997)



Key Existing Guidelines	
Groundwater quality management	Groundwater Quality Management Strategy (DWAF, 2000) Groundwater Resource Directed Measures, Version 3. Software Package developed by the Institute for Groundwater Studies (DWAF, 2007) Integrated Water Resource Management Plan Guidelines for Local Authorities (DWAF & WRC, 2006) Protocol to manage the Potential of Groundwater Contamination from on-site Sanitation (DWAF, 2003)
Groundwater assessment	Guidelines for Groundwater Resources Management in Water Management Areas, South Africa: Integrated Water Resource Management Strategies, Guidelines (DANIDA, 2004) Guideline for the Assessment, Planning and Management of Groundwater resources in South Africa (DWAF, 2008) Groundwater Strategy: Supporting Reports Guideline development for the Assessment, Planning and Management of groundwater resources within Primary aquifers in South Africa Guideline development for the Assessment, Planning and Management of groundwater resources within Karoo aquifers in South Africa Guideline development for the Assessment, Planning and Management of groundwater resources within Crystalline Basement aquifers in South Africa
Wellfield O&M	A Framework for Groundwater Management of Community Water Supply. Produced under: The NORAD-Assisted Programme (DWAF, 2004) Guidelines for the monitoring and management of ground water resources in rural water supply schemes. WRC Report 861/1/02a. (Meyer, 2002)
Groundwater infrastructure development	Minimum Standards and Guidelines for Groundwater Resource Development for the Community Water Supply and Sanitation Programme. (DWAF, 1997)
Institutional development	Analysis for the Preparation of Institutional Arrangements for Groundwater Management in the NWDWA. (Stephens et al., 2002)
Valuation of groundwater	The Economics of Sustainable Aquifer Ecosystem Services: A Guideline for the Comprehensive Valuation of Aquifers and Groundwater (Pearce et al., 2013) Groundwater Management Framework (Riemann et al., 2011)

Criteria	Weighting	**Hermanus**	**Stanford**	**KKRWSS**
1. Aquifer Management Plan	20	13.24	11.44	11.24
2. Integration of groundwater into municipal planning	20	14.56	15.28	11.88
3. Monitoring Protocol	20	20.00	19.00	16.60
4. Operations and Maintenance Plan	20	18.80	14.40	11.20
5. Institutional arrangements for groundwater management	10	8.18	6.30	4.50
6. Authorisation of water use.	10	10.00	6.00	6.75
Total	100	84.78	72.42	62.17

Critical state	<33%
Poor performance	33% - 50%
Average performance	50% - 75%
Good status groundwater management	75% - 90%
Excellent performance	>90%

Application of draft scoring system to aquifers in the Overstrand Municipality (Hermanus and Stanford) and a water supply scheme in the Oudtshoorn Municipality (KKRWSS)

However, Blue Drop water quality management assessment currently does not require municipalities to submit information on small schemes supplied by boreholes, and there is no national picture of municipal water quality management systems for groundwater. A scoring system to assess sustainable groundwater management at municipal level was therefore developed (Riemann et al., 2013), based on the structure of the Blue Drop system for Drinking Water Quality. The scoring system contains a number of criteria, indicators and requirements that are linked to the different aspects of the Groundwater Management Framework and promote sustainable groundwater management at municipal level. Using this approach and the selected criteria (1-6) in a questionnaire action to a number of municipalities, brought the above results (see table above) (Riemann et al, 2013).

Rather than going for a separate groundwater system, discussions with DWS brought the consideration to integrate groundwater and surface water/dam management aspects into a single drop. In that way a municipality with excellent surface water/dam management would not qualify for their "drop", if they still had poorly managed boreholes. This would send a clear message where improvements were still necessary. A strategy will now be pursued with DWS in which the current Blue Drop form is updated to allow for collecting all relevant data and information for the groundwater assessment.

Recommendations

The framework provides a practical summary where and what local groundwater resource management support is required. It should be adopted by DWS as part of an overall strategy to make the management of local groundwater resources work and to provide effective support for this objective;

A strong national groundwater leadership / champion should be established by DWS, together with appropriate national government groundwater support capacity (guidance, regulation, implementation monitoring, information support and ensuring professional assessment and development of groundwater resources);

The Framework and its supporting Guidelines should become official DWS documents, to be updated and improved as required;

The Blue Drop Assessment, updated to allow for the proposed groundwater assessment, should be implemented as soon as possible, as part of an overall strategy to improve local groundwater management.

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Capacity Development

Capacity building is a long-term, continuing process, in which all stakeholders should participate (ministries, local authorities, non-governmental organizations and water user groups, professional associations, academics and others). It is important to note that all levels of capacity development must be addressed, the individual, the institutional and societal levels.

Overall, the country has an excellent capacity in the groundwater resources field, on par with the best in the world. Many new groundwater consulting companies were established throughout South Africa during the past twenty years. There is a strong hydrogeologist and groundwater technical corps, well-coordinated and represented by the Ground Water Division of the Geological Society and the Borehole Water Association of Southern Africa. Appropriate academic institutions were established and wide-ranging research has been undertaken for 40 years and more. The Council for Geosciences, the Department of Water and Sanitation, the Water Research Commission and the CSIR have all been major role players at different points in time. *The capacity challenge in South Africa at this point in time lies at the institutional level.*

Lack of appropriate capacity in critical stakeholders, in particular in municipalities where groundwater has, in many instances, become the sole source of domestic water supply, is regarded by many as the most important factor holding back sustainable development and management of groundwater resources in South Africa.

The Hydrogeological Mapping Programme

The sentence on the concluding composite map for the whole country, prepared by the mapping team of the Department of Water Affairs in 2004 speaks of growth and achievement:

"This is an acknowledgement and recognition of all the individuals involved in the compilation of the 1:500 000 Hydrogeological Map Series of South Africa. Considering the divergent hydrogeological conditions of the country, the novel mapping concept, and the learning curve for all involved, the completion of the Map Series signifies a landmark achievement."

The task was completed over a period of nine years. Each of 21 different maps was authored or co-authored by a Departmental member of staff. The mapping team consisted of 33 people (Geohydrologists, GIS specialists, Cartographers and Technicians) stationed at Departmental offices across the country.

Jonck and Meyer (2004)

Water Research Commission

During the droughts of the sixties, the SA government, at the time, identified the need to establish a water research facility which could assist in more informed decision-making. The added challenge was that this institution should be sustained and resourced by the water users themselves to ensure that it remained relevant and responsive to current and future challenges faced by the sector.

Since its inception, now 40 years ago, the WRC has been striving to fulfil its mandate of serving the water sector, including:

- Promoting co-ordination, co-operation and communication in the area of water research and development
- Stabilising water research needs and priorities
- Stimulating and funding water research according to priority
- Promoting effective transfer of information and technology
- Enhancing knowledge and capacity-building within the water sector.

Investment into groundwater research in South Africa by the Water Research Commission has been strategic and ongoing during all this time. This investment has, in all probability, been the most significant contribution to the building of capacity for the sustainable utilization and management of groundwater resources in South Africa.

Ground Water Division of the Geological Society of South Africa

The Ground Water Division (GWD), established in 1978 by members of the groundwater community of South Africa, is a non-profit association of scientists, academics and technicians with an interest in the optimal development of the country's groundwater resources and committed to upholding and promoting professionalism in their field.

The GWD's focus is on networking; knowledge transfer and capacity and awareness building through initiatives such as:

- Events (Conferences, Seminars, Courses)
- Sponsorships / Scholarships
- Communication events and media relations
- Publications (Newsletters / Articles)
- Public Affairs and Community Relations

The Division has well-working links with the International Association of Hydrogeologists (IAH) and twice already jointly hosted international events in South Africa.

The Division operates in five branches – the National Branch (Gauteng) and the Western Cape, Central (Bloemfontein), Eastern Cape and the newly established Limpopo branch. Its overall membership now stands at 442.

GWD Delegates attending the 2013 Groundwater Conference themed "Groundwater: The New Paradigm" in Durban.

Already in 1973, the then Minister of Water Affairs and Forestry started negotiation with the **University of the Free State** concerning an Institute for Groundwater Studies (IGS). It was to be established at the same time as the Water Research Commission to train potential researchers which could contribute to the working of the WRC.

IGS: Five students received their PhD at the June 2013 graduation (www.ufs.ac.za/igs)

Almost 20 years later, with the re-opening of the global science world to South Africa, a UNESCO Chair in Groundwater was created at the **University of the Western Cape** to serve the southern African region with groundwater expertise.

Approximately 600 students graduated in the last 10 years from these two institutions alone, 127 with a Masters or PhD (see table). Approximately seventy percent of these post-graduate qualifications would have been achieved through a WRC project.

2004-2013	*IGS*	*UWC*
Masters total Masters presently studying	**77** **37**	**18** **11**
PhD's total PhD's presently studying	**21** **10**	**11** **8**

The WRC also supports several other universities (Fort Hare, Venda, Pretoria, Zululand, KwaZulu-Natal, North West and Witwatersrand), science councils, NGOs and consulting firms. Through the academic institutions that have developed and that had the benefit of this research investment, a significant human resources development impact has been achieved nationally (example below), in the southern African region and on the continent as a whole. Very importantly, experience from the groundwater industry is increasingly being made available on a voluntary basis for education and training at academic institutions. Young graduates are thus the key carriers of the country's groundwater capacity.

Curriculum Vitae

Nationality	South African
Date of birth	1 May 1976
Years of experience	8 years
Profession/Specialisation	Hydrogeologist
Academic qualifications	BSc (Hons)
Professional registration	Cert Sci Nat
Languages	**English, Sepedi, Venda**
Present position in firm	Hydrogeologist
Countries of work experience	South Africa

The candidate is a qualified hydrogeologist from the University of Venda with a BSc Hons degree. He specializes in groundwater development, planning and supervision. He also has furthered himself with GIS skills and data manipulation.

From Carel Haupt, WMS Leshika Consulting

Borehole Water Association of Southern Africa

The BWA is a non-profit and trade association representing all aspects of the groundwater industry. Included in its membership are central and local government departments, leading private enterprises that manufacture drilling, pumping, electronic and ancillary equipment, professional consultants, contractors and interested individuals.

The BWA was formed in 1980 with the strategy to promote awareness via education of the consumer of the responsible use of the resource and its future management. At all times guaranteeing the protection of groundwater by demanding the application of minimum standards of practice. Its BWA Membership Directory and website (www.bwa.co.za) is an important and widely used service to customers and to the industry.

The BWA (www.bwa.co.za) key products include:

- Standard Form Drilling Contract
- Membership Directory
- The Borehole Water Journal
- Water Talk – an electronic newsletter
- A Laymans Guide to Borehole Ownership (had many editions)

The **Council for Scientific and Industrial Reasearch** (CSIR) has been active in groundwater research and development since the mid-1950s a decade after its establishment in 1945. The many different technical competencies and excellent laboratory infrastructure within the organization has allowed it to undertake significant multi-disciplinary work in this field (*see also page 65*).

The **Council for Geoscience** (CGS) is in a unique position through its huge geological knowledge base and expertise and the established branch offices of the organization to support the increasingly decentralised water management and be a partner in specialized groundwater research (*see also p 66*).

This overall groundwater research and development capacity also plays a major regional role in southern Africa and wider.

At this stage there are only about three other institutions in SADC outside South Africa, which have groundwater research and development (R&D) and teaching capacity. Not surprising then that the Institute of Groundwater Studies on University of the Free State campus was requested to host the *newly inaugurated SADC Groundwater Management Institute.*

Serious capacity shortcomings in the national Department of Water Affairs (DWA) were pointed out in a submission by the groundwater sector, represented by the Groundwater Division of the Geological Society to the Parliamentary Portfolio Committee on Water Affairs and Forestry during their Review of the

International Cooperation

International cooperation has greatly benefited the South African groundwater sector, in particular during challenging period of making groundwater a part of IWRM. Some examples in this regard were:

- **1992:** Development of the DWAFs national hydrogeological mapping programme with significant input from the International Association of Hydrogeologists.
- **1998:** UNESCO/WMO Mission to assess E&T needs of the water resources management services in South Africa, resulting in the Framework for Education and Training in Water (FET-Water).
- **2001:** The DWA-DANCED cooperative project intended to support the implementation of programs towards achieving IWRM in three selected Water Management Areas
- **2002:** The NORAD-assisted programme for the sustainable development of groundwater sources under the Community Water Supply and Sanitation Programme – it was piloted in three Districts across the country.
- **2008:** The Africa Groundwater Network (AGW-Net – www.agw-net.org), a network of groundwater professionals across Africa, was established to increase awareness of the potential and value of groundwater across Africa and to contribute to the capacity development in the groundwater sector. AGW-Net is a member of Cap-Net/UNDP and has valuable international links.

National Water Act (Groundwater Division, 2008): *"An inability to implement the National Water Act, as a result of a lack of sufficient skilled and experienced staff, prevents groundwater from being used productively and sustainably to promote economic growth and social upliftment."*

Even though a Departmental Groundwater Strategy was prepared in 2010, with considerable input from the private sector, very few of the recommendations have been rolled out so far, because the Department does not have the capacity and leadership / organisation to act on them.

The weakness in the groundwater function in national government is of particular concern at a time when new groundwater capacity has to be built in CMAs and in local government. It is clear that local government, which has the devolved water services responsibility, is presently unable to meet its objectives, including the achievement of the MDGs with respect to water and sanitation delivery, because of a complete lack of capacity for the sustainable utilisation and management of local groundwater resources.

Lack of a national groundwater champion also prevents a proper synchronization of research and national development objectives and prevents the academic sector to fully play its science leadership role. *(refer also to the box on the next page)*

Government and academic institutions can support each other in their respective responsibilities as part of the national objective of cooperative governance. World-wide, government is losing much needed technical capacity. Mentoring of new entries becomes a problem in this situation. Universities, on the other hand, are unable to provide practical education and training (E&T) without real life problems, access to technical infrastructure and funding support for mobility. Ways to support each other could be captured in MOUs towards a long-term, sustainable relationship:

- Universities willing to adjust E&T programmes to needs experienced by partners;
- Government partners commitment to an annual bursary provision;
- Government partner activities/projects opened to universities for achieving post-graduate qualifications;
- Academic partners (specialists in their

Reasons for the lack of capacity in the Groundwater Sector

The public sector in general has great difficulty in retaining skilled experienced specialists and technical managers. Most of the professional capacity in South Africa is located outside the public sector and will remain so. We are seriously missing the public sector as a major player in capacity building.

The groundwater function in the national Department of Water Affairs received a serious blow as a result of the major Departmental restructuring in 2003. The integration of groundwater into all water resource management functions was critically important, but has only been partly successful, e.g. in Water Resources Planning. The national leadership and internal champion role of a Directorate Geohydrology is seriously lacking in a time when so much needs to be done.

While the public sector work continues largely through outsourcing, the private sector has not yet taken on a role in national capacity building.

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 and in human resources for this purpose.

To date there has only been a piece-meal and not a holistic approach to groundwater capacity building. Initiatives like UNESCOs Framework for Education and Training in Water (FET-Water) have never been used, as intended, to achieve role player cooperation in groundwater capacity building.

various fields) on call to help solve technical problems as they occur in government;

- Universities to present short courses to the sector in critical fields.

This kind of relationship also needs to be extended to the private sector in the form of Public/Private sector partnerships. To realise the goal of devolved water resource management, the lack of knowledge and experience at local level, particularly concerning groundwater, will necessitate the use of the private sector, to provide for the transition of management functions from national to local institutions. This should allow for the facilitation of innovation and the rewarding/funding of excellence. It should be a relationship of mutual trust in which the performance of the regulator can also be evaluated by his partners to allow for a joint growth. This approach was already foreseen in the regulatory framework for the management of groundwater proposals to the Water Law Review Drafting Team (Lazerus, 1997).

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 and in human resources for this purpose.

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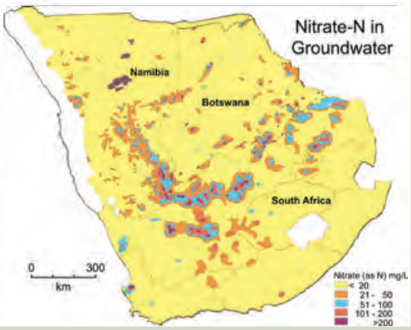
The Council for Scientific and Industrial Research (CSIR)

The contribution of the CSIR to groundwater research, development and implementation dates back to the mid-1950s. The period since 1994 is characterised by a shift from a mainly scientific and technological research and development focus targeting regional groundwater resources, to the application of scientific research with a focus on practical implementation in the service of society and the environment. A more recent shift is that from a groundwater-centric staff complement to one which offers expertise across a broader spectrum of water resources science. Disciplines now include surface water hydrology, vadose zone hydrology, agro-hydrology and environmental hydrology/hydrogeology driven by the paradigm of Integrated Water Resource Management (IWRM).

The application of geophysics in groundwater studies is a historical competence of the CSIR. This was maintained with studies on the application of radiowave tomography for the characterisation of fractured rock aquifers, the evaluation and application of nuclear magnetic resonance to the study of South African primary and fractured rock aquifers, the application of resistivity tomography in the delineation of dense non-aqueous phase liquids, and investigations into the identification of deep fractured rock aquifers. The implementation of managed aquifer recharge and storage schemes such as at Atlantis and Langebaan on the West Coast and at Windhoek in Namibia, continues to serve a research and development purpose.

Groundwater quality has also continued to receive attention. Examples are studies such as the investigations of high nitrate and ammonia compounds in industrial settings, the origin of naturally elevated nitrate concentrations in groundwater across southern Africa, nitrate removal for groundwater supply to rural communities, and updating of the comprehensive guide for groundwater sampling methods. The Quaternary Dating Research Unit (QUADRU) laboratory supported the often pioneering application and use of a wide range of isotopes in surface water and groundwater studies across the subcontinent. The self-sufficiency founded on this facility was unfortunately lost with its closure in 2012. The integration of complementary hydroscientific disciplines has underpinned research into groundwater dependent ecosystems in various biomes across the country, an assessment of aquifer vulnerability in South Africa, and an assessment of acid mine water impacts on the receiving surface and subsurface water resource environments.

Abstraction wellhead in the Atlantis wellfield



Groundwater nitrate map

The Council for Geosciences

The Council for Geoscience (CGS) is one of the National Science Councils of South Africa and is the legal successor of the Geological Survey of South Africa, which was formed in 1912. The Geoscience Act, Act 100 of 1993, established the CGS in its present form. Today, the Council is a modern institution, boasting excellent facilities and expertise, ranking among the best in Africa.

The organization has a Water Geoscience Unit which provides professional consulting and contract research in the broad field of hydrogeology, groundwater resource management, rural water supply, environmental management, groundwater characterisation, and groundwater contamination management. Overall, the Council is in a unique position through its huge geological knowledge base and expertise and the established branch offices of the organization to support the increasingly decentralised water management and be a partner in specialized groundwater research.

It research focus is determined by its statutory funded projects that bear national importance, as well as collaborative research projects and research funded by various institutions, including the Water Research Commission. Some of the more recent projects are shown here to illustrate the scope and depth of involvement:

- Strategic Mine Water Management Plan (SWMP): seeking to predict and prevent harm to the environment, apportion pollution sources and liabilities and address ingress prevention in mining basins
- Hydrogeological Mapping of Malawi and partnering in the production of The Hydrogeological Map of SADC
- Sustainable Development of Groundwater Sources under the Community Water Supply and Sanitation Programme in Southern Africa – various projects in this major NORAD-assisted project.
- The Application of Groundwater Vulnerability Assessments at Water Management Area (WMA) Scale
- Groundwater Flow Modeling in Unsaturated Zone Considering Groundwater Vulnerability to Various Impacts – A South African Approach
- A Groundwater Monitoring Protocol for Non-Aqueous Phase Liquids (NAPLs) at Fuel Service Stations
- Hydrogeology of the Main Karoo Basin: Current Knowledge and Future Research Needs
- Impact of Fault Structures on the Occurrence of Groundwater in Fractured Rock Aquifers
- Investigation of the Relationship Between Groundwater Chemistry and Radioactive Elements in Namaqualand

Recommendations

Capacity development at all management levels is critical and will have to be addressed strategically by the groundwater sector as a whole in order to make a difference;

This will have to be linked to a roll-out of the National Groundwater Strategy, with leadership coming from national government through a re-established groundwater champion in the Department of Water and Sanitation;

The Water Research Commission's key groundwater capacity building role will need to continue, as catalyst and mobilizer and as knowledge hub;

For maximum impact, there will have to be synergy between capacity building for groundwater and that of related IWRM components, in particular community water supply;

There must be recognition of the excellent capacity available in the private sector and ways need to be found to formalise its capacity building role, as already informally happening for the municipal level;

Partnerships need to be created and systematically rolled out in which government, the private sector and the academic sector can work together in mutually supportive ways;

The Groundwater Division of the Geological Society could play a major role as neutral player to bring sector stakeholders together and focus them on the common objectives – in a similar role to that of the American Ground Water Trust. A full-time staff member should seriously be considered for the Division to maintain the necessary momentum in this critical liaison role.

Gerrit † van Tonder

Prof. Gerrit Johannes van Tonder has been very much on our minds during the writing of this booklet: he passsed suddenly on 22 April 2014. He had been with the University of the Free State since 1976 and had become synonymous with the Institute for Groundwater Studies (IGS). Here a few reflections from his former students and colleagues:

Prof van Tonder grew the love for groundwater in each student.

He was an absolute bastion of the groundwater community – believed his science and acted on the evidence before him – and leaves a wonderful legacy of a generation of hydrogeologists.

The Groundwater Community is poorer without Prof Van Tonder. He was instrumental in developing groundwater hydrology and the capacity we have today.

It is through his and others efforts that we now have a knowledgeable groundwater industry to the benefit of South Africa, Africa and the world with many of his students working abroad.

We will miss him dearly.

Awareness Building

Awareness building is a critical component in the sustainable development and management of widely used and impacted local groundwater resources.

Awareness building cannot stay general, but needs to be focused around the role and utility of the resource for different stakeholders. Conjunctive use benefits of the resource will always be a key message. Awareness comes through formal and ongoing stakeholder interaction. It cannot depend on ad-hoc initiatives only, but must become ongoing programmes with different stakeholder communities. Information products with a lasting message are important for continuity.

Minister Kader Asmal was a wonderful champion of groundwater. A colourful event in Bisho in 1996 with the MEC, mayors from a number of towns, various school choirs, cultural items, a slide show and the Minister addressing the people, was for nothing less than the launching of the first hydrogeological map for the Eastern Cape.

Some of the information products that have been very successful and continue to be used are shown on the composite picture.

Hidden treasure
Water from Stone
Arteries of Life
Blue Gold

A Groundwater Resource Message

Contrary to belief, groundwater supply can be sustainable. "Farmers in the Western Cape have shown me boreholes that have been handed down with the farm from one generation to another. One borehole drilled 80 years ago is still a prime source of drinking water for the small community resident on the farm. Maintenance is the farm manager's responsibility. He has technical skills and the borehole has never been out of action for longer than four days.

Local government decision makers must be educated on why groundwater schemes have failed in the past. They should know that basic, but solid planning for effective maintenance is critical and that groundwater can be relied on in well-sited and designed schemes.

We should be promoting groundwater as a resource that is buffered from the impacts of climate change. Groundwater-based schemes could provide employment in rural areas and develop low cost, low carbon resources that make best use of our natural capital."

Christene Colvin, Worldwide Fund for Nature in The Water Wheel, November/December 2011

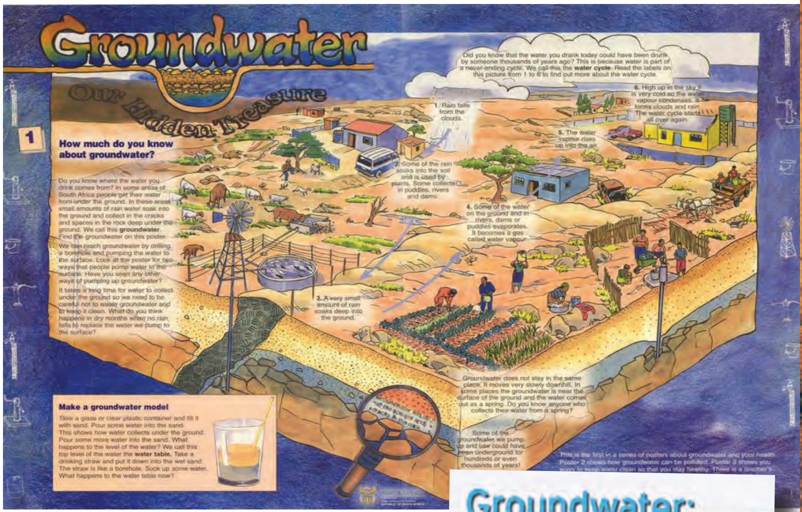
Recommendations

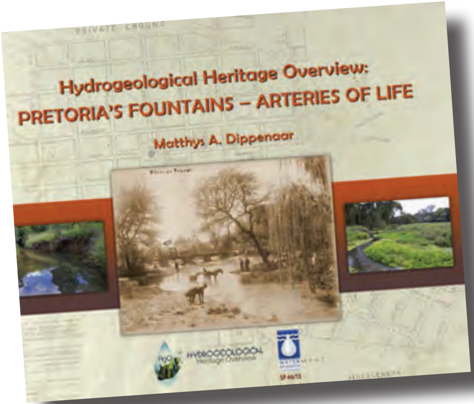
Groundwater awareness-building must not be once-off, but on-going and part of a strategy of building capacity for the sustainable utilisation of the resource;

The whole water sector, including the academic sector, should take responsibility for groundwater awareness building;

Wherever possible, the structures and processes already existing for IWRM, should also be used for groundwater awareness-building;

Education of children should become the key strategy to create the desired shift in society's awareness and understanding of groundwater's role and sustainable utilisation.





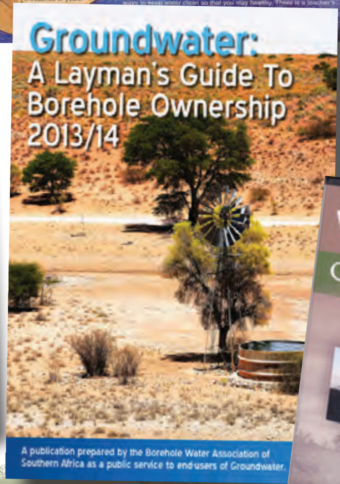



Photo: AGES Eastern Cape


Photos: DWA Western Cape

Emerging Issues

Acid mine drainage

Underground mining operations in Witwatersrand Basin began to decline from the 1970s; underground operations in the West Rand Basin (WRB) ceased in 1998. Decanting of mine water from a borehole was observed for the first time in the WRB in August 2002. This was followed by discharges from local inclines/ shafts as the mine void became saturated and pressurized and acid mine water flowed down the Twee Lopies Spruit into the Krugersdorp Game Reserve with serious environmental consequences. This event initiated a series of emergency processes led by a Cabinet Committee to investigate management scenario's for the acid mine drainage problem in the Witwatersrand Region as a whole.

To scientifically support these processes, a hydrological monitoring program to observe the mine void water hydrochemistry and flow dynamics of the Witwatersrand Region has been established and maintained by the private sector (mining houses) and the Department Water and Sanitation. The results illustrate that the mine void water characteristics are complex and differ largely from basin to basin (Van Wyk, et al., 2013).

This situation should also be a lesson for managing the impacts of coal mining in various part of the country. A large number of the mines have reached the end of their productive life resulting in numerous mine closures. With closures, groundwater levels have rebounded, resulting in decant of mine water into the environment (Johnstone et al., 2013). Future mining expansion on this scale (see below) will have to be tackled much more strategically and holistically and with the best groundwater systems understanding and with much improved mining planning and authorization processes.

Acid mine drainage - decommissioned borehole next to the Twee Lopies Spruit (Van Wyk, 2011)

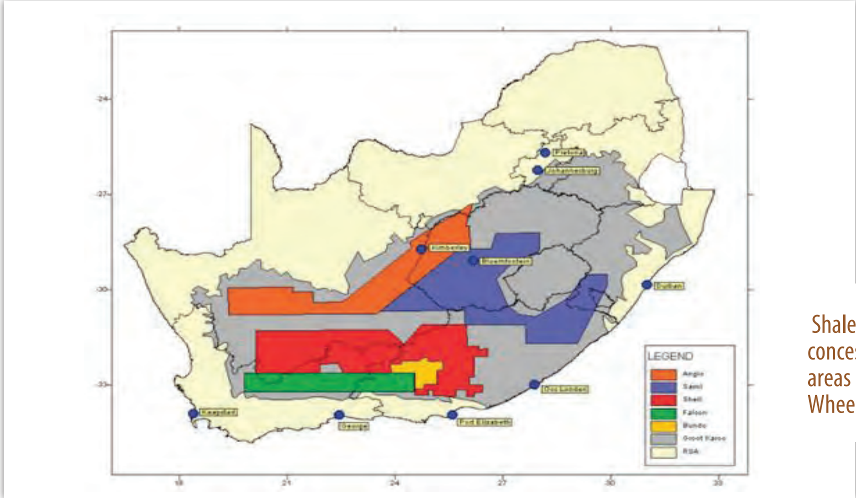
Literature

Van Wyk, E., Mokgatle, T. and N. de Meillon (2013). Witwatersrand mine voids – their hydrochemistry and hydrodynamic characteristics. 13th Biennial Groundwater Division Conference, Durban, 17-19 September 2013.

Johnstone, A., Dennis, I. and N. McGeorge (2013). Groundwater stratification and impact on coal mine closure. 13th Biennial Groundwater Division Conference, Durban, 17-19 September 2013.

Hydraulic fracturing and coal bed methane extraction

The mining of shale gas and the associated hydraulic fracturing could bring enormous economic benefits to South Africa. However, hydraulic fracturing also poses a threat to already limited groundwater resources in areas such as the Karoo and will need to be strictly regulated. The DWS is currently developing a regulatory framework in close partnership with the WRC, the DEA and the Department of Mineral Resources (DMR) to lead to a policy that guides the conditions that will be imposed on



Shale gas concession areas (Water Wheel, 2013)

hydraulic fracturing to ensure the protection of the groundwater resource. Coal-bed methane extraction is another emerging mining practice that can extract valuable gases from coal beds in areas such as Limpopo and Mpumalanga. In this case too, the current regulatory framework and policies and legislation need to be amended to protect the water resource (DWA, 2013).

The University of the Free State Centre for Environmental Management (CEM) has been commissioned by the Water Research Commission (WRC) to undertake a project that will assist with addressing some of the knowledge gaps. Particular aims are to develop an interactive map of areas vulnerable to unconventional gas mining and make recommendations how hydraulic fracturing activities should be monitored. An interdisciplinary team has been brought together from various South African and also international institutions. This follows on a WRC project already commissioned in 2011 and a visit by a group of researchers to a shale area in the USA, where hydraulic fracturing is currently taking place (Steyl et al, 2012). Indications are that the impact of groundwater pollution could be enormous in years to come and mitigation measures should be in place before fracking is started in South Africa.

Literature

DWA (2013). National Water Resource Strategy. Second Edition. Department of Water Affairs, South Africa.

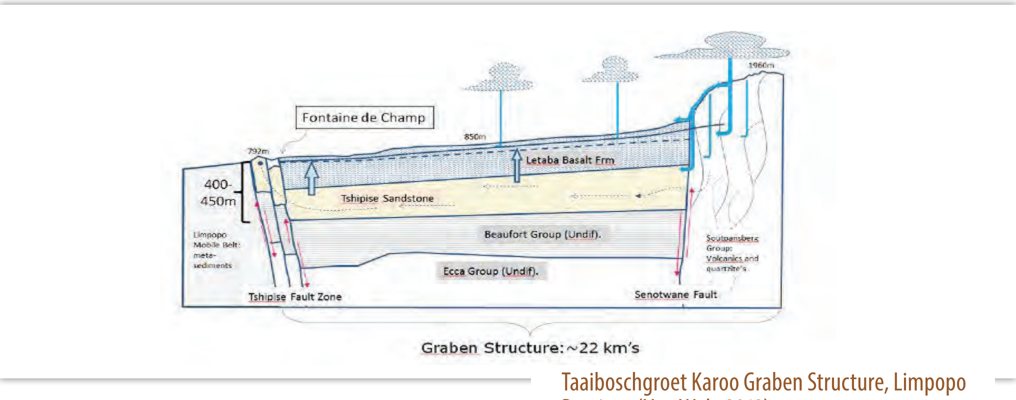
Steyl, G., van Tonder, G. J. and Chevallier, L. (2012). State of the Art: Fracking for Shale Gas explortaion in South Africa and the Impact on Water Resources. Water Research Commision, Report KV 294/11, Pretoria.

Van Tonder, G., de Lange, F., Steyl, G. and Vermeulen, D. (2013). Potential impacts on groundwater in the Karoo Basin of South Africa. 13th Biennial Groundwater Division Conference, Durban, 17-19 September 2013.

Water Wheel (2013). Call for debate on unconventional gas mining to be broadened. The Water Wheel. Groundwater Special Edition 2013.

Deep groundwater development

To date South Africa has largely developed shallow, unconfined groundwater resources. However, increasing water scarcity and greater reliance on groundwater resources, for example in the Limpopo province, will require a systematic exploration effort to locate possible deeper systems. Several deep drilling projects in South Africa, Botswana and Namibia



Taaiboschgroet Karoo Graben Structure, Limpopo Province (Van Wyk, 2013)

have proven the existence of pressurized groundwater strikes below 300 m (Northern Kalahari) to as deep as 3000 m (western Karoo Basin). South African results were not significant, except for the Cretaceous Uitenhage Artesian Basin and recently investigated folded Table Mountain Group Aquifer systems (Van Wyk, 2013). Unfortunately, very little information on the general water bearing characteristics of the Karoo formations, and especially the Dwyka and Ecca Groups, were noted during the drilling of a number of ultra-deep core boreholes by SOEKOR in the Main Karoo Basin in the 1960s and 1970s.

It is important to not only look at the deep reservoir, but also how it is sustained. Many pressurised artesian/subartesian systems have lost their pressurised character soon after multiple deep abstraction boreholes were drilled into the confined aquifer (currently observed in the Taaiboschgroet Karoo Graben Structure, Limpopo Province). Modern recharge events did not balance the requirements of deep flow mechanisms and started to depressurise and change the hydraulic parameters of these systems (Van Wyk, 2013).

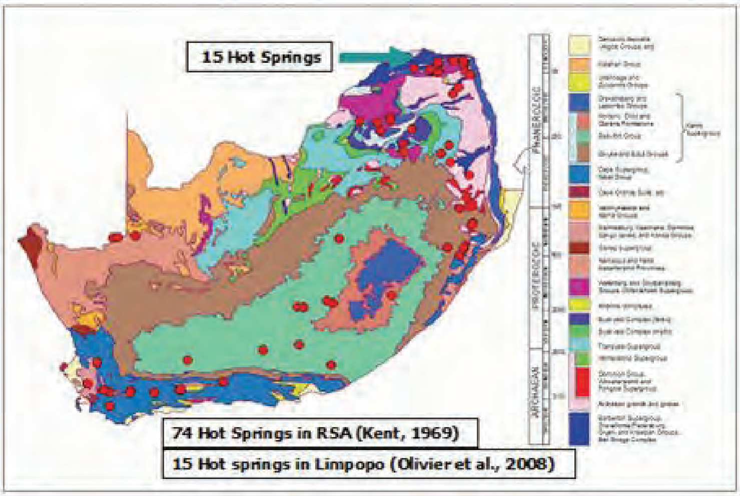
Literature

Van Wyk, E. (2013). Southern African pre-cretacious deep groundwater flow regimes: evidence and drivers. 13th Biennial Groundwater Division Conference, Durban, 17-19 September 2013.

Geothermal resources

In South Africa, about half of the documented 74+ thermal springs have been developed as family leisure and recreational resorts alone, while the rest remain undeveloped. Internationally their potential as versatile natural resources has become increasingly apparent during the last few decades. In addition to being popular tourist resorts, recent thermal spring uses include: the generation of electricity (geothermal power) and for agriculture, aquaculture, bottling, the extraction of rare elements, and the use of thermophilic bacteria for industrial purposes. Moreover, the natural health industry is expanding rapidly and the possible therapeutic properties of thermal spring waters are being reinvestigated by scientists in many different countries.

It is thus clear that South African thermal springs – although being of only low enthalpy – have considerable development potential, which can be optimised by cascading the



Location of hot springs in South Africa and associated geology Olivier and Jonker, 2013)

water through multiple tiers of uses. If the considerable potential of geothermal resources in South Africa is to be realised, government and industry should play an active role in creating an environment where private and outside investments can be justified and reasonable rate of returns are realized (Olivier and Jonker, 2013). Improved understanding of the physical/chemical functioning of the natural groundwater systems will be foundational to any such development.

Literature

Olivier, J. and Jonker, N. (2013). Optimal Utilisation of Thermal Springs in South Africa. WRC Report No. TT 577/13. Water Research Commission. Pretoria.

Climate change

The Southern African region is one of the most affected regions by climate variability and change. Water resources have been at the epicenter of climate change impacts, characterized, in particular by an increasing frequency of extreme events in the form of floods and droughts.

Climate change impacts in the region are exacerbated by the very low resilience of poor communities in coping with such events.

Adaptation to Climate Change

Adaptation to climate change refers to the capacity of natural and human systems to reduce vulnerability against actual and expected climatic stimuli and their effects on society, the economy and the environment

United Nations Framework Convention on Climate Change

Water storage (available in aquifer systems) is an important adaptation mechanism to reduce seasonal and longer term variations in water availability and is therefore essential to protect local communities against climate and rainfall variability.

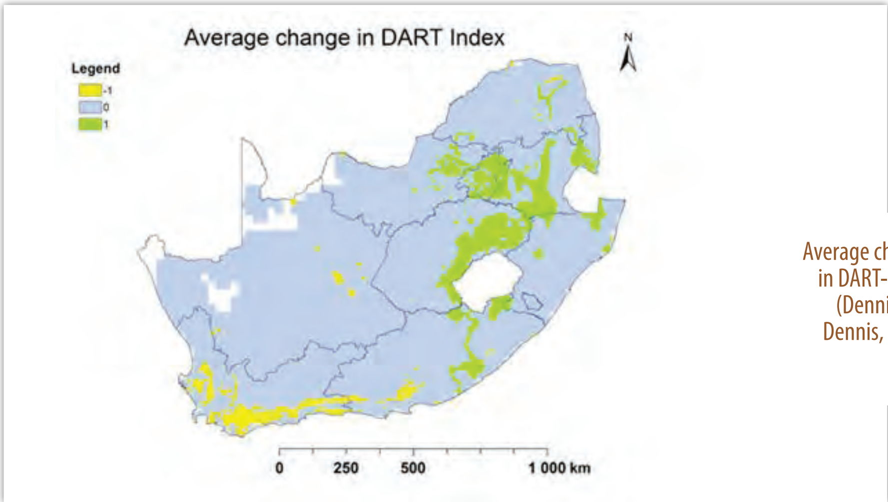
Groundwater in Climate Change Adaptation in SADC

Groundwater provides a secure, sufficient and cost-effective water supply. This is particularly true in dry regions where surface water is scarce and seasonal, and in rural areas with dispersed populations. Groundwater is likely to play an even greater role for human survival and economic development under changing climatic conditions as it provides a cushion against drought and uncertainty in surface water availability. A range of technical options are available for improving access to groundwater and securing recharge mechanisms in the long run. (SADC, 2012)

In comparison to the expected adaptation role highlighted above, the potential impact of climate change on groundwater systems, in particular the impact on groundwater recharge, groundwater levels and the contribution to baseflow of rivers and aquifer-dependent ecosystems, is still very poorly researched. A step forward has been the development of a vulnerability index to climate change based on available groundwater parameters – depth to water level, aquifer type (storativity), recharge, and transmissivity. The index is used as a regional screening tool to identify areas that could experience possible changes in their groundwater resources as a result of climate change. While on average the index shows a relatively limited impact (see figure), the impact as expressed by the index is much higher in certain months (Dennis and Dennis, 2012). This indicates the need for detailed local-scale studies.

Importantly, the Department of Environmental Affairs' Long-Term Adaptation Scenarios for the Water Sector have taken note of the adaptation role of groundwater resources and can provide pointers for future focus (DEA, 2013):

- Increase conjunctive use and multiple sources to spread the risk and be more resilient.
- Develop new groundwater sources and secure appropriate recharge including artificial recharge where appropriate.
- Monitor groundwater systems and ensure appropriate maintenance plans are in place.
- Set climate change objectives for each national monitoring programme.
- Develop tools to measure the effect of climate change on groundwater.



Average change in DART-index (Dennis and Dennis, 2012)

Literature

SADC (2012). Climate Change Adaptation in SADC – A Strategy for the Water Sector. Southern African Development Community.

DEA (Department of Environmental Affairs). (2013). Long-Term Adaptation Scenarios Flagship Research Programme (LTAS) for South Africa. Climate Change Implications for the Water Sector in South Africa. Pretoria, South Africa.

Dennis, I. and Dennis, R. (2012). Climate change vulnerability index for South African aquifers. Water SA. 38 (3).

Outlook for
Groundwater Governance in South Africa

A watershed for groundwater resources

1994 was a landmark year which changed every sector of South African society. It also brought out the true value of the hidden and neglected resource, groundwater. Through the government policy of meeting the massive basic needs backlogs of the population as highest priority, approximately 27 million people in South Africa have gained access to improved water supplies. This has brought basic water infrastructure coverage to over 95% of the population in less than two decades – a remarkable achievement by any measure. Country-wide, more than 50% of these communities now have a groundwater source and in some provinces it is more than 80%. This is because the backlog was spread over thousands of villages, often remote, and only locally available resources could have filled this need.

The writers of the National Water Act recognised this strategic role of groundwater and with its promulgation, groundwater lost its previous status of private water and became public water. The Act states that water is an indivisible national resource (rivers, streams, dams, and groundwater) for which national government is the custodian. It contains rules about the way the water resource is protected, used, developed, conserved, managed and controlled in an integrated manner.

Much improved understanding and information

Registration of all water use in terms of the National Water Act, including groundwater, has for the first time provided a country-wide picture of groundwater use per economic sector. At the same time national hydrogeological mapping and assessment programmes have brought readily available and understandable country-wide information about groundwater occurrence and development potential. This information formed the basis for including groundwater for the first time in the regular national assessment of Water Resources of South Africa.

Understanding of the role of groundwater has improved greatly by bringing hydrogeological expertise into the national planning function and introducing groundwater into planning at all levels from national/strategic to local feasibility studies. Conjunctive use has become an important consideration, at present and even more so under changing climate conditions. The much needed Groundwater Strategy, linked to the 2nd Edition National Water Resource Strategy, was developed in this environment.

Looking forward, much improved understanding of the dynamics of groundwater, its recharge, discharge and water ecosystem linkages, will be required. For this purpose groundwater monitoring needs to be greatly expanded at the appropriate spatial and temporal scales and integrated with other monitoring. Groundwater data and information will have to come from many new quarters, and information management will become a critical success factor. User focus and regular reporting will be essential.

Limited impact of regulation for groundwater

All groundwater resources are for the first time regulated by the National Water Act. This represents a major mindshift, especially for land owners under whose land most groundwater occurs. Here there is still a lot of unregistered (illegal) use as well as over-registered use to stake a claim to the water which was previously held as one's own.

Only verification of registered use, compulsory licensing, where necessary, and ongoing compliance monitoring will gradually bring the understanding of sustainable development. The initial focus in water resource protection has been on the Resource Directed Measures (RDM) and in particular, the setting of the Reserve. Despite a lot of attention to groundwater RDM, groundwater resources have not really benefitted, because the whole approach is surface water and ecosystem focused. The Reserve requirements as part of groundwater abstraction licensing, has been a dilemma, because licences have sometimes been delayed for several years. On the other hand, other instruments like the National Environmental Management Act, 1998, have improved groundwater source protection significantly.

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Originally a groundwater chapter was intended in the National Water Act, but this was not pursued in order to maintain the integrated water resource management approach. However, it has become clear that special groundwater regulation is now required to address unique characteristics of the resource. This includes the pro-active protection of the underground resource, the maintenance of professional standards in the development and maintenance of water supplies from groundwater and the securing of data and information from other parties for a national groundwater information system.

Problems with water services from groundwater

Despite the raised profile at a national planning level, experience on the ground indicates that many municipalities only turn to groundwater as a last resort. There have been much publicised reports of scheme failure, not long after municipalities took over the water services responsibility. It is well known that management of local groundwater schemes by municipalities is generally poor. Statistics in this regard are still lacking, because most smaller groundwater supplies are not covered by the Blue Drop reporting system. The problem is one of lack of capacity in municipalities as well as lack of systematic support and regulation, where necessary, from national government. This is serious because it makes the major achievements of infrastructure development undone and gives strategically important groundwater resources a bad name. **The turn-around of this situation can only start with national government. Adequate geohydrological capacity needs to be created in the Department of Water Affairs, both nationally and in the regions to empower and support municipalities for this responsibility. The Framework for Groundwater Management, a compendium of best practice guidelines, is already available and needs to be implemented and the performance monitored with the Blue Drop system, suitably adapted for groundwater-specific issues. The groundwater private sector, located in almost every part of the country, should be brought into this endeavour as a partner. Particular attention will have to be given to developing and maintaining local water resources in the challenging deep rural areas, where most of the remaining backlog exists.**

Institutional development for groundwater governance

Proper governance of localised, open access groundwater resources is a world-wide challenge. It is generally agreed that the required governance approach is one of 'national facilitation of local actions.'

We have not yet seen much local action in South Africa – groundwater managed by the local users or at least with their full participation. A key reason for this situation is that the institutional development that the National Water Act had foreseen, the devolution of water resource management to CMAs and Water User Associations, has for all practical purposes not yet happened. At the same time government has lost its national groundwater champion and much of its capacity in the groundwater field, a major bottleneck in its national facilitation responsibility.

This groundwater capacity at national level is required in all aspects of groundwater governance, from assessment and planning to regulation and local institutional development. There is capacity in the private and academic sectors, which needs to be harnessed in win-win partnerships. But without a groundwater champion and a critical capacity in government we will not be able to move forward meaningfully. At the same time the capacity of local government needs to be systematically developed jointly with relevant role players in national government, SETAs and professional associations. The recent joining of the water and sanitation functions in national government and the strong focus on regional implementation and support should greatly help in this regard.

Groundwater Research & Development

Groundwater research and development (R&D) has played a major role in each aspect of progress made in groundwater governance in South Africa. It underpinned the strategy development, all the national and regional resource assessments, the best practice formulations, the development of guidelines and regulations and the beginning of interaction with users. It ensured tapping into best available expertise in the country, it helped grow the various academic institutions and was, without doubt, the main vehicle for groundwater capacity building in the country. Years of nurture, for example, bore fruit when the Institute for Groundwater Studies at the University of the Free State was recently asked to host the SADC Groundwater Management Institute.

Investment into groundwater R&D needs to be maintained and grown in partnerships with managers and users to address the obvious challenges that lie ahead and achieve more rapid roll-out of research and development findings. This new phase will need to return to a focus on geology as the foundation of groundwater systems functioning and at the same time a widened focus on the social dimension of groundwater as key to its sustainable development.

Appendix 1:

Persons visited / interviewed

Department of Water and Sanitation (DWS) Head Office	
Ms. D. Mochotlhi	DDG: Planning & Information
Mr. L.S. Mabuda	Integrated W/R Planning
Mr. T. Nditwani	National W/R Planning
Mrs. I. Thompson	National W/R Planning
Dr. B.L. Mwaka	W/R Planning Systems
Mr. E.A. Nel	W/R Planning Systems
Dr. S.K. Mgquba	Climate Change
Mr. L.Z. Maswuma	Hydrological Services
Mr. W.E. Bertram	Geohydro Information
Ms. S. Naidoo	W/R Classification System
Ms. A.U. Okonkwo	W/R Classification System
Mrs. A. Muir	Water Abstraction and Instream Use
Mr. S.J. Marais	W/S Planning & Information
DWS Limpopo Region	
Mr. W. du Toit	Geohyrology
DWS Western Cape Region	
Mr. M. Smart	Geohydrology
DWS Eastern Cape Region	
Ms. I. Viljoen (by telephone)	Planning
Private Sector	
Ms. R. Hay	Umvoto Africa, Cape Town
Dr. K. Riemann	Umvoto Africa, Cape Town
Mr. J. Conrad	GEOSS, Stellenbosch
Dr. K. Pietersen	SLR Consulting, Cape Town
Mr. G. Nel	SRK, East London
Mr. J. Gibson	Maluti Water, East London
Mr. C. Haupt	WSM Leshika, Polokwane
Dr. K. Sami	WSM Leshika, Pretoria
Mr. J. Cobbing	SLR Consulting, Pretoria
Academic Sector	
Dr. M. Dippenaar	University of Pretoria, Pretoria
Prof. Y. Xu	University of the Western Cape, Cape Town
Prof. D. Vermeulen	Institute for Groundwater Studies, University
Dr. F. Fourie	of the Free State (Telephone Conference)
Prof. J. Botha	" "
Mr. E. Lukas	" "
Mr. F. de Lange	" "

"Sink in despair on the red parched earth,
and then ye may reckon what water is worth,
Traverse the desert and then ye can tell,
What treasures exist in the cool deep well."

Elisa Cook (poet: Southern Africa 19th Century).