

South African Groundwater Governance Case Study

Report
prepared for the

WorldBank
in partnership with the
**South African Department of Water Affairs and the
Water Research Commission**

by

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EXECUTIVE SUMMARY

This report presents a case study on groundwater governance in South Africa at national and local levels. The case study forms part of a World Bank economic and sector analysis on “*Too Big to Fail: The paradox of groundwater governance*”. At the local level, groundwater governance was studied for four highly productive aquifer systems demonstrating various degrees in the implementation of groundwater governance: (i) Botleng Dolomite Aquifer (Delmas area); (ii) Gauteng Dolomites (Steenkoppies and Bapsfontein compartments); (iii) Houdenbrak Basement Aquifer (Mogwadi (Dendron)-Vivo area); and (iv) Dinokana-Lobatse Transboundary Dolomite Aquifer.

Methodology

At the national level, the case study includes an analysis of the policy, legal and institutional frameworks for groundwater provisions, knowledge and capacity availability and gaps and financing arrangements to strengthen groundwater governance. For each aquifer system the governance status was determined based on an evaluation of potential threats. Technical, legal and institutional, cross-sector policy coordination and operational groundwater governance provisions and institutional capacity for implementation were evaluated using a priority list of 20 benchmarking criteria. Management measures were proposed accordingly to strengthen the groundwater governance status. Also the relevance of groundwater governance arrangements for coping with impacts of climate change was reviewed according to a risk-based framework.

The case study builds upon a vast amount of work carried out in recent years on groundwater governance in South Africa. Especially the National Groundwater Strategy which addresses deficiencies in groundwater provisions in the National Water Resource Strategy, the Department of Water Affairs (DWA) Implementation of Dolomite Guideline Project – Phase 1 and a multi-stakeholder workshop proved to be invaluable sources of data and information.

Groundwater governance at national level

- Technical, legal and institutional and operational governance provisions are reasonable but weak for cross-sector policy coordination
- Institutional capacity is weak across all thematic areas except for the technical provisions.

Groundwater governance at local level

- There is similarity in governance provisions for the dolomite aquifers across all thematic areas with the Steenkoppies dolomite aquifer consistently scoring higher
- Basic technical provisions such as hydrogeological maps and aquifer delineation with classified typology are in place for all case study aquifers
- Other governance provisions across all thematic areas are weak or non-existent
 - ❖ Steenkoppies dolomite compartment scores highest; Bapsfontein dolomite compartment and Houdenbrak basement aquifer score lowest
 - ❖ Groundwater monitoring is weak and assessment of groundwater resources is poor, both in terms of quantity and quality (e.g. lack of numerical groundwater model)
 - ❖ There are fair provisions for water well drilling and groundwater use rights but provisions to control groundwater abstraction and pollution are weak (poor compliance monitoring)
 - ❖ Provisions for establishment of aquifer management organizations are weak or non-existent
 - ❖ Cross-sector policy coordination is weak

- ❖ From an operational point of view, a groundwater management action plan which includes both water quantity and water quality aspects only exists for the Botleng aquifer but has not been implemented to date
- Institutional capacity across all thematic areas is weak or non-existent except for the Steenkoppies dolomite aquifer where the situation is better.

Climate change adaptation

- At national and local level, adaptation measures to climate change are not yet a consideration in planning. Only at the national level an artificial groundwater recharge strategy was developed and awaits implementation.

Recommended management measures

Groundwater management measures are recommended at national level and at local level for each of the case study aquifers to address existing and potential hazards as well as to improve on the effectiveness of existing groundwater governance provisions and institutional capacity. Most critical are considered (i) the integration of the National Groundwater Strategy into the National Water Resource Strategy (NWRS), Catchment Management Strategies (CMSs) and other strategies, (ii) strengthening of the groundwater related regulatory environment and (iii) strengthening of the institutional capacity, both in terms of existing institutions (DWA) and establishment and operationalising of Catchment management Agencies (CMAs) and Water User Associations (WUAs). Regarding the inadequacy of groundwater expertise we recommend DWA to develop a strategy to augment national GW capacity. Furthermore, investigation and implementation of climate change adaptation measures at local aquifer level are recommended.

Specific recommendations include:

- (i) Strengthening and implementing groundwater governance measures should preferably follow a ‘parallel track and adaptive approach’ within the existing legal and institutional framework. Such an approach would strengthen the said frameworks without disruption, taking cognizance of capacity and willingness to implement.
- (ii) Pilot projects in the case study aquifers to improve on the groundwater governance provisions and institutional capacity:
 - Botleng Dolomite Aquifer: “Implementation constraints at local and regional level” (DWA Regional Office (RO) and Delmas Local Municipality (LM))
 - Gauteng Dolomite Aquifers:
 - ❖ Steenkoppies compartment: “Strengthening institutional framework” (DWA RO and establishment and operation of WUA-Stakeholders)
 - ❖ Bapsfontein compartment: “Licensing of groundwater use and compliance”
 - Houdenbrak Basement Aquifer: “Perspectives on sustainable groundwater management and use” (Irrigators, DWA RO and stakeholders)
 - Dinokana-Lobatse Dolomite Aquifer: “Water allocation” (DWA RO, local government and irrigators).
- (iii) The same methodology which was used in this case study can be applied to identify management measures for other aquifer systems in South Africa such as the Karoo aquifer of Beaufort West.

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ACRONYMS AND ABBREVIATIONS

| | |
|----------|--|
| AGA | Anglo Gold Ashanti |
| AMC | Aquifer Management Committee |
| AMCOW | African Ministers' Council on Water |
| CCs | Catchment Committees |
| CGS | Council for Geoscience |
| CMAs | Catchment Management Agencies |
| CMSs | Catchment Management Strategies |
| COP | Flow <u>C</u> oncentration, <u>O</u> verlying layers and <u>P</u> recipitation vulnerability assessment method |
| CRDP | Comprehensive Rural Development Programme |
| CSIR | Council for Scientific and Industrial Research |
| DANIDA | Danish International Development Agency |
| DEA | Department of Environmental Affairs |
| DEAT | Department of Environmental Affairs and Tourism |
| DGS | Department of Geological Survey (Botswana) |
| DME | Department of Minerals and Energy |
| DMR | Department of Mineral Resources |
| DPLG | Department of Provincial and Local Government |
| DRDLR | Department of Rural Development and Land Reform |
| DWA | Department of Water Affairs (previously called DWAF) |
| DWAF | Department of Water Affairs and Forestry |
| DWQ | Drinking Water Quality |
| EC | Electrical Conductivity |
| E&R | Environment and Recreation |
| ERM | Environmental Resource Management |
| ERWAT | East Rand Water Care Company |
| ESKOM | Electricity Supply Commission |
| ESSD | Environmentally and Socially Sustainable Development |
| ESW | Economic and Sector Work |
| FETWater | Framework Programme for Research, Education and Training in Water |
| GB | Governing Board |
| GCS | Groundwater Consulting Services |
| GDACEL | Gauteng Department of Agriculture, Conservation, Environment and Land Affairs |
| GDEs | Groundwater Dependent Ecosystems |
| GEF | Global Environment Facility |
| GGP | Gross Geographic Product |
| GMA | Groundwater Management Area |
| GMISA | Groundwater Management Institute for Southern Africa |
| GMUs | Groundwater Management Units |
| GNP | Gross National Product |
| GRAM | Groundwater Resource Assessment and Monitoring |
| GRIP | Groundwater Resource Information Project |
| GWP | Global Water Partnership |
| IDP | Integrated Development Plan |
| IGS-UFS | Institute for Groundwater Studies – University of the Free State |
| IRP | Institutional Realignment Project |
| ISP | Internal Strategic Perspectives |

| | |
|----------|---|
| IWRM | Integrated Water Resources Management |
| LM | Local Municipality |
| M | Million |
| MAP | Mean Annual Precipitation |
| MAR | Managing Aquifer Recharge |
| m.b.g.l. | Metres below ground level |
| MDGs | Millennium Development Goals |
| MPRDA | Minerals and Petroleum Resources Development Act |
| MRCC | Magalies River Crisis Committee |
| MSc | Master of Science |
| MW | MegaWatt |
| NEM | National Environmental Management |
| NEMA | National Environmental Management Act |
| NERSA | National Energy Regulator South Africa |
| NGO | Non Governmental Organization |
| NGS | National Groundwater Strategy |
| NGA | National Groundwater Archive |
| NGDB | National Groundwater Database |
| NIPF | National Industrial Policy Framework |
| NORAD | Norwegian Aid Agency |
| NSSD | National Strategy on Sustainable Development |
| NW | North West |
| NWA | National Water Act |
| NWP | National Water Policy |
| NWRS | National Water Resource Strategy |
| NW WSF | North West Water Sector Forum |
| ODA | Official Development Assistance |
| ORASECOM | Orange-Senqu River Commission |
| PhD | Doctor of Philosophy |
| PSP | Professional Service Provider |
| R | South African Rand |
| RDP | Reconstruction and Development Programme |
| RO | Regional Office |
| SA | South Africa |
| SADC | Southern African Development Community |
| SANRAL | South African National Roads Agency Limited |
| SANS | South African National Standards |
| SKM | Sinclair Knight Merz |
| TDS | Total Dissolved Solids |
| T/S | Transmissivity/Storativity |
| UFS | University of the Free State |
| URV | Unit Reference Value |
| US | United States |
| UWC | University of the Western Cape |
| VUKA | Vulnerability of Karst, an adaptation of the COP groundwater vulnerability mapping method |
| WARFSA | Water Research Fund for Southern Africa |
| WARMS | Water Use Authorisation Registration Management System |
| WB | World Bank |
| WGC | Water Geosciences Consulting |

| | |
|------|----------------------------------|
| WMAs | Water Management Areas |
| WRC | Water Research Commission |
| WRM | Water Resource Management |
| W/S | Water Supply |
| WSA | Water Services Authority |
| WSDP | Water Services Development Plan |
| WSP | Water Services Provider |
| WTE | Water Trading Entity |
| WUAs | Water User Associations |
| WULA | Water Use License Application |
| WWQ | Waste Water Quality |
| WWTF | Waste Water Treatment Facilities |
| WWTW | Waste Water Treatment Works |
| ZAR | South African Rand |

1. BACKGROUND

The World Bank with the support from other partners is undertaking an economic and sector analysis (ESW) titled “*Too Big to Fail: The paradox of groundwater governance*”. The ESW objectives are to:

- (i) Understand the impediments to better governance of groundwater, and to identify the opportunities for ensuring that groundwater forms a key element of integrated water resources management (IWRM) in developing countries; and
- (ii) Explore opportunities for using groundwater to help developing countries adapt to climate change.

The ESW will include case studies on groundwater governance in seven selected countries – India, Kenya, Peru, Morocco, Philippines, South Africa, and Tanzania – with the aim to identify governance issues (including cross-sectoral linkages) and develop key policy to propose activities to support management needs under different socio-economic and hydrogeological settings. This report refers to the South African case study.

1.1. Objectives of case study

The objectives of the case study are to:

- (i) Describe the characteristics, uses and issues of selected aquifers
- (ii) Describe the governance arrangements for managing groundwater
- (iii) Review the relevance of groundwater governance arrangements for coping with impacts of climate change, and
- (iv) Develop findings about successful (and less successful) aspects of groundwater governance

1.2. Methodology

The case study was carried out at two complementary levels – at the national strategic planning level and at the local institutional level.

At the national level, the case study (i) includes an analysis of policy, legal and institutional frameworks for groundwater provisions, (ii) includes an assessment of knowledge and capacity availability and gaps and (iii) provides an overview on financing priority actions to strengthen groundwater governance.

At the local level, the case study comprises an analysis of four highly productive, yet vulnerable, karst (dolomite) and basement, aquifer systems in the Gauteng, Limpopo and Mpumalanga Provinces (Figure 1). The aquifer systems represent various degrees in the implementation of groundwater governance:

- Botleng Dolomite Aquifer (Delmas area; Chapter 3): low progress
- Gauteng Dolomites (Steenkoppies and Bapsfontein compartments; Chapter 4): good progress
- Houdenbrak Basement Aquifer (Mogwadi (Dendron)-Vivo area; Chapter 5): low progress
- Dinokana-Lobatse Transboundary Dolomite Aquifer (Chapter 6): very low progress

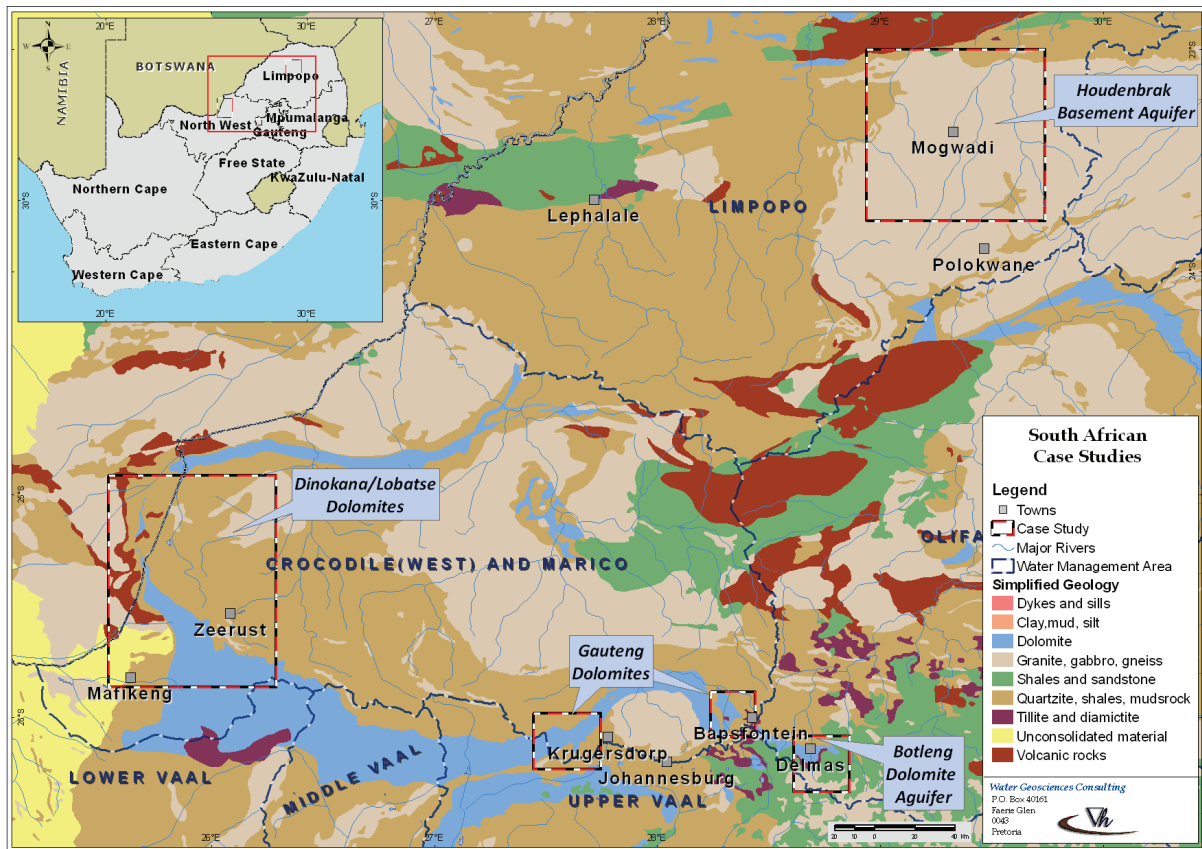


Figure 1: Location of selected aquifers

For each aquifer system the risk of potential threats (mostly related to exploitation and pollution) was assessed and the groundwater governance status determined following the pragmatic Foster et al. (2009) classification of groundwater issues. Based on a priority list of 20 benchmarking criteria (Foster et al., 2009), the effectiveness of technical, legal and institutional, cross-sector policy coordination and operational groundwater governance provisions and institutional capacity for implementation was assessed based on which management measures were proposed to strengthen the groundwater governance status. The relevance of groundwater governance arrangements for coping with impacts of climate change was next reviewed according to a risk-based framework developed by SKM (2009). The framework consists of five steps: (1) establish the context, (2) identify climate risks, (3) analyse risks, (4) evaluate risks and (5) treat risks. Typologies and threats to the case study aquifers in terms of vulnerability to degradation were accounted for in the review.

The case study builds upon knowledge of the hydrogeology and groundwater management at the national and local aquifer levels gained through a vast amount of work carried out in recent years. Especially the National Groundwater Strategy (2010) which addresses deficiencies in groundwater provisions in the National Water Resource Strategy (NWRS, 2004) and the DWA Implementation of Dolomite Guideline Project – Phase 1 (2006-2009) proved to be invaluable sources of data and information.

On 8 November 2010, a multi-stakeholder workshop was held at the offices of the Water Research Commission to discuss the first draft of the case study and to solicit input from a variety of stakeholders on how to improve groundwater governance in South Africa. The

workshop was attended by DWA, WRC, WB and SADC staff; the DWA National Office was well represented (see Annex A).

1.3. Structure of the Report

The report is divided into 8 chapters.

Chapter 1 (this chapter) gives an introduction and background to the case study.

Chapter 2 discusses at the national level policy, legal and institutional frameworks for groundwater provisions, knowledge and capacity availability and gaps and provides an overview on financing priority actions.

Chapters 3, 4, 5 and 6 discuss groundwater governance provisions of four aquifer systems in the Gauteng, Limpopo and Mpumalanga Provinces. For each aquifer system, a summary is given of the hydrogeologic condition and socio-economic situation and the risk of potential threats (mostly related to exploitation and pollution) to the respective aquifer system. Only for the Steenkoppies compartment of the Gauteng Dolomites was a hydrogeological cross-section available. Following the determination of the groundwater governance status, local groundwater management is discussed in the context of (i) water management institutions, (ii) water services institutions and (iii) knowledge and capacity availability and gaps. Subsequently, the effectiveness of technical, legal and institutional, cross-sector policy coordination and operational groundwater governance provisions and institutional capacity for implementation is discussed for each aquifer system and management measures are proposed to strengthen the groundwater governance status. Each case study example is concluded by a good practice example of groundwater management.

Chapter 7 discusses the relevance of groundwater governance arrangements for coping with impacts of climate change.

Findings of the groundwater governance case study are summarized in Chapter 8 and recommendations are made for strengthening the groundwater governance status at both national and local levels.

2. GROUNDWATER GOVERNANCE AT NATIONAL LEVEL

2.1. Introduction

South Africa is a semi-arid country and average rainfall is well below the world average of about 860 mm per year. As a result, South Africa's water resources are scarce and limited in extent. Increased and sustained investment, economic growth and poverty reduction requires that all potential water resources are appropriately utilised. Groundwater is recognised as a significant and strategic resource for meeting the needs of rural communities, urban water supply, overall water security, food security, and the environment.

Groundwater meeting the needs of rural communities. Since 1994 most rural communities have been served from groundwater resources. More than 80% of rural communities in KwaZulu-Natal and Northwest Provinces derive their water from groundwater sources, and the same applies to more than 50% of rural communities in the Eastern Cape Province. This access to groundwater resources is one of the critical factors ensuring sustainable livelihoods in many of these communities. Groundwater has great potential to serve even more communities in those areas where large bulk water infrastructure does not exist and arid conditions prevail.

Groundwater meeting the needs for urban water supply. For example, the City of Tshwane obtains a significant portion of its water supply from boreholes and springs, which is blended with surface water within the bulk distribution system. More than 60% of Capricorn District Municipality water is derived from groundwater resources. The City of Cape Town is considering developing future water supplies from the Cape Flats and Table Mountain Group Aquifer systems. Major aquifers and potential drilling target areas close to Nelson Mandela Municipality have also been identified, and groundwater has the potential to provide about 20% of Nelson Mandela Municipality's current requirements. Major towns such as De Aar, Mafikeng and others rely solely on groundwater resources.

Conjunctive use of surface and groundwater adds to ensure overall water security. It is recognised that developing and managing water resources to achieve water security remains at the heart of the struggle for growth, sustainable development and poverty reduction. Conjunctive use of surface and groundwater resources refers to the coordinated operation of a groundwater basin and a surface water system to increase total water supplies and enhance total water supply reliability. Conjunctive use relies on the principle that by using surface water when it is plentiful, recharging aquifers and conserving groundwater supplies in wet years, water will then be available for pumping in dry years.

Groundwater important for food security. An important component of South African agricultural policy is to increase incomes of the poorest groups in society through opportunities for small to medium-scale farmers. Most of these farmers will be totally dependent on groundwater for domestic and agricultural use.

Groundwater has important environmental functions. Many ecosystem services have a direct linkage with groundwater storage, recharge and discharge. However, the interdependencies between ecosystem services and groundwater are not yet recognised and valued in decision making and in the management of water resources and river basins. Groundwater is generally interpreted as falling outside the definition of the ecological reserve, except where groundwater discharges sustain surface water bodies. Wetlands are

frequently groundwater discharge zones. For example Lake Sibaya in KwaZulu-Natal is dependent on nearby aquifers. Groundwater may also play an important role in maintaining habitats for freshwater organisms in Lake St Lucia during periods when salinities are high. Groundwater provides baseflow to rivers and sustains them during low flow periods.

The country faces growing water demands and will increasingly rely on groundwater as surface water reaches the limits of its availability. There is the potential to considerably increase groundwater supplies in South Africa. Sustainable groundwater governance is required to ensure socially equitable, economically efficient and environmentally sustainable use of this precious resource. The South African reform of the legislative and institutional frameworks of the water sector which started in mid to late nineties provided the opportunity for the judicious management of groundwater resources.

2.2. Policies and legislation

Prior to 1994, water related policy and functions were limited exclusively to irrigation and forestry and this had far reaching consequences for the water sector and the environment in general. Water supply responsibility was fragmented with no single national government department responsible for its management. Together with the lack of a coherent national water legislation, this resulted in different and unacceptable levels of service between different groups of the society (Muller and Lane, 2002). The first non-racial democratic government of 1994 was sensitive to the urgent need for new policies for the country, of which the water sector was just one. A strong political will was demonstrated to implement sustainable water development through sound water governance in the context of IWRM and this led to major reforms in water policies and institutions (Box 1).

A brief overview of key policies and legislation directly related to the water sector is as follows:

- Water Services Policy (White Paper, 1994) addresses the backlogs in the country's water service and the institutions and mechanisms needed to remedy the backlogs.
- Republic of South Africa Constitution (Act 108 of 1996) establishes a human right dimension for access to adequate and sustainable water supply and services and enshrines the Bill of Rights.
- Water Services Act (Act 108 of 1997) ensures the right of access to basic water supply and sanitation, and also provides a regulatory framework and establishment of water services institutions such as water boards, water services providers, etc.
- National Water Policy of 1997 (DWA 1997) redefines ownership and allocation of water. It declares that all water irrespective of where it occurs in the hydrological cycle is public water, and that the national government will act as a public trustee.
- National Water Act of 1998 (Act 36 of 1998) is founded on 3 pillars: equity, efficiency and sustainability, it amongst other things required the establishment of a National Water Resource Strategy (NWRS) to set out a national framework for managing water resources.
- National Water Resource Strategy (DWA, 2004a) provides the national implementation framework and divides the country into 19 Water Management Areas (WMAs).

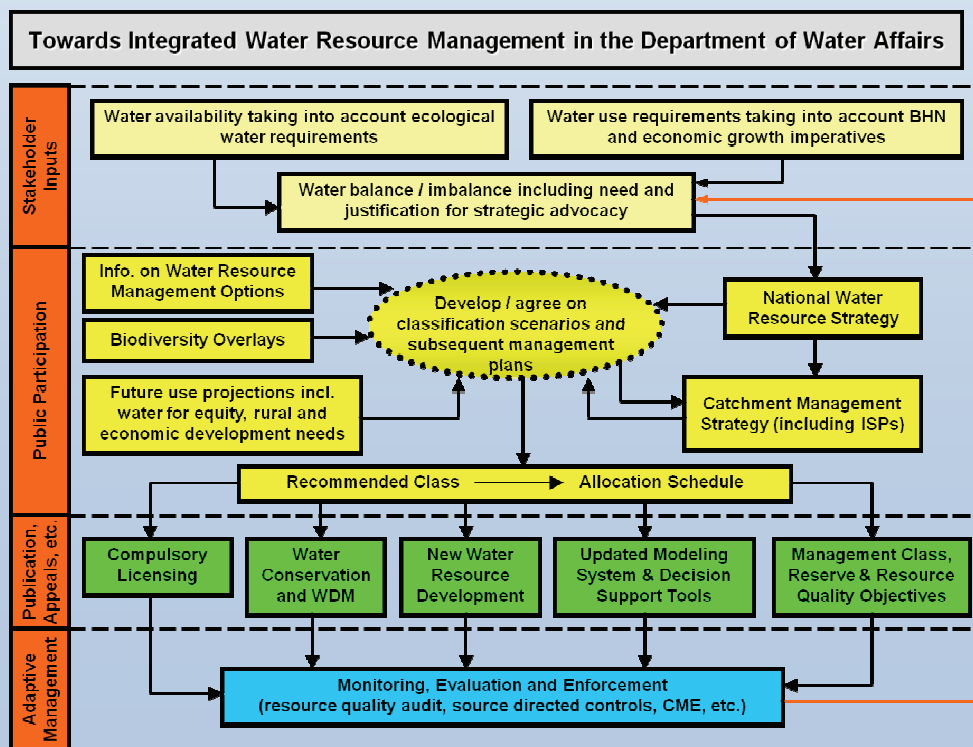
In the subsequent sections we will examine, from a water governance point of view, in more detail how the South African National Water Policy, the National Water Act and the National Water Resource Strategy accommodate for groundwater provisions.

Box 1: National perspectives on IWRM.

Integrated water resource management (IWRM) in the South African context manifests as an increasingly iterative process with stakeholders in order to set the vision for a catchment. Scenarios are assessed in terms of their economic, social and ecological implications, with each offering, in effect, different pathways into the future. Each represents a different trade-off between water-resource development and use on the one hand and protection of the resource on the other. After public consultation, the Department of Water Affairs (DWA) is mandated and has the authority to decide on what that future will be in terms of water resource management. It is intended that this iterative process will ultimately be captured in a countrywide coverage of catchment management strategies. At present, these are represented by DWA's internal strategic perspectives (ISPs), but these will eventually be produced and managed by the newly-forming catchment management agencies (CMAs).

The overall strategy in terms of the move toward IWRM, as envisaged by DWA illustrates the importance and consideration of four key water management aspects (Figure 2). Firstly, water availability taking into account ecological water requirements (top left section) represents the current situation with preliminary Reserves (with limited stakeholder inputs) included. This phase, including water use requirements (top right section), together provide information on the existing water balance for each catchment. Secondly, the planned in-depth investigations and activities linked to water resource classification, with much greater stakeholder involvement, will result in recommended Management Classes for the various parts of a catchment and a linked schedule for the allocation of available water. What follows, thirdly, is an itemisation of the information that will then be available for publication and appeals. These include details of the Management Classes, Reserves and other resource quality objectives (RQOs) set for various parts of the catchment, the details of compulsory licensing emanating from the water allocation schedule, and any proposed new water-resource structures or revision of design and operating rules for existing ones. The fourth step indicates the monitoring, enforcement and evaluation activities that will provide on-going management and oversight of the process. Such a coherent approach can be time-consuming and costly if not properly managed, hence it is important to ensure close cooperation between resource protection, water use, planning and information (among other DWA functions), as well as greater emphasis on sector wide collaboration through strengthening of well established and ongoing partnerships.

Source: H. Pienaar, pers. comm.



2.2.1. National Water Policy

The National Water Policy (NWP; DWAF, 1997) directs the management of both quality and quantity of South Africa's water resources. It builds upon the Water Services Policy (White Paper, 1994) and was a critical step in reviewing the 1956 Water Act and the practices and institutional arrangements for water management in South Africa. It guided the preparation of new water legislation and the creation of practical programs of action. The Policy is based on a set of 28 principles (DWAF, 1997). Key to water resource management in South Africa is Principle 7:

“The objective of managing the quantity, quality and reliability of the nation's water resources is to achieve optimum, long-term, environmentally sustainable social and economic benefit for the society from their use”

Rights and access to groundwater

Combined with Principle 1 that South Africa's new water law shall be *“subject to and consistent with the Constitution (Act 108 of 1996) in all matters”* and will *“actively promote the values enshrined in the Bill of Rights”* it translates to equity in access for all South African citizens to (i) water services, (ii) water resources and (iii) benefits from water resource use (Principles 12, 13, 14 and 25).

The policy recognizes that all water (including groundwater) forms part of a unitary, interdependent water cycle (Principle 5). Although groundwater is not always explicitly mentioned in the policy, it receives the same status as surface water.

Different from the past is that water is now considered a resource common to all (public) and that its use shall be subject to national control (Principle 2). There is no ownership of water but only a right (for environmental and basic human needs, named the “Reserve”) or an authorization (for all other purposes) for its use (Principles 3, 8, 9, 10). The recognition of Government's role as custodian of the “public trust” in managing, protecting and determining the proper use of South Africa's scarce resources (Principles 12 and 13) is central to the new approach to water management.

Groundwater allocation

Water allocation and water use authorization is included in an allocation licensing policy (Section 6) and special provisions are made for groundwater development (Section 6.6.3: *“due to the relatively poorly understood source of water, whose management is a complex matter”*):

- Registration of new wells with the provision of technical information for planning and monitoring purposes, registration of drillers, and the possibility to declare a sensitive area where notice of intention to drill will be required;
- Groundwater use must be carried out in the context of an adequate catchment management plan, based on an understanding of the sustainable yield of the local groundwater resources.

The Policy states the need for development of groundwater permitting systems.

Protection of water resources

The Policy makes provision for the establishment of two sets of measures to protect the water resource (quality and quantity; Section 6.3) and which forms the basis for groundwater allocation: (i) resource directed measures which set clear objectives for the desired level of protection for each resource, and (ii) source directed controls aiming at controlling what is done to the water resources so that resource protection objectives are achieved (Figure 2).

Recharge zone protection is not explicitly mentioned in the policy but a provision for this under allocation licensing procedures can be interpreted from: “provisions will be made to license land uses which substantially impact on the availability of water in an area” (Section 6.2.4). In 2000, the DWA published the ‘Policy and Strategy for Groundwater Quality Management in South Africa’ which includes functional approaches on resource-directed measures and source-directed controls specifically focusing on groundwater. Regarding recharge zone protection an “Artificial Recharge Strategy” was published in 2007 which provides further detail (DWAf, 2007b).

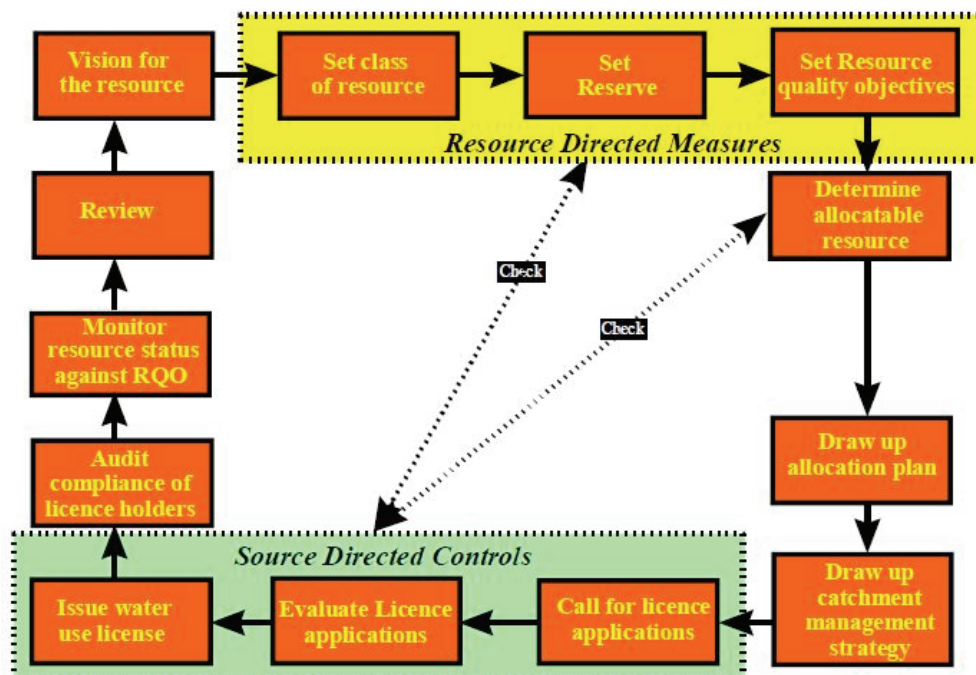


Figure 2: Legislative framework for groundwater management (DWAf, 1999).

Climate change impacts on groundwater resources and opportunities for adaptation

The National Water Policy indirectly refers to climate change as follows (Section 6.7): “human activities are beginning to have a noticeable impact on our climate which could affect the amount and distribution of rainfall and rates of evaporation, all of which must be taken into account in our water resource policy”. Under public safety and disaster prevention, extreme events such as floods and droughts are discussed and under the policy on safety and disaster prevention, a “new approach to disaster management” is called for that “will focus more on developing pro-active and pre-emptive approaches in the field of water related disaster prevention”. The policy recognizes the need for “ongoing monitoring, and investigations, where appropriate, of (amongst others) impact of climatic conditions on water

resources” (Section 6.8.1). It does not explicitly discuss climate change impacts on groundwater resources and opportunities for adaptation.

Conjunctive use and management of surface water and groundwater

Although conjunctive use and management of surface water and groundwater is not explicitly mentioned in the Policy, Section 6.4 discusses the establishment of a water conservation and utilization policy in relation to optimum use of water for each of the main user sectors, agriculture, industry and mining. Furthermore, Section 6.6.3 states that the development and use of all water resources should be undertaken in accordance with the principles of Integrated Environmental Management (DEA, 1992), thereby placing water use and management in a broader perspective.

Groundwater monitoring

A detailed account is given in the Policy on resource monitoring and information management functions. For both surface water and groundwater it states that (Section 6.8.2):

- Monitoring and assessment programmes are needed on the status of water resources (quantity, quality, demands and impacts on water resources) in consultation with all users to support decision-making on development and allocation of water resources, and
- Monitoring and information are functions of national Government, specifically DWA.

Water pricing

To achieve the objectives of water management with the support from local and national management institutions, the Policy provides for a Water Pricing Policy (Section 6.5.3): “*all significant water resource use will be charged for, regardless of where it occurs, and including the use of water for effluent disposal or the interception of water to the detriment of other users*”. The Policy, however, is not clear on compliance regimes.

Transboundary water management

Transboundary water management is captured in Principle 11: “*International water resources, specifically shared river systems, shall be managed in a way that optimizes the benefits for all parties in a spirit of mutual co-operation. Allocations agreed for downstream countries shall be respected*”. South Africa is signatory to the SADC Protocol on Shared Water Course Systems and has established bi-lateral and multi-lateral institutional arrangements to meet specific (transboundary) co-operation requirements. There is no specific mentioning of transboundary groundwater management.

Transboundary water management initiatives under the SADC Regional Groundwater Management Programme include:

- Capacity Building within the Context of Regional Groundwater Management Programme
- Develop Minimum Common Standards for Groundwater Development in the SADC Region
- Development of a Regional Groundwater Information System
- Establishment of a Regional Groundwater Monitoring Network
- Compilation of a regional Hydrogeological Map and Atlas for the SADC Region
- Establish a Regional Groundwater Research Institute/Commission
- Construct a Website on Internet and publish quarterly News letters
- Regional Groundwater Resource Assessment of Karoo Aquifers

- Regional Groundwater Resource Assessment of Precambrian Basement Aquifers
- Groundwater Resource Assessment of Limpopo/Save Basin

At a larger, continental, scale transboundary groundwater management forms part of the agenda of the African Groundwater Commission which was established in 2008. The Commission will act as a sounding board for implementing decisions by AMCOW and other multi-stakeholder consultations in order to provide strategic advice on collaborative and coordinative aspects on groundwater resources management in Africa.

Institutions for water management

Section 7.2 of the National Water Policy presents the new organizational arrangement for South Africa's integrated water resource management at national Government (DWA) and regional (Catchment Management Agencies) levels. It recognizes local organizations such as water boards and irrigation boards but there is no explicit mentioning of local groundwater management arrangements.

Stakeholder participation

Stakeholder participation is and has been a crucial and integral part of South Africa's water sector reform. A well designed and elaborate process to ensure stakeholder participation has been adopted for the development of water related policies and legislation (Box).

Box 2: Consulting South Africa's diverse population about the country's NWRS

As a result of the diverse nature of the South African population, and because water means different things to different people, several different approaches and methods were used to consult about the National Water Resource Strategy (NWRS).

In order to reach all the stakeholders, information on the Strategy was presented verbally, visually and in writing at national level sectoral workshops and public consultation meetings/ open houses held in each of the Water Management Areas (WMAs), throughout the country. A total of 29 national level sectoral workshops and public consultation meetings/ open houses were held in different areas within each WMA, with more meetings in the larger WMAs. Thousands of issues and comments were gathered during the meetings and in writing and submitted to the Department of Water Affairs and Forestry.

Source: Maharaj and Pietersen, 2005

2.2.2. Legislation

The National Water Act (NWA; Act 36 of 1998) which has grown out of the National Water Policy of 1997 is the cornerstone of groundwater governance in South Africa and is based on the three pillars of social equity, economic efficiencies and environmental sustainability. The fundamental principles and objectives of South Africa's water law with implications for groundwater are that:

- All water resources are common to all (*water considered as a public asset*), and are subject to national control (*trusteeship vested in the state*)
- All water has a consistent status in law, irrespective of where (and where in the water cycle; *includes groundwater*) it occurs
- Groundwater is an integral part of the water resource and must be managed as such (*supporting the principles of IWRM: groundwater should not be seen in isolation*).

In accordance with the National Water Policy (1997) and the National Water Act (1998), the National Water Resource Strategy (NWRS; DWAF, 2004) describes in general terms how South Africa’s water resources should be “protected, used, developed, conserved, managed and controlled”.

Controlling groundwater use

The NWA and NWRS make provisions for the regulation of water use through registration of water use and different types of authorisations (schedule 1 water use; general authorizations; existing lawful use and water use licenses). The position regarding the licensing of groundwater, however, is often unclear to both users and planners, especially with regards to regulating local government (as a water user). Together with the slow process of assessment and approval of applications it has resulted in a backlog in issuing groundwater licenses. Only about 20% of registered groundwater use has thus far been verified. The limited capacity within the Department of Water Affairs (DWA) to carry out this task is detrimental to effectively controlling groundwater use, and hence the enforcement of water use licensing conditions is weak. The DWA has initiated a process to update the general authorisations for groundwater abstractions as it pertains to the water use ‘taking water from a water resource (abstraction)’. This latter process resulted in revised general authorisations for groundwater abstractions per quaternary catchment with the aim to improve the control of groundwater use.

The DWA has launched the Letsema programme to deal with the backlog in issuing water use license applications (WULAs). The backlog was 4318 applications and to date 3039 have been finalised, while 1279 are left to be processed (PMG, 2010). Statistics are not available to make the distinction between groundwater licenses and others. Sectoral breakdown of finalised WULAs is given in Table 1. The license application fee is a nominal amount.

**Table 1: Sectoral breakdown of WULAs
(PMG, 2010)**

| Sector | Number of WULAs |
|---|------------------------|
| Agriculture | 825 |
| Power Generation | 13 |
| Local Government (Municipalities) | 191 |
| Stream Flow Reduction Activities | 1130 |
| Mining (includes small scale mining – alluvial diamond mining, sand mining) | 433 |
| Others (includes other industries, government agencies and property – SA road agencies-SANRAL developers) | 447 |
| Total | 3 039 |

Regulating the construction of wells and boreholes

Construction of boreholes (which includes wells) is only mentioned under ‘Conditions for issue of general authorisations and licenses (Chapter 4, Section 29e of the NWA): “*in the case of taking or storage of water (iii) specifying the method of construction of a borehole and the method of abstraction from the borehole*”. Chapter 11 of the NWA refers to the acquisition, construction, alteration, repair, operation and control of government waterworks. There is, however, no explicit regulation concerning the construction of boreholes. Technical guidelines and procedures for drilling, testing and sampling of boreholes are given in “A Guideline for the Assessment, Planning and Management of Groundwater in South Africa” (DWAF, 2008).

Controlling groundwater pollution

The NWA and NWRs make provisions for a waste discharge charge system which is based on the polluter pays principle. A system has been established but has not yet been implemented. There are several examples of groundwater pollution in South Africa (most prominent is acid mine drainage) which is not being effectively addressed. Control of groundwater pollution is further hampered by limited (and in some cases deteriorating) groundwater monitoring networks.

In 2008 DWA introduced a nation-wide incentive based regulation process to monitor the status of drinking water quality (DWQ) management – the blue drop system, and waste water quality (WWQ) management – the green drop system with the aim to improve on the operation and functioning of water services institutions as and when required. A so-called drop score is calculated based on a weighted set of criteria and the results are published in DWA blue and green drop reports and on the DWA web-site (www.dwa.gov.za) which is open to the public. The blue drop score for DWQ management for example is based on the following set of criteria (in brackets % weighting):

- Water safety plan (5%)
- Process control and maintenance competency (10%)
- Efficiency of drinking water quality monitoring programme (15%)
- Credibility of sample analysis (5%)
- Regular submission of DWQ data to DWA (5%)
- Drinking water compliance with the South African National Standards (SANS 241) (30%)
- DWQ failure response management (15%)
- Responsible publication of DWA asset management (5%)
- Efficacy of basic DWQ asset management (10%)

Once a water services authority scores higher than 95% it receives a blue drop status. For the green drop status the score has to be higher than 90%. Blue or Green Drop status will allow consumers to drink water from the taps in the town with confidence, and be secure in the knowledge that wastewater is managed and discharged in a sustainable, environmentally-acceptable manner. In towns which have not yet been awarded Blue Drop, it should not be perceived that the water is unsafe for human consumption but rather that the manner in which drinking water quality is being managed still requires improvement. To date the programme has already resulted in significant improvements of the operation of water services institutions.

Private sector participation in groundwater exploration and development

Section 116 (1) (iii) of Chapter 11 on Government Waterworks states that the Minister may make regulations providing for “*the private development of a government waterwork*” (which includes groundwater development). Box 4 gives some examples of private sector participation in exploration and development of groundwater

Organizational arrangements and responsibilities for groundwater management and protection

Chapters 6, 7, 8, 9 and 10 of the NWA exclusively deal with the institutional arrangements in water resources management. They describe the general powers and duties of Minister and Director-General (6), the establishment and organisational arrangements of Catchment Management Agencies (7), Water User Associations (8), Advisory Committees (9), and International Water Institutions (10). Schedules 3 to 6 also deal with institutional matters.

Section 80 of the NWA refers to initial functions of a catchment management agency and implicitly to groundwater management and protection:

Box 3: Private sector participation in exploration and development of groundwater

The private sector is involved in a number of groundwater exploration and development activities. These activities are procured through the government tender process. Recent examples include:

- Appointment of a professional service provider for the high confidence groundwater reserve determination study in the Mzimvubu to Keiskamma Water Management Area
- Appointment of a professional service provider for the high confidence groundwater reserve determination study in the Mvoti to Mzimkhulu Water Management Area
- Appointment of a professional service provider for the high confidence groundwater reserve determination study in the Limpopo Water Management Area
- Appointment of a professional service provider: Provision of support to the implementation and maintenance of the Water Conciliation Strategy for the KwaZulu-Natal Coastal Metropolitan Area
- Appointment of a professional service provider for the development of a reconciliation strategy for the Olifants River Water Supply System

The involvement of the private sector means that a number of products and solutions can be delivered timeously. In recent years, however, because of a lack of capacity within the public sector, there is inadequate follow-up and implementation of solutions developed by the private sector.

- *To investigate and advise interested persons on the protection, use, development, conservation, management and control of the water resources in its water management area;*
- *To develop a catchment management strategy;*
- *To co-ordinate the related activities of water users and of the water management institutions within its water management area;*
- *To promote the co-ordination of its implementation with the implementation of any applicable development plan established in terms of the Water Services Act, 1997 (Act No. 108 of 1997); and*
- *To promote community participation in the protection, use, development, conservation, management and control of the water resources in its water management area.*

A detailed description of the institutional landscape is also given in part 5 of Chapter 3 of the NWRS (2004).

Linkages with policies and legislation from other sectors

The National Environmental Management Act No. 107 of 1998 (NEMA; DEAT, 1998) – The Act makes provision for co-operative environmental governance by establishing principles for decision-making on matters affecting the environment, institutions that promote cooperative governance and procedures for co-coordinating environmental functions exercised by organs of state.

Parsons et al. (2008) conducted a review of groundwater use approval procedures and concluded that:

- Both DWA and DEA require potential groundwater users to obtain a licence or approval when certain levels of use or conditions are exceeded;
- The two departments follow different procedures with respect to assessing groundwater use applications; and that
- No effective co-operative governance procedures have been established; with different procedures, guidelines and definitions preventing the departments and their officials functioning in a standardized and integrated manner.

The lack of clear guidance regarding procedures, information requirements and co-operative governance results in officials adopting conservative, uninformed positions regarding information they require before considering approval for groundwater development and use.

This has a number of consequences (Parsons et al., 2008):

- The officials become overloaded with applications, many of which could be approved without requiring formal study;
- A significant (and unnecessary) backlog of applications develops, proving frustrating to officials and applicants alike; and
- Proponents are required to undertake expensive specialist and public consultation studies, some of which are unnecessary.

Other sectoral legislation that impacts on groundwater includes the: Conservation of Agricultural Resources Act 1973 (protecting wetlands); the White Paper on Spatial Planning & Land Use Management: Wise Land Use (2001) (including the Land Use Management Bill 2001 (which is intended to replace the Development Facilitation Act 1995)); the National Strategy on Sustainable Development (NSSD) 2010 and its Draft Act Plan for 2010-2014 (Tobias, 2010). Further legislation of importance for groundwater are the Mineral and Petroleum Resources Development Act 2002 (chapter 4 which regulates water licences for mining activities); the National Environment Management: Air Quality Act 2004 (indirectly mitigating the impact of climate change and global warming on both surface water and groundwater by regulating activities that might produce greenhouse gases); and the National Environmental Management: Waste Act 2008 (Tobias, 2010).

Tobias (2010) concluded that the following sections of the innovative NEM: Waste Act can have a potentially far-reaching effect on groundwater sources in South Africa (Table 2): the articulation of the general duty of the State regarding waste management regulation (section 3); the explicit provision for the application of NEMA (section 5); the publication of national norms & standards with respect to waste management (section 8) as well as provincial and municipal waste services standards (sections 7-9); the extension of the legal responsibility of producers of material and substances that can become waste (section 18); the provision for listed and controlled waste management activities (sections 19-20); the general duty of care in respect of waste (section 16); and the treatment of contaminated land (sections 35-41).

The NSSD covers three main topics: directing the development path towards sustainability, changing values and behaviour, and restructuring the governance system and building capacity. The Draft Action Plan deals with responses to climate change, greening the economy, building sustainable communities, sustaining ecosystems and natural resources, and enhancing governance systems and capacity (Tobias, 2010).

Table 2: Sectoral policies and legislation and implications for groundwater management

| Act/Policy | Implications for groundwater management |
|---|---|
| the White Paper on Spatial Planning & Land Use Management: Wise Land Use (2001) | <ul style="list-style-type: none"> • Considers “best use” for a given area of land and prohibits activities on land that may be harmful to the broader environment thus contributing to groundwater protection. |
| National Strategy on Sustainable Development (NSSD) 2010 | <ul style="list-style-type: none"> • Promotes integrated planning and should consider water as part of the planning process. • Prioritises sustaining ecosystems and using natural resources such as water efficiently. • Responds to environmental challenges which include climate change and dealing with its consequences such as droughts and floods. |
| Mineral and Petroleum Resources Development Act 2002 | <ul style="list-style-type: none"> • Requires environmental management plans that requires minimisation of polluting activities that impacts on groundwater. The plans must be supported by detailed groundwater investigations. |
| National Environment Management: Air Quality Act 2004 | <ul style="list-style-type: none"> • Regulates greenhouse gases and its potential impacts on the water environment. |
| National Environmental Management: Waste Act 2008 | <ul style="list-style-type: none"> • Requires reasonable measures for the prevention of pollution and ecological degradation and for securing ecologically sustainable development. • Requires remediation of land that may have a negative impact on the environment. |

National Groundwater Strategy

In 2007 a process was started, which was led by the Department of Water Affairs (DWA) and is nearing completion, to formulate a National Groundwater Strategy (NGS, 2010). The NGS addresses shortcomings in groundwater provisions in the 1st edition of the NWRS. The 3 year consultative process involved many public sector experts and consultants. The strategy serves as input to the second edition of the NWRS which is due in 2011. NGS objectives are that:

- 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.

The NGS proposes priority actions in the areas of (i) policy, legislation and regulation, (ii) water resources planning, (iii) human capacity, (iv) sustainable groundwater management, (v) institutional capacity, (vi) information management, (vii) groundwater research, and (viii) communication and awareness (Box 4).

2.2.3. Summary

South Africa's National Water Policy of 1997 and its supporting legislation, the National Water Act of 1998, are recognized internationally as being amongst the most progressive initiatives in the area of water resource management. They may well provide a model for many other countries in the world to shift and adapt to the newer realities of managing scarce natural resources, in an environment which is uncertain and continually changing, influenced by global (e.g. climate change), regional and localized processes. The National Water Act

provides for a powerful set of regulatory tools for groundwater assessment, planning and management. The NWRS (2004) provides for an implementation framework for the NWA but is incomplete with regards to groundwater governance provisions. The NGS (2010) addresses these groundwater management related deficiencies in the NWRS (2004) and provides input to the new NWRS (2011). As key to its success is appropriate implementation, the NGS (2010) formulated priority actions to be undertaken (Box 4).

2.3. Institutions

2.3.1. Institutional landscape for water resource management

Water resource management of both surface water and groundwater in South Africa takes place at various levels with responsibilities progressively being decentralised. Table 3 presents an overview of the roles and responsibilities of institutions involved in water resource management.

At the national level, the role of the Department of Water Affairs (DWA) is to provide a “national policy and regulatory framework” for regional and local institutions to conduct the management of water resources. Implementation of the national water policy and strategy is currently carried out by DWA Regional Offices and the two existing prototype CMAs namely the Inkomati and the Breede-Overberg CMAs.

During the restructuring of DWA which commenced in 2002-2003, the two Directorates of Hydrology and Geohydrology were abolished and a new directorate was created called Hydrological Services. Functions of the Geohydrology Directorate were transferred to other Chief Directorates such as Resource Directed Measures, Water Use, Planning and only monitoring programmes remained within Water Resources Information and Management. The Directorate Hydrological Services deals with Geohydrological Information (sub-directorate) and groundwater resources monitoring and assessment (sub-directorate). The chief directorates mentioned above, do have sub-directorates that deal with groundwater as follows: Resource Directed Measures – reserves; Water Use – licenses; and Planning – incorporate groundwater in the planning scenarios, etc. The Directorate Hydrological Services generates groundwater related data from all monitoring programmes across the country and from transboundary aquifers. They also manage the National Groundwater Information System portfolio.

The country is divided into 19 Water Management Areas (WMAs) and these are or will be managed by Catchment Management Agencies (CMAs) based on Catchment Management Strategies (CMSs). Except for the Inkomati CMA and the Breede-Overberg CMA, which have been established in 2005 and 2007 respectively, a moratorium has been imposed on the establishment of the other (17) CMAs until DWA’s Institutional Realignment Project (IRP) is finalized (Box 5). It is envisaged that CMAs will be financially self-sufficient, through revenue generation by means of the collection of water use charges, with the possible exception of a few of the smaller WMAs where this may not be feasible. However, this intention may need to be reviewed and sufficient financial support may have to be provided to CMAs via the fiscus to ensure effective staffing and management without overburdening water users with increased tariffs. Until such time as CMAs are established and fully operational, water management in the WMAs is carried out by a DWA Regional Office and is guided by a precursor of the CMSs, a series of documents developed by DWA called Internal Strategic Perspectives (ISPs).

Box 4: Overview of NGS priority actions (NGS, 2010)

Policy, Legislation and Regulation:

- All groundwater water use license applications must be resolved within six months
- All larger groundwater users must be registered and possess water use licenses
- Existing groundwater use must be verified within a reasonable time period
- Borehole drillers must be registered with DWA, and must submit drilling data from all boreholes drilled

Water Resources Planning:

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

Human Capacity:

- DWA should develop adequate capacity to fulfil its groundwater functions
- DWA to develop and implement a national capacity building strategy
- DWA to mobilise private sector support where necessary to capacitate regional offices
- Implement practical, in-service training courses on priority aspects (e.g. licensing process, the Reserve, groundwater monitoring, etc.) for DWA staff

Sustainable Groundwater Management:

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

Institutional Capacity:

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

Information Management:

- DWA to announce the National Groundwater Archive (NGA) to the Public Domain, including Catchment Management Agencies (CMAs), Water Resources and other external stakeholders, as well as finalize the adoption of measures to incorporate privately held datasets, including the registration of drillers
- Develop and implement an integrated groundwater information system to support water services provision at municipal level

Groundwater Research:

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

Communication and Awareness:

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

Table 3: Roles and responsibilities of institutions in water resource management (after DWAF, 2008)

| Level | Institution | Roles and Responsibilities |
|----------|---|--|
| National | Department Water Affairs (National Office) | <ul style="list-style-type: none"> Responsibility to “protect, use, develop, conserve, manage and control water resources in a sustainable manner. for the benefit of all” Develop policies, strategies and guidelines for effective resource management. Organizational approach <ul style="list-style-type: none"> Centralized planning and policy making Support function to Regional Offices Decentralized implementation, regional and catchment level |
| | Department of Environment Affairs | <ul style="list-style-type: none"> Protection, conservation and maintenance of terrestrial and aquatic ecosystems and water resources |
| Regional | Department Water Affairs (Regional Offices) | <ul style="list-style-type: none"> Delegated responsibility of water resource management Implementing agents for the Department of Water Resources policy and strategy Audit of CMA with its related functions and responsibilities |
| | Catchment Management Agency (CMA) | <ul style="list-style-type: none"> Responsible for the day-to-day management of groundwater resources Delegated responsibility for some water management activities, including water use allocation Delegation managed and monitored against a specific catchment management strategy for each WMA |
| | Environmental Section of the Department of Agriculture and Land Affairs | <ul style="list-style-type: none"> Protection, conservation and maintenance of terrestrial and aquatic ecosystems and water resources |
| | Aquifer Management Committee | <ul style="list-style-type: none"> Responsible for cross-boundary coordination where the aquifer spans more than one WMA |
| Local | Catchment Committee | <ul style="list-style-type: none"> Responsible for day-to-day management of the groundwater resources within the WMA or local catchment |
| | Water User Association | <ul style="list-style-type: none"> Responsible for the management of the water resources being utilized, including groundwater resources |
| | District and Local Municipalities | <ul style="list-style-type: none"> Planning and developing water services and infrastructures to ensure acceptable minimum levels of provision to their constituents Management of local water sources |
| | Water Boards | <ul style="list-style-type: none"> Organs of state established to provide water services to other water services institutions |
| | Water Forums and Reference groups | <ul style="list-style-type: none"> Monitoring and management of water resource development schemes |
| | Ward Councillors and Ward Committees | <ul style="list-style-type: none"> Representation of committee needs Local management of water schemes Set up and operate water management committees |
| | Task Teams | <ul style="list-style-type: none"> Responsible for specific projects of a short-term nature, relating to assessment, planning and management of water resources. |

Box 5: Establishment of CMAs

In 2007, the Institutional Realignment Project (IRP) was initiated by the Minister. The project was intended to investigate the viability of some of the water sector institutions. In the case of CMAs, there were concerns regarding the viability of some owing to the limited technical human resources capacity and low revenue base in certain WMAs. The primary objectives of the IRP were to assess the institutional arrangements and to propose institutional models that would facilitate more efficient and effective provision of water services and water resources management. The IRP recommended the establishment of 9 CMAs as opposed to 19 CMAs as envisaged in the 2004 NWRS. This would entail CMAs managing water resources in multiple WMAs instead of having one WMA per CMA as originally intended. With the exception of the CMA in the Vaal catchment which would manage water resources in 3 WMAs, the remaining 8 CMAs would each manage water resources in two “adjacent” WMAs. The reduction in the number of CMAs was motivated on the assumption that the new organisations would be able to leverage economies of scale and facilitate internal cross-subsidisation between WMAs in order to create financially viable institutions. The IRP determined that only 4 of the 19 CMAs were financially viable as at 2009. Projections indicated, however, that should the CMAs be consolidated and the economies of scale be achieved, then 7 out of the 9 CMAs could be viable by 2012.

Although Water User Associations (WUAs) are water management institutions that operate at local level, their primary purpose is not water management. They are assisted by Advisory Committees and non-statutory bodies such as Catchment Forums. Existing irrigation boards, subterranean water control boards and water boards established for stock watering purposes will continue in operation until they are restructured as water user associations. Water Boards established in terms of the Water Services Act, 1997 (Act 108 of 1997), provide bulk water services to other water services institutions within their respective service areas, including municipalities and industry. Some Water Boards (e.g. Rand Water and Umgeni Water) undertake elements of (ground)water resource management; managing dams and other water resources infrastructure on behalf of DWA, undertaking water quality and flow monitoring, water resources planning, etc. At municipal level there is the requirement of a Water Services Development Plan (WSDP as part of an Integrated Development Plan; IDP) which is to be formulated by a Water Services Authority (WSA) and focuses on access to water taking into account water supply sustainability.

In areas where an aquifer(s) span(s) more than one WMA, DWAF (2008) proposed to establish an Aquifer Management Committee (AMC; Figure 3), an advisory body (not legislated) set up by the various role-players in the catchments to provide strategic input to the assessment, planning and management of the groundwater resources in the affected areas. Catchment Committees (CCs), a legal entity set up by the CMA in accordance with Section 82(5) of the NWA, are envisaged to address site-specific issues. Figure 3 shows the positioning of the proposed AMC in a broader context including linkages with water institutions at various levels. Note that a WUA takes into account the interests of groundwater users and other stakeholders. In the case of groundwater resources, however, Garduño et al. (2009) advocate the establishment of a higher level Aquifer Management Organization in which WUAs and other key stakeholders are represented.

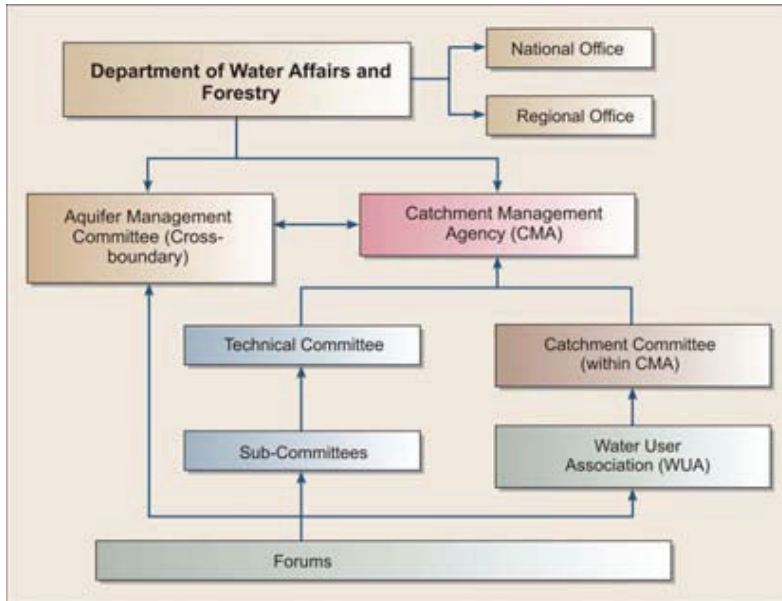


Figure 3: Institutional framework for (ground)water resource management (DWA, 2008)

Other institutions involved in water resource management

Other institutions involved in water resource management include the Department of Environment and the Department of Agriculture, Forestry and Fisheries for protection, conservation and maintenance of terrestrial and aquatic ecosystems and water resources. The Departments of Environment, Tourism, Energy, Health, Human Settlements, Mineral Resources and Cooperative Governance and Traditional Affairs are important users of water.

National Treasury is involved through the allocation of budget to implement the mandates of the different departments. Figure 4 provides an overview of the linkages to water related planning in the national planning framework.

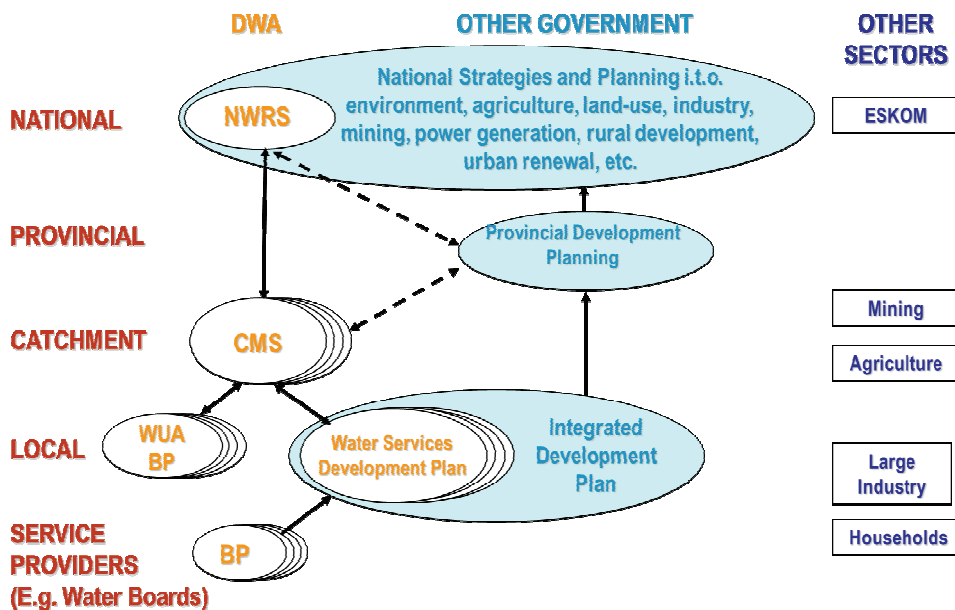


Figure 4: Water related planning in the national planning framework (NWRS, 2004)

From a transboundary water resources point of view, South Africa's focus has been on shared management of surface water, although management of shared aquifers is beginning to gain more prominence. Before embarking on the preparation of complex international agreements, however, it is advisable to assess hydrogeologically the degree of actual 'upstream-downstream' interaction (H. Garduño, pers. comm.; Box 6).

Box 6: South Africa's transboundary aquifers

South Africa shares approximately 5 116 km of land border with Namibia, Botswana, Zimbabwe, Mozambique, Swaziland and Lesotho. A recent analysis indicates that 50 % of South Africa's border is underlain by class 1 or 2 aquifers (that is, aquifers with a median yield < 0.5 l/s, according to the Department of Water Affairs' classification system). A further 46 % of the border is underlain by class 3 aquifers (median yield 0.5 to 2 l/s). Aquifers with better yields account for only about 4 %, of South Africa's total transboundary aquifers (classes 4 and 5). The majority of groundwater along South Africa's land borders therefore occurs in aquifers of low transmissivity. In aquifers with low transmissivities, the common perception of groundwater flowing across political borders becomes problematic, particularly where population densities (and consequently abstractions) are low.

In general, management attention should concentrate on general technical cooperation over transboundary groundwater, since transmissivities and demands are often too low to lead to disputes over the resource in the "traditional" sense of conflict over a shared resource. This does not mean that transboundary groundwater is unimportant in southern Africa, just that transboundary groundwater management should be focused on the limited hydrogeological knowledge in many areas, and the necessary training, cooperation and access to the data to ensure sustainable utilisation by the states concerned.

There are however some important, albeit smaller, areas of higher-transmissivity transboundary aquifers shared by South Africa, such as the alluvium associated with the Limpopo River and areas of dolomite such as the Pomfret-Vergelegen dolomite aquifer. These aquifers do have the potential for transboundary conflict over shared water, and need to be managed with care. Better data collection, and improved sharing of data, are likely to be central to mitigating and resolving any future conflicts.

Source: Cobbing et al. 2008; NGS 2010

During a "*Groundwater in the SADC-IWRM Initiative*" workshop in Gaborone, Botswana (18-19 November 2008) it was advocated to proactively include the incorporation of groundwater into River Basin Organisation programs; that groundwater should form part of conjunctive resource management; and to improve communication/awareness creation. The SADC Groundwater Management Program has also been facilitating the establishment of the Groundwater Management Institute for Southern Africa (GMISA) at the Institute for Groundwater Studies, Orange-Free State University in Bloemfontein since 2008. The GMISA will provide a regional integrated focal point for the coordination of groundwater activities in the SADC Region. To date, however, the GMISA is still not operational. Presently, there is only one international body dealing directly with a shared aquifer, and that is the Vioolsdrif WUA which deals with irrigation from a shared aquifer that falls across the border with Namibia.

2.3.2. Integration of DWA's groundwater with surface water sections

With the promulgation of the NWA of 1998 the status of groundwater changed from largely "private water" to "public water", hence the role of the state changed considerably with regards to ensuring sustainable (integrated) management of groundwater. Major changes also

occurred in the institutional setup of the water sector over the past 12 years with the establishment of CMAs, revision of local government powers, functions and boundaries, the establishment of new WUAs as well as the conversion of water and irrigation boards to WUAs.

Restructuring within DWA over the past few years in order to implement the National Water Act and the Water Services Act effectively resulted in major changes in the organisational setup for the management, protection and use of groundwater, with groundwater being integrated into all other water management functions, such as planning, information management, and resource protection. The former Directorate Geohydrology was dissolved and geohydrologists were redeployed to a number of directorates (integrated with surface water sections). While the purpose of this restructuring was to ensure integrated water resource management, it did leave the new DWA without a central co-ordinating point or “champion” for groundwater. Interviews with staff (DWAF, 2008) revealed that the lack of a central focus or champion is perceived as a problem; it also results in inadequate co-ordination with and support to regional offices and municipalities. To improve co-ordination, a new post may be created at senior level within the Directorate Hydrological Services with the tasks of (i) ensuring co-ordination of groundwater activities within DWA, between groundwater practitioners and other relevant line functions, (ii) promoting groundwater as a key water resource, and (iii) ensuring that groundwater officials are made aware of their broader suite of functions in supporting and implementing the National Water Act and the Water Services Act. Preferably, such a senior groundwater person should have a multi-disciplinary team including ecologists and socio-economists and should have a say on groundwater related budget allocation within DWA at central, regional and local levels to play an effective role (H. Garduño, pers.comm.). What remains a critical issue is the very limited hydrogeological capacity within the Department.

2.3.3. Corruption

Water corruption in southern Africa hit the headlines earlier this decade when the chief executive of a US\$8 billion construction project was found guilty of having accepted more than US\$2 million in bribes from multinational construction companies to secure contracts. Lesotho succeeded in bringing the erring parties to justice—the chief executive was sentenced to 18 years in prison in 2002 and some of the companies involved received multi-million fines and have been debarred from receiving World Bank contracts. Since the incident, the governments of both Lesotho and South Africa have stepped up their fight against corruption in the water sector as it can seriously undermine the effectiveness of institutions. In South Africa, compliance with water regulations is monitored and enforced by a special unit in the Department of Water Affairs. The unit is nicknamed the “Blue Scorpions”. The Blue Scorpions, set up in 2005, fight a range of water-related crime, from pollution to unlawful abstraction from South Africa’s water courses.

The South African legislative framework for water resource management is comprehensive and key to its success is appropriate implementation. The NGS (2010) identified priority actions to address weaknesses in the implementation of the NWA and NWRS (2004). Delayed and non-action results in unsustainable utilization and protection of water resources and may provide opportunities for corruption (bribery). Some of the most common forms of dodgy dealings with regards to water-related crime are fast-tracking procurement contracts and giving consultancy jobs to pals. Another area vulnerable to ‘friendly’ decisions, bribery and corruption relates to the lack of clear guidance on water use licenses regarding

procedures, information requirements and co-operative governance. Recently, the capacity of the Compliance, Monitoring and Enforcement Directorate of the DWA (Blue Scorpions) has increased significantly, and 14 water management inspectors have been recruited and trained. In the 2009/10 financial year, the department had issued 239 directives; 31 of these were “resolved positively” and 14 were pending in court. The others were in the process of being resolved.

In 2010, South Africa ranked 54 with a Corruption Perceptions Index (CPI) of 4.5 out of 178 countries (TI, 2010). The CPI measures the degree to which public sector corruption is perceived. The index scores countries on a scale from 10 (very clean) to 0 (highly corrupt). South Africa is perceived as one of the five least corrupt African countries (the other four countries being Botswana, Mauritius, Cape Verde and Seychelles). Stronger water reforms and lower corruption (higher CPI) correlate with higher levels of access to water supply as is the case for South Africa (Campos and Pradhan, 2007).

2.3.4. Other sectors linked to groundwater

Agriculture

Agriculture currently directly contributes about 3% of Gross Domestic Product (GDP; down from close to 10% in the 1960s), however, forward and backward linkages are strong (Laker, 2009). For example, the food processing industry contributes about 14% of GDP and agricultural exports (mainly wine, fruit and sugar) are important sources of foreign currency earnings (Laker, 2009).

Agriculture is the single largest user of water in South Africa. This includes groundwater. It is estimated that about 78% of all groundwater abstracted is used for irrigation. The introduction of central pivot irrigation systems has led to substantial use of groundwater resources in the country. For example, in the Sandveld region of the Western Cape Province, expansion of potato farming has resulted in the last 10 years that the number of centre pivots increased from 599 to 1355 (Zahn and Conrad, 2009). This is resulting in a negative water balance. Currently, about 20% of total agricultural water use in South Africa is from groundwater sources. The National Department of Agriculture, Forestry and Fisheries has set a target of bringing an additional 600 000 ha under irrigation. This will put additional pressure on water resources and may lead to an increase in groundwater demand.

The use of fertilizers, pesticides, herbicides and growth hormones are contributing to groundwater quality problems, specifically diffuse pollution. Nitrate is the most common agricultural contaminant. Salinisation of groundwater is occurring beneath lands that are subjected to extensive irrigation. At the Vaalharts irrigation scheme in the Northern Cape Province approximately 30 000 tons of dissolved salts reach the groundwater annually (Conrad et al, 1999).

Mining

South Africa is a leading world supplier of a range of minerals and mineral products. In 2007, some 53 different minerals were produced from 1 414 mines and quarries, 50 of which produced gold, 31 platinum-group minerals, 96 coal and 344 diamonds, all as primary commodities (DME, 2008). Mining contributes about 10% of the national GDP.

The mining sector uses about 3-4% of available water. Approximately 85% of the mines use groundwater as a water source. The new mining developments planned for South Africa are

often in water scarce areas such as in the Waterberg coalfields of the Limpopo Province and the Steelpoort Valley in the Limpopo/Mpumalanga Provinces. This means that extensive water transfer schemes are required and local groundwater resources will be under threat.

The discharge or decant of contaminated water and highly saline effluents from mining activities and/or abandoned mines (commonly referred to as acid mine draining) is a serious environmental threat and social concern. In particular, acid mine drainage from gold mines in the Witwatersrand area and coal mines in Mpumalanga needs urgent attention. Mining operations also pose other groundwater quality threats, including hexavalent chromium resulting from beneficiation of chrome ore and radionuclide contamination from gold mining operations.

Power generation

Power generation uses approximately 2% of total water in South Africa. However, assurance of water supply is critical as any failure in water supply will directly affect electricity production and hence economic activity. About 26% of the liquid petroleum in South Africa is from coal and gas. The electricity, gas and water sectors account for 2% of the national economy.

Many small scale groundwater schemes in rural areas are dependent on energy such as electricity or diesel. Consequently, increased energy costs have implications for water access and water use (water treatment costs, etc.). Eskom, the Electricity Supply Commission of South Africa, currently offers 24 tariffs to its customers, nine are for business and industry, seven are for residential customers and eight for rural customers. On average, rural customers (predominantly farmers) pay 74 cents per kWh compared to an average 96 cents per kWh to supply them (http://simbalism.co.za/press_Africa_and_Eskom.php?articleid=233). 'Inclining block rate' tariffs will be introduced by Eskom and municipalities in accordance with the requirements of the National Energy Regulator of South Africa (NERSA). A rational power supply and pricing policy for pump irrigation is a powerful tool for the indirect management of both groundwater and energy use. Consumption-linked pricing of power can improve efficiency of water and power usage. Metering is a possibility but has the drawback of high transaction costs and strong farmer resistance. Another solution, which has not received enough attention, is a transformed, rational flat-rate tariff, combined with restrictions on power supply.

The draft Integrated Electricity Resource Plan of South Africa (DE, 2010) indicates that 52 248 MW of new capacity is required in order to meet the projected demand and provide adequate reserves over the next 20 years. Whilst water efficient technologies are proposed there will be a reliance on coal for the foreseeable future. The coal reserves are located in water-scarce areas. There will be a reliance on groundwater resources and increasing competition with other sectors.

Contaminants in unlined dams, including ash containment structures, which are associated with power stations, are polluting groundwater resources. In power station water balances groundwater is normally indicated as an unspecified sink.

Large industries

The industrial sector produces value-added goods through the processing of primary raw materials, the use of semi-processed inputs and/or the assembly of components through a diverse mix of value-adding activities (Hoffman, 2010). It is estimated industrial water use is

about 5% of the total national freshwater use. This share is expected to grow as the National Industrial Policy Framework (NIPF) emphasises expansion of industrial output from agriculture and commodities to sectors such as manufacturing (Hoffman, 2010).

Depending on the industrial activity there is a high risk of impact on groundwater quality, through waste discharges. Some industries may also be intensive water users.

Environment

The protection of groundwater resources in South Africa is often neglected. This is evidenced by numerous pollution incidences and the inability to deal with the serious mine water question. Protection measures have been developed but these approaches have not been implemented at a national scale.

Groundwater has important environmental functions. Many ecosystem services have a direct linkage with groundwater storage, recharge and discharge. However, the interdependencies between ecosystem services and groundwater are not yet fully recognised and valued in decision making and in the management of water resources and river basins (Braune, 2009). Groundwater is generally interpreted as falling outside the definition of the ecological reserve in terms of the National Water Act (Act 36 of 1998), except where groundwater discharges sustain surface water bodies (Braune, 2009).

There is an increasing awareness about the impact on groundwater resources and various environmental legislative requirements necessitate that groundwater is considered in land use planning such as solid waste sites etc.

Spatial planning

The White Paper on Spatial Planning and Land Use Management (DLA, 2001) states that land use and development decisions must promote a harmonious relationship between the built and the natural environment while ensuring that land development is sustainable in the longer term.

Currently, 35% of the national economy is linked to Gauteng and is growing faster than average. Employment growth is taking place in the north of the country, parts of KwaZulu-Natal and some secondary cities. The unemployment rate increases in the Western Cape and parts of the Eastern Cape. Similarly, employment is declining over much of the central interior (North West, Free State, Northern Cape and parts of Eastern Cape). Economic growth is associated with areas that are water-deficit. As expected, there is migration to the cities with resultant population increases and increasing demand for water.

A National Planning Commission has been established to produce a long term plan for South Africa. This commission will need to consider water resource issues and implications for spatial development.

Land use planning at local level, in some cases, does not consider groundwater resources. Groundwater protection zoning and vulnerability mapping are concepts that have not yet been adopted and implemented at local level in South Africa but has been done at national and research levels. There has been mostly a reactive response to groundwater pollution through remediation attempts and examples include dealing with groundwater pollution from electroplating processes, waste sites, timber yards and so forth.

Rural development

South Africa is on target to meet the MDG goals of providing access to water to its most vulnerable households. Most of the outstanding needs are located in rural areas. These communities are mostly reliant on groundwater resources.

The new National Department of Rural Development and Land Reform (DRDLR) are developing a Comprehensive Rural Development Programme (CRDP) throughout the country. Water and groundwater will be important for improved economic infrastructure in the rural areas.

2.3.5. Strengths and weaknesses of institutional capacity

The National Water Policy and National Water Act can be considered groundbreaking legislation in the management of water resources and from this a well-defined institutional landscape evolved. DWA's role at national level will progressively change, becoming more concerned with national policy, the regulatory framework for water resource management, and monitoring the performance of other (regional and local) institutions. Each of the 19 WMA's must be managed by a CMA in collaboration with local institutions. Most CMAs, however, are not yet established nor are they operational and assistance in water resource management through ISPs, which were developed between 2002 and 2004, is provided by DWA Regional Offices. Key issues related to water resource management at WMA level are:

- Lack of updating of ISPs (the initial requirement was a yearly update)
- Lack of trained hydrogeological staff (see Section 2.4)
- Inadequate information on groundwater

Due to the delay in establishing and operationalizing CMAs, with corresponding delays in updating ISPs and formulation and implementation of CMSs, it often happens that at local level (ground)water issues are not adequately being taken care of in the general planning (IDPs). Some of the measures proposed by the NGS (2010) to improve the institutional capacity include:

- DWA should capacitate and provide adequate resources to DWA regional offices to fulfil their water resource management functions and should support/re-establish WUAs to improve management of groundwater resources at local level
- Roles and responsibilities for groundwater development and management must be re-defined within the constraints of limited capacity within both water resource management and water services institutions (see also Section 2.4), and
- Improve cooperation between government departments and the private sector to leverage capacity and resources; e.g. public – private partnerships to assist in managing aquifers.

2.4. Knowledge and capacity

2.4.1. South Africa's information systems on groundwater

The Department of Water Affairs kept groundwater data in a database called the National Groundwater Database (NGDB), which contained data on ~247 300 boreholes. The NGDB has recently been replaced by a National Groundwater Archive (NGA) to enable users to upload data remotely. Another database, the Water Use Authorisation Registration Management System (WARMS) keeps data on volumes of groundwater used, mainly based

on registered volumes. Key issues related to the groundwater information systems are (NGS, 2010):

- Inaccessibility of data (especially those held by the private sector),
- Registration of drillers,
- Weak institutional arrangements for data collection and databases, and
- Incompatibility of various databases and information systems.

Most groundwater consultants and contractors maintain extensive private databases for their own use, in a variety of formats and standards. There is an urgent need for registration of drillers with the legal (NWA) requirement to submit details of drilled boreholes to DWA for inclusion in the National Groundwater Archive (NGA). The private sector and the drillers in return would benefit from access to a much improved and up to date database. Similarly, there is also evidence that municipalities collect groundwater data but retain it for internal use and are not aware of the requirement for wider distribution.

Some of the measures proposed by the NGS (2010) to improve DWA data quality, accessibility and exchange are:

- DWA must finalize the National Groundwater Archive (NGA) as well as the incorporation of privately held groundwater datasets
- Registration of drillers and capturing of driller's groundwater data in public databases.
- Support water services institutions in the development and implementation of asset registers on groundwater infrastructure and monitoring of groundwater use and groundwater quality
- Engage with relevant authorities to maintain hydrological and environmental monitoring programmes necessary for groundwater management; such as the rainfall monitoring systems maintained by the South African Weather Service
- Develop and implement an integrated groundwater information system to support water services provision at municipal level. Improve the compatibility (and/or integration) of existing groundwater databases / information systems maintained by different institutions (including water quality databases and municipal groundwater asset registers)
- Re-assess the funding required by DWA head and regional offices for groundwater monitoring, data capture as well as the operation and maintenance of groundwater infrastructure.

In 2002, DWA started the Groundwater Resource Information Project (GRIP) in the Limpopo Province to gather, verify, upload and use groundwater data to improve management and development of rural groundwater resources. The project serves as a role model for other provinces (Box 7).

User surveys should also be carried out to ensure that improvements to groundwater information systems are demand-driven, cost-effective and pragmatically focused (H. Garduño, pers. comm.). These surveys and institutional and social related data and information (such as groundwater use and user profiles) will form part of the NGA.

Box 7: Groundwater Resource Information Project (GRIP)

The Groundwater Resource Information Project (GRIP) is a good example of how to improve quality and quantity of groundwater data. GRIP is a national DWA project to improve data holdings by accessing unpublished or “private” data as well as “new” groundwater data collected by visiting boreholes in the field – particularly in priority areas. GRIP would also develop systems and procedures for the collection and verification of unpublished data. To date, GRIP has been fully implemented in the Limpopo Province, where it began in 2002. More than 2 500 villages have been visited in the province, 15 500 borehole sites have been verified, and 1 500 pumping tests have been added to the provincial database. Limpopo Province has now probably the most extensive and best verified dataset on rural groundwater resources in the country, and enough is known about groundwater in the province to allow it to be much better integrated into general water resource management. The extra data has led to a higher borehole drilling success rate in the province, saving a considerable amount of money. It is planned that all GRIP data be entered into the DWA national WARMS database. The GRIP project in the Limpopo Province serves as a role model for the other provinces.

2.4.2. Water sector human capacity

The new water legislation in South Africa has triggered wide spread reforms in the sector demanding decentralized management and a shift from a supply driven approach to a demand oriented approach. This comes at a time of challenges to human resources capacity in the water sector, such as an ageing workforce, emigration of professionals, and constraints on university training. Today, there is need for a greater number of skilled water professionals entering and staying in the public sector, with better training, improved working conditions and clearer career trajectories.

National government

One of the major institutional challenges in relation to groundwater management is the shortage in human resource capacity both in the DWA and in other institutions. Currently, DWA Directorate Hydrological Services – Sub-Directorate Groundwater Resources Monitoring and Assessment (GRAM) has around 50% vacancy in geotechnician and geohydrologist positions (Figure 5).

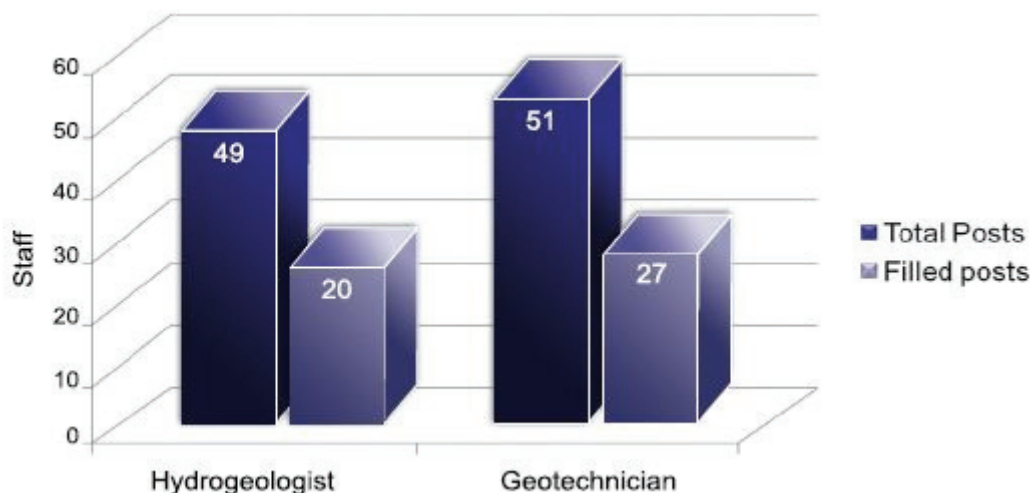


Figure 5: Vacancies for staff at DWA Sub-Directorate GRAM (2008 figures; NGS, 2010)

More than 50% of the current groundwater personnel have fewer than 5 years experience and did not have an experienced mentor to guide them. A particular concern is that most of the geotechnician and geohydrologist positions have been vacant for a number of years and retired personnel are often not replaced. While there is a challenge in relation to retention of geohydrologists (who are mainly leaving for the private sector) there is a much bigger challenge in relation to recruitment of new staff. There is also a challenge in terms of recruiting the appropriate staff to manage pollution of groundwater. This has not been given sufficient priority, particularly in key regional offices such as Gauteng, where pollution of groundwater is a major issue. Reasons for the inability to recruit and retain staff are:

- A national shortage of geohydrological skills;
- Uncompetitive salaries in the face of scarce skills and high demand; and
- Non-conducive working conditions, with long hours, lack of incentives, and high levels of stress.

The DWA should put in place a programme to address the above shortfall in groundwater human resources capacity. Some of the actions to be undertaken (NGS, 2010) are to (i) include capacity-building milestones in DWA PSP contracts similar to WRC contract research programmes, (ii) provide practical in-service training courses on priority topics, (iii) review and improve working conditions, career development and remuneration packages, and (iv) strengthen DWA's bursary programmes.

The lack of adequate capacity in the field of hydrogeology in the DWA and South Africa as a whole negatively impacts on all functions of groundwater operations and management as well as on the efficiency of water resource management institutions. Adequate capacity plays a very important role in the realization of the successful implementation of the NGS, thereby ensuring that the necessary skills exist to support South Africa's National Water Act (1998).

Comparing the number of geohydrologists versus hydrologists employed (where the distinction can be made) within DWA shows a ratio of 1 to 4 (Table 4). As the use of groundwater increases and management of wellfields are required it is expected that this ratio would increase with more geohydrologists employed within DWA, especially in the regions to support local municipalities.

**Table 4: Geohydrologists vs. hydrologists positions in DWA
(Motebe. Pers. Comm.)**

| Description | National Office | Regional Office | Branch name |
|--|------------------------|------------------------|---------------------|
| Geohydrologists (4) | 22 | 17 | Policy & Regulation |
| Geotechnicians (2) | 6 | 10 | Policy & Regulation |
| Hydrologists (Maybe Engineers in some instances) | 143 | 70 | Policy & Regulation |
| Technicians | 30 | 62 | Policy & Regulation |
| Environmental Officers (May be hydro/ geohydro) | 22 | 38 | Policy & Regulation |
| Technicians (May be hydro/ geohydrologist) | 2 | 19 | Policy & Regulation |

Note:

- The numbers exclude some 226 Graduate Trainees rotating within the Policy & Regulation Branch
- The numbers reflected also include senior managers
- The numbers only reflect filled post and NOT vacant posts
- The National Water Resources Infrastructure Branch was excluded in all categories

Local government

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. No local government has its own groundwater expertise and 74 out of 231 local authorities did not even employ technical experts (MacKay and Koster, 2005).

SA's institutions of higher learning

South Africa's groundwater academic sector is not yet institutionally well established and is presently seriously hampered by staff losses in key positions, which will take years to rebuild (Braune et al., 2010). Institutions involved in capacity building in groundwater are: Institute for Groundwater Studies (IGS-UFS), University of Western Cape, University of Pretoria, University of KwaZulu-Natal, University of Witwatersrand, University of Venda, Rhodes University, Tshwane University of Technology, and Stellenbosch University.

The following institutions are also important role players in facilitating training of water professionals through either continuing professional development programmes and/or funding of such programmes: Water Research Commission (WRC), Framework Programme for Research, Education and Training in the Water sector (FETWater), WaterNet, and the Water Research Fund for Southern Africa (WARFSA).

Figure 6 shows the increasing WRC allocation to groundwater research since 1975, whereas Box 8 discusses the impact of WRC projects on capacity building in the groundwater sector. The achievement of post-graduate qualifications is strongly encouraged as part of research projects and has become a standard requirement in project proposals. Figure 7 shows the number of postgraduates in South Africa (MSc and PhD) since 1977. A sharp increase can be seen ("Grant Total" line) over the period of 1997 to 2008 which is mainly due to contributions from the Universities of Free State, Rhodes, Western Cape (especially since 2002), and Pretoria (since 1998).

Private Sector

The private sector has been experiencing a groundwater boom since the late nineties through the widespread development of groundwater infrastructure for community water supply and through the attention to environmental impact management in the mining industry and parastatals. The technical groundwater dimension in both areas, however, is often neglected and should get more attention (H. Garduño, pers.comm.).

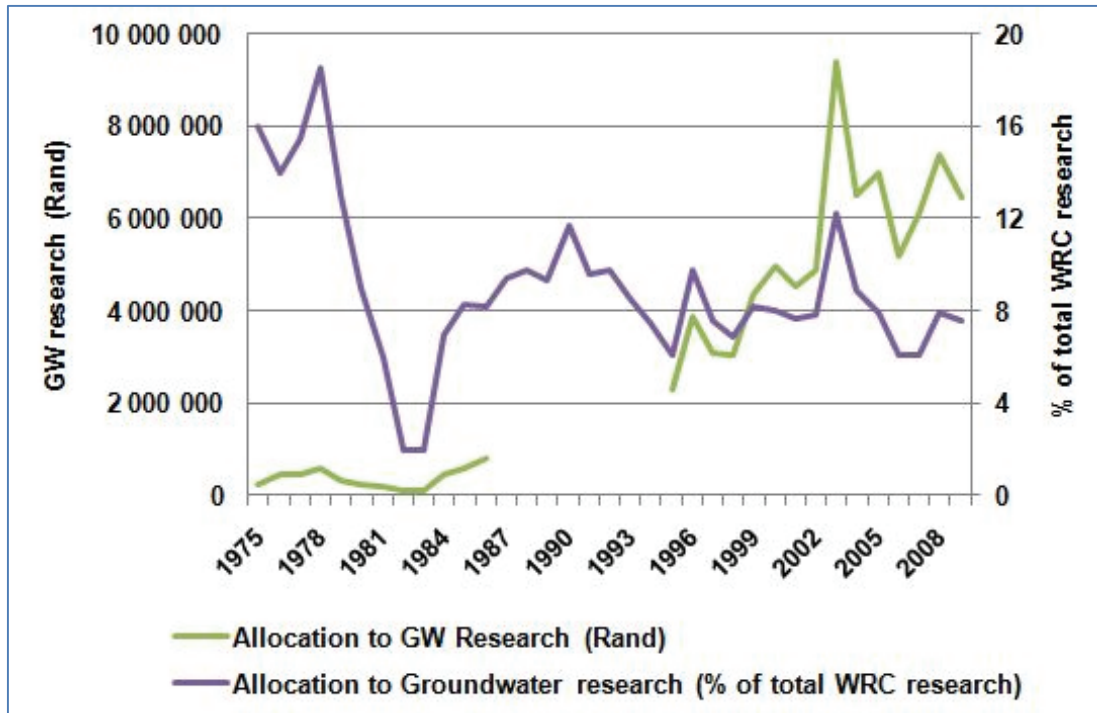


Figure 6: WRC funding of groundwater research
(S. Adams, updated from 2009 WRC Business Plan)

Box 8: Impact of WRC research projects on capacity building in the groundwater sector

WRC investment into groundwater research in South Africa has been strategic and ongoing for 35 years. This investment has been the most significant contribution to the building of capacity for the groundwater setcor in South Africa.

The research priorities over many years were of a resource characterization and groundwater technology nature. Since 2000 a greater resource management focus within an IWRM framework was added. This progression in research focus reflects the progression of groundwater attention nationally, before and after the National Water Act, 1998.

The Water Research Commission was instrumental in developing the strong research and teaching centers in groundwater hydrology in South Africa (e.g. Institute for Groundwater Studies at the University of the Free State and the groundwater programme within the Earth Science Department at the University of the Western Cape). The WRC also supported several other universities (Fort Hare, Venda, Pretoria, KwaZulu-Natal 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, in the southern African region and on the continent as a whole.

Groundwater research undertaken in South Africa can be classified as applied research and significant knowledge transfer has taken place through the freely available WRC reports.

The highest impact on improving groundwater resource development, utilization and management was obtained when there had been a planned synchronization of research and national development objectives. Examples are artificial groundwater recharge, resource directed measures (including reserve determination) and groundwater quality management

Source: Braune et al. (2010)

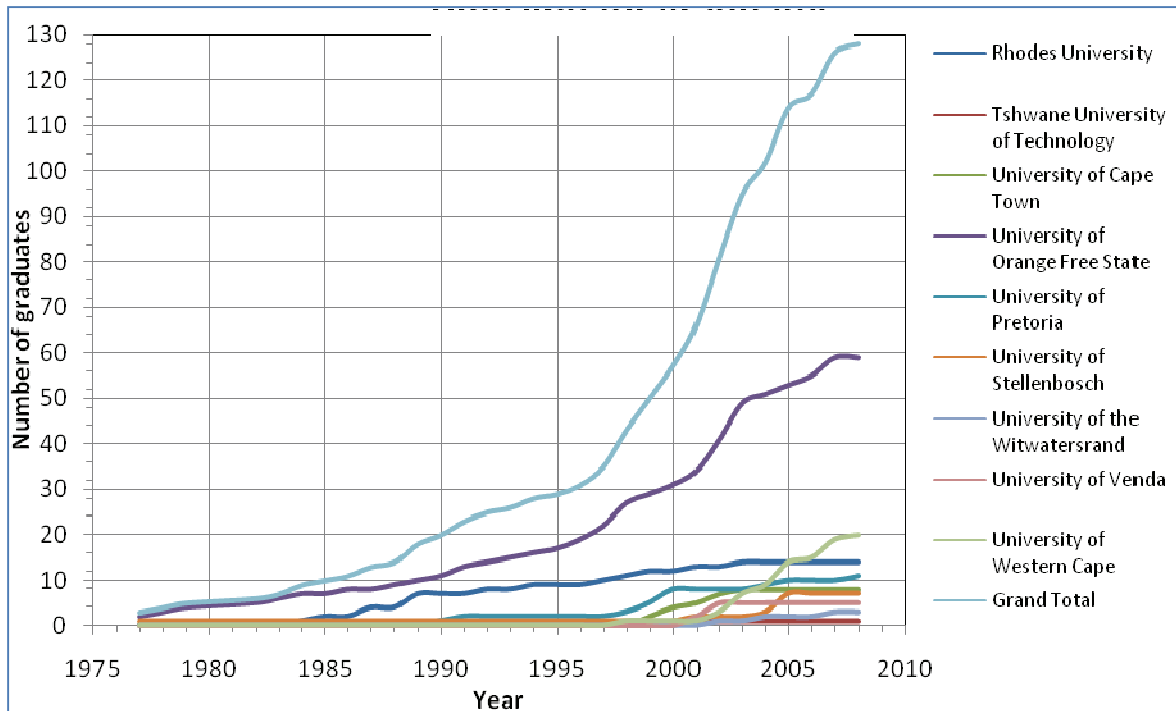


Figure 7: Timeline for hydrogeology graduates (NGS, 2010).

2.5. Financing implementation of the NGS

A detailed review of the actions listed by the NGS reveals that implementation of the strategy could result in additional (once off) expenditure of R273m for the DWA over the next 5 years (with the bulk of this – R212m – reserved for the completion of GRIP projects across all regions; note that the US\$-ZAR exchange rate on 15 October 2010 was 1:6.78). Additional annual expenditure could amount to R66m. The cost estimates of actions that require additional funding are divided into eight separate strategies and are summarised in Table 5.

Table 5: Summary of operational expenditure associated with implementing the NGS (NGS, 2010).

| | Commissioning (establishment) | Routine (on-going) |
|------------------------------------|-------------------------------|-----------------------|
| Combined Summary of Costs | R273,450,000.00 | R65,900,000.00 |
| Policy, Legislation and Regulation | R11,100,000.00 | R0.00 |
| Water Resource Planning | R10,500,000.00 | R500,000.00 |
| Human Capacity | R 4,700,000.00 | R29,300,000.00 |
| Sustainable Groundwater Management | R2,100,000.00 | R10,000,000.00 |
| Institutional Capacity | R1,250,000.00 | R950,000.00 |
| Information Management | R31,000,000.00 | R20,000,000.00 |
| - GRIP completion (RO's)* | R212,000,000.00 | R0.00 |
| Groundwater Research | R200,000.00 | R2,550,000.00 |
| Communication and Awareness | R300,000.00 | R2,600,000.00 |

*Groundwater Resource Information Project implemented by DWA Regional Offices.

Cost of implementing the NGS

Commissioning costs

- *Policy, Legislation and Regulation:* The primary cost of R10m is to supplement the budget for reserve determination over the next 2 years, with R1.1m provided for finalising the strategy on the rehabilitation of abandoned mines.
- *Water Resource Planning:* R10.5m could be spent on commissioning activities related to WRP over the next 2 years. R7.5m of this relates to the development and dissemination of best practice guidelines with respect to WRM (and groundwater in particular) whilst R3m relates to improvement of the GRA3 methodology and setting up the appropriate monitoring network.
- *Human Capacity:* Most of the costs under human capacity are ongoing. However a budget of R4.2m is provided for the establishment costs related to recruiting the full complement of groundwater staff required for each Regional Office. An additional R500 000 may be needed to complete a formal review of working conditions, career development, etc.
- *Sustainable Groundwater Management:* A number of the actions impose costs on other institutions – such as the requirement to investigate and develop favourable aquifer systems – a cost to local government. Other costs are for the department as a whole – such as the implementation of the waste discharge charge system. Establishment costs of R2.1m have been associated with this sub-strategy – mainly relating to collaborating with the Department of Mineral Resources (DMR) and the DEA on the establishment of an integrated authorisation system and supporting the DMR in the improvement and implementation of regional mine closure strategies.
- *Institutional Capacity:* Many of the costs associated with the Institutional Capacity actions are already being incurred by the Department, or are the responsibility of other institutions. For example, the bulk of costs associated with the establishment of Water User Associations are typically borne by the Associations themselves. A number of actions associated with strengthening institutional capacity are also resolved by implementation of the actions related to human capacity – such as ensuring adequate staffing of the Regional Offices. Establishment costs associated with the Institutional Capacity actions are expected to amount to R1.25m, with R1m of this to support the establishment of the SADC Groundwater Management Institute.
- *Information Management:* The bulk of the establishment costs associated with the NGS can be attributed to this sub-strategy – a total of R243m. The completion of GRIP, on its own, will potentially require funding of R212m over the next 5 years. Another R23m over 3 to 5 years is provided for the completion of the NGA (completion of modules, transfer of data, and training of data capturers in LG and private drilling companies). Completion of the groundwater monitoring strategy could require another R3m, although implementation thereof has not been provided for (but could be in excess of R20m). Developing an integrated groundwater information system and ensuring compatibility or integration between databases could cost R4m over 2 years.
- *Groundwater Research:* There are very few establishment costs associated with the Groundwater research actions. R200 000 has been provided to conduct a once-off review to assess the impact of research investment in groundwater.
- *Communication and Awareness:* Many of the costs associated with communication and awareness are already provided for, or are on-going. A budget of R300 000 has been provided for the design of brochures to be used in groundwater awareness campaigns.

Routine costs

A significant proportion of these costs relate to increasing the groundwater capacity within the Regional Offices, with the second major contributor being the maintenance of an extended monitoring network.

Sources of funding

The Department's water resource management activities are mainly funded through revenue from Water Resource Management (WRM) charges collected by the Water Trading Entity (WTE), and allocations from the government's Exchequer Account. The Department also benefits from some international donor funding. The WRM charges do not make a distinction between surface water and groundwater. DWA staff confirmed that surface water and groundwater are also not separated in the financial budgets.

The WTE has received sufficient income to meet its operating costs, but has not been able to make any provision for the rehabilitation or refurbishment of existing assets. A proportion of the WTE's income is from the agricultural sector, which has traditionally enjoyed water tariff caps that have kept their charges well below the rates required for cost recovery and provision for replacement. Removing these caps will require support from a number of different sectors. In the absence of significant increases in water use charges (in agreement with the latest Pricing Strategy; DWAF, 2007a), the WTE will continue to operate at a loss. The additional funding required by the National Groundwater Strategy will therefore have to be provided for from DWA's parliamentary appropriation from the Exchequer Account. Donor funding makes up a very small percentage of funds utilised in the water sector but is essential to the viability of some DWA programmes, such as the Masibambane Water Programme. Official Development Assistance (ODA) is a potential source of funds, and could be targeted for use on specific projects – such as the eradication of backlogs in the licensing process, and completion of groundwater resource assessments.

Cost of not implementing the NGS was estimated in terms of:

- exclusion of groundwater as a cost effective alternative to other water sources (see Box 9)
- groundwater contamination
- inappropriate groundwater development
- environmental damage due to poor groundwater management
- missed knowledge and technology benefits from groundwater research

and was found to be at least one (10 times more) if not two (100 times more) orders of magnitude higher than the cost of implementing the NGS. Box 9 presents a comparative analysis of the cost of groundwater versus other sources of water, including surface water augmentation. The cost of groundwater was found to be similar, if not cheaper, than the cost of surface water augmentation.

Box 9: Assessing the marginal cost of alternative water sources compared to groundwater

It is stated that groundwater resources in South Africa total approximately 10 billion m³ per annum. Of this, some 2-4 billion m³ are used, with a remainder of circa 6 billion m³ per annum. Based on an analysis of where this groundwater is located and existing groundwater quality, it is conservatively assumed that 25% of the 6 billion m³ are available¹ for utilisation.

This implies that annually 1.5 billion m³ of groundwater is available for development. In addition to groundwater, the common sources of water are:

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

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

- Groundwater: R3-5/kl
- Surface water augmentation: R3-7/kl
- Effluent reuse: R7-10/kl
- Desalination²: R7-15/kl

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

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

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

¹ Available here means that it is (1) located close to where it is required, (2) readily accessible and (3) of adequate quality for its determined purpose

² Incorporating the escalation of energy prices

Source: NGS (2010)

2.6. Climate change and adaptation

Climate change and groundwater has recently come to the forefront of policy making with the National Groundwater Strategy (2010) emphasizing the important role groundwater plays in the context of climate change:

“Groundwater has to be used and managed in a sustainable way in order to maintain its buffering and contingency supply capabilities, as well as adequate water quality for human consumption, under predicted climate change conditions. Land-use planning has to consider groundwater resources as a precious and finite resource, and take all necessary measures to protect groundwater resources and their recharge mechanisms in the long run”.

The strategy recognizes that South Africa’s understanding of the impact of climate change on groundwater is limited and that further research is needed. The following opportunities for adaptation form part of the groundwater strategy and will reduce the vulnerability of the water resources to climate variability and change:

- *Integrating the management of surface water and groundwater* – including conjunctive use of both groundwater and surface water to meet the water demand;
- *Managing aquifer recharge (MAR)* – including building infrastructure and/or modifying the landscape to intentionally enhance groundwater recharge (Artificial Recharge Strategy for South Africa – DWAf, 2007b); and
- *Land use change* – changing land use may provide an opportunity to enhance recharge, to protect groundwater quality and to reduce groundwater losses from evapotranspiration.

Groundwater can be used to supplement surface water flows, when the latter are seasonally low. In the wet season, when surface flows recover, surplus water can be released into the aquifer to recharge it. The use of tube-wells can also assist drainage, when otherwise the soil would become waterlogged or saline. In practice, conjunctive use requires the ability to transfer water between various parties, which may require the definition of rights, and calls for an active management role for public authorities. Conjunctive use in South Africa is currently practised at only a limited scale. Examples include coastal towns that receive a large influx of visitors during the summer holidays, and use of groundwater and dams in the drier parts of the country like Beaufort West and Graaff-Reinet. There is, however great potential in South Africa for conjunctive use of surface water and groundwater.

In the context of increasing groundwater storage as an adaptation option for climate variability and climate change, the Artificial Recharge Strategy for South Africa (DWAf, 2007b) developed national maps on theoretical storage potential (Figure 8) and on potential areas for artificial recharge.

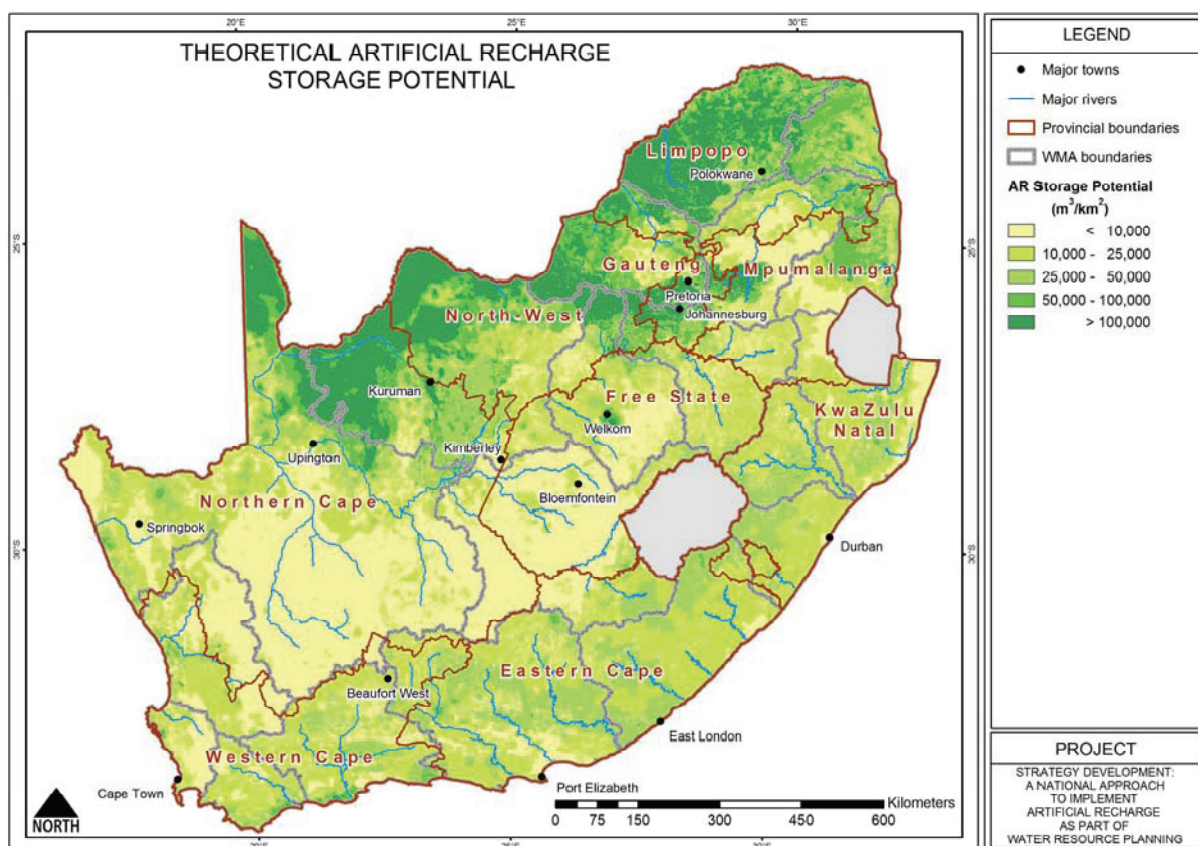


Figure 8: Theoretical artificial recharge storage potential (DWAf, 2007b)

These maps form a good starting point for groundwater resource planning at the larger catchment scale. From Figure 8 it can be seen that the four selected aquifer systems for this case study are located in areas of relatively high theoretical storage potential. The Strategy also contains practical guidelines and criteria for establishing artificial recharge schemes at the local scale.

The Aquifer Recharge Strategy is based on the vast experience of South Africa in artificial recharge, e.g.:

- Atlantis with urban stormwater and treated domestic wastewater recharge since the end of the 1970s
- Polokwane with wastewater recharge since the 1970s
- Kharkams with the capturing of runoff for borehole injection since 1995
- Calvinia with dam water recharge and storage for emergency supplies since 2001

The Strategy comprises seven thematic areas that need to be addressed: (1) Knowledge; (2) Legislation and regulation; (3) Planning; (4) Implementation; (5) Management; (6) Research; and (7) Strategy implementation. Management actions have been defined for each thematic area with responsibility and priority of action (immediate, within 2 years or within 5 years). DWA began implementing the Strategy in November 2007. Recent initiatives include feasibility studies for the towns of Plettenberg Bay (subsurface storage to augment the summer peak demand), Prince Albert (replenishing the aquifer in a single month when surface water is available for recharge), Williston (transferring groundwater from one aquifer to another), and Langebaan (borehole injection in a confined sandy aquifer). A number of criteria have been formulated to successfully implement an artificial recharge project (DWA, 2009b). Critical for its success is that the artificial recharge scheme is designed according to current and future management capabilities and that the scheme is well planned.

The new 2nd edition of the NWRS (2011) will include a disaster management and climate change thematic area. DWA is currently in the process of developing (i) a water sector disaster management plan and (ii) a climate change response strategy. Prioritisation of the thematic area and application of measures will be through the IWRM process.

In the previous (1st) edition of the NWRS (2004) the strongly linked thematic area for disaster management and climate change response, which also has strong linkages to other thematic areas such as water resources protection, water allocation reform, augmentation and infrastructure and water for growth and development, followed different approaches. With regard to disaster management, relatively few targets, as set out in the 1st edition of the NWRS, have been fully met due to inadequate institutional capacity. An example is the preparation of a Phase 1 Disaster Management Plan which is currently still in progress. With regard to climate change response, the previous edition of the NWRS advocated the inclusion of climate change in catchment management strategies, particularly for those geographic areas that could experience the greatest impact. Institutionally, steps taken towards the development and implementation of climate change response measures will be closely coordinated by the newly established Climate Change Directorate in DWA's Chief Directorate: Integrated Water Resources Planning, which falls under the Policy and Regulation branch of DWA.

Most recently there has been the development by a DWA working group of an internal draft working document towards developing the climate change response strategy for the South African water sector, such a sector strategy also being a requirement of the National Climate

Change Response Strategy. The DWA strategy on climate change response has progressed further and more quickly than was envisaged in the 1st edition of the NWRS. Mainstreaming of climate change considerations into DWA functions has as yet not been achieved. Although DWA has recently appointed a Director for Climate Change, the Climate Change Strategy still has to be completed.

Some of the gaps and challenges that the revised disaster management and climate change response thematic area will have to address in the 2nd edition of the NWRS are identified as follows:

- Institutional arrangements for appropriate disaster management and climate change response strategy implementation within DWA and the broader water sector;
- Actively contribute to the building of preparedness and resilience in vulnerable societies;
- Assessment and addressing of capacity and skills needs;
- Adapt and implement IWRM process as needed to fully accommodate and give direction to climate change response measures;
- Prioritisation and drafting of implementation plans for adaptation and mitigation measures; and
- Monitoring and information.

3. BOTLENG DOLOMITE AQUIFER

3.1. Introduction

The Botleng Dolomite Aquifer is the main source of water for large scale agricultural irrigation and for domestic use by the Delmas community. The small town of Delmas in the Mpumalanga Province with approximately 59 000 residents is situated in one of the productive maize growing areas of South Africa. The quality of groundwater, however, has become a great concern with a number of diarrhea and typhoid outbreaks over the past two decades (Mthetwa, 2008). In 2008 the DWA signed a contract for a water pipeline to the town of Delmas to import potable water, supplied by Rand Water. Although the pipeline is one of the measures to prevent the outbreak of waterborne diseases, it will only partially solve the problem. Special attention needs to be given to promoting more effective municipal management of water resources, as well as management of storm water, sewage and environmental health in general in the municipal area of Delmas (Nealer et al., 2009). Management of the Botleng Dolomite Aquifer by the local and national authorities could well serve as a benchmark in the management of groundwater resources in the more rural areas of South Africa.

3.2. Resource setting

3.2.1. Hydrogeologic condition

Aquifer type and characteristics

The Botleng dolomite aquifer emerges from the Malmani Subgroup which mainly consists of chert-rich dolomite and chert breccias, and outcrops as a northwest to southeast strip around the town of Delmas dipping 15° northeast (Figure 9). The area south and east of the dolomite outcrop is extensively covered by younger Karoo rocks consisting mainly of sandstones, shales, tillite and clay. The Pretoria Group towards the northeast of the Botleng aquifer consists mainly of shale and quartzite, which has a lower groundwater potential compared to the dolomites.

The Botleng aquifer is a karst aquifer with more than half of the boreholes exceeding 5 l/s. Water bearing properties of the dolomite stem from carbonate dissolution along structural and lithological discontinuities (such as faults, fractures and joints). Storativities of South African dolomite aquifers generally vary between 1 and 5 % (Barnard, 2000), but this property depends greatly on the extent of weathering and dissolution. Transmissivities can be several hundred m²/day or more.

Four well fields (A, B, C and D) have been developed within the dolomites by the Delmas local municipality. From the twenty municipal boreholes, seventeen have been pumped on a regular basis. All seventeen boreholes were recently refurbished and old infrastructure (pumps, pipes, etc.) were replaced (WGC, 2009a). Recommended abstraction rates vary between 10 and 25 l/s and are based on schedules, which allow for sufficient recovery of the water level.

The aquifer can be regarded as a water-table aquifer with mostly unconfined conditions. Groundwater levels vary between 1.2 and 78 metres below ground level (m.b.g.l.) and generally show an immediate response to rainfall indicating a concentrated recharge component through either sinkholes or depressions in addition to leakage through river beds.

This is also indicative that the aquifer is highly susceptible to pollution as contaminants and pollutants can easily migrate into the groundwater.

Groundwater quality of the Botleng aquifer has been affected by (Nealer et al., 2009):

- Salinisation – due to anthropogenic sources such as industrial effluent discharges, irrigation return flows and urban run-off,
- Eutrophication – increase in nitrates and phosphates resulting from sewage effluent discharges to rivers, and
- Bacterial contamination – rising faecal contamination levels associated with increasing population densities and inadequate sanitation levels, especially with regards to informal settlements.

Nealer et al. (2009) made the following observations:

- Both wastewater treatment facilities (WWTF) of the town of Delmas (Figure 9) are suspected to discharge sub-standard quality effluent into downstream receiving streams,
- Groundwater from well-field A, downstream of the old WWTF in the centre of town, is heavily contaminated and the quality of the water was found to be deteriorating,
- Due to declining groundwater levels by over-abstraction (for both irrigation and municipal use) sinkhole formation has occurred in certain areas and this will accelerate the infiltration and percolation of (polluted) surface water to groundwater.

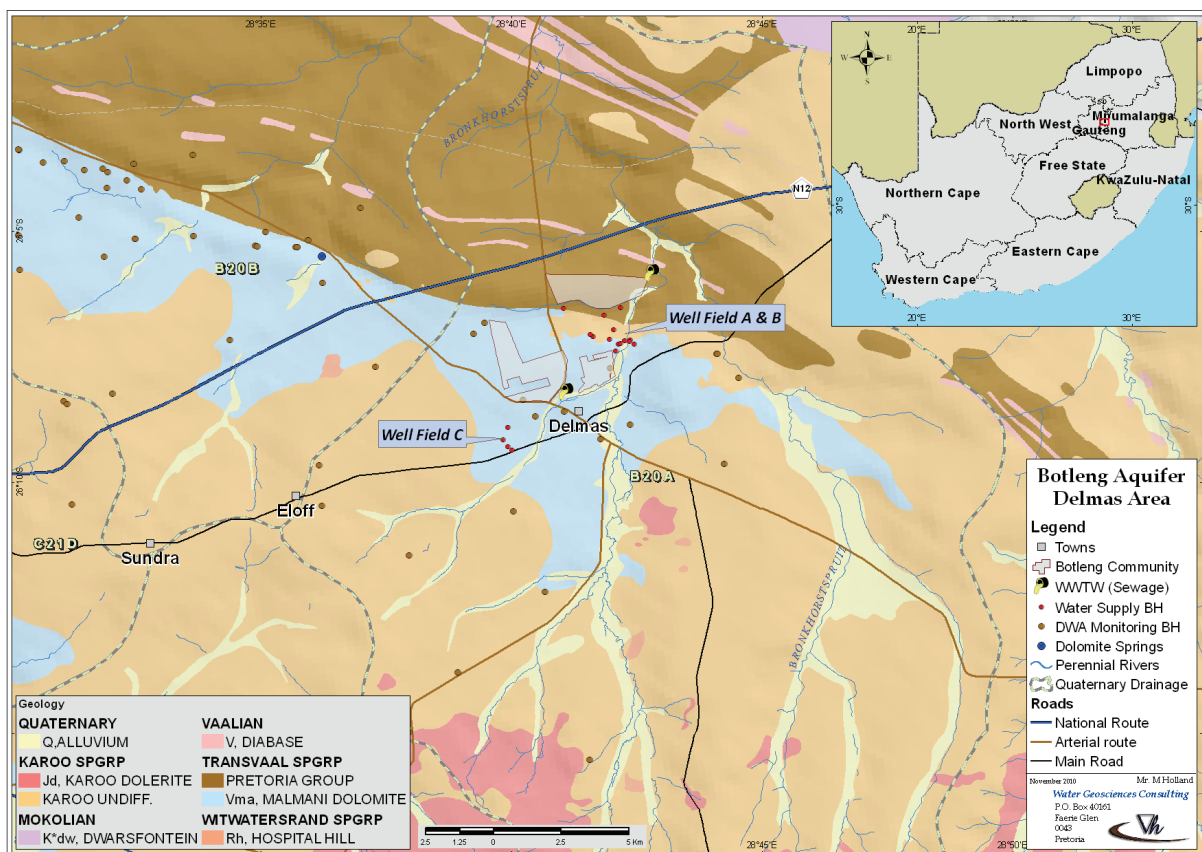


Figure 9: Botleng Dolomite Aquifer – Delmas area

Resource renewability and surface water interactions

The few rivers and streams in the area and the low surface water drainage density suggest relatively high recharge and a predominance of underground water flow. Groundwater discharges into streams at topographic lows or occurs as springs or seepages next to dykes or lithologic/formation contacts. The interaction of surface water and groundwater requires that the upper drainage area of quaternary catchment B20A be included in the groundwater management area of the Botleng aquifer. Recharge rates for the dolomite aquifer have been estimated between 8 and 12 % of Mean Annual Precipitation (MAP=670 mm; GCS, 2006).

Aquifer vulnerability

The vulnerability to contamination can be defined as high for all well fields since they are located on a dolomitic aquifer, and a higher connectivity of the aquifer to the surface is expected (Box 10). Well field A has a shallower water level compared to well field B and C and will therefore be more vulnerable to contamination. Also well fields located near human activities or surface drainage or downstream of the WWTW, are at a higher risk to contamination (i.e. well fields A and B). Over-exploitation may lead to declining water levels, which reduces the available volumes of groundwater. High groundwater abstraction occurs within the study area but the dolomites have very high storage capacity. However, dewatering of cavities within the dolomite can lead to the formation of sinkholes.

Box 10: Assessment of the vulnerability of South Africa's dolomite aquifers

Karst landforms such as sinkholes and dolines together with thin soils allow surface pollutants to rapidly percolate to the groundwater. There have been only limited attempts to date to assess the vulnerability of South Africa's dolomite aquifers (WGC, 2009b). There are various options for the groundwater planner, ranging from simply characterizing all dolomite aquifers as "vulnerable", the determination of groundwater protection zones, to more sophisticated methods which differentiate between different areas of dolomite aquifers in terms of their vulnerability depending on physical characteristics. Aquifer protection may be divided into "resource protection" methods (i.e. mapping the vulnerability of a whole aquifer) and "source protection" methods that protect individual boreholes or springs (i.e. source protection zones). A combination of the two is recommended for South Africa's dolomite aquifers. The COP aquifer vulnerability mapping method, developed by Vias et al. (2003), was modified with respect to South African karst terrains by the University of Pretoria (WRC Project No: K8/669) for the wider Cradle of Humankind area near Krugersdorp. The method is based on the determination of the protection offered by the unsaturated zone of the aquifer against a contaminant event, i.e. the capability of the unsaturated zone to filter or attenuate contamination. The protection provided by the overlying layers (the O factor) is modified by surface settings (e.g. slope) that control water flow towards areas of rapid infiltration (the C factor) and the characteristics of the transport agent (water), that transfers the contaminants through the unsaturated zone (the P factor). The three factors are multiplied to obtain a vulnerability index, which is classified into five vulnerability classes, ranging from "very low" to "very high", known as the VUKA index. The COP/VUKA method was also applied to the dolomites of the Sudwala / Pilgrim's Rest area (WGC, 2008).

3.2.2. Socio-economic situation

Groundwater use and user profiles

Potable water demand by the Delmas area (town and surrounding) is about 16 Ml per day; about 10 Ml/d is abstracted from the well-fields, whilst the remainder is being augmented via a 250 mm pipeline of Rand Water from Bloemendal. This is mainly to supply the small towns of Ellof and Sundra to the west of Delmas. Due to a shortage of potable water supply in Delmas, especially in dry seasons, the water from the pipeline is periodically diverted to

augment the Delmas water supply. Even with this augmentation, the municipality is unable to fully secure Delmas potable water reserves (Nealer et al., 2009). This is mostly due to water losses and leakages in the reticulation system including maintenance, and infrastructure issues of boreholes (GCS, 2006). The Delmas population which depends on municipal potable water supply is estimated at 56 208 people. Delmas has 13 389 households of which 9 6462 households have running (tap) water on their sites (Nealer et al., 2009). A much greater demand for groundwater arises from the agricultural sector with large scale irrigation practices occurring extensively in the Delmas area mainly for the production of maize and vegetables. Meat and poultry abattoirs also make use of large quantities of water for their manufacturing process. Precise figures on groundwater use are not recorded but according to the registered water user datasets (DWA WARMS database) a total of 22 Ml/day is registered for agricultural use (WGC, 2007). Declining water levels in monitoring boreholes north of Delmas are attributed to over-abstraction by irrigators.

Future groundwater demand

According to the GCS (2006), demand for potable water will increase to 21 Ml/d by 2015 for the Delmas town area based on a population growth rate between 2 and 6 %. This increase in demand can be met by water from the proposed 38 km pipeline (Rand Water) from Bloemendal, but water conservation and water management must have the highest priority. In order to avoid over-exploitation and the risks associated with dewatering of dolomite aquifers (e.g. land subsidence) major groundwater users (beyond Schedule 1 or domestic use) will have to apply for a water use license from the DWA. There is the possibility that no license be granted due to the strategic importance of the resource or due to unacceptable surface instability risks.

3.2.3. Current and emerging issues

The effectiveness of the Delmas Local Municipality and the DWA Regional Office in as far as groundwater management and protection is concerned is weak. This is evidenced by the diarrheal outbreaks related to groundwater pollution from various anthropogenic sources. Also the current IDP does not take into account measures to protect groundwater resources. Table 6 presents an overview of typologies and threats to the Botleng dolomite aquifer.

Table 6: Typologies and threats to the Botleng dolomite aquifer

| Typology | Situation / process | High Risk | Medium Risk | Low Risk |
|--|---|-----------|-------------|----------|
| | | ✓ | ✓ | ✓ |
| Risk of extensive quasi-irreversible aquifer degradation and subject to potential conflict amongst users | Intensive exploitation (leading to land subsidence, saline or polluted water intrusion) | ✓ | | |
| | Vulnerable to pollution from land surface (vulnerability, pollution) | ✓ | | |
| | Depletion of non-renewable storage (in aquifers with low contemporary recharge) | | ✓ | |
| Potential water use conflict but not at risk of quasi-irreversible aquifer degradation | With growing large-scale abstraction (especially in aquifers with high T/S ratios) | | | ✓ |
| | Vulnerable to point-source pollution (vulnerability, pollution) | ✓ | | |
| | Shared transboundary resource | | | |
| Insufficient (or inadequate use of) scientific knowledge to guide development policy & process | Potential to improve rural welfare & livelihoods (not fulfilling MDG potential) | | | ✓ |
| | Natural quality problems (e.g. As, F) | | | ✓ |
| | Scope for large-scale planned conjunctive use (urban W/S or irrigated agriculture) | | | ✓ |

3.3. Local groundwater management

3.3.1. Water management institutions

The CMA responsible for the management of water resources in the Olifants WMA, which encapsulates the Botleng aquifer, has not yet been established and as a result the regional office of the DWA acts as the interim CMA. A draft establishment proposal for the Olifants CMA was developed a number of years ago but requires updating to take the changing circumstances into account.

The Delmas Local Municipality forms part of the Nkangala District Municipality and is the responsible Water Services Authority supplying water from the Botleng aquifer. Groundwater supply is augmented by water from Rand Water. The National Health Act (No. 61 of 2003) assigns responsibility for municipal health services to Metropolitan and District Municipalities and includes water quality monitoring. The Nkangala District Municipality has the responsibility for water quality monitoring in the Delmas Municipal area (Kolisa, n.d).

3.3.2. Blue and green drop certification

The right to access water is a constitutional right. The government policy currently defines this as 6 kiloliters per household. The total backlog in water services in 1994 was 17 863 persons. This backlog has since been cleared with all receiving water services above the Reconstruction and Development Programme (RDP) defined standards. Water quality management, however, remains an issue. The municipality did not adhere to the call to be assessed in terms of the blue-drop certification process. In terms of the green-drop certification process an average score of 52% was achieved, and the following areas were identified which need to be improved (Green drop report DWA, 2009):

- Registration and classification of the works as well as the operating staff (in process);
- WWQ Monitoring Programme efficiency;
- Regular submission of WWQ results to DWA;
- WWQ compliance; and
- Management planning related to the Waste Water Treatment Works capacity.

The development of the IDP is supported by a public participation process. The Municipal Systems Act (32 of 2000) requires municipalities to promote public participation and to build the capacity of residents, councilors and municipal officials to engage in participatory processes (DPLG, 2009). In the case of the Delmas Local Municipality IDP process, Ward participatory meetings culminated in an IDP forum which includes representation of the different political parties, various government agencies, business representatives, traditional leaders, youth organizations, etc. The representation of these organizations facilitated feedback to their various constituencies, and resulted in prioritization of issues, identification of projects and evaluation in terms of their relevance.

3.3.3. Knowledge and capacity

A groundwater management plan for the Delmas Local Municipality was developed using baseline information of the aquifer system and includes both water quantity and water quality

aspects. The following hazards with regards to groundwater supply were identified (GCS, 2006):

- Over-abstraction leading to declining water levels and ground instability
- Point source contamination
- Non-point source contamination
- Insufficient supply
- Treatment and reticulation problems
- Prolonged drought conditions, and
- Recharge with poor quality surface water.

Most likely emergency situations, based on a risk evaluation were found to be:

- Sinkhole formation and subsidence
- Insufficient water supply
- Water contamination, and
- Reticulation breakdown and infrastructure breakdown

The knowledge exists to deal with most groundwater management issues. One of the problems is the lack of human resource capacity to implement the recommendations that follow from numerous studies that have been conducted.

3.4. Evaluation of groundwater governance provisions

3.4.1. Effectiveness of governance provisions

From a groundwater governance point of view, the Delmas Local Municipality lacks the human resource capacity to effectively implement groundwater governance provisions. It should also be noted that there is no funding explicitly allocated to groundwater management in the municipal budget. The effectiveness of existing governance provisions and capacity to implement adequate groundwater governance is evaluated against a priority list of 20 benchmarking criteria and is listed in Table 7.

3.4.2. Management measures

Measures to address identified potential hazards are as follows (GCS, 2006):

- A groundwater protection strategy needs to be developed and implemented within the Delmas area. It should include the establishment of a groundwater model, a monitoring plan and a public awareness campaign. It should also include the establishing of protection zones around wells and pollution pathways such as sinkholes or swallow holes (sinking streams).
- A groundwater model should be constructed to evaluate the dynamics of the groundwater system with the aim to determine optimum and sustainable groundwater abstraction.
- A monitoring plan and the establishment of a groundwater monitoring network and monitoring schedule is proposed in order to observe the aquifer's response to groundwater abstraction as well as to monitor the water supply (GCS, 2006). The monitoring includes groundwater quantity and quality, surface water and effluent, reticulation systems, and treated water.

Table 7: Effectiveness groundwater governance provisions & capacity: Botleng.

| Capacity | Criterion | Context | Provision | Inst. capacity |
|---|--|--|-----------|----------------|
| Technical | Basic hydrogeological maps | For identification of groundwater resources | 3 | 1 |
| | Groundwater body/aquifer Delineation | With classification of typology | 3 | 1 |
| | Groundwater piezometric monitoring network | To establish resource status | 2 | 1 |
| | Groundwater pollution hazard assessment | For identifying quality degradation risks | 1 | 1 |
| | Availability of aquifer numerical 'management models' | At least preliminary for strategic critical aquifers | 0 | 0 |
| | Groundwater quality monitoring network | To detect groundwater pollution | 1 | 1 |
| Legal & Institutional | Water well drilling permits & groundwater use rights | For large users, with interests of small users noted | 2 | 1 |
| | Instruments to reduce groundwater abstraction | Water well closure/constraint in critical areas | 1 | 1 |
| | Instruments to prevent water well construction | In overexploited or polluted areas | 2 | 1 |
| | Sanction for illegal water well operation | Penalizing excessive pumping above permit | 1 | 1 |
| | Groundwater abstraction & use charging | 'Resource charge' on larger users | 2 | 1 |
| | Land use control on potentially polluting activities | Prohibition or restriction since groundwater hazard | 1 | 0 |
| | Levies on generation/discharge of potential pollutants | Providing incentives for pollution prevention | 0 | 0 |
| | Government agency as 'groundwater resource guardian' | Empowered to act on cross-sectoral basis | 1 | 1 |
| | Community aquifer management organisations | Mobilising and formalising community participation | 0 | 0 |
| Cross-Sector Policy Coordination | Coordination with agricultural development | Ensuring 'real water saving' and pollution control | 1 | 1 |
| | Groundwater based urban/industrial planning | To conserve and protect groundwater resources | 0 | 0 |
| | Compensation for groundwater protection | Related to constraints on land-use activities | 0 | 0 |
| Operational | Public participation in groundwater management | Effective in control of exploitation and pollution | 1 | 1 |
| | Existence of groundwater management action plan | With measures and instruments agreed | 3 | 0 |

0 = non-existent, 1 = incipient, 2 = fair, and 3 = excellent.

- ❖ Not only boreholes at the well fields, but also selected observation boreholes away from the well fields have been included in the monitoring program in order to obtain an insight into 'natural' groundwater level variations. At present, a large number of boreholes are included in the monitoring program. Optimisation of the monitoring network could take place once more information becomes available.
- ❖ Monitoring of geotechnical stability is recommended and includes checking for any possible cracks, subsidence, or other possible early signs of sinkhole formation and subsidence.
- ❖ A groundwater database system should be established. The program AQUIMON, developed by CSIR and funded by NORAD, is proposed to be used for capturing and storing all the historical and newly collected groundwater data. Quality assurance procedures are proposed to ensure that the data is checked by the technical manager and

the data capturer. Each 6th month, the data should be submitted to a qualified hydrogeologist for review, assessment, and to allow for comment and recommendations. The audit also serves as an early warning system to check for anomalies in groundwater data, and to make sure that the necessary actions are taken to remediate the situation.

- An awareness campaign should be developed and implemented to educate the public on the impacts of human solid waste disposal in the ground, open surface holes and streams.

3.4.3. Good practice example of groundwater management

Due to the physical characteristics of the host rock, water resources in dolomitic areas are particularly vulnerable to over-exploitation, unsustainable practices and pollution. This vulnerability aggravates the potential impact of land use on the dolomitic groundwater resources. Assessment, planning and management as described within the Dolomite Guideline by DWAF (2006) provide three interrelated steps that will assist in the sustainable development, protection and management of the groundwater resources and will assist in achieving the overall goal of integrated water resources management (IWRM). The groundwater management plan which was developed in 2006 (GCS) for the Delmas Municipality comprises both assessment, planning, development and management elements of the Dolomite Guideline and includes both water quantity and water quality aspects. Reasons why the plan has not yet been implemented require further investigation.

4. GAUTENG DOLOMITE AQUIFERS (STEENKOPPIES AND BAPSFONTEIN)

4.1. Introduction

The Gauteng dolomites are among the most productive aquifers in South Africa and are pivotal in meeting the increasing demand of the urban areas. Groundwater from the Steenkoppies and Bapsfontein dolomite compartments (Figure 10) in the western and eastern parts of the Province is extensively used for irrigation and also contributes to public water supply (e.g. Johannesburg and Tshwane municipalities). They are important for thousands of small-scale groundwater users and also for sustaining ecosystems. Ongoing over-exploitation of the resource has resulted in declining water levels, diminishing spring flows and sinkhole formation, thereby calling for appropriate management of the resource to secure future water supplies.

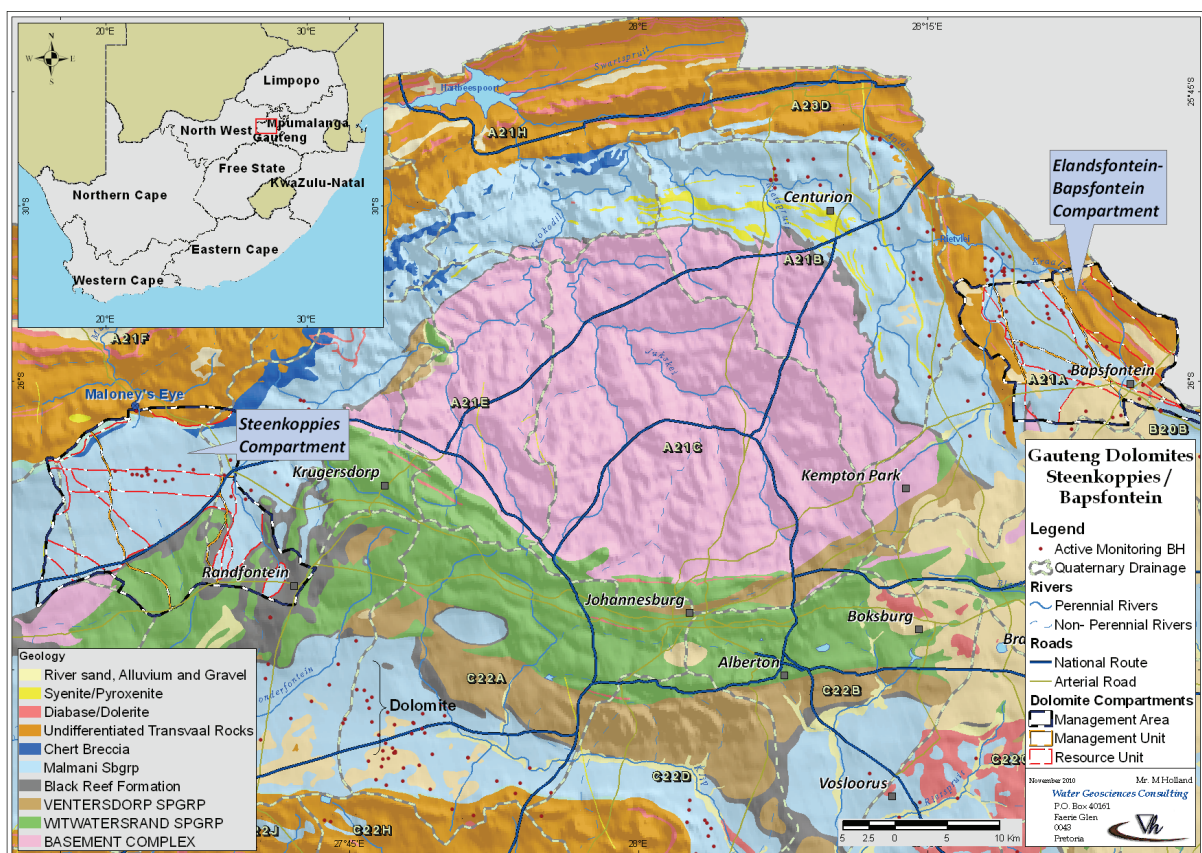


Figure 10: Gauteng Dolomites

Groundwater from the Steenkoppies dolomite compartment near Tarlton supports a specialised agricultural industry worth hundreds of millions of Rands which employs thousands of people (WGC, 2009c). Groundwater abstraction started in the early 1980s and recent studies indicated declining groundwater levels suggesting over-exploitation (Barnard, 1997; WGC, 2009c). The natural spring of the Steenkoppies compartment, known as “Maloney’s Eye”, one of the largest and best-known springs in the country, even reached the lowest flow on record and this has major consequences for downstream water users.

A better understanding of the hydraulic functioning of the Bapsfontein dolomite compartment has become crucial since the development of a large sinkhole on 28 January 2004 next to a

surfaced road, a few hundred metres from an informal settlement (Wagener, 2009). Intensive farming is being practiced in the immediate surroundings and as far afield as Delmas, with many centre-pivot installations irrigating maize and vegetable crops.

4.2. Resource setting

4.2.1. Hydrogeologic condition

Aquifer type and characteristics

The Gauteng dolomites stretch from the Steenkoppies compartment in the west to beyond Delmas in the east (Delmas and Bapsfontein compartments). The dolomites (Figure 10) are subdivided into ‘compartments’ due to the cross-cutting of impervious sub-vertical dykes of dolerite and syenite, as well as due to silicified faults, creating hydrogeologically isolated units with similar characteristics across that unit (Vegter, 1986). Dissolution of dolomite has led to an aquifer with high groundwater potential and borehole yields, commonly above 5 l/s. The Gauteng dolomites are capped by rocks of the Pretoria Group in the north, notable as quartzite ridges. To the south-west, the Gauteng dolomites are underlain by the gold bearing Witwatersrand formations. Dipping off the eastern and south-eastern flank of the Johannesburg Dome with a disconformable contact is the basal formation of the Transvaal Super-Group consisting of the Black Reef Quartzite formation underlying the Malmani dolomite sub-group of the Chuniespoort Group. Immediately south of the Delmas and Bapsfontein compartments younger rocks of the Karoo Super-Group prevail.

The Steenkoppies dolomite compartment falls within the larger 312 km² Steenkoppies groundwater management area (GMA) and was recently subdivided into three groundwater management units (GMUs; WGC, 2009c; Figure 11 and Figure 12). The GMUs are based on surface water drainage and hydrogeological considerations that require consistent management actions to maintain the desired level of use or protection of the resource. Water levels in the Steenkoppies compartment vary between 50 and 60 m.b.g.l. and aquifer conditions are unconfined to (semi-)confined (the latter due to weathered overlying material). Groundwater drainage in the Steenkoppies compartment is to the north towards Maloney’s Eye and the flat groundwater gradient suggests highly transmissive or conductive conditions.

The water level of the main drainage area of the Eye represents the discharge elevation of the spring. Although DWA has monitored groundwater levels since 1985, only 18 of the 31 stations are actively being monitored. Some of the stations have been monitored on a monthly basis, while others have relatively long time gaps between measurements. The flow at Maloney’s Eye correlates very well with rainfall over most of the 100 year records. In the past fifteen years, the spring flow has declined more than rainfall records would suggest (divergence of spring flow and rainfall cumulative averages). In addition, groundwater level data from boreholes in the area under irrigation show a clear correlation between water levels in the compartment, and flows at the Eye. Therefore, declines observed in groundwater levels (up to 2 m) in recent years can be attributed mainly to over-exploitation. The mean annual discharge of Maloney’s Eye since 1908 to the late 1980s is 14 Mm³/a, but has decreased to 9.8 Mm³/a over the last decade.

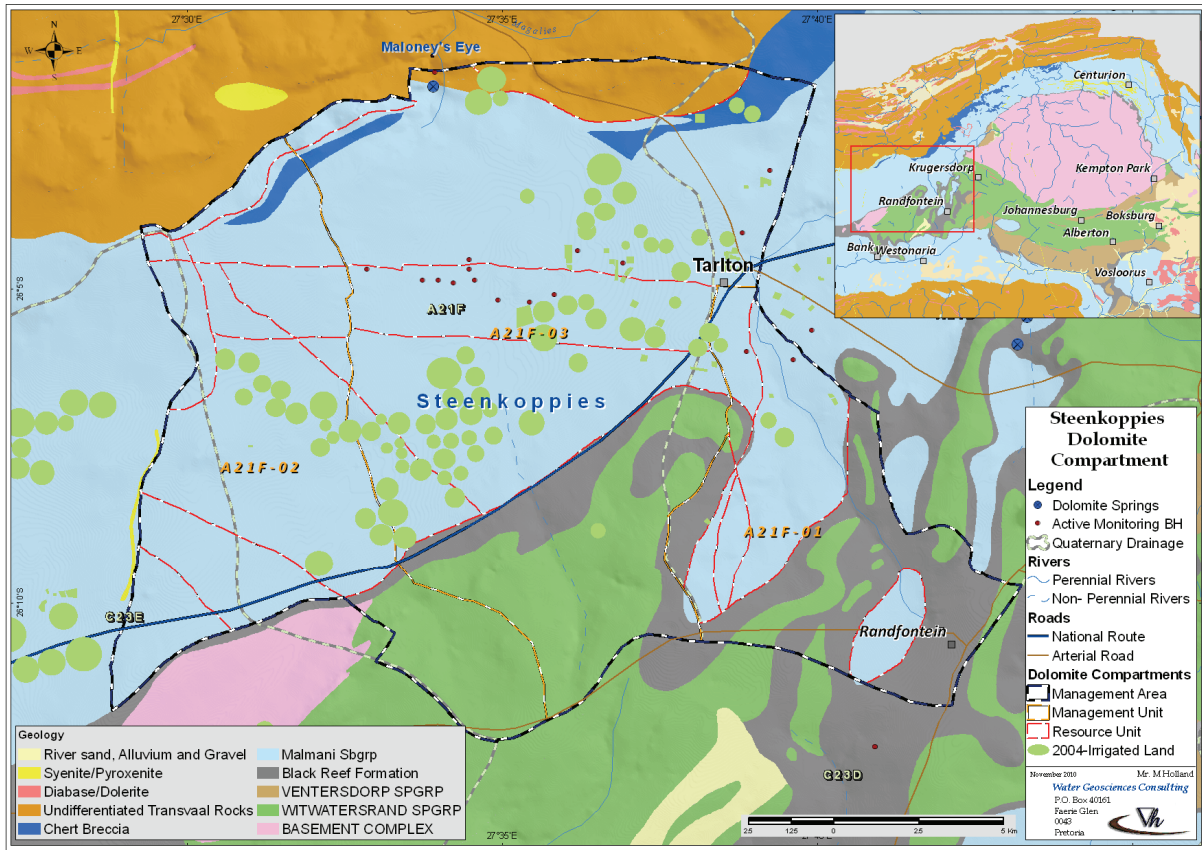


Figure 11: Steenkoppies compartment

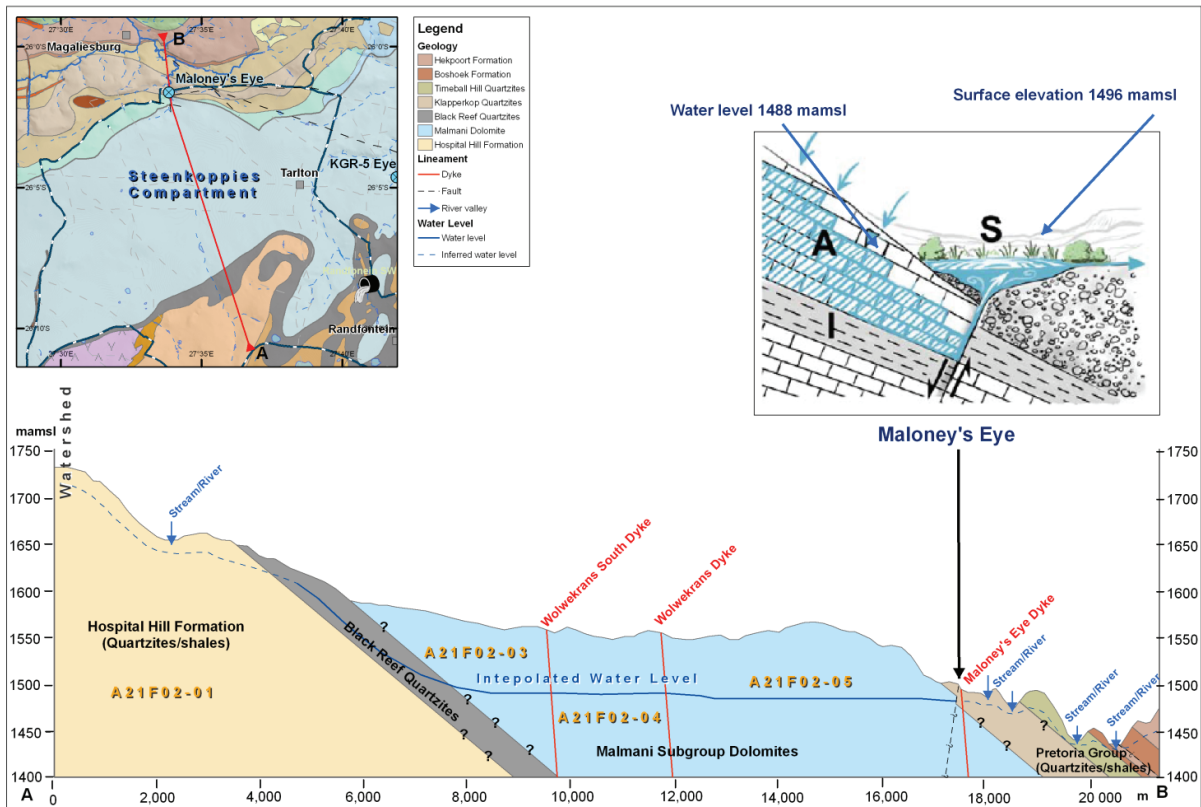


Figure 12: Cross-section Steenkoppies compartment

The Bapsfontein dolomite compartment is one of four GMUs within the 207 km² Elandsfontein-Bapsfontein GMA (WGC, 2007; Figure 13) and is covered by an intermittent layer of Karoo rocks comprising sandstone, shale and dolerite. This layer can vary in thickness from zero to tens of metres and is draped over a much older, unevenly weathered dolomite surface. Two aquifer systems can be identified, namely the overlying Karoo aquifer and the deeper dolomite aquifer. Due to large-scale pumping from the dolomite aquifer at Bapsfontein since the late 1990s, the water table declined to below the level of solution caverns, subsurface valleys and hollows. The lowering of the water table and the removal of the residuum that filled the caverns and hollows resulted in increasing instability of the overburden. The precise drop in water level is not known, as no long-term monitoring of groundwater levels takes place. From one monitoring borehole to the south it is known that water levels have dropped by 20 m between 1998 and 2004.

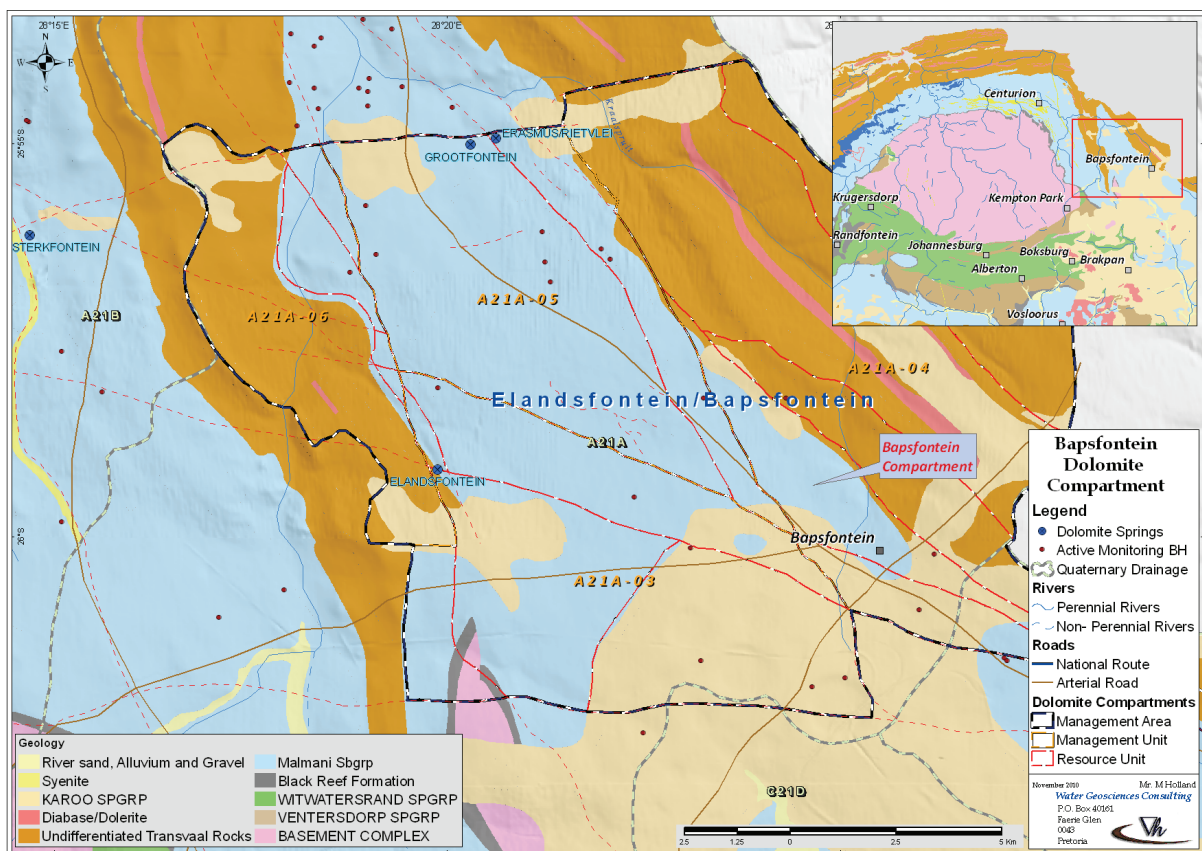


Figure 13: Bapsfontein compartment

Resource renewability and over-exploitation

Both the Steenkoppies and the Bapsfontein dolomite compartments are virtually devoid of surface water drainage suggesting a predominance of subsurface water flow. Recharge rates of both compartments are in the order of 10% of the MAP of 670 mm. For both compartments, however, abstractions exceed the rate of natural recharge. A water balance study of the Steenkoppies compartment revealed a deficit of 3 Mm³/a between inflows and outflows of the 213 km² dolomite aquifer system (WGC, 2009c). Abstraction rates for the Steenkoppies compartment were estimated between 25 and 29 Mm³/a. For the Bapsfontein dolomite compartment, Wagener (2009) calculated a negative water balance of 1.4 Mm³/a and estimated groundwater use in the order of 2.9 Mm³/a.

Aquifer vulnerability

Due to the physical characteristics of the host rock, water resources in these dolomitic areas are particularly vulnerable to over-exploitation, unsustainable practices and pollution. Over-exploitation has led to development of sinkholes and land subsidence in the Bapsfontein compartment and to declining spring flows in the Steenkoppies compartment.

4.2.2. Socio-economic situation

Groundwater use and user profiles

Groundwater in both compartments supports local economic development, and threats to the resource (over-exploitation) are a risk to employment, local domestic product and environmental sustainability. In the case of Steenkoppies, the precise causes of the low flows at Maloney’s Eye have been a subject of dispute between a group representing the Tarlton farmers, also known as the Steenkoppies Aquifer Management Association on the one hand, and the Magalies River Crisis Committee representing the downstream users of the Magalies River on the other hand. In the case of Bapsfontein two main agricultural users (for irrigation) account for 96.5% of the total groundwater abstraction from the aquifer (2.21 Mm³/a from 24 registered boreholes). Other users, including the informal settlement, only abstract 0.08 Mm³/a (Wagener, 2009).

4.2.3. Current and emerging issues

The Steenkoppies dolomite compartment has been extensively impacted mainly by two anthropogenic sources: 1) discharge of inadequately treated sewage from the waste water treatment plants and 2) run-off of fertilizers and livestock excrement from the agricultural areas. In addition to the identified pollution risks, exploitation of the aquifer has resulted in declining groundwater levels. The exploitation of the dolomitic aquifer has increased costs associated with irrigation as well as having a detrimental effect on springs and other groundwater-dependent features. The large spring known as Maloney’s Eye in particular has significantly lower flow rates compared to the early 1980’s. In Table 8 an overview of typologies and threats to the Steenkoppies compartment is given.

Table 8: Typologies and threats to the Steenkoppies compartment

| Typology | Situation / process | High Risk | Medium Risk | Low Risk |
|--|---|-----------|-------------|----------|
| Risk of extensive quasi-irreversible aquifer degradation and subject to potential conflict amongst users | Intensive exploitation (leading to land subsidence, saline or polluted water intrusion) | | ✓ | |
| | Vulnerable to pollution from land surface (vulnerability, pollution) | ✓ | | |
| | Depletion of non-renewable storage (in aquifers with low contemporary recharge) | | ✓ | |
| Potential water use conflict but not at risk of quasi-irreversible aquifer degradation | With growing large-scale abstraction (especially in aquifers with high T/S ratios) | ✓ | | |
| | Vulnerable to point-source pollution (vulnerability, pollution) | ✓ | | |
| | Shared transboundary resource | | | |
| Insufficient (or inadequate use of) scientific knowledge to guide development policy & process | Potential to improve rural welfare & livelihoods (not fulfilling MDG potential) | | ✓ | |
| | Natural quality problems (e.g. As, F) | | | ✓ |
| | Scope for large-scale planned conjunctive use (urban W/S or irrigated agriculture) | | ✓ | |

The Bapsfontein dolomite compartment is being dewatered at an alarming rate of four times the recharge rate (Wagener, 2009). Two main (agricultural) users (irrigators) are responsible for 96.5% of the groundwater abstractions but are using less water than authorised. The dewatering has resulted in:

- Widespread instability in the area in the form of sinkholes and dolines,
- Endangering lives and damaging infrastructure, and
- The drying up of boreholes, depriving inhabitants of their source of potable water.

Another issue is the pollution of groundwater from pit latrines and contaminated storm water where instability occurs in densely populated areas. An overview of typologies and threats to the Bapsfontein compartment is given in Table 9.

It should be noted that the DWA approach to managing groundwater in dolomitic areas (DWAF, 2008), has not yet been adopted in the case of the Steenkoppies and Bapsfontein dolomite compartments. There is even less monitoring of groundwater levels in recent years.

Table 9: Typologies and threats to the Bapsfontein compartment

| Typology | Situation / process | High Risk | Medium Risk | Low Risk |
|--|---|-----------|-------------|----------|
| Risk of extensive quasi-irreversible aquifer degradation and subject to potential conflict amongst users | Intensive exploitation (leading to land subsidence, saline or polluted water intrusion) | ✓ | | |
| | Vulnerable to pollution from land surface (vulnerability, pollution) | ✓ | | |
| | Depletion of non-renewable storage (in aquifers with low contemporary recharge) | | ✓ | |
| Potential water use conflict but not at risk of quasi-irreversible aquifer degradation | With growing large-scale abstraction (especially in aquifers with high T/S ratios) | ✓ | | |
| | Vulnerable to point-source pollution (vulnerability, pollution) | ✓ | | |
| | Shared transboundary resource | | | |
| Insufficient (or inadequate use of) scientific knowledge to guide development policy & process | Potential to improve rural welfare & livelihoods (not fulfilling MDG potential) | | ✓ | |
| | Natural quality problems (e.g. As, F) | | | ✓ |
| | Scope for large-scale planned conjunctive use (urban W/S or irrigated agriculture) | | ✓ | |

4.3. Local groundwater management

Local groundwater management of the Steenkoppies compartment illustrates two phenomena which are also relevant to the Bapsfontein compartment. The first is the classic “tragedy of the commons” (Hardin, 1968 in Foster et al., 2009) a situation in which there is little immediate incentives for individuals to voluntarily reduce their groundwater consumption (and consequently income) in return for a longer-term improvement of the common resource. The short-term benefits of over-abstraction accrue to the individual, whilst the longer-term damage to the shared groundwater resource is shared by all farmers. However, the coordinated action required to address this cannot be convincingly (or possibly even legally) motivated without good groundwater data. The second phenomenon is that, despite key importance of groundwater sustainability to economic growth and opportunity in the area, groundwater hardly appears in available municipal spatial planning documents at local or district levels. This is probably because, groundwater being invisible, planners simply do not realize the importance of the resource.

4.3.1. Water management institutions

The Crocodile West – Marico CMA, which will be responsible for water management in the Steenkoppies and Bapsfontein compartments, is fairly advanced with regards to the process of establishing a Governing Board (GB). Currently, the DWA regional office is carrying out its functions until such time that a CMA with responsibility of the two compartments is fully established and operational.

Steenkoppies is in the process of establishing a WUA and the farmers are keen to install flow meters, rainfall stations and equip boreholes with loggers to improve management of their groundwater resource. DWA's role is unclear at the moment but it's hoped that they will assist with the interpretation of the data and assist with management of the resource. There remains, however, the problem of inadequate technical capacity at DWA.

There is a joint responsibility for water resource management of the Bapsfontein compartment between the DWA as national and regional (Gauteng) government authority, the Gauteng Department of Agriculture, Conservation, Environment and Land Affairs (GDACEL) as custodian of the environment at provincial level, and mainly the Metsweding, Tshwane Metropolitan and Greater East Rand Metro District Municipalities as local government structures.

4.3.2. Blue and green drop certification

The Mogale City Local Municipality, the water services authority in charge of water services and water quality monitoring of the Steenkoppies compartment, with Rand Water as the water service provider, received an average blue drop score of 92% and an average drinking water compliance of 94.6% in 2009 (DWA, Blue Drop Report 2009 Version II). In 2010 the blue drop score improved to 97.75% resulting in the Municipality receiving the blue drop status. The drinking water quality is considered excellent. From a regulatory point of view DWA recommended the finalization of a water safety plan and to dedicate funds to ensure continuous DWQ management. The Mogale City-rural boreholes system, which is currently at a score of 86% could see a further blue drop score increase. The average waste water quality management performance (green drop certification process) of the Mogale Local Municipality as a whole, however, is poor (36%) and substantial effort is required in process controller classification of waste water quality compliance and response management to waste water failures. According to the Mogale City Local Municipality IDP ~70 Million Rand is budgeted for water and sanitation related infrastructure for 2010/2011 for the area which falls under their jurisdiction. Only a small fraction of the budget (~135 K Rand) is allocated to infrastructure development in the Steenkoppies compartment. No provision is made for groundwater management activities.

Ekurhuleni Metropolitan Municipality, the water services authority in charge of the water quality monitoring of the Bapsfontein compartment with Rand Water as the water services provider, slightly improved the blue drop score from 96% to 96.83% from 2009 to 2010. The Ekurhuleni Metropolitan Municipality is providing consumers within their area of responsibility (including Bapsfontein compartment) with continuous safe water. Water Supply Systems within jurisdiction of the Metro again received the blue drop status. Finalisation of the risk assessment process, formally documented within the water safety plan, inclusive of management's commitment for continued endorsement, could result in further improvement of the DWQ performance of the authority. The Bapsfontein informal

settlement boreholes were not assessed. The waste water treatment works (WWTWs) are operated by ERWAT as the WSP and the average green drop score for the 2009 assessment was 65%. Most of the WWTWs are performing adequately but substantial improvement is required in terms of regular submission of waste water quality results to DWA and waste water quality compliance. The budget allocated for infrastructure development in water and waste water for 2010/2011 is 186 Million Rand.

4.3.3. Knowledge and capacity

Recently, numerous geohydrological assessments have been undertaken of the Steenkoppies dolomites (Bredenkamp et al., 1986; Barnard, 1997, ERM, 2007; WGC, 2009c). These assessments provide a valuable overview of the water resources (in terms of both water quantity and quality) within the Steenkoppies dolomites and present various challenges related to the management of these aquifers. The same applies to the Bapsfontein compartment where the Council for Geoscience (CGS) carried out an aero-magnetic study to delineate the aquifer, and geohydrological studies were carried out which included a hydrocensus of 153 private boreholes, a groundwater reserve determination, and the formulation of a conceptual groundwater management plan (Hobbs, 2004; Jasper Müller Associates CC, 2005). Fairly complete monthly water level data from 1985 to 2005 are available for three boreholes towards the south of the Bapsfontein compartment.

As was the case for groundwater management of the Botleng dolomite aquifer, knowledge exists to deal with most groundwater management issues. The problem is not only lack of human resource capacity to implement the recommendations from various studies but also the (political) will to act by the stakeholders involved in the interest of all.

4.4. Evaluation of groundwater governance provisions

4.4.1. Effectiveness of governance provisions

The established DWA approach to managing groundwater (assessment, planning, development and management stages), as laid down in their document (DWA, 2008), has not been followed in the case of the Steenkoppies nor Bapsfontein compartments until recently.

Assessment of the Steenkoppies resource, whilst arguably never sufficient for such a valuable body of water, has in fact been given lesser priority in recent years – at exactly the time when declines in flow at Maloney’s Eye have made national headlines (Business Day, 2007). Nobody knows exactly how much water is being used today for irrigation purposes, although DWA is implementing steps to rectify this. Planning, the second stage of the DWA process depends on a sound interpretation of hydrogeological and other data. However, at present no single conceptual model of the aquifer is agreed upon by all parties, and no detailed reserve determination has been done. The total available resource is still under dispute. Failures in assessment and planning have made it difficult to implement management actions. The 2008 directive to restrict groundwater abstraction based on observed flows at the eye is an improvement of the 2004 directive which sought to halt all groundwater use that did not fall under Schedule One of the National Water Act, since this threatened a valuable and long-established agricultural industry. However, without knowledge of what is currently being abstracted, and without the means to measure reductions, it will be difficult to implement this directive as intended.

The effectiveness of existing governance provisions for the Steenkoppies compartment and capacity to implement adequate groundwater governance is evaluated against a priority list of 20 benchmarking criteria and is listed in Table 10.

Table 10: Effectiveness groundwater governance provisions & capacity: Steenkoppies

| Capacity | Criterion | Context | Provision | Inst. capacity |
|---|--|--|-----------|----------------|
| Technical | Basic hydrogeological maps | For identification of groundwater resources | 3 | 2 |
| | Groundwater body/aquifer Delineation | With classification of typology | 3 | 2 |
| | Groundwater piezometric monitoring network | To establish resource status | 1 | 1 |
| | Groundwater pollution hazard assessment | For identifying quality degradation risks | 2 | 2 |
| | Availability of aquifer numerical 'management models' | At least preliminary for strategic critical aquifers | 2 | 1 |
| | Groundwater quality monitoring network | To detect groundwater pollution | 2 | 1 |
| Legal & Institutional | Water well drilling permits & groundwater use rights | For large users, with interests of small users noted | 2 | 2 |
| | Instruments to reduce groundwater abstraction | Water well closure/constraint in critical areas | 1 | 1 |
| | Instruments to prevent water well construction | In overexploited or polluted areas | 2 | 2 |
| | Sanction for illegal water well operation | Penalizing excessive pumping above permit | 3 | 2 |
| | Groundwater abstraction & use charging | 'Resource charge' on larger users | 1 | 2 |
| | Land use control on potentially polluting activities | Prohibition or restriction since groundwater hazard | 2 | 1 |
| | Levies on generation/discharge of potential pollutants | Providing incentives for pollution prevention | 0 | 0 |
| | Government agency as 'groundwater resource guardian' | Empowered to act on cross-sectoral basis | 2 | 2 |
| | Community aquifer management organisations | Mobilising and formalising community participation | 2 | 2 |
| Cross-Sector Policy Coordination | Coordination with agricultural development | Ensuring 'real water saving' and pollution control | 2 | 2 |
| | Groundwater based urban/industrial planning | To conserve and protect groundwater resources | 0 | 0 |
| | Compensation for groundwater protection | Related to constraints on land-use activities | 0 | 0 |
| Operational | Public participation in groundwater management | Effective in control of exploitation and pollution | 2 | 3 |
| | Existence of groundwater management action plan | With measures and instruments agreed | 0 | 2 |

0 = non-existent, 1 = incipient, 2 = fair, and 3 = excellent.

Governance provisions regarding the Bapsfontein compartment appear to be adequate and in place but should be implemented, especially with regards to revisiting the licensing of the two main water users. The effectiveness of existing governance provisions and capacity to implement adequate groundwater governance for the Bapsfontein compartment is evaluated in Table 11.

Table 11: Effectiveness groundwater governance provisions & capacity: Bapsfontein

| Capacity | Criterion | Context | Provision | Inst. capacity |
|---|--|--|-----------|----------------|
| Technical | Basic hydrogeological maps | For identification of groundwater resources | 3 | 1 |
| | Groundwater body/aquifer Delineation | With classification of typology | 3 | 1 |
| | Groundwater piezometric monitoring network | To establish resource status | 1 | 1 |
| | Groundwater pollution hazard assessment | For identifying quality degradation risks | 1 | 1 |
| | Availability of aquifer numerical 'management models' | At least preliminary for strategic critical aquifers | 0 | 0 |
| | Groundwater quality monitoring network | To detect groundwater pollution | 1 | 0 |
| Legal & Institutional | Water well drilling permits & groundwater use rights | For large users, with interests of small users noted | 2 | 1 |
| | Instruments to reduce groundwater abstraction | Water well closure/constraint in critical areas | 0 | 0 |
| | Instruments to prevent water well construction | In overexploited or polluted areas | 0 | 0 |
| | Sanction for illegal water well operation | Penalizing excessive pumping above permit | 0 | 0 |
| | Groundwater abstraction & use charging | 'Resource charge' on larger users | 1 | 1 |
| | Land use control on potentially polluting activities | Prohibition or restriction since groundwater hazard | 1 | 1 |
| | Levies on generation/discharge of potential pollutants | Providing incentives for pollution prevention | 0 | 0 |
| | Government agency as 'groundwater resource guardian' | Empowered to act on cross-sectoral basis | 1 | 0 |
| | Community aquifer management organisations | Mobilising and formalising community participation | 0 | 0 |
| Cross-Sector Policy Coordination | Coordination with agricultural development | Ensuring 'real water saving' and pollution control | 1 | 1 |
| | Groundwater based urban/industrial planning | To conserve and protect groundwater resources | 1 | 0 |
| | Compensation for groundwater protection | Related to constraints on land-use activities | 0 | 0 |
| Operational | Public participation in groundwater management | Effective in control of exploitation and pollution | 1 | 0 |
| | Existence of groundwater management action plan | With measures and instruments agreed | 0 | 0 |

0 = non-existent, 1 = incipient, 2 = fair, and 3 = excellent.

4.4.2. Management measures

Management measures addressing key issues in the Steenkoppies compartment include (WGC, 2009c):

- Accurate estimates for current irrigation abstraction amounts need to be made, and the issue of abstraction licensing needs to be resolved. This issue is also addressed in the DWAF 2008 notice which restricts the use of irrigation water in the compartment to certain days and times, and dependent on the volume of flow at Maloney's Eye.
- A full inventory of all irrigation boreholes in the compartment needs to be made. This is linked to the licensing issue. This issue is also addressed in the DWA 2008 notice.
- The decline in groundwater level monitoring infrastructure in the compartment needs to be reversed. If necessary new boreholes need to be drilled. Several existing boreholes and the

Maloney's discharge point need to be accurately surveyed to determine absolute elevations above a common datum. Monitoring of groundwater levels is the basis for continued groundwater management in the compartment, and the "fine-tuning" of management interventions.

- Improved rainfall measurements over the Steenkoppies compartment should be considered, which take into account both the total volume and the intensity of rainfall events (e.g. tipping-bucket rain gauge system).
- Whilst it is difficult to agree on exact figures at present, it is very likely that over-abstraction by irrigators is at least partly to blame for declines in the flow at Maloney's Eye. Measures to reduce groundwater abstractions need to be implemented, although a gradual approach to implementation is suggested to ensure as little as possible disruption to this valuable industry.
- As new groundwater data is collected, the technical and conceptual model of the compartment can be refined, and management interventions (such as irrigation abstraction restrictions) further developed. This is along the lines of the principles of "Adaptive Management" discussed by Seward et al. (2006).
- Outstanding technical issues, which stand in the way of coordinated and united management actions, need to be resolved. These include estimating the rough size of the catchment for Maloney's Eye, and the relationship between declining flows at the eye and declining flows further downstream in the Magalies River.
- Decisions made around the sustainability of the Steenkoppies groundwater resource and the flow at Maloney's Eye should be captured in local and regional planning documents.

Although the issue of the water "budget" for the compartment, and the associated flow of Maloney's Eye is the most important groundwater management issue that needs attention in the Steenkoppies compartment, there are several other technical groundwater issues that should also be considered, and which have a bearing on future management:

- How is groundwater quality in the Steenkoppies compartment being affected by various practises, including the irrigation with treated wastewater, the application of fertilisers and biocides by commercial farming operations?
- How "leaky" are the boundaries of the Steenkoppies compartment, and how might groundwater in the compartment be affected by changes in the quantity and quality of groundwater in adjoining compartments?
- What is the potential for artificial recharge in the compartment, perhaps using treated wastewater?
- Improved public participation in the management of groundwater in the Steenkoppies compartment is desirable. This would provide all stakeholders (e.g. farm employees, Magalies River water users, environmentalists, etc) with information about on-going management, and also help to ensure that the concerns of all stakeholders are incorporated into management deliberations.

Due to the strategic importance of the groundwater source (e.g. Maloney's Eye) and due to unacceptable surface instability risks (e.g. Bapsfontein) water use licenses should be revisited with the aim to ensure sustainable utilization of the groundwater resources.

4.4.3. Good practice example of groundwater management

The Maloney's Eye of the Steenkoppies dolomite compartment is a good example of shared management of a groundwater source at local level. Groundwater abstraction appears to have grown steadily through the 1980s and 1990s, both in terms of volume and the number of boreholes. In 1994, following low flows in the Magalies River, DWA ordered that abstraction of water from the Magalies River cease for an interim period, pending review of water allocations from the river. In September 2004 a group of concerned water users downstream of the Maloney's Eye formed the Magalies River Crisis Committee (MRCC) to "address the problems associated with the flow of the [Magalies] river and to engage DWA in seeking a solution to the problem and in following up on the promises that had been made." In December 2004 DWA issued a series of directives aimed at stopping unlawful water use in the Steenkoppies Compartment. In 2007 the MRCC was reconvened, and made a submission to the South African Presidency regarding the low flows at Maloney's Eye and the possible impact on the Magalies River, seeking amongst other things a temporary cessation of all groundwater abstractions from the Steenkoppies Compartment to allow the flow at the eye to recover (MRCC, 2007). The submission also emphasised the risk of sinkholes forming as a consequence of declining water levels in the compartment. Essentially, the 2007 submission by the MRCC states that the primary cause of low flows at Maloney's Eye is irrigation using groundwater by farmers in the Steenkoppies compartment, and that such irrigation needs to be drastically reduced.

The 2007 submission by the MRCC to the presidency led to a response by 21 groundwater users (the "Tarlton farmers") in the Steenkoppies Compartment in the form of a submission to the Director-General of DWA, dated November 2007 (Tarlton, 2007). The Tarlton farmers dispute that irrigation is to blame for the low flows at Maloney's Eye, although they agree that water resources in the greater Magalies area are under stress. They state that "no credible evidence has been put forward to show that the water difficulties in the Tarlton and Magalies River area is attributable to the existing lawful use of water by the Tarlton Farmers" (Tarlton, 2007). The Tarlton farmers therefore dispute the restrictions on groundwater irrigation contained in the DWA directive of 2004. The Tarlton farmers commissioned and paid for a groundwater study by the environmental consultancy ERM (Pty) Ltd which supports their views (ERM, 2007). In particular, the ERM report states that changing rainfall patterns, changing sewage inputs to the compartment, changing water uses downstream of Maloney's Eye, alien vegetation along the banks of the Magalies, mining activities and other factors are also to blame for the decline in flow at the eye and in the Magalies River (ERM, 2007). The study done by Barnard in 1997 estimated a catchment size (177 km²) and a water balance for the Steenkoppies area (Barnard, 1997). The ERM report states that the catchment is in fact likely to be considerably larger (about 500 km²) than stated by Barnard, based on geochemical evidence. The ERM report does however state that aquifer management needs to be instituted, and that a detailed hydrogeological study needs to be carried out.

In 2008 DWA published a notice in the Government Gazette of 14 March 2008 restricting the use of irrigation water in the compartment to certain days and times, and dependent on the volume of flow at Maloney's Eye. When flows at the eye are less than 93 L/s, then all abstractions apart from schedule 1 use are prohibited. The notice also called for the details of all irrigators to be submitted to DWA within 21 days of publication of the notice.

The value of agricultural activities in the greater Tarlton area is large, both in terms of money flowing into the area and in terms of employment. The Tarlton Farmers estimate that the

activities are worth more than three quarters of a billion rand and employ 3500 people directly, as well as supporting large numbers of people and economic activities indirectly. Any major reduction in farming activities could have severe economic and social consequences for the area.

In 2007 the Tarlton farmers started negotiations for the establishment of a Water User's Association (WUA) for the area, the "Steenkoppies Aquifer Management Association", with the assistance of the Danish government aid organisation DANIDA through the DWA. The WUA is essentially aimed at furthering joint interests of groundwater users from the Steenkoppies Compartment and surface water users downstream of the compartment. A draft constitution for the WUA has been prepared and submitted to the DWA. Currently (November 2010) the application is awaiting approval by the Minister of Water Affairs. It is expected that the WUA will provide the appropriate platform for disputes to be resolved before they go to court.

5. HOUDENBRAK BASEMENT AQUIFER (MOGWADI (DENDRON) – VIVO AREA)

5.1. Introduction

Agriculture is the biggest user of groundwater in South Africa. It contributes to diffuse contamination with nitrate being the most common agricultural contaminant and often increases groundwater salinity. Over-exploitation of groundwater resources results in declining water levels, and combined with contamination of the resource endangers both water and food security, and increases the potential for water use conflict. Houdenbrak provides for a classical example of over-exploitation of a groundwater resource mainly due to agricultural activities. For decades Houdenbrak has been a government controlled subterranean groundwater area and includes the Mogwadi (Dendron) and Vivo area. The groundwater potential in the Mogwadi-Vivo area far exceeds the typical expectations of basement rock aquifers with blow yields of more than 40 l/s. Large scale irrigation from groundwater has sustained (though not necessarily sustainably) agricultural activities in the area for the past 40 years. Despite early warnings since the mid 1980s of declining water levels posing a threat to a large number of rural communities and other domestic users, the Houdenbrak basement aquifers are still being over-exploited.

5.2. Resource setting

5.2.1. Hydrogeologic condition

Aquifer type and characteristics

The Mogwadi-Vivo basement aquifers are located about 60 km north of Polokwane in the Limpopo Province of South Africa within the Sand River Basin (Figure 14), and partly cover the Brak and Hout catchments. The area is underlain by basement rocks, drains to the northeast, is generally flat and almost featureless, and can be referred to as the Limpopo Plateau. The occurrence of groundwater is likely to be related to secondary porosity developed by weathering, faulting, fracturing and the influence of intrusives (e.g batholiths and dykes).

Aquifers systems developed on the Plateau are:

- Composite aquifers; comprising a variable thickness of regolith overlying bedrock, the upper part of which is frequently fractured.
- Deeper fractured aquifers; composed mainly of crystalline material (igneous and metamorphic rocks) characterised by an intact and relatively unweathered matrix with a complex arrangement of interconnected fracture systems.
- Alluvial aquifers; alluvial material overlies or replaces the weathered overburden and develops a distinct intergranular aquifer type. These elongated aquifers follow rivers (so called valley trains), sand rivers or drainage lines with limited width and depth, which typically vary according to topography and climate.

The thickness of the regolith on the Plateau generally extends to between 15 and 50 metres below surface. Below the weathered zone is a zone of fracturing, which according to geohydrological studies done by Jolly (1986) in the Dendron/Mogwadi area may extend to depths in excess of 120 m. Higher yields (> 3 l/s) are often associated with the fractured fissure layer, irrespective of the thickness of the overlying weathered layer. The weathered-fractured aquifer is unconfined in some areas and (semi-)confined in others.

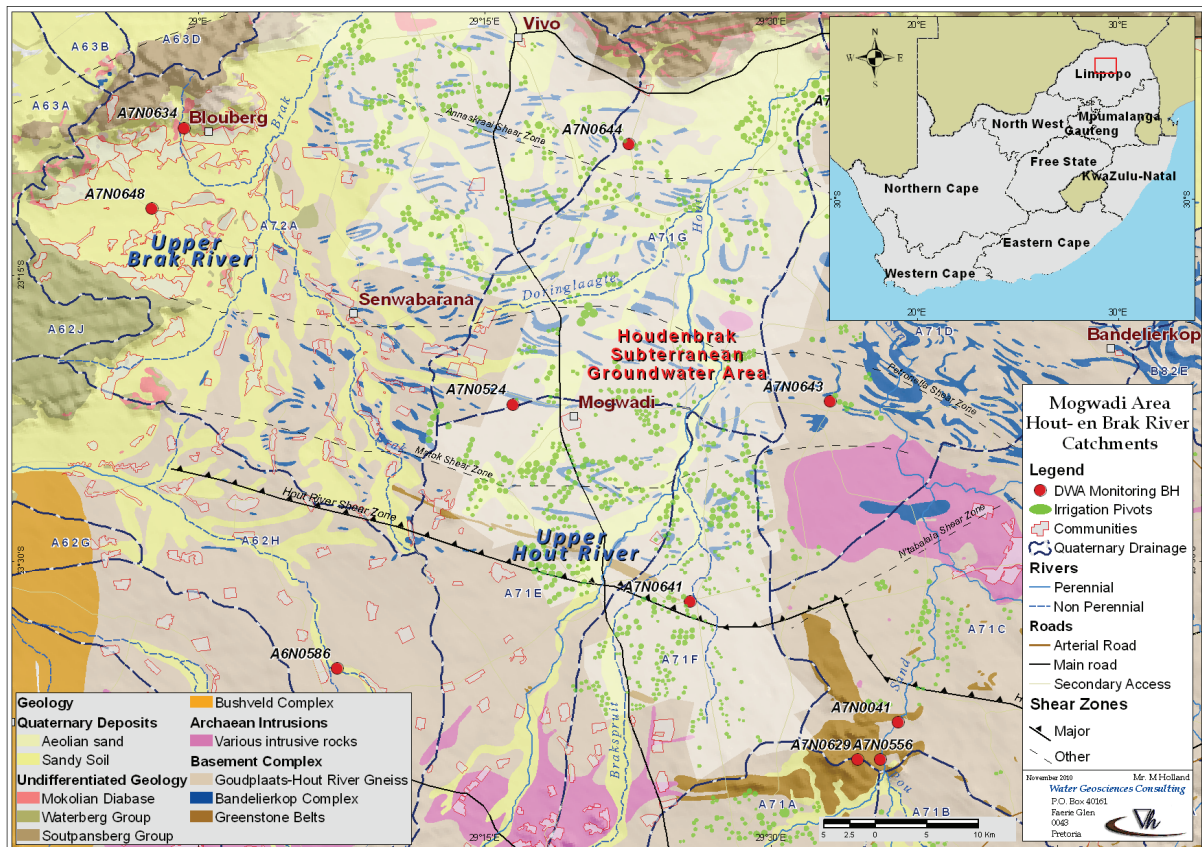


Figure 14: Houdenbrak basement aquifers

Based on the Groundwater Resources Information Project (GRIP) Limpopo database of the DWA, seventy percent of the transmissivities are within the range of 4 m²/d and 40 m²/d; however, several boreholes with significantly higher transmissivities (outliers), especially in the Mogwadi (Dendron) area, “push” the arithmetic mean for this area to 38 m²/d.

The natural groundwater quality of the basement aquifers of the region is generally suitable for human consumption, though elevated salinities, nitrate or trace element concentrations may render the water source detrimental to human health. Thirty one percent of samples within the Limpopo Plateau show ion concentrations exceeding recommended drinking water limits (Holland, 2010; SANS 2006; Table 12). Nitrate (measured as nitrogen N) and fluoride are of most concern.

The single most important reason for groundwater resources in South Africa being declared unfit for drinking water is nitrate levels exceeding 10 mg/l (as N; Marais, 1999). While nitrate contamination is often related to agricultural effluent, in the larger Mogwadi-Vivo area the main occurrence of elevated nitrate concentrations is related to rural communities to the west of the demarcated subterranean control area. Inappropriate on-site sanitation and wastewater treatment, improper sewage sludge, drying and disposal, and livestock concentration at watering points near boreholes all contribute to elevated nitrate levels. Elevated nitrate concentrations in groundwater to the east of the Mogwadi-Vivo area (Figure 15) originate from both anthropogenic activities (agricultural practices; fertilisers) and non-anthropogenic sources related to evaporative enrichment of dry and wet deposition, biogenic point sources through N-fixing organisms, or to a geogenic origin (Tredoux and Talma, 2006).

**Table 12: Potability classification of the Mogwadi-Vivo area
(EC in mS/m, all other in mg/l)**

| SANS 241:2006 | EC | Ca | Mg | Na | K | SO ₄ | Cl | NO ₃ as N | F |
|---|-------------|-------------|------------|-------------|------------|-----------------|-------------|----------------------|-----------|
| Class I Rec. operational Limit | < 150 | < 150 | < 70 | < 200 | < 50 | < 400 | < 200 | < 10 | < 1 |
| Class II Max. allowable limited | 150- 370 | 150- 300 | 70- 100 | 200- 400 | 50- 100 | 400- 600 | 200- 600 | 10-20 | 1-1.5 |
| Exceeding Class II (Consumption period) | 7 years | | | | | | | | 1 year |

| Limpopo Plateau | | | | | | | | | | |
|-----------------|-----|-----|-----|-----|-----|-----------------|-----|----------------------|-----|-------------------|
| | EC | Ca | Mg | Na | K | SO ₄ | Cl | NO ₃ as N | F | Combined Class |
| Class I | 70% | 94% | 75% | 85% | 99% | 99% | 73% | 54% | 87% | 34% |
| Class II | 26% | 4% | 15% | 11% | 1% | 0% | 20% | 27% | 5% | 34% |
| > Class II | 4% | 2% | 9% | 4% | 0% | 1% | 6% | 19% | 8% | 31% |

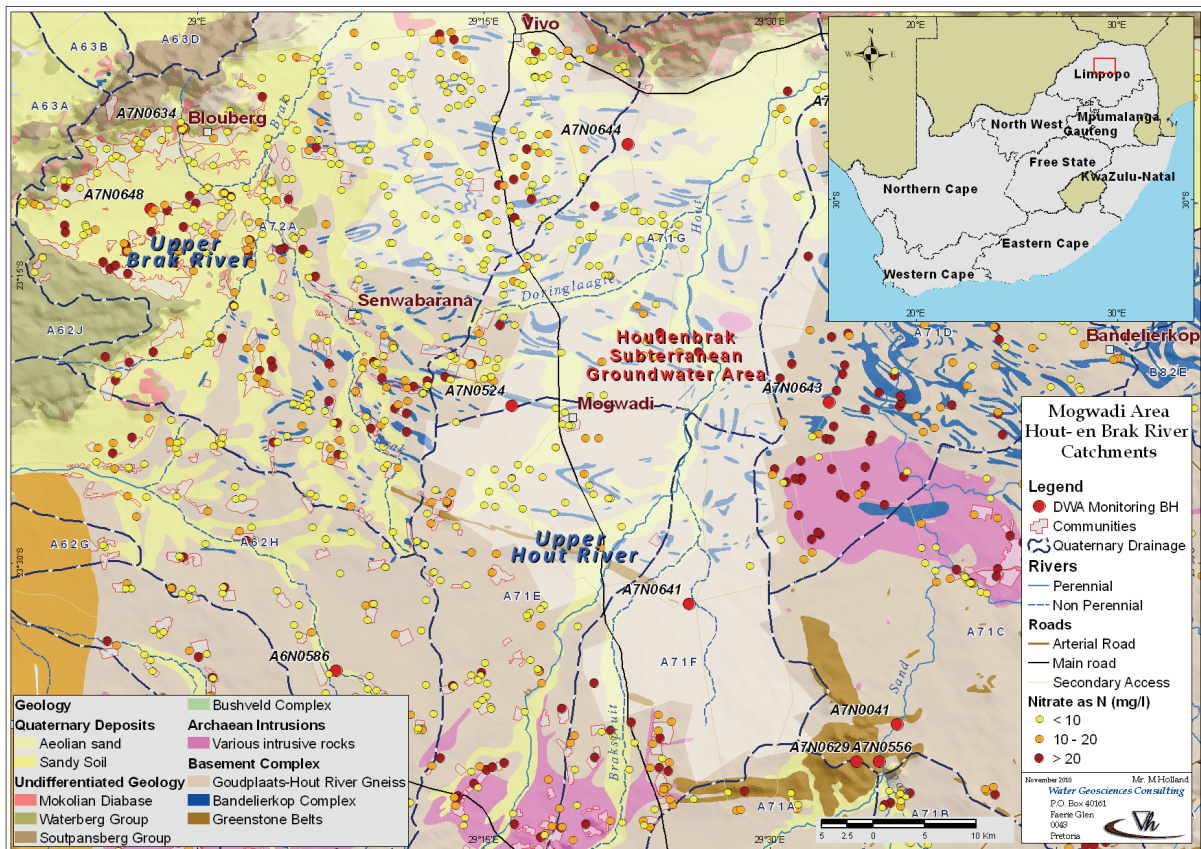


Figure 15: Nitrate concentrations of Houtenbrak basement aquifers

Resource renewability and over-exploitation

Recharge to the underlying basement aquifer has been estimated at between 2 % and 5 % of the MAP of 400 mm. Considering the high groundwater potential of these basement aquifers and the relatively low recharge it is obvious that groundwater abstractions in the Mogwadi-Vivo area will exceed the rate of natural recharge, especially in below average rainfall years.

While a number of national monitoring stations are within the Mogwadi-Vivo subterranean control area, only one borehole has continuous data (monthly) since the onset of monitoring in the early 1970s. Several monitoring boreholes have been abandoned in the late 1980s and mid 1990s and the lack of data over the last decade has led to speculations about the volume of groundwater abstracted from these basement aquifers and the extent of water level decline. The reasons for the inadequate groundwater monitoring and data collection are difficulties in obtaining access to monitoring boreholes, lack of budget for rehabilitating monitoring boreholes, or the lack of field staff to carry out monitoring activities. In the Mogwadi-Vivo area the blame is partially on the Irrigation Board for not adequately monitoring water levels and abstractions or where monitoring is done data are not submitted to the DWA.

Recent literature on the Houdenbrak aquifer (e.g. Masiyandima et al., 2002; Masiyandima, 2009) mostly refers back to numerous studies carried out in the 1970s and 1980s (e.g. Dziembowski, 1976; Jolly, 1986). Jolly (1986) described an increase in groundwater abstraction for irrigation from 9 million m³/a in 1968 to 21 million m³/a in 1986 (no recent estimates are available). Long-term water level trends can be best observed from the single monitoring borehole on the western outskirts of the Mogwadi-Vivo subterranean area. As illustrated in Figure 16, although over-abstraction occurs in times of below average rainfall, the groundwater level declined by 6 m since early 1970s until present; groundwater levels declined steadily for a decade from 1990 to 2000. According to Masiyandima (2009) certain management interventions were implemented in the 1990s which together with an above average rainfall for 2000 led to a recovery of groundwater levels in 2001/2002. Continued decline of the groundwater level after 2002 suggests that management interventions were not effective in controlling over-abstraction. One of the reasons is a lack of communication and support from the DWA. This may have changed farmers' perspective of managing the aquifer. Note that groundwater level declines are also enhanced by a number of consecutive below average rainfall years.

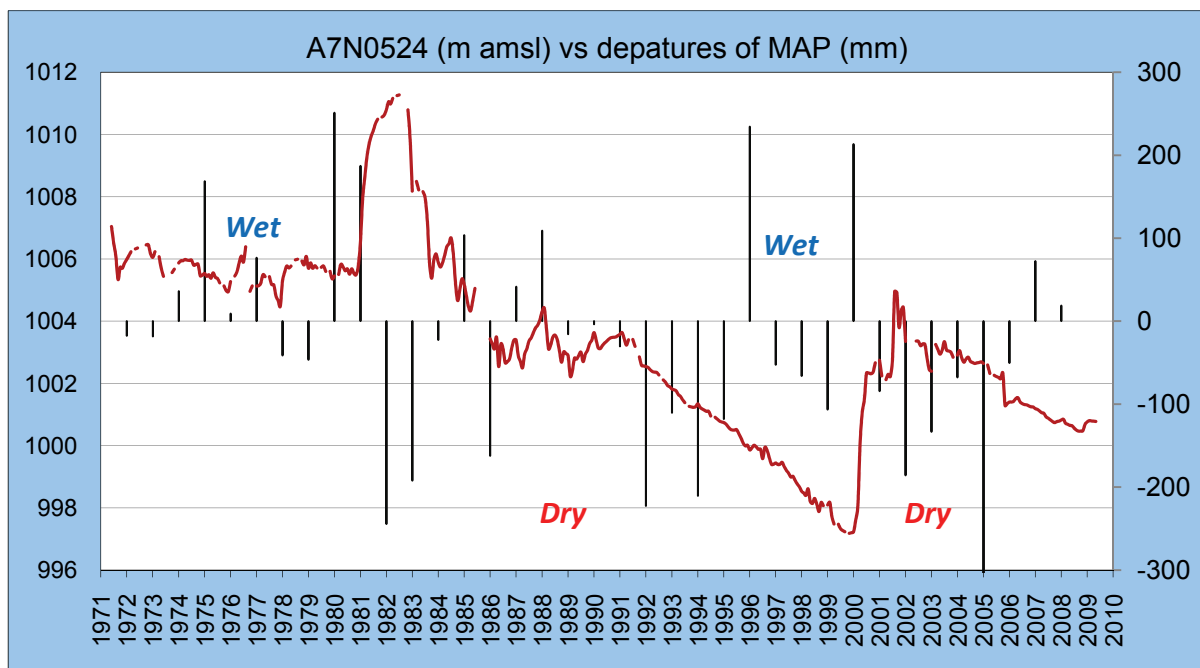


Figure 16: Well hydrograph of long term monitoring station A7N0524 near Mogwadi (Holland, 2010)

Aquifer vulnerability

The Houdenbrak basement aquifers have a complex tectonic history and intense shearing and fracturing of the basement rock has created highly productive fractured aquifers with large storage potentials and hydraulic conductivities increasing the vulnerability to contaminants compared to typically low yielding basement aquifers.

5.2.2. Socio-economic situation

Groundwater use and user profiles

Within the Limpopo Province, groundwater is often the sole source of water for many users. Apart from the Mogwadi-Vivo irrigation area a number of rural development irrigation schemes have been put in place. Towns such as Senwabarwana (Bochum) are completely dependent on groundwater, in addition to the hundreds of communities scattered throughout the region.

The Blouberg Municipality falls partly within quaternary catchment A72A. According to the DWA-Groundwater Resources Assessment Project – Phase II, rural and municipal groundwater use within A72A is approximately 1.5 Mm³/a. Based on the GRIP Limpopo dataset, 149 boreholes have a combined recommended pumping rate of 10.4 Mm³/a which makes one believe that the groundwater resource could be underutilized, especially away from the irrigated areas. Note that only a limited number of boreholes are functional or being pumped at the recommended rates due to the lack of infrastructure and power supply (i.e. electricity).

Future groundwater demand

Population growth and development will lead to an increase in water requirements. Despite groundwater being the main water source in the region, the low confidence in groundwater for bulk water supply, has led to a resource which is generally under-utilised in most rural settlements. Based on a simple water balance, the Limpopo ISP (2004) calculated over-exploitation of groundwater in the irrigated areas.

5.2.3. Current and emerging issues

Especially in below average rainfall years large scale irrigation in the area has resulted in over-exploitation of the groundwater resource with declining water levels. There has been inadequate monitoring of groundwater abstractions, groundwater levels and groundwater quality in recent years which hinders timeous assessment, planning, development and management of the resource. This is mainly due to the relatively weak involvement of the DWA, the Irrigation Board and research organizations.

Groundwater pollution in the Mogwadi-Vivo area is widespread, with elevated Nitrates from fertilizer application. Furthermore, most scattered rural settlements and communities in the catchment, which rely on groundwater for their drinking water have poor sanitation levels, while others rely on pit latrines. High concentration of pit latrines and increasing population pose a risk of pollution of the groundwater source, with elevated TDS and Nitrate concentrations.

An overview of typologies and threats to the Houdenbrak aquifer is given in Table 13.

Table 13: Typologies and threats to the Houdenbrak basement aquifers (Mogwadi-Vivo)

| Typology | Situation / process | High Risk | Medium Risk | Low Risk |
|--|---|-----------|-------------|----------|
| Risk of extensive quasi-irreversible aquifer degradation and subject to potential conflict amongst users | Intensive exploitation (leading to land subsidence, saline or polluted water intrusion) | | ✓ | |
| | Vulnerable to pollution from land surface (vulnerability, pollution) | | ✓ | |
| | Depletion of non-renewable storage (in aquifers with low contemporary recharge) | | ✓ | |
| Potential water use conflict but not at risk of quasi-irreversible aquifer degradation | With growing large-scale abstraction (especially in aquifers with high T/S ratios) | ✓ | | |
| | Vulnerable to point-source pollution (vulnerability, pollution) | | | ✓ |
| | Shared transboundary resource | | | |
| Insufficient (or inadequate use of) scientific knowledge to guide development policy & process | Potential to improve rural welfare & livelihoods (not fulfilling MDG potential) | | ✓ | |
| | Natural quality problems (e.g. As, F) | | | ✓ |
| | Scope for large-scale planned conjunctive use (urban W/S or irrigated agriculture) | ✓ | | |

5.3. Local groundwater management

5.3.1. Water management institutions

Public participation processes towards the development of a CMA establishment proposal are advanced for both the Limpopo and the Luvuvhu Letaba water management areas. A draft proposal for the Limpopo WMA is available and the Luvuvhu Letaba is about to finalise their process. Until such time of establishment of a Limpopo CMA the regional Limpopo DWA Office is carrying out its functions.

The Irrigation Board under which jurisdiction the Mogwadi-Vivo study area falls has not yet been transformed into a Water User Association. Some of the factors influencing the slow pace of transformation of Irrigation Boards in general include:

- Limited capacity within DWA. The transformation process requires considerable stakeholder engagement, focused change management and a process of rigorous evaluation of the proposal documents for WUA establishment.
- Resistance to transformation from members of Irrigation Boards due to concerns about the protection of existing interests and assets (irrigation infrastructure) owned by the Boards (fear of loss of control and ownership in future).
- Difficulty in meeting race, gender and sector representation quotas for stakeholder participation and for constitution of management committees, as imposed by DWA in the interests of transforming the sector. The reality is that there have been very few female farmers and very few previously disadvantaged individuals with water use entitlements.
- The main challenge faced by most WUAs established to support emerging farmers is their financial and operational sustainability. Most small-scale irrigation schemes have limited viability without government (Department of Agriculture) support, especially in relation to the provision and maintenance of irrigation infrastructure.

The Capricorn District Municipality (Water Services Authority) and the Blouberg Local Municipality (serving as an interim water services provider) are responsible for supplying the

towns, villages and communities with safe drinking water. WSAs in the Limpopo Province do not provide a good example with regard to service delivery. Due to inappropriate selection and inadequate supervision of drilling contractors, boreholes are often not sited properly, drilled too shallow, not constructed (cased) properly or even not drilled at all. Groundwater monitoring is often also inadequate.

5.3.2. Blue and green drop certification

The Capricorn District Municipality, the water services authority in charge of water services and water quality monitoring of the Mogwadi-Vivo area, received an average blue drop score of 45% in 2009 (DWA Blue Drop Report 2009 Version II). According to the 2010 assessment, there was an improvement in performance since the previous reporting cycle (to 55.88%; DWA Blue Drop Report, 2010) but not yet according to expectations. The main issue would be to ensure an improvement in microbiological compliance as well as incident management. The commencement of the water safety plan process is a step in the right direction. It is required for the municipality in its entirety (including management) to support the implementation of this process by availing funding for a preventative drinking water quality management approach. The water treatment works of the Blouberg Local Municipality which is the water services provider for the Mogwadi-Vivo area was not assessed in the context of the green drop certification. The proposed water related infrastructure investment for 2009/2010 for the Mogwadi-Molemole Local Municipality, according to the Capricorn District Municipality IDP, amounts to 3 Million Rand whereas investment in sanitation related infrastructure amounts to 6.6 Million Rand.

5.3.3. Knowledge and capacity

Groundwater monitoring of water levels and abstractions started in the early 1970s and numerous hydrogeological studies were carried out until mid 1980s. Since late 1980s there has been a paucity in groundwater monitoring in the irrigated areas. Although it is known that water levels have declined, the extent of the declines and volumes of abstractions are largely unknown. A conceptual hydrogeological model is in place but no quantitative numerical groundwater modeling has been carried out. The paucity in data collection and relatively weak institutional capacity clearly hinders management of the resource.

5.4. Evaluation of groundwater governance provisions

5.4.1. Effectiveness of governance provisions

The effectiveness of existing governance provisions and capacity to implement adequate groundwater governance is evaluated against a priority list of 20 benchmarking criteria and is listed in Table 14.

5.4.2. Management measures

The development and implementation of a strategy is proposed for improved groundwater resource management of the Houdenbrak aquifer, and once agreed to by all role-players, it should have as a primary outcome the return of the area's groundwater resources to sustainable use. The strategy should include the following (ISP, 2004; DWA, 2009a):

Table 14: Effectiveness of groundwater governance provisions & capacity: Houdenbrak

| Capacity | Criterion | Context | Provision | Inst. capacity |
|---|--|--|-----------|----------------|
| Technical | Basic hydrogeological maps | For identification of groundwater resources | 3 | 1 |
| | Groundwater body/aquifer Delineation | With classification of typology | 2 | 1 |
| | Groundwater piezometric monitoring network | To establish resource status | 0 | 1 |
| | Groundwater pollution hazard assessment | For identifying quality degradation risks | 0 | 1 |
| | Availability of aquifer numerical 'management models' | At least preliminary for strategic critical aquifers | 0 | 0 |
| | Groundwater quality monitoring network | To detect groundwater pollution | 0 | 0 |
| Legal & Institutional | Water well drilling permits & groundwater use rights | For large users, with interests of small users noted | 1 | 1 |
| | Instruments to reduce groundwater abstraction | Water well closure/constraint in critical areas | 0 | 1 |
| | Instruments to prevent water well construction | In overexploited or polluted areas | 0 | 0 |
| | Sanction for illegal water well operation | Penalizing excessive pumping above permit | 0 | 0 |
| | Groundwater abstraction & use charging | 'Resource charge' on larger users | 2 | 1 |
| | Land use control on potentially polluting activities | Prohibition or restriction since groundwater hazard | 0 | 0 |
| | Levies on generation/discharge of potential pollutants | Providing incentives for pollution prevention | 0 | 0 |
| | Government agency as 'groundwater resource guardian' | Empowered to act on cross-sectoral basis | 1 | 1 |
| | Community aquifer management organisations | Mobilising and formalising community participation | 1 | 1 |
| Cross-Sector Policy Coordination | Coordination with agricultural development | Ensuring 'real water saving' and pollution control | 1 | 1 |
| | Groundwater based urban/industrial planning | To conserve and protect groundwater resources | 0 | 0 |
| | Compensation for groundwater protection | Related to constraints on land-use activities | 0 | 0 |
| Operational | Public participation in groundwater management | Effective in control of exploitation and pollution | 1 | 1 |
| | Existence of groundwater management action plan | With measures and instruments agreed | 1 | 0 |

0 = non-existent, 1 = incipient, 2 = fair, and 3 = excellent.

- More involvement of the Department of Water Affairs on issues which include licensing, future rights to water and the establishment of a Dendron Water Users Association (e.g. through the transformation of the Irrigation Board).
- A unified and coordinated involvement in groundwater management on the part of the commercial farmers in the area in the interest of all stakeholders.
- Proper assessment of groundwater use, rural and urban population figures and growth rates and future sectoral water requirements including water requirements of rural communities.
- Development and implementation of a groundwater quantity and quality monitoring programme.
- Development of a long-term groundwater allocation plan for the area. If this plan entails reductions in allocations, implement compulsory licensing.

- The potential involvement of an “outside” organization which could provide independent technical advice.
- Protection of well heads in informal areas and rural settlements and positioning of new boreholes well away from settlements.

5.4.3. Good practice example of groundwater management

Aquifers in crystalline basement rocks occur widely in southern Africa and are increasingly considered to be a favourable low-cost water supply option for rural communities (Masiyandima, 2009). An adaptive approach was recommended for successfully managing basement aquifers. Adaptive management comprises time-variable interventions based on methods from direct (conventional or regulatory) and indirect (community management and economic and policy tools) management approaches.

Direct management measures to control abstractions in the Houdenbrak aquifer, e.g. by limiting the cropping area or monitoring of water levels without analysis were not successful. Limiting of the cropping area was unsuccessful because irrigation use is related to the type of crop and intensity of cropping. There was also no mechanism in place to monitor compliance of groundwater use. Indirect, collective/community, management measures were unsuccessful in as far as the transformation of the Irrigation Board and establishment of a CMA and WUA are concerned. Note that the Irrigation Board is no longer in full operation so there is no forum for the farmers to meet, discuss and attend to their issues. A combination of direct and indirect management measures, e.g. monitoring for abstraction control in combination with feedback given to users and managers provides incentives for users to contribute to the sustainable management of the groundwater resource in the interest of all.

Adaptive management also prepares for changing conditions of the groundwater system and of the uses and users. An example is reduced permitted groundwater abstraction based on a decreased percentage of rainfall in drier periods. As a result of the rainfall pattern, the Houdenbrak area is prone to long periods of little or no recharge. If abstraction would have been based on a fixed percentage of average annual rainfall over-exploitation would have taken place only in years of low or no recharge. Managed Aquifer Recharge is another adaptive management measure to accommodate for climate variability and change in the context of securing water supply.

6. DINOKANA-LOBATSE DOLOMITE AQUIFER

6.1. Introduction

The Dinokana-Lobatse Dolomite Aquifer is a transboundary aquifer and is shared between Botswana and South Africa. On the South African side the Dinokana aquifer forms part of the North-West dolomites. The Dinokana dolomites are used for domestic water supply (urban and rural), agriculture (irrigation and livestock), industry and the environment in general (wetland areas around springs and river channels). The North-West dolomites receive considerable interest from national water planners because of rising water demands on the South Africa side of the transboundary aquifer, which includes the city of Mafikeng. On the Botswana side, water supply for Lobatse is mainly from surface water; the Gaborone Dam, while the Nywane Dam is used as a backup supply². Groundwater from the dolomites is used as a strategic reserve in the case of severe droughts.

6.2. Resource setting

6.2.1. Hydrogeologic condition

Aquifer type and characteristics

The Dinokana-Lobatse Dolomite Aquifer corresponds to the Malmani dolomite, a lithostratigraphic unit within the Transvaal Super-Group. The aquifer is situated in the northwestern part of the dolomite outcrop, west of Zeerust (Figure 17).

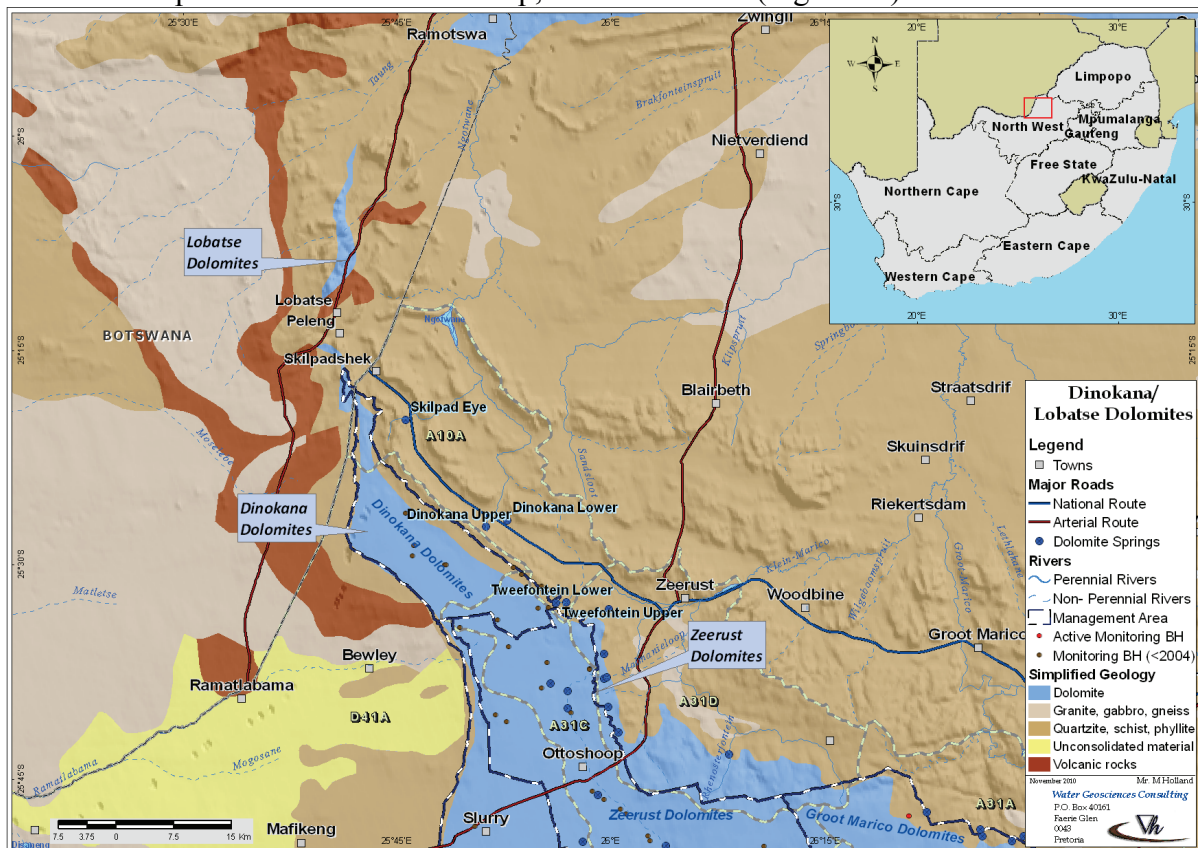


Figure 17: Dinokana-Lobatse Dolomite Aquifer

² Botswana Water Statistics (2009). Environment Statistics, Department of Printing and Publishing Services. Botswana Government.

The study area is characterised by a relatively subdued topography, with local relief seldom exceeding 100 m and mostly averaging less than 30 m. Precipitation varies between 400 mm along the Botswana border to around 600 mm south of Zeerust. The occurrence of groundwater is related to secondary porosity and the aquifer's geometry is controlled by chert horizons, karst development, weathering, dolerite dyke intrusions and tectonics (faults).

Transmissivities of the aquifer are often high: $>1\ 000\ \text{m}^2/\text{d}$, with relatively large storage and borehole yields: $> 25\ \text{l/s}$. The entire NW Province dolomite is sub-divided into smaller compartments based on the occurrence of dolerite dykes. Springs within the compartments and along the eastern outcrop boundary (Figure 17) result from outflow against impervious contact zones (faults and dolerite dykes) and thinning of dolomite lithologies. Major springs discharging from the Dinokana-Lobatse dolomites are the Skilpads Eye, Dinokana Eye and Tweefontein Upper Eye (Table 15).

Table 15: Springs discharging the Dinokana Dolomites

| Spring Name | Gauge ID | Observation Start | Observation End | Last Observation | |
|-------------------|----------|-------------------|-----------------|---------------------------------|------|
| | | | | Flow (Mm^3/a) | Year |
| Dinokana Upper | A1H001 | 1960 | Active | 3.1 | 2009 |
| Dinokana Lower | A1H002 | 1960 | 1995 | 0.5 | 1994 |
| Tweefontein Upper | A1H003 | 1960 | 1993 | 0.5 | 1992 |
| Tweefontein Lower | A1H004 | 1960 | 1993 | 0.3 | 1990 |
| Skilpad Eye | A1H005 | 1960 | 1999 | 0.03 | 1993 |

Groundwater quality in the study area is good with little evidence of pollution. The average EC is 52.8 mS/m and pH is 7.9 (DWA, 2009). However, groundwater quality may be compromised by informal settlements, aggregations of people in the vicinity of springs, poultry farming activities and fertilizer and pesticide applications on farming land.

The Dinokana-Lobatse Dolomite Aquifer comprises three groundwater management units on the South African side, namely Skilpads Eye, Dinokana and Tweefontein. Together they form part of the Zeerust compartment. Three well fields: Dinokana, Doornfontein and Rietpoort were established to meet the demands of Zeerust and surrounding communities with average abstractions of $1.1\ \text{Mm}^3/\text{a}$, $1.7\ \text{Mm}^3/\text{a}$ and $2.7\ \text{Mm}^3/\text{a}$ respectively (Hubert et al., 2005). Rural communities of Khunotswana and other smaller villages and numerous farm homesteads all rely on groundwater. Irrigation is being practiced along the Malmanielloop, mostly south of Ottoshoop.

Resource renewability and over-exploitation

Table 16 summarises the components of the groundwater balance for the Zeerust compartment and shows that already in 2005 the total estimated abstraction exceeded the sustainable abstraction limit. Groundwater recharge ranges from 5 to 15% of MAP (Vegter, 1995).

Table 16: Groundwater Balance Components of the Zeerust dolomite compartment.

| Dolomitic Compartment | Irrigation (Mm^3/a) | Domestic and Environmental Requirements (Mm^3/a) | Industry (Mm^3/a) | Total 2005 Estimated Abstraction (Mm^3/a) | Sustainable Abstraction (Mm^3/a) |
|-----------------------|---------------------------------------|--|-------------------------------------|---|--|
| Zeerust | 10 | 29.02 | 0.84 | 44.8 | 39.9 |

(After Stephens et al., 2005)

Despite the numerous boreholes monitored prior to 2005 (1970s to 2004), no active groundwater level monitoring is being conducted by the DWA regional offices. Ad-hoc groundwater level measurements from well fields were conducted between, 2005 and 2007 by WAS (Water Service Authorities) but the data is hardly available and rarely reaches stakeholders. As at 2009 the monitoring had temporarily stopped and the situation is currently unknown.

The need for proper management of both groundwater and surface water resources in dolomitic areas was recognised by numerous researchers and practitioners, including Bredenkamp et al. (1995), Stephens and Bredenkamp (2002). Stephens et al. (2005) conducted a study with the broad goals of allowing current users of water resources in the North West Dolomites to use the resource in an economical, efficient, and sustainable manner, such that marginal and historically disadvantaged users be allowed to gain better access to the resource, and that the resource can support both growing population trends and the economic development initiatives of the region.

Aquifer vulnerability

The Dinokana dolomites are already fully utilised. The upper Eye of Dinokana, which is being fed from highly permeable dolomite, is especially vulnerable. Any pumping within the boundaries of this compartment would diminish the flow of the Dinokana spring.

6.2.2. Socio-economic situation

Demographic data of the study area reveal strong imbalances and disparities in living conditions and opportunities between rural and urban areas. Conditions in rural areas, particularly in former Bophuthatswana districts (towards the Botswana border), are difficult with poor standards of infrastructure and basic services, as well as low levels of employment and livelihood opportunities:

- In general, population densities are low, with around 6 people per km² for most of the study area.
- Although statistics show that most people have water supplied to their dwellings, higher densities and better service levels in urban areas introduce an urban bias.
- Pit latrines (especially around Zeerust) are predominantly used for sanitation, followed by water borne sewage. A small percentage of people use a bucket system or no sanitation system at all.
- The North West has the second lowest growth in Gross Geographic Product³ (GGP) in South Africa, and the lowest contribution to the Gross National Product⁴ (GNP).

Agriculture has played and will play a key role in the economy of the region, providing employment and improving livelihoods. However, GGP figures of the area show that the growth and contribution of agriculture to the local economy is declining.

³ The gross geographic product (GGP) of a particular area amounts to the total income or payment received by the production factors (land, labour, capital, and entrepreneurship) for their participation in the production within that area.

⁴ Gross National Product (GNP) is the total value of all final goods and services produced within a nation in a particular year, plus income earned by its citizens (including income of those located abroad), minus income of non-residents located in that country.

Groundwater use and user profiles

Groundwater from the Dinokana Dolomites is being used for domestic water supply (urban and rural), agriculture (irrigation and livestock), industry and the environment in general (wetland areas around springs and river channels).

Future water demand

Future regional development will be facilitated through the North West Spatial Development Initiative, a long term planning initiative designed to promote economic growth and job creation through manufacturing, mining, agriculture and tourism activities. However, the availability of sufficient water is a key factor controlling development, which needs to be carefully evaluated in planning activities. Currently, Mafikeng, Zeerust and Lichtenburg are the growth nodes of the region and most future developments will take the form of housing as none of the existing industrial activities are planning significant expansion (DWAf, 2000).

Despite the minus 0.3 % growth rate in the case of Zeerust, villages in the Dinokana area need to upgrade to RDP standard, and water reticulation may require additional boreholes. Based on domestic water demands from the dolomite aquifer in the year 2008, between 75MI and 142 MI had to be developed.

6.2.3. Current and emerging issues

The Dinokana-Lobatse dolomite aquifer is currently being over-exploited. In Table 17 an overview of typologies and threats to the Dinokana-Lobatse aquifer is given.

Table 17: Typologies and threats to the Dinokana-Lobatse dolomite aquifer

| Typology | Situation / process | High Risk | Medium Risk | Low Risk |
|--|---|-----------|-------------|----------|
| Risk of extensive quasi-irreversible aquifer degradation and subject to potential conflict amongst users | Intensive exploitation (leading to land subsidence, saline or polluted water intrusion) | ✓ | | |
| | Vulnerable to pollution from land surface (vulnerability, pollution) | ✓ | | |
| | Depletion of non-renewable storage (in aquifers with low contemporary recharge) | | | ✓ |
| Potential water use conflict but not at risk of quasi-irreversible aquifer degradation | With growing large-scale abstraction (especially in aquifers with high T/S ratios) | | ✓ | |
| | Vulnerable to point-source pollution (vulnerability, pollution) | ✓ | | |
| | Shared transboundary resource | | ✓ | |
| Insufficient (or inadequate use of) scientific knowledge to guide development policy & process | Potential to improve rural welfare & livelihoods (not fulfilling MDG potential) | | ✓ | |
| | Natural quality problems (e.g. As, F) | | | ✓ |
| | Scope for large-scale planned conjunctive use (urban W/S or irrigated agriculture) | | ✓ | |

6.3. Local groundwater management

6.3.1. Water management institutions

The Dinokane-Lobatse aquifer is located in the Crocodile-West and Marico WMA. The CMA in the WMA is finalizing Governance Board nominations and appointments. There are a number of Irrigation Boards in the region that require transformation to Water User Associations. DWA currently serves as the interim CMA.

At provincial level, the North West Water Sector Forum (NW WSF), established in 2004, continues to operate as a coordinating structure for all water sector activities in the Province. The NW WSF comprises subcommittees that deal with sanitation coordination, transfers and institutional support, water resources and infrastructure planning and development. District forums have also been established by municipalities to coordinate municipal level activities.

The major town closest to the Dinokana-Lobatse aquifer is Zeerust and is part of Ramotshere Moiloa Local Municipality. The Ramotshere Moiloa Local Municipality forms part of the Ngaka Modiri Molema District Municipality. The Botshelo Water Board operates as a Water Services Provider in the area under consideration.

The existing institutional environment for water resource management is in a relatively poor state for the following reasons (Stephens et al., 2005):

- The DWA regional office does not have adequate capacity or resources to implement the devolution of the water management functions as effectively as they would like to;
- Policy is being formulated at the Head Office to ensure that processes are stakeholder-based but since these processes are often consultant-driven, the linkages between local stakeholders and the Regional Offices are rather weak;
- Communication between Head Office and Regional Office, and between Regional Office and local stakeholders is inadequate;
- There are no WUAs (i) because applications for establishment generally do not comply with policy and (ii) because of lack of interest;
- The Crocodile (west) Marico CMA is not yet established;
- Stakeholders often do not have adequate know-how which makes their involvement in water resource management less effective. This particularly affects Water Services Providers (Local Government).

6.3.2. Blue and green drop certification

In the blue drop certification process the water supply system of the Ramotshere Moiloa Local Municipality was not assessed because the water source is groundwater. This is a serious omission. The regulatory impression of the water supply systems in the blue drop report was that a concerted effort is required by the Ngaka Modiri Molema District Municipality to improve DWQ management, and that almost every aspect of the DWQ management business needs attention. Without improvement, the Department has no alternative than to inform the public that it has no confidence in the management of DWQ by the authority. The actual drinking water quality (microbiological) should be improved as a matter of urgency.

The waste water treatment systems assessed in the Ramotshere Moiloa Local Municipality scored only 3% in the green drop certification. This means frequent failures in operation and the resultant adverse impacts on the water environment.

The Ngaka Modiri Molema District Municipality has developed an IDP which has followed a public participation process.

6.3.3. Knowledge and capacity

The lack of reliable data and information of the study area is a serious concern and hinders the implementation of effective management recommendations. Recent hydrogeological investigations of the Zeerust compartment, however, have shown a more detailed understanding of the aquifer. A model that was developed for the area could:

- Identify compartments that can be managed as a unit;
- Quantify steady state and temporal water balance flow components spatially (recharge) as well as laterally (leakage through compartment boundaries); and
- Quantify steady state and transient drawdown impacts on spring flows and leakage across boundaries.

6.4. Evaluation of groundwater governance provisions

6.4.1. Effectiveness of governance provisions

The effectiveness of existing governance provisions and capacity to implement adequate groundwater governance is also evaluated against a priority list of 20 benchmarking criteria and is listed in Table 18. Note that in the IDP, provision is made for R650 000 for groundwater investigations.

6.4.2. Management measures

The following management measures are required from a technical point of view:

- Reviewing the state of knowledge regarding the potential and limitations of the dolomitic aquifers in the study area
- Quantification of key parameters for the different dolomitic aquifers
- Formulation of guidelines for decision making, revision of groundwater policies and legislation
- Incorporation of the principles of uncertainty and risk of failure, using probability analysis in assured yield analyses.
- Continuous monitoring of aquifer performance and periodic assessment of exploitation potential.

Institutional measures include:

- Clarity is needed on the timescales for the establishment of the Crocodile West – Marico CMA, and the various Water User Associations. In the absence of these institutions, a clear demarcation of responsibility regarding the role of the DWA Regional Office needs to be communicated to all stakeholders
- Progress needs to be made particularly for those Water User Associations which have “stalled” – this is partly due to a lack of clarity on the part of stakeholders as to the benefits of the new WUAs. It is recognized that the diversity of stakeholders in the area is complicating matters

Table 18: Effectiveness governance provisions & capacity: Dinokana-Lobatse.

| Capacity | Criterion | Context | Provision | Inst. capacity |
|---|--|--|-----------|----------------|
| Technical | Basic hydrogeological maps | For identification of groundwater resources | 3 | 1 |
| | Groundwater body/aquifer Delineation | With classification of typology | 3 | 1 |
| | Groundwater piezometric monitoring network | To establish resource status | 1 | 1 |
| | Groundwater pollution hazard assessment | For identifying quality degradation risks | 1 | 1 |
| | Availability of aquifer numerical 'management models' | At least preliminary for strategic critical aquifers | 2 | 0 |
| | Groundwater quality monitoring network | To detect groundwater pollution | 1 | 1 |
| Legal & Institutional | Water well drilling permits & groundwater use rights | For large users, with interests of small users noted | 2 | 1 |
| | Instruments to reduce groundwater abstraction | Water well closure/constraint in critical areas | 1 | 1 |
| | Instruments to prevent water well construction | In overexploited or polluted areas | 1 | 1 |
| | Sanction for illegal water well operation | Penalizing excessive pumping above permit | 0 | 0 |
| | Groundwater abstraction & use charging | 'Resource charge' on larger users | 1 | 1 |
| | Land use control on potentially polluting activities | Prohibition or restriction since groundwater hazard | 0 | 0 |
| | Levies on generation/discharge of potential pollutants | Providing incentives for pollution prevention | 0 | 0 |
| | Government agency as 'groundwater resource guardian' | Empowered to act on cross-sectoral basis | 1 | 1 |
| | Community aquifer management organisations | Mobilising and formalising community participation | 1 | 0 |
| Cross-Sector Policy Coordination | Coordination with agricultural development | Ensuring 'real water saving' and pollution control | 1 | 1 |
| | Groundwater based urban/industrial planning | To conserve and protect groundwater resources | 0 | 0 |
| | Compensation for groundwater protection | Related to constraints on land-use activities | 0 | 0 |
| Operational | Public participation in groundwater management | Effective in control of exploitation and pollution | 1 | 1 |
| | Existence of groundwater management action plan | With measures and instruments agreed | 2 | 1 |

0 = non-existent, 1 = incipient, 2 = fair, and 3 = excellent.

- Where capacity at the DWA Regional Office is lacking, this needs to be addressed with an appropriate strategy. In particular, regular monitoring of groundwater resources needs to be resuscitated, the results turned into useful information products, and these must be communicated to decision makers
- Much closer communication between the DWA Regional Office and the DWA National Office is needed
- Municipalities need to address areas of poor technical capacity in terms of water service provision, waste-water treatment and other water-related areas. A component of this is to improve cash-flows by minimizing non-payment of service charges.

6.4.3. Good practice example of groundwater management

The SADC hydrogeology map and atlas were recently published (SADC, 2010). The SADC hydrogeology map is a general hydrogeological map providing information on the extent and geometry of regional aquifer systems. The map is a first, but necessary, step to support groundwater resource planning at multi-national level as well as regional trans-national levels. The map was compiled at a scale of 1:2 500 000 from the SADC geology map developed by the Council for Geoscience. The SADC geology map formed part of a SADC project on geology, under the auspices of the SADC Mining Committee and the Geology Subcommittee (SADC, 2010). The following aquifer types have been mapped based on the groundwater flow regime.

- Unconsolidated/ intergranular aquifers
- Fissured aquifers
- Karst aquifers (e.g. Dinokana – Lobatse dolomite aquifer)
- Layered aquifers
- Low permeability formations

The aquifer types were grouped into eight classes according to aquifer productivity (Table 19).

Table 19: Hydrogeology and aquifer productivity of rock bodies

| Productivity Class Aquifer Type | 1. High productivity | 2. Moderate productivity | 3. General low productivity but locally moderate productivity | 4. Generally low productivity |
|--|----------------------|--|---|-------------------------------|
| A. Unconsolidated Intergranular aquifers | A1 | A2 | X | X |
| B. Fissured aquifers | B1 | B2 | X | X |
| C. Karst aquifers | C1 | C2 | X | X |
| D. Low permeability formations | X | X | D1 | D2 |
| | | Denotes an extensive aquifer overlain by cover | | |

The Dinokana – Lobatse dolomite aquifer forms part of the Ramotswa Dolomite Basin and has been delineated as a transboundary aquifer (Figure 18).

The map is intended to serve as a base map for hydrogeologists and water resource planners, whilst at the same time presenting information to non-professionals. The map is a visual representation of groundwater conditions in SADC and serves as a starting point for the design of more detailed regional groundwater investigations by exposing data and knowledge gaps. This provides an opportunity for the respective River Basin Organizations (in this case Limpopo Water Course Commission) to engage in transboundary groundwater management.

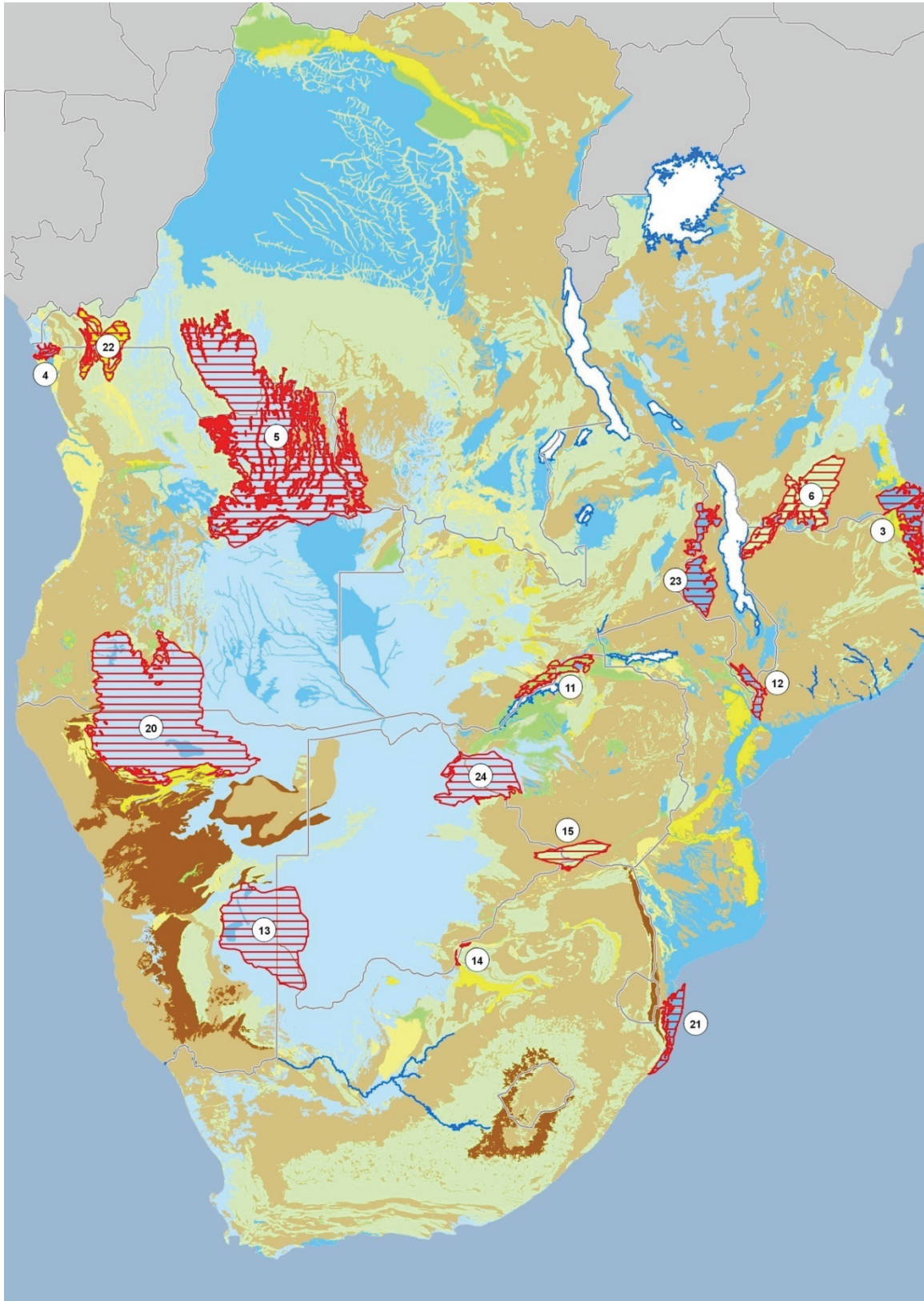


Figure 18: Transboundary aquifers in the SADC Region.
 (delineated as an outcome of the SADC hydrogeological map compilation; see Table 20 for codes)

Table 20: Transboundary aquifer names

| Name | Code | States |
|-------------------------------------|-------------|----------------------------------|
| Karoo Sandstone Aquifer | 6 | Tanzania, Mozambique |
| Tuli Karoo Sub-basin | 15 | Botswana, South Africa, Zimbabwe |
| Ramotswa Dolomite Basin | 14 | Botswana, South Africa |
| Cuvelai and Etosha Basin | 20 | Angola, Namibia |
| Coastal Sedimentary Basin 1 | 3 | Tanzania, Mozambique |
| Shire Valley Aquifer | 12 | Malawi, Mozambique |
| Congo Intra-cratonic Basin | 5 | D R Congo , Angola |
| Coastal Sedimentary Basin 2 | 4 | D R Congo , Angola |
| Coastal Sedimentary Basin 6 | 21 | Mozambique, South Africa |
| Medium Zambezi Aquifer | 11 | Zambia and Zimbabwe |
| Dolomitic | 22 | D R Congo , Angola |
| Sands and gravel aquifer | 23 | Malawi, Zambia |
| Kalahari/Karoo Basin | 13 | Botswana, Namibia, South Africa |
| Eastern Kalahari/Karoo basin | 24 | Botswana and Zimbabwe |

7. CLIMATE CHANGE AND ADAPTATION

The SKM (2009) risk-based framework was used to assess the vulnerability of the case study aquifers to climate change and also to formulate options for adaptation. The framework consists of five steps: (1) establish the context, (2) identify climate risks, (3) analyse risks, (4) evaluate risks and (5) treat risks. Typologies and threats to the case study aquifers in terms of vulnerability to degradation (see Sections 3.2.3, 4.2.3, 5.2.3 and 6.2.3) were included in the assessment and the results of the assessment are briefly discussed in the following sections and presented in Tables 21, 22 and 23.

7.1. Establishing the context

The Botleng dolomite aquifer is used to provide the communities with water whilst the other aquifer systems are mainly used for the purpose of local economic development. The aquifer systems are particularly vulnerable to pollution and are subject to intensive exploitation. The case study areas are in relative close proximity to one another and the climate change scenarios should be largely similar. The predicted change in rainfall is qualitative and it is expected that the change in rainfall will be negligible. It is expected that rainfall variability may increase and that the rainfall season will start later. Drivers for adaptation are:

- Intensive exploitation leading to land subsidence
- Vulnerability to pollution from land surface
- Large scale groundwater abstraction
- Vulnerability to point-source pollution
- Depletion of non-renewable storage
- Scope for large-scale planned conjunctive use (agriculture vs. rural water supply)

7.2. Identifying and analyzing the risk

The most significant climate hazard is an increase in rainfall variability. The hazards for the groundwater system include: delay in the start of the recharge season; a shorter recharge season; increased evapotranspiration and possibly reduced recharge. In areas which experience higher rainfall intensities, recharge may be enhanced. Unfortunately, none of the case study areas demonstrated pre-existing climate risk controls. The consequences and likelihood of potential climate change impacts may result in reduced water quantity and quality. This will aggravate water demand conflicts. The risk rating for climate change impacts are moderate to high for the case study areas.

7.3. Evaluating and treating the risk

Climate change is not a consideration in planning for the case study aquifers. As a result adaptation options have not been considered and implemented.

Table 21: Context of case study aquifers

| | Botleg Dolomite Aquifer | Gauteng Dolomite Aquifers | Houdenbrak Basement Aquifer | Dinokana – Lobatse Dolomite Aquifer |
|---------------------------------|---|---|--|---|
| Location | Delmas, Mpumalanga Province | Eastern and Western Gauteng | Limpopo Province | Northwest Province/Botswana |
| Planning timeframe | None | None | None | None |
| Groundwater system | <ul style="list-style-type: none"> • Chert rich dolomite unconfined karst aquifer • Four wellfields to supply Delmas Municipality • Groundwater quality issues – salinisation, eutrophication, bacterial contamination: diarrhea and typhoid outbreaks | <ul style="list-style-type: none"> • Chert rich dolomite unconfined karst aquifer • Over-exploitation • Negative water balances • Declining spring flows in the Steenkoppies Compartment • Sinkholes/land subsidence in Bapsfontein Compartment • Anthropogenic pollution | <ul style="list-style-type: none"> • Basement aquifers: deeper fractured aquifers and alluvial aquifers • Nitrate pollution • Low recharge but high abstraction rates • Declining groundwater levels | <ul style="list-style-type: none"> • Dolomite karst aquifer • Good groundwater quality • Negative water balance |
| Stakeholders | <ul style="list-style-type: none"> • Communities • Local and National Government | <ul style="list-style-type: none"> • Downstream user communities • Commercial agricultural users • Local and National Government | <ul style="list-style-type: none"> • Communities • Emerging farmers • Commercial farmers • Local and National Government | <ul style="list-style-type: none"> • Communities • Agricultural users • Local and National Government |
| Key objectives | <ul style="list-style-type: none"> • To provide the communities with safe drinking water | <ul style="list-style-type: none"> • To use groundwater for local economic development without compromising the sustainability of the resource and environment | <ul style="list-style-type: none"> • To use groundwater for local economic development without compromising the sustainability of the resource | <ul style="list-style-type: none"> • To use groundwater for local economic development without compromising the sustainability of the resource |
| Success criteria | <ul style="list-style-type: none"> • Meet water quality guideline criteria – blue and green drop certification • Implement groundwater management plan | <ul style="list-style-type: none"> • Measurement of abstraction – water use and rainfall • Revisit groundwater licensing • Groundwater monitoring | <ul style="list-style-type: none"> • Develop and implement strategy for improved groundwater adaptive management • Groundwater allocation plan | <ul style="list-style-type: none"> • Assessment of exploitation potential • Monitoring of aquifer performance • Develop and implement groundwater management |
| Climate change scenarios | <ul style="list-style-type: none"> • Increase in rainfall and increase in rainfall variability • Late start of the rainfall season | <ul style="list-style-type: none"> • Negligible change in rainfall • Increase in variability • Late start of the rainfall season | <ul style="list-style-type: none"> • Negligible change in rainfall • Increase in variability • Late start of the rainfall season | <ul style="list-style-type: none"> • Reduction in rainfall • Increase in variability • Late start of the rainfall season |
| Drivers for adaptation | <ul style="list-style-type: none"> • Intensive exploitation • Vulnerability to pollution • Depletion of non-renewable storage • Water use conflict due to pollution | <ul style="list-style-type: none"> • Over-exploitation (land subsidence/ sink hole formation) • Vulnerability to pollution • Depletion of non-renewable storage • Water use conflict due to over-abstraction • Water use conflict due to pollution • Insufficient aquifer knowledge • To improve rural welfare and livelihoods • Insufficient knowledge for large-scale planned conjunctive use | <ul style="list-style-type: none"> • Intensive exploitation • Vulnerability to pollution • Depletion of non-renewable storage • Water use conflict due to over-abstraction • Insufficient aquifer and water use knowledge • To improve rural welfare and livelihoods • Insufficient knowledge for large-scale planned conjunctive use | <ul style="list-style-type: none"> • Intensive exploitation • Vulnerability to pollution • Water use conflict due to over-abstraction • Water use conflict due to pollution • Insufficient knowledge • To improve rural welfare and livelihoods • Insufficient knowledge for large-scale planned conjunctive use |

Table 22: Identification and analysis of climate risks

| | Botleng Dolomite Aquifer | Gauteng Dolomite Aquifers | Houdenbrak Basement Aquifer | Dinokana – Lobatse Dolomite Aquifer |
|--|--|--|--|--|
| Climate hazards | <ul style="list-style-type: none"> • Increase in rainfall • Increase in variability • Late start to the rainfall season | <ul style="list-style-type: none"> • Negligible change in rainfall • Increase in variability • Late start to the rainfall season | <ul style="list-style-type: none"> • Negligible change in rainfall • Increase in variability • Late start to the rainfall season | <ul style="list-style-type: none"> • Reduction in rainfall • Increase in variability • Late start to the rainfall season |
| Climate related hazards for the groundwater system | <ul style="list-style-type: none"> • Delay in the start of the recharge season • Shorter recharge season • Increased recharge due to higher rainfall and increased intensity • Reduced water quality | <ul style="list-style-type: none"> • Delay in the start of the recharge season • Shorter recharge season • Increased demand for water • Increased evapotranspiration | <ul style="list-style-type: none"> • Delay in the start of the recharge season • Shorter recharge season • Increased evapotranspiration | <ul style="list-style-type: none"> • Delay in the start of the recharge season • Shorter recharge season • Reduced recharge • Increased evapotranspiration |
| Pre-existing climate risk controls | None | None | None | None |
| Assess consequences and likelihood of potential climate impacts | <ul style="list-style-type: none"> • Reduced water quality and availability | <ul style="list-style-type: none"> • Water demand conflicts | <ul style="list-style-type: none"> • Water demand conflicts | <ul style="list-style-type: none"> • Water demand conflicts |
| Risk rating | High | Moderate | Moderate | Moderate |

Table 23: Evaluating and treating risks

| | Botleng Dolomite Aquifer | Gauteng Dolomite Aquifers | Houdenbrak Basement Aquifer | Dinokana –Lobatse Dolomite Aquifer |
|--|--|---|---|--|
| Prioritize risks and assess uncertainty | Not formally assessed | Not formally assessed | Not formally assessed | Not formally assessed |
| Identify adaptation options | <ul style="list-style-type: none"> • Drinking water quality management • Implement Water Conservation and Demand Management • Land use management | <ul style="list-style-type: none"> • Groundwater allocation reform • Reduction in water use • Investment in more efficient irrigation technologies | <ul style="list-style-type: none"> • Groundwater allocation reform • Reduction in water use | <ul style="list-style-type: none"> • Groundwater allocation reform • Reduction in water use • Land use management |
| Assess adaptation options | Not formally assessed | Not formally assessed | Not formally assessed | Not formally assessed |
| Plan and implement options | Not done | Not done | Not done | Not done |

8. FINDINGS AND RECOMMENDATIONS

8.1. Governance provisions & institutional capacity

Analyses of the effectiveness of groundwater governance provisions and institutional capacity at local aquifer level (Sections 3.4.1, 4.4.1, 5.4.1 and 6.4.1) are combined in Table 24. The table is complemented with an analysis at national level. Results indicate that:

At national level:

- Technical, legal and institutional and operational governance provisions are reasonable but weak for cross-sector policy coordination
- Institutional capacity is weak across all thematic areas except for the technical provisions.

At local aquifer level:

- There is similarity in the governance provisions for the dolomite aquifers across all thematic areas with the Steenkoppies dolomite aquifer consistently scoring higher
- Basic technical provisions such as hydrogeological maps and aquifer delineation with classified typology are in place for all case study aquifers
- Other governance provisions across all thematic areas are weak or are non-existent
 - ❖ Steenkoppies dolomite compartment scores highest; Bapsfontein dolomite compartment and Houdenbrak basement aquifer score lowest
 - ❖ Groundwater monitoring is weak and assessment of groundwater resources is poor, both in terms of quantity and quality (e.g. lack of numerical groundwater model)
 - ❖ There are fair provisions for water well drilling and groundwater use rights but provisions to control groundwater abstraction and pollution are weak (poor compliance monitoring)
 - ❖ Provisions for establishment of aquifer management organizations are weak or non-existent
 - ❖ Cross-sector policy coordination is weak
 - ❖ From an operational point of view, a groundwater management action plan which includes both water quantity and water quality aspects only exists for the Botleng aquifer but has not been implemented to date
- Institutional capacity across all thematic areas is weak or non-existent except for the Steenkoppies dolomite aquifer where the situation is better.

8.2. Recommended management measures

Groundwater management measures were recommended at national level (Chapter 2) and at local level for each of the case study aquifers (see Sections 3.4.2, 4.4.2, 5.4.2 and 6.4.2) to address existing and potential hazards as well as to improve on the effectiveness of existing groundwater governance provisions and institutional capacity. Table 25 presents an overview of the recommended management measures grouped into macro-policy adjustments, regulatory provisions and community participation. Most critical are considered the integration of the National Groundwater Strategy (NGS, 2010) into the NWRS, CMSs and other strategies, strengthening of the groundwater related regulatory environment and strengthening of the institutional capacity, both in terms of existing institutions (DWA) and establishment and operationalising of CMAs and WUAs. Regarding the inadequacy of groundwater expertise we recommend DWA to develop a strategy to augment national GW

capacity. Furthermore, we recommend to investigate and to implement climate change adaptation measures at local aquifer level.

Table 24: Groundwater governance provisions and institutional capacity

| Capacity | Criterion | Governance Provisions | | | | | | Institutional Capacity | | | | | |
|---|--|-----------------------|----|----|----|----|----|------------------------|----|----|----|----|----|
| | | Na | Bo | St | Ba | Ho | Di | Na | Bo | St | Ba | Ho | Di |
| Technical | Basic hydrogeological maps | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 1 | 2 | 1 | 1 | 1 |
| | Groundwater body/aquifer Delineation | 3 | 3 | 3 | 3 | 2 | 3 | 2 | 1 | 2 | 1 | 1 | 1 |
| | Groundwater piezometric monitoring network | 2 | 2 | 1 | 1 | 0 | 1 | 2 | 1 | 1 | 1 | 1 | 1 |
| | Groundwater pollution hazard assessment | 2 | 1 | 2 | 1 | 0 | 1 | 2 | 1 | 2 | 1 | 1 | 1 |
| | Availability of aquifer numerical 'management models' | 1 | 0 | 2 | 0 | 0 | 2 | 1 | 0 | 1 | 0 | 0 | 0 |
| | Groundwater quality monitoring network | 2 | 1 | 2 | 1 | 0 | 1 | 2 | 1 | 1 | 0 | 0 | 1 |
| Legal & Institutional | Water well drilling permits & groundwater use rights | 1 | 2 | 2 | 2 | 1 | 2 | 1 | 1 | 2 | 1 | 1 | 1 |
| | Instruments to reduce groundwater abstraction | 3 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 |
| | Instruments to prevent water well construction | 3 | 2 | 2 | 0 | 0 | 1 | 1 | 1 | 2 | 0 | 0 | 1 |
| | Sanction for illegal water well operation | 3 | 1 | 3 | 0 | 0 | 0 | 1 | 1 | 2 | 0 | 0 | 0 |
| | Groundwater abstraction & use charging | 1 | 2 | 1 | 1 | 2 | 1 | 0 | 1 | 2 | 1 | 1 | 1 |
| | Land use control on potentially polluting activities | 3 | 1 | 2 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 |
| | Levies on generation/discharge of potential pollutants | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Government agency as 'groundwater resource guardian' | 3 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 2 | 0 | 1 | 1 |
| | Community aquifer management organisations | 3 | 0 | 2 | 0 | 1 | 1 | 0 | 0 | 2 | 0 | 1 | 0 |
| Cross-Sector Policy Coordination | Coordination with agricultural development | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 |
| | Groundwater based urban/industrial planning | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Compensation for groundwater protection | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Operational | Public participation in groundwater management | 3 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 3 | 0 | 1 | 1 |
| | Existence of groundwater management action plan | 3 | 3 | 0 | 0 | 1 | 2 | 1 | 0 | 2 | 0 | 0 | 1 |

0 = non-existent, 1 = incipient, 2 = fair, and 3 = excellent.

Na = National, Bo = Botleng, St = Steenkoppies, Ba = Bapsfontein, Ho = Houdenbrak, Di = Dinokana-Lobatse.

Table 25: Selected management measures

| Macro policy adjustments | Regulatory provisions | Community participation |
|--|---|--|
| <ul style="list-style-type: none"> • Integration of NGS into NWRS, CMS, and other strategies • Include groundwater abstraction in the water pricing strategy • Harmonize water related legislation • Integrate groundwater resource planning between different spheres of government | <ul style="list-style-type: none"> • Registration of new wells and boreholes • Review of general authorizations • Registration of drillers • Registration and verification of water use • Simplification of groundwater licensing and other procedures (e.g. single license for DWA and DEA) • Timeous issuing of water use license • Compliance monitoring and enforcement • Protection zoning around boreholes and pollution pathways • Establish regulations for borehole construction • In stressed catchments implement compulsory licensing | <ul style="list-style-type: none"> • Accelerate establishment of CMAs and WUAs • Establishment of Aquifer Management Committees • Stakeholder engagement in decision-making |

The following specific recommendations are proposed:

- (i) Strengthening and implementing groundwater governance measures should preferably follow a ‘parallel track and adaptive approach’ within the existing legal and institutional framework. Such an approach would strengthen the said frameworks without disruption, taking cognizance of capacity and willingness to implement.
- (ii) We recommend carrying out the following pilot projects in the case study aquifers to improve on the groundwater governance provisions and institutional capacity:
 - Botleng Dolomite Aquifer: “Implementation constraints at local and regional level” (DWA RO and Delmas LM)
 - Gauteng Dolomite Aquifers:
 - ❖ Steenkoppies compartment: “Strengthening institutional framework” (DWA RO and establishment and operation of WUA-Stakeholders)
 - ❖ Bapsfontein compartment: “Licensing of groundwater use and compliance”
 - Houdenbrak Basement Aquifer: “Perspectives on sustainable groundwater management and use” (Irrigators, DWA RO and stakeholders)
 - Dinokana-Lobatse Dolomite Aquifer: “Water allocation” (DWA RO, local government and irrigators).
- (iii) We recommend applying the same methodology which was used in this case study to identify and implement management measures for other aquifer systems in South Africa such as the Karoo aquifer system of Beaufort West.

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