

Groundwater Management in the Southern African Development Community

Prepared for



Supported by



Prepared by

Kevin Pietersen and Hans Beekman



ABSTRACT

An assessment of groundwater management in the Southern African Development Community (SADC region) was carried out. Numerous sources of information (peer-reviewed journal articles, books, published reports and databases in the public domain) were solicited, reviewed, and data was mined using a framework analysis approach.

Groundwater in the SADC region is prone to degradation from various land-use activities and in some areas over-abstraction. In many cases, groundwater infrastructure in SADC countries is not maintained resulting in failure to supply communities.

There is a good understanding of aquifer systems at the regional level. Transboundary aquifers have been delineated and areas prone to groundwater drought have been identified. Information systems to manage groundwater data, however, are disparate throughout the region and institutions to manage groundwater are inadequate and are functioning within an environment of scarce financial and human resources. The hydrogeological capacity in public institutions such as government departments is a major concern and regulations to protect groundwater resources are often not in place. This includes instruments to control groundwater abstraction and potentially-polluting activities. Where regulatory instruments are in place, often no enforcement or sanctions of unlawful activities are taking place. There is also limited coordination with other sectors such as energy and mining. Furthermore, the implementation of groundwater management action plans, where developed, is weak. Overall, groundwater management in the SADC region was found to be poor.

Whilst the groundwater management challenges are great there are opportunities for the SADC-Groundwater Management Institute (SADC-GMI) to support diagnostic analysis of transboundary aquifer systems, competency development, establishing regional groundwater monitoring networks, strengthening institutional frameworks, and development of groundwater resources to clear the backlog in access to improved water supply, amongst others.

CONTENTS

1.	Introduction	1
2.	Importance of groundwater in SADC	1
3.	Approach to the study	3
4.	Country status overview	4
4.1	Water Management	4
4.1.1	Water Resources	4
4.1.2	Water use and water access	9
4.2	Water Governance	11
4.2.1	Formal institutional environment: water law and policy	11
4.2.2	Institutional arrangements	12
4.2.3	Information management	12
4.2.4	Hydrogeological capacity and training	13
5.	Transboundary aquifers	14
5.1	Classification of the TBAs within the SADC region	14
5.2	Legal mechanisms and institutional frameworks	18
6.	Conclusions and recommendations	18
6.1	Water management	18
6.2	Water Governance	19
6.2.1	Formal institutional environment: water law and policy	19
6.2.2	Institutional arrangements	19
6.2.3	Information management	19
6.2.4	Hydrogeological capacity and training	23
6.3	Transboundary Aquifers	23
6.4	Recommendations	23
7.	Acknowledgements	24
8.	References	24
8.1	Publications used for position paper	24
8.2	Key databases and publications used for SADC country reports	26
Angola	27
	Introduction	27
	Water Management	27
	Water resources	27
	Water use and water access	28
	Water Governance	29
	Formal institutional environment: water law and policy	29
	Institutional arrangements	29
	Information management	30
	Hydrogeological capacity and training	30
	Key challenges and opportunities	31
Botswana	32
	Introduction	32
	Water Management	32
	Water resources	32
	Water use and water access	34
	Water Governance	34
	Formal institutional environment: water law and policy	34
	Institutional arrangements	35
	Information management	35
	Hydrogeological capacity and training	35
	Key challenges and opportunities	35
Democratic Republic of Congo (DRC)	37
	Introduction	37
	Water Management	37

Water resources	37
Water use and water access	38
Water Governance.....	39
Formal institutional environment: water law and policy.....	39
Institutional arrangements	39
Information management.....	40
Hydrogeological capacity and training	40
Key challenges and opportunities	40
Lesotho	42
Introduction	42
Water Management	42
Water resources	42
Water use and water access	43
Water Governance.....	44
Formal institutional environment: water law and policy.....	44
Institutional arrangements	44
Information management.....	45
Hydrogeological capacity and training	45
Key challenges and opportunities	45
Madagascar	46
Introduction	46
Water Management	46
Water resources	46
Water use and water access	47
Water Governance.....	48
Formal institutional environment: water law and policy.....	48
Institutional arrangements	48
Information management.....	49
Hydrogeological capacity and training	49
Key challenges and opportunities	49
Malawi	51
Introduction	51
Water Management	51
Water resources	51
Water use and water access	52
Water Governance.....	53
Formal institutional environment: water law and policy.....	53
Institutional arrangements	53
Information management.....	54
Hydrogeological capacity and training	54
Key challenges and opportunities	54
Mauritius	55
Introduction	55
Water Management	55
Water resources	55
Water use and water access	56
Water Governance.....	57
Formal institutional environment: water law and policy.....	57
Institutional arrangements	57
Information management.....	58
Hydrogeological capacity and training	58
Key challenges and opportunities	58
Mozambique	59
Introduction	59
Water Management	59
Water resources	59

Water use and water access	60
Water Governance.....	61
Formal institutional environment: water law and policy.....	61
Institutional arrangements	61
Information management.....	62
Hydrogeological capacity and training	62
Key challenges and opportunities	62
Namibia.....	63
Introduction	63
Water Management	63
Water resources	63
Water use and water access	65
Water Governance.....	65
Formal institutional environment: water law and policy.....	65
Institutional arrangements	66
Information management.....	66
Hydrogeological capacity and training	67
Key challenges and opportunities	67
Seychelles.....	68
Introduction	68
Water Management	68
Water resources	68
Water use and water access	69
Water Governance.....	70
Formal institutional environment: water law and policy.....	70
Institutional arrangements	70
Information management.....	70
Hydrogeological capacity and training	71
Key challenges and opportunities	71
South Africa	72
Introduction	72
Water Management	72
Water resources	72
Water use and water access	74
Water Governance.....	75
Formal institutional environment: water law and policy.....	75
Institutional arrangements	75
Information management.....	76
Hydrogeological capacity and training	76
Key challenges and opportunities	76
Swaziland.....	78
Introduction	78
Water Management	78
Water resources	78
Water use and water access	79
Water Governance.....	80
Formal institutional environment: water law and policy.....	80
Institutional arrangements	80
Information management.....	81
Hydrogeological capacity and training	81
Key challenges and opportunities	81
Tanzania	82
Introduction	82
Water Management	82
Water resources	82
Water use and water access	84

Water Governance.....	84
Formal institutional environment: water law and policy.....	84
Institutional arrangements	85
Information management.....	85
Hydrogeological capacity and training	86
Key challenges and opportunities	86
Zambia	87
Introduction	87
Water Management	87
Water resources	87
Water use and water access	88
Water Governance.....	89
Formal institutional environment: water law and policy.....	89
Institutional arrangements	89
Information management.....	90
Hydrogeological capacity and training	91
Key challenges and opportunities	91
Zimbabwe	92
Introduction	92
Water Management	92
Water resources	92
Water use and water access	93
Water Governance.....	94
Formal institutional environment: water law and policy.....	94
Institutional arrangements	94
Information management.....	95
Hydrogeological capacity and training	95
Key challenges and opportunities	95

1. INTRODUCTION

The Southern African Development Community Groundwater Management Institute (SADC-GMI) is a regional centre for groundwater under the strategic guidance of the SADC Secretariat, Directorate of Infrastructure and Services – Water Division, in Gaborone, Botswana. The roles of the SADC-GMI are: (i) to promote sustainable groundwater management and solutions to groundwater challenges in the SADC region through building capacity, providing training, advancing research, supporting infrastructure development, and enabling dialogue and exchange of groundwater information; and (ii) to conduct and support SADC Member States in groundwater research, and serve as a focal interlocutor with national, regional and international groundwater initiatives (SADC, 2014).

The SADC-GMI commissioned a position paper to provide an overview of groundwater and groundwater management in the SADC region. Section 2 discusses the importance of groundwater in the SADC region. Following a brief on the approach of the study (Section 3), Section 4 presents a country status overview of water management in the SADC region in terms of water resources (the different aquifer types in the region) and water use and water access and water governance (formal institutional environment: water law and policy, institutional arrangements, information management and hydrogeological capacity and training). A more detailed account of the 15 SADC Member States which includes key challenges and opportunities is attached to the paper as appendices. Section 5 pays attention to transboundary aquifers (TBAs) in the SADC region: a classification of the TBAs, the status of groundwater monitoring and legal mechanisms. Conclusions and recommendations are presented in Section 6.

2. IMPORTANCE OF GROUNDWATER IN SADC

Water security is pivotal for economic growth, sustainable development and poverty reduction in SADC. Increasing aridity and dwindling surface water supplies are resulting in new opportunities for groundwater. Drivers that have a major bearing on its unfolding role and governance [in SADC] include the widespread poverty and food insecurity in the region, the continuing need for a basic domestic water supply in both rural and informal urban areas, rapid urbanisation, and the need for drought security as part of all water provision (Braune and Adams, 2013). Pietersen et al. (2010) documented the following beneficial uses for groundwater in the region:

- **Rural water supply:** Most rural communities in SADC are served from groundwater resources. Already, about 60 per cent of the Mozambican population, mostly rural, relies on groundwater resources (Pavelic et al., 2012). Similarly, a significant number of rural communities in Angola are dependent on groundwater resources with groundwater being the main source of drinking water outside the larger towns. The same applies to Zambia (Pavelic et al., 2012). In the Democratic Republic of Congo (DRC), more than 90 per cent of the rural population relies on groundwater resources (Partow, 2011). Botswana and Namibia, in rural areas, are even more reliant on

groundwater resources due to the scarcity of surface water (Republic of Botswana, 2016, Krugmann and Alberts, 2012).

- **Urban water supply:** The City of Tshwane in South Africa obtains a significant portion of its water supply from boreholes and springs, which is blended with surface water within the bulk water distribution system (Dippenaar, 2013). Lusaka, the capital of Zambia, obtains about 60 per cent of its water requirements from groundwater resources (Nussbaumer et al., 2016). Current abstraction of groundwater in Lusaka is estimated at 90 million cubic metres per annum (m^3/annum) (Bäumle and Kang'omba, 2013). Dodoma, the capital city of the Tanzania, mainly depends on groundwater (Elisante and Muzuka, 2015). Groundwater has played a crucial role during droughts in Bulawayo, the second largest city in Zimbabwe (Mukhlani and Nyamupingidza, 2014).
- **Water security:** In the case of Windhoek, the capital of Namibia, groundwater contributes about 10 per cent to the water supply (Christelis and Struckmeier, 2011). A system of artificially recharging groundwater resources has been put in place. The aim is to make available up to 8 million m^3/annum of groundwater for abstraction (Tredoux et al., 2009). The present Windhoek water demand is about 20 million m^3/annum (Christelis and Struckmeier, 2011). The town of Atlantis in South Africa has further enhanced its water supplies through artificial recharge.
- **Food security:** An important component of agricultural policies in the region is to increase incomes of the poorest groups in society through opportunities for small to medium-scale farmers. In Angola, groundwater irrigation is important in areas where rainfall is not sufficient for crops and where rivers are unreliable. Groundwater irrigation is also important in the coastal areas and in the southwestern provinces of Angola. Shallow groundwater resources are particularly suitable for use by farmers, since access costs are relatively low. In Zimbabwe, alluvial aquifers associated with the Shashani River, a tributary of the Limpopo River, supply water to a number of irrigation schemes.
- **Environmental services:** Many ecosystem services have a direct linkage with groundwater storage, recharge and discharge. During drought conditions the Lake St Lucia estuary on the east coast of South Africa experiences high salinity, with values above that of seawater. Groundwater flowing into the estuary from prominent sand aquifers along its eastern shoreline supports low-salinity habitats for salt-sensitive biota until conditions regains tolerable salinity (Taylor et al., 2006). Wetlands are frequently groundwater discharge zones. For example, Lake Sibaya in KwaZulu-Natal is dependent on nearby aquifers. The interaction between surface water and the groundwater strongly influences the structure and function of the Okavango wetland ecosystem in northwestern Botswana. The cycling of seasonal flood water through the groundwater reservoir plays a key role in creating and maintaining the biological and habitat diversity of the wetland, and inhibits the formation of saline surface water (McCarthy, 2006). In the Namib Desert, springs allow vegetation and wildlife to flourish in certain areas.

The economic uses and value of groundwater are not fully appreciated in SADC. The protection and management of groundwater is a catalyst for job creation in both the private

and public sectors. Besides jobs related to consultancy services, there is employment linked to drilling services and operators of groundwater supply systems. During the start-up phases of mining and industry operations, especially mega-scale projects, groundwater is often critical for water supply. Exploiting energy resources such as shale gas requires groundwater resources for its operations.

3. APPROACH TO THE STUDY

The objective of this paper is to put forward a baseline of the groundwater management situation in SADC. Numerous sources of information (peer-reviewed journal articles, books, published reports and databases in the public domain; see Section 8: References) were solicited, reviewed, and data mined using a framework analysis (Dixon-Woods, 2011) and qualitative context analysis approaches (Srivastava and Thomson, 2009, Hsieh and Shannon, 2005). The framework method is an excellent tool for supporting thematic (qualitative content) analysis because it provides a systematic model for managing and mapping the data (Gale et al., 2013).

There have been numerous efforts to understand and manage groundwater in a SADC context (Box 1):

BOX 1: PREVIOUS SADC PROGRAMMES/PROJECTS
<p>Transboundary Water Management in SADC Programme: From 2005 to 2015, GIZ has implemented the Transboundary Water Management in SADC Programme on behalf of the German Federal Ministry for Economic Cooperation and Development (BMZ) with co-financing agencies, the Australian Agency for International Development (AusAID) and the UK Department for International Development (DFID). The Programme took a multi-dimensional approach, operating at three levels of intervention: (i) the entire SADC region; (ii) transboundary river basins and their organisations, and (iii) local municipalities and water utilities. At each level, GIZ advised and assisted its partners in the three strategic areas of water governance, water management and infrastructure development. Human, institutional and organisational capacities have been strengthened in the SADC water sector. Basin-wide integrated water resources management plans have been developed; water infrastructure in different regions has improved, and tailor-made training programmes and information and knowledge management systems have been established, including awareness-raising measures.</p>
<p>Groundwater and Drought Management Project (GDMP): SADC developed a Groundwater and Drought Management Project (GDMP) in 2009 with support from the World Bank in recognition of Member States' increasing dependence on groundwater for both domestic and commercial water needs. The GDMP comprised four main components: (i) testing of practical local groundwater drought management strategies at pilot level; (ii) the development of groundwater drought management tools and guidelines; (iii) research into Groundwater Dependent Ecosystems (GDEs), their occurrence, vulnerability, value, protection and monitoring, and (iv) establishment of a SADC GMI to continue long-term groundwater and drought monitoring and the promotion of better management and awareness in the SADC region and at national levels.</p>
<p>SADC hydrogeology map: SADC compiled a SADC hydrogeology map providing information on the extent and geometry of regional aquifer systems at a scale of 1: 2 500 000.</p>
<p>SADC Groundwater Grey Literature Archive: Regional studies form the basis of the current knowledge of regional aquifers systems. An important initiative of SADC was to set up the "SADC Groundwater Grey Literature Archive" website to make available books, reports, maps, notes and datasets that were unpublished or published in limited quantities. The Grey Data Project focused on making part of the large body of useful information on African groundwater held by the British Geological Survey more accessible.</p>

In addition to the above-mentioned relatively large-scale studies, a number of regional projects with the support from international donors were conducted over time contributing to the general state of knowledge about groundwater management in the SADC countries and the region.

4. COUNTRY STATUS OVERVIEW

The SADC is an inter-governmental organisation with a membership of 15 countries: Angola, Botswana, DRC, Lesotho, Madagascar, Malawi, Mauritius, Mozambique, Namibia, Seychelles, South Africa, Swaziland, Tanzania, Zambia and Zimbabwe. This section summarises the country reports which are attached as appendices.

4.1 WATER MANAGEMENT

4.1.1 Water Resources

Surface Water

More than 70 per cent of the region's surface water resources are shared between countries. SADC has 15 international shared rivers. The Congo River basin is the largest and the Congo is also the longest river in SADC. The second largest is the Zambezi River, which extends to 8 Member States. The region also has a number of large lakes: Lake Victoria, Lake Tanganyika and Lake Malawi/Nyassa.

Groundwater

The SADC region has a varied and complex geological history. Macy (2010) provided a comprehensive account of the SADC geology based on the SADC geology map prepared by the Council for Geoscience (CGS) in South Africa. The geology map formed the basis for the compilation of the SADC Hydrogeological Map and Atlas (SADC-HGM) (Pietersen et al., 2010). The objectives of the Hydrogeological Map and Atlas are to improve: (i) the understanding of groundwater occurrence in the SADC region; (ii) cooperation between member states; and (iii) understanding of groundwater resource management. The SADC-HGM is a general hydrogeology map (1:2 500 000), which provides information on the extent and geometry of regional aquifer systems (Figure 1). The following aquifer types are shown based on the groundwater flow regime:

- **Unconsolidated intergranular aquifers:** Examples include the Mushawe alluvial aquifer in the Limpopo River Basin, Zimbabwe, or the extensive shallow aquifer of the quaternary alluvial plain in the DRC, which formed as a result of deposition of unconsolidated material in river channels, banks and flood plains and the Kalahari aquifer system which consists of undifferentiated inland deposits of unconsolidated to semi-consolidated sediments extending across parts of the DRC, Angola, Namibia, Zambia, Botswana and South Africa.
- **Fissured aquifers:** Aquifer systems associated with Karoo formations are found extensively throughout the SADC-region. The formations normally have low

permeability and are low-yielding. However, where the rocks have been subjected to deformation and intrusion of dolerites, a secondary permeability resulting in good aquifers may be found. The Cape Fold Mountains of South Africa are also associated with fractured rock aquifers. Groundwater occurrence is dependent on tectonic and structural controls resulting in higher hydraulic conductivities and transmissivities.

- **Karst aquifers:** Karst aquifers are water-bearing, soluble rock layers in which groundwater flow is concentrated along secondary enlarged fractures, fissures, conduits, and other interconnected openings. They are formed by the chemical dissolving action of slightly acidic water on highly soluble rocks, most notably limestone and dolomite. Extensive use is made of karst aquifers in Botswana, Namibia, South Africa, Zambia and Zimbabwe.
- **Layered aquifers:** The Kalahari/Karoo aquifer system shared between Botswana, Namibia and South Africa is an example of a layered aquifer. In the “Stampriet Artesian Basin” there are two confined regional artesian aquifers in the Karoo sediments overlain by the Kalahari sediments that often contain an unconfined aquifer system.
- **Low permeability formations:** Low permeability formations are normally associated with basement aquifers. These formations occur extensively throughout the SADC-region.

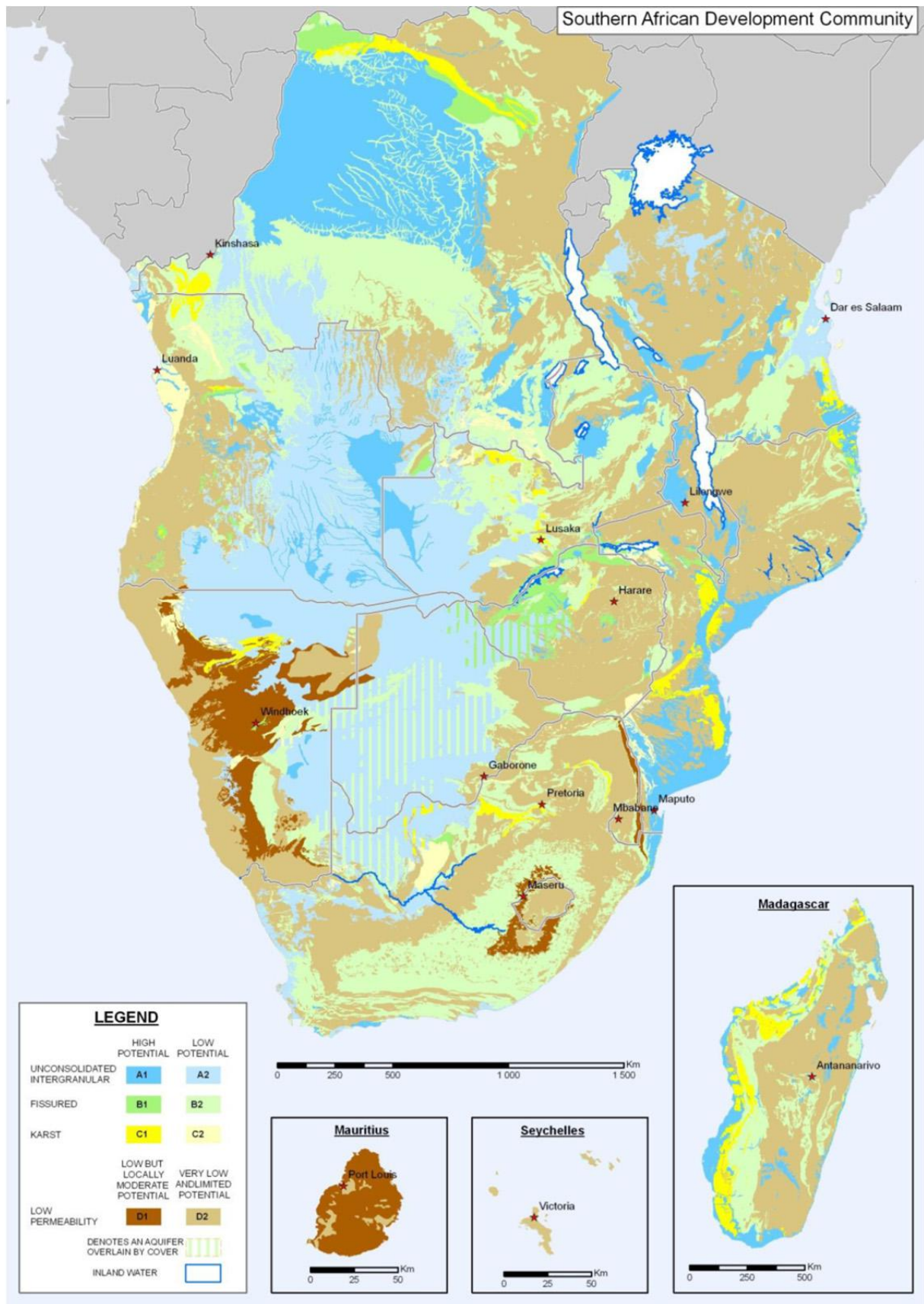


Figure 1: SADC-HGM (here represented at scale 1:30 000 000).

For the SADC region as a whole, and excluding layered aquifers, porous-intergranular aquifers cover 45 per cent of the total surface area, followed by low-permeability formations: 33 per cent, fissured aquifers: 19 per cent and karst aquifers: 3 per cent (Figure 2).

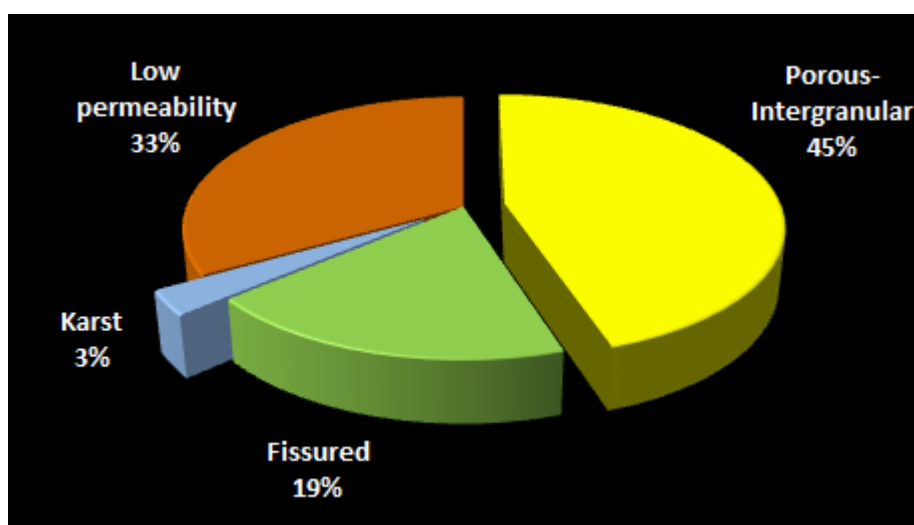


Figure 2: Groundwater occurrence in SADC.

Groundwater availability¹ in SADC is estimated at 13 per cent of the total water availability² of 7 199 m³/capita/annum (Figure 3).

¹ Döll and Fiedler (2007) developed an algorithm to estimate diffuse groundwater recharge at the global scale, with a spatial resolution of 0.5°. This algorithm was adopted to create a recharge layer for the SADC Hydrogeological Map. The layer was used to calculate average annual recharge over the various aquifer types. It is assumed that the aquifers are unconfined and that groundwater availability (m³/capita/annum) for sustainable use amounts to 40% of the calculated recharge (Ponce, 2007).

² Total Water Availability (m³/capita/annum) = Total Renewable Water Resources (TRWR; km³ per year) *10⁹ / total population; TRWR = Total renewable surface water + total renewable groundwater – overlap between surface water and groundwater (Aquastat-FAO; <http://www.fao.org/nr/water/aquastat/data/glossary/search.html>).

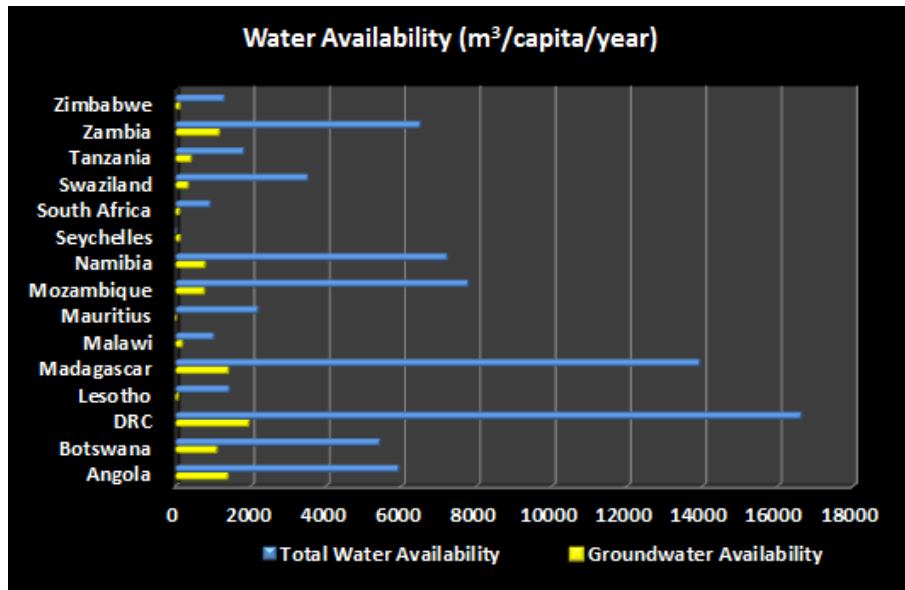


Figure 3: Groundwater availability in SADC.

Groundwater availability, however, will be less than estimated when the presence of poor natural groundwater quality and pollution is taken into account.

Poor natural groundwater quality

Human health can be affected by long-term exposure to either an excess or a deficiency of certain constituents in groundwater (Pietersen et al., 2010). In particular, high fluoride and nitrate levels in drinking water may cause significant health problems. For example, fluoride occurs in both surface water and groundwater around volcanoes and many parts within the East African Rift Valley in regions including Arusha (10 mg/l), Shinyanga (2.9 mg/l) and Singida (1.8 mg/l) (Bhattacharya et al., 2016). An estimated 90 per cent of the population living along the Rift Valley region are affected by dental or skeletal fluorosis and bone crippling because of long term exposure to very high levels of fluoride in drinking water sources (Bhattacharya et al., 2016). High fluoride areas are normally associated with basement aquifers of granitic origin which include parts of Malawi, Tanzania and South Africa. High nitrate values are normally associated with anthropogenic influences but there are cases of natural production in SADC. In southern Africa elevated concentrations of nitrate can be traced in some linear bands, particularly along the southern fringes of the Kalahari and a northwest-southeast oriented band through the Stampriet Basin region (Stone and Edmunds, 2014). In addition, salinity is also a problem in many groundwaters found in the region. As a result, the poor natural quality of groundwater in some areas poses a risk to human health and requires continual monitoring systems in place.

Pollution of groundwater resources

Mining development is a foreign exchange earner for SADC countries but poses a hazard to groundwater resources. For example, Rwiza et al. (2016) investigated the geochemical distribution of trace elements in groundwater from the North Mara large-scale gold mining area of Tanzania and found elevated levels of trace elements in groundwater resources

above drinking water quality standards. The Katanga Copperbelt in the DRC is a major producer of copper and cobalt but is causing metal contamination of groundwater (Pourret et al., 2016, Atibu et al., 2016). Mozambique has huge reserves of coal and gas deposits (Kirshner and Power, 2015). This has attracted international operators. The risk of acid mine drainage (AMD) in Mozambique is real (Nhantumbo et al., 2015) with widespread problems already occurring in the South African gold basins (Lusilao-Makiese et al., 2016, Matsumoto et al., 2016) and also the coal basins (Matsumoto et al., 2016). The above examples illustrate the challenge for SADC countries to put environmental systems in place to protect groundwater resources from extractive industries.

Rapid urbanisation, as is the case, in many large cities in SADC has resulted in the pollution of urban aquifers. There are already examples of emerging contaminants found in groundwater sources located in urban areas such as the insect repellent N,N-Diethyl-m-toluamide, commonly known as DEET (Sorensen et al., 2015). Lusaka obtains large parts of its water from a dolomite aquifer. Inadequate sanitation and waste disposal practices has led to widespread contamination of the aquifer in Lusaka resulting in high Total Coliform counts and high nitrate loads, especially in unplanned residential, peri-urban (high density settlement) areas (Bäumle and Kang'omba, 2013). The unchecked contamination of urban aquifers is putting water security at risk in cities such as Dar es Salaam (Elisante and Muzuka, 2015, Mahenge, 2013), Dodoma (Elisante and Muzuka, 2015), Johannesburg (Mengistu et al., 2015) and Maputo (Juízo and Matsinhe, 2006).

Agriculture also contributes to diffuse contamination. Nitrate is the most common agricultural contaminant (Ouedraogo and Vanclooster, 2016) and salinity, pesticides and herbicides are likely to be a problem in some areas. In the Namibian sector of the Stampriet Artesian Aquifer (AF5) groundwater pollution is due to irrigated agriculture (UNESCO, 2016). Aza-Gnandji et al. (2013) showed that the concentrations of chloride, nitrate, potassium and sodium exceeded the target maximum limit according to set guidelines mostly due to agricultural activities in the Cape Flats aquifer. Many of the aquifer systems in SADC are at risk of groundwater pollution due to intensive agricultural practices that may include indiscriminate application of fertilisers.

4.1.2 Water use and water access

The total water use in SADC is 55 052 million m³/annum; 7.7 per cent is from groundwater. Sectoral water use varies from country to country (Figure 4) but for the SADC region as a whole, the agriculture sector (including irrigation) is the largest water user with 82 per cent followed by the domestic sector with 14 per cent and the industry sector (including mining) with 4 per cent (Figure 5). Groundwater use is only a fraction (1.4 per cent) of the total (potentially) available groundwater resources which creates an opportunity for further development. Note that this situation varies from country to country.

Drinking water supply has improved tremendously since 1990 with now 87 per cent of the urban population having access to an improved drinking water supply and 49 per cent for the rural population. There are countries where the backlog in access to an improved drinking water supply is fully cleared and there are countries which are still in urgent need, especially

with regards to the rural population. Groundwater could play a key role in meeting urgent water supply needs.

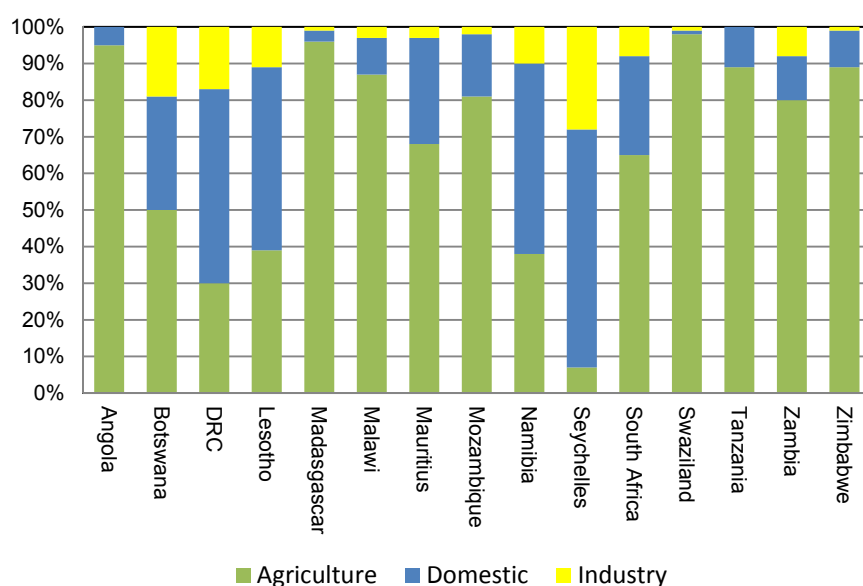


Figure 4: Water use by sector in SADC countries.

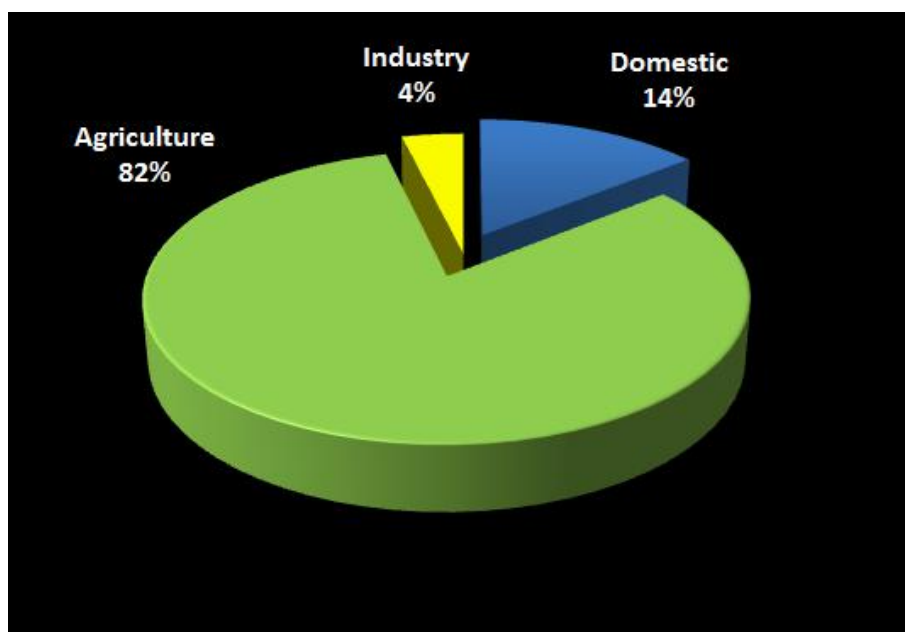


Figure 5: Sectoral water use in SADC.

Over-abstraction of groundwater resources

Over-abstraction of groundwater is causing declining water levels in some areas of SADC. This is often due to irrigation but also due to domestic demand exceeding resource potential. Robins et al. (2013) demonstrated in the basement aquifers of the South and Central regions of Malawi that there is an imbalance of resource availability and demand suggesting new

sources will likely fail in the short to medium term. Failure will result from recharge being unable to match demand (Robins et al., 2013). The implications of long-term groundwater mining in parts of Malawi are important and urgently need further investigation in order to underpin a sustainable remedial strategy with which to safeguard rural community livelihoods (Robins et al., 2013). Over-abstraction of alluvial aquifers associated with active river channels is also a source of concern e.g. the impact on the Limpopo River flows (Owen, 2011). Another example of the potential for over-abstraction is the groundwater exploitation of the Nyamandhlovu aquifer in Zimbabwe for both Bulawayo water supply and commercial agriculture. Detailed hydrogeological investigations since the late nineties including recent groundwater modelling recommend a sustainable yield for the aquifer as a whole (Beekman and Sunguro, 2015). More work, however, is needed to evaluate groundwater behaviour under different abstraction and climate scenarios. Unsustainable utilisation of groundwater resources may be a source of conflict between communities and countries.

Operation and maintenance of groundwater infrastructure

The failure of groundwater supply schemes is often blamed on the resource rather than on the failure of infrastructure associated with the resource. This is supported by Cobbing et al. (2015) who found that operation and maintenance (O&M) of groundwater supplies is more important to groundwater sustainability than primary or “physical” groundwater availability. They studied groundwater supply in a number of municipalities in South Africa and found that there are few resources for institutionalising O&M procedures, and few guidelines for the O&M tasks themselves. The lack of focus on the “real” issues affecting groundwater management is threatening groundwater infrastructure and by implication sustainable groundwater management.

4.2 WATER GOVERNANCE

4.2.1 Formal institutional environment: water law and policy

Most SADC countries have legal frameworks in place to support Integrated Water Resource Management principles. Figure 6 shows the promulgation of water resources laws in the SADC Member States. In most of the countries the water laws were promulgated within a time period of ~10 years (between 1998 and 2007). The regulatory instruments to support judicious use of groundwater, however, are either lacking or are not enforced. Instruments such as groundwater protection zoning are hardly used; water use licenses never enforced and fines never imposed.

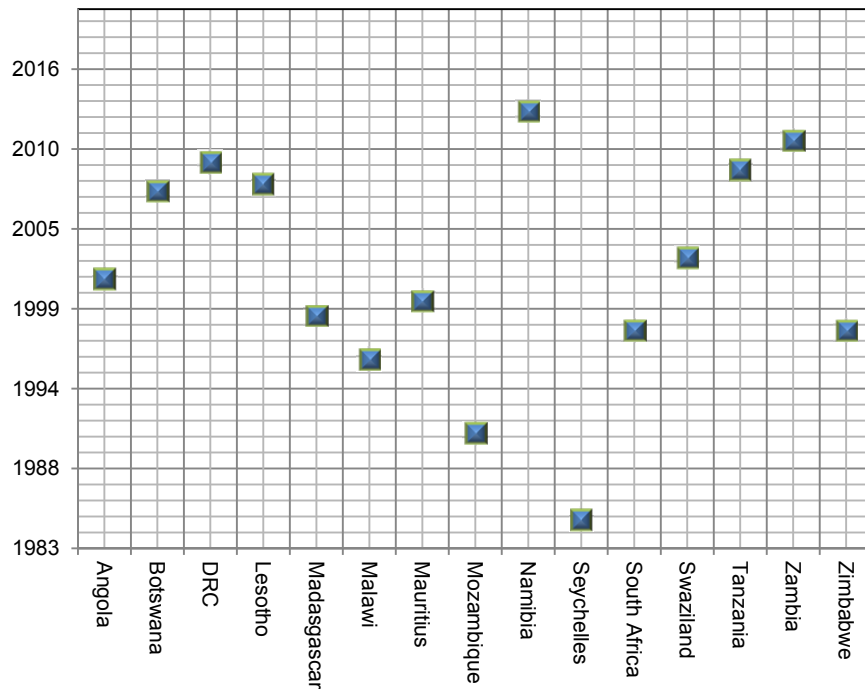


Figure 6: Promulgation of water resources legislation SADC countries.

4.2.2 Institutional arrangements

There are no explicit groundwater agencies responsible for groundwater management. Rather groundwater management is accommodated in a Directorate/Division or a sub-Directorate within a government department. Most country legislation requires the participation of stakeholders in the management of groundwater resources through Catchment Management Agencies or Councils. Implementation and proper functioning of the institutional framework as required by the legislation has been slow or non-existent in most SADC countries. The most widespread use of groundwater is for village level 'garden-scale' irrigation of vegetables and seedlings, which helps to improve food and nutritional security at a local scale (Pavelic et al., 2012). There is limited coordination between Departments of Agriculture to both control groundwater use and to prevent groundwater contamination from agricultural activities. The same lack of coordination applies to government agencies responsible for urban and industrial development. At best there is coordination with government departments responsible for rural water supply. The lack of institutions for groundwater management and coordination with other sectors is increasing the risk of groundwater depletion and pollution and puts communities at risk.

4.2.3 Information management

All SADC Member States have hydrogeological maps at various scales. Most maps were produced during the late eighties to early nineties. The most recent hydrogeological map of the SADC region is at a scale of 1:2 500 000 from 2010 and was based on input from hydrogeologists from the Member States (Figure 1).

The availability and quality of groundwater data and groundwater databases vary from country to country. There are several Member States who will need support in establishing and improving their groundwater databases.

Groundwater monitoring is weak throughout most of the Member States of SADC. The groundwater monitoring networks vary in technical aspects, such as the spatial density of monitoring wells; the duration and frequency of measurements; amount of metadata; and in its data management and coordination of the work (IGRAC, 2013). Please refer to Table 1 for the level of assessment of groundwater monitoring networks in selected SADC countries.

Table 1: Development of groundwater monitoring networks in SADC region (IGRAC, 2013).

Country	Development of monitoring network
Angola	1
Botswana	3
Lesotho	3
Mozambique	2
Namibia	3
South Africa	4
Tanzania	2
Zimbabwe	2
Zambia	2

Level of development: Scale 1 – 5.

Note that the level of assessment of the South African groundwater monitoring network is perhaps optimistic. Problems with the South Africa groundwater monitoring network include (AECOM, 2015):

- Gaps in the data record;
- The need for training of monitoring staff, and possibly formal accreditation of monitoring skills along with regular calibration of monitoring equipment;
- Lack of standardisation of terms (e.g. recorder type);
- The need for some of the provinces to increase the number of groundwater level monitoring stations, in line with average densities in other provinces and taking into account operational needs and human requirements; and
- The regular conversion of “raw” groundwater level monitoring data into knowledge products such as short reports on sensitive areas (e.g. dolomite compartments, wetlands, sole-source aquifers, etc.).

Another issue which requires attention for the whole SADC region is vandalism of groundwater monitoring infrastructure.

4.2.4 Hydrogeological capacity and training

The hydrogeological capacity of most of the SADC Member States is weak. There is a need for additional qualified hydrogeologists at MSc level and geoscience technicians to

strengthen both the public and private sectors. There is also need for further training of groundwater professionals and technicians in both technical fields of hydrogeology (e.g. in basic hydrogeology, drilling and borehole construction, and specialised training in topics such as GIS, groundwater modelling, hydrochemistry, groundwater monitoring and database management) and in groundwater governance (e.g. water legislation, institutional frameworks, etc.).

Formal training in hydrogeology up to MSc/PhD level is offered by the Department of Geology at the University of Botswana, and the Institute for Groundwater Studies (IGS) at the University of the Free State and the Department of Earth Sciences at the University of the Western Cape in South Africa. A WaterNet Masters training programme in IWRM was set up in SADC countries with modules offered by the University of Zimbabwe, the University of Dar es Salaam, the University of Botswana, the University of Malawi, the Polytechnic of Namibia, the University of the Western Cape, University of Witwatersrand and the University of KwaZulu-Natal. Modules in hydrogeology are taught by the College of Engineering and Technology, University of Dar es Salaam and the Department of Civil Engineering, University of Zimbabwe.

5. TRANSBOUNDARY AQUIFERS

Transboundary river basins and aquifers in SADC provide an instrument of cooperation between Member States. A transboundary aquifer (TBA) is a groundwater unit that crosses a political boundary. This boundary may include municipal, provincial or national. In the case of SADC, transboundary is defined as a groundwater unit shared by two or more SADC nations or states (Davies et al., 2012, Altchenko and Villholth, 2013). This definition precludes transboundary aquifers shared by non-SADC states.

5.1 CLASSIFICATION OF THE TBAs WITHIN THE SADC REGION

IGRAC (2015) presented an updated TBA map of Africa (Figure 7). Twenty-eight of these TBAs are shared between two or more SADC Member States (Table 2).

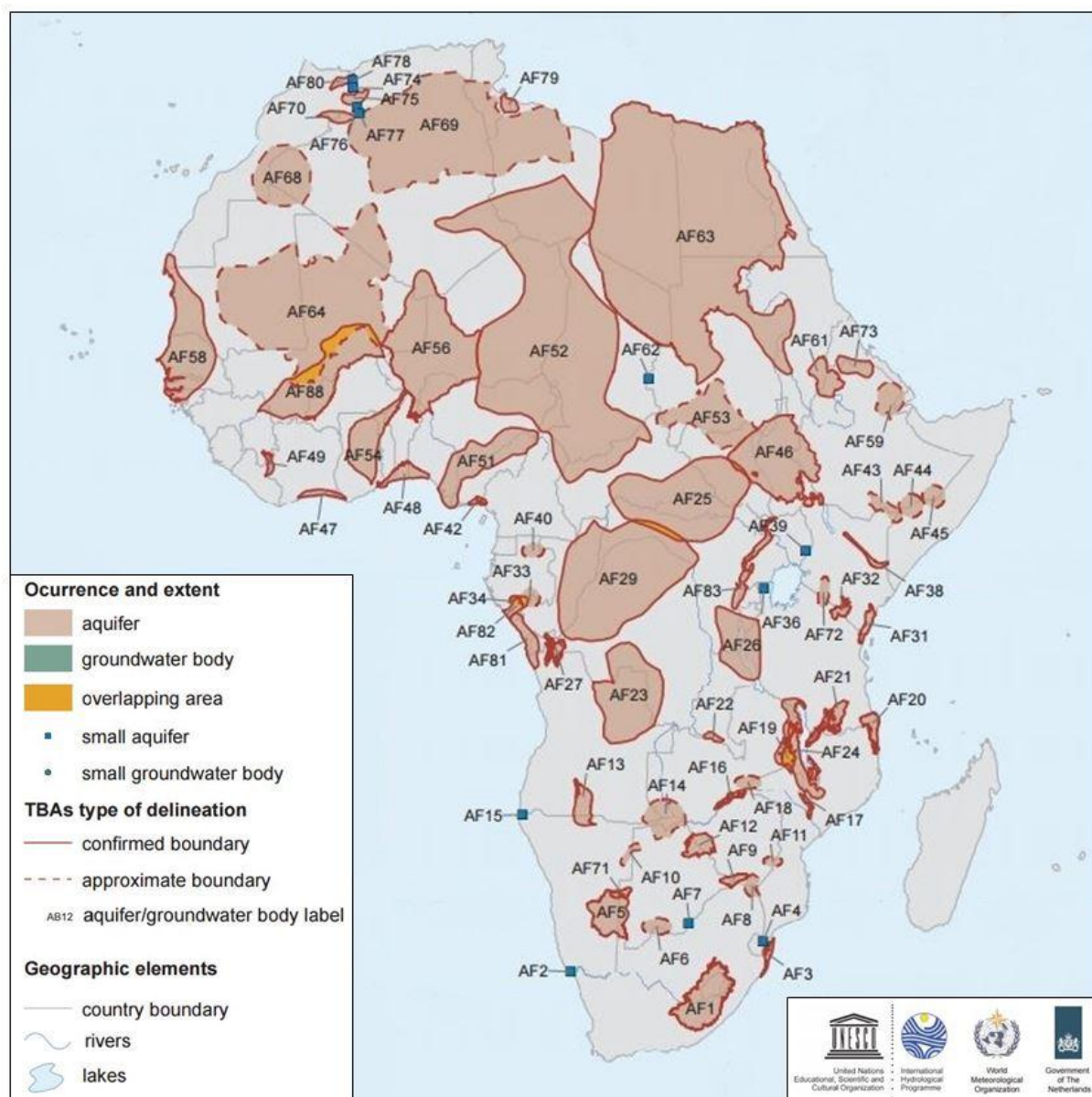


Figure 7: Transboundary aquifers in Africa (modified from IGRAC, 2015).

Table 2: Transboundary aquifers in SADC (Altchenko and Villholth, 2013; IGRAC, 2015).

Proposed ID	Main name	Countries sharing	Aquifer type
AF1	Karoo sedimentary aquifer	Lesotho South Africa	Consolidated sedimentary rocks
AF2	Coastal Sedimentary basin V	Namibia South Africa	Quaternary and consolidated sedimentary rocks
AF3	Coastal Sedimentary basin VI / Coastal Plain Sedimentary Basin Aquifer	Mozambique South Africa	Quaternary and consolidated sedimentary rocks
AF4	Rhyolite-Breccia aquifer	Mozambique South Africa Swaziland	Volcanic/Quaternary
AF5	Stampriet Aquifer System	Botswana	Kalahari groups aquifer and Karoo

Proposed ID	Main name	Countries sharing	Aquifer type
		Namibia South Africa	Supergroup aquifers
AF6	Khakhea/Bray Dolomite	Botswana South Africa	Dolomite
AF7	Zeerust / Lobatse / Ramotswa Dolomite Basin Aquifer	Botswana South Africa	Malmani subgroup of the Transvaal Supergroup
AF8	Limpopo basin	Mozambique South Africa Zimbabwe	Volcanic and basement rocks
AF9	Tuli Karoo Sub-Basin	Botswana South Africa Zimbabwe	Volcanic and basement rocks
AF10	Northern Kalahari / Karoo Basin / Eiseb Graben Aquifer	Angola Botswana Namibia Zambia	Consolidated sedimentary rocks
AF11	Save alluvial aquifer	Mozambique Zimbabwe	Alluvial
AF12	Eastern Kalahari Karoo Basin	Botswana Zimbabwe	Upper Karoo Sandstone
AF13	Cuvelai and Etosha Basin / Ohangwena Aquifer System	Angola Namibia	Consolidated sedimentary rocks
AF14	Nata Karoo Sub-basin / Caprivi deep-seated Aquifer	Botswana Namibia Zimbabwe	Ecca sequence
AF15	Coastal Sedimentary Basin IV	Angola Namibia	Quaternary and consolidated sedimentary rocks
AF16	Medium Zambezi aquifer	Mozambique Zambia Zimbabwe	Quaternary and consolidated sedimentary rocks (Lower and upper Karoo Sandstone)
AF17	Shire Valley Alluvial Aquifer	Malawi Mozambique	Tertiary/Quaternary
AF18	Arangua Alluvial	Mozambique Zambia	Alluvial
AFS19	Sand and Gravel aquifer	Malawi Zambia	Alluvial
AF20	Coastal Sedimentary Basin III	Mozambique Tanzania	Quaternary and consolidated sedimentary rocks
AF21	Karoo-Sandstone aquifer	Mozambique Tanzania	Consolidated sedimentary rocks
AF22	Kalahari/Katangian Basin/Lualaba	DRC Zambia	Katangian sequence (semi-consolidated Aeolian sandstone and gravels deposits) and Kalahari sequence (consolidated sedimentary rocks)
AF23	Coango	Angola DRC	Consolidated sedimentary rocks and alluvial
AF24	Weathered basement	Malawi Tanzania Zambia	[Basement rocks]
AF26	Tanganyika aquifer	Burundi DRC Tanzania	Fractured basalt and sandstone

Proposed ID	Main name	Countries sharing	Aquifer type
AF27	Dolomitic Basin	Angola DRC	Karst weathered dolomite
AF71	Ncojane Basin	Botswana Namibia	Consolidated sedimentary rocks
AF81	Aquifere Cotier	Angola DRC Congo Gabon	Unconsolidated sedimentary rocks

An assessment of transboundary aquifers, worldwide, using the following indicators: groundwater recharge, groundwater depletion, per-capita groundwater recharge, dependency on groundwater, population density, and groundwater development stress (groundwater withdrawals to groundwater recharge) identified hotspots (Riedel and Döll, 2016). Whilst the global scale modelling (Riedel and Döll, 2016) did not highlight hotspots in SADC, it predicts medium to high development stress under the worst-case global climate and irrigation scenarios for 2030 for the following TBAs:

- Karoo sedimentary aquifer (AF1);
- Stampriet Artesian Aquifer System (AF5);
- Khakhea/Bray Dolomite (AF6);
- Eastern Kalahari/ Karoo Basin (AF12); and
- Cuvelai and Etosa Basin / Ohangwena Aquifer (AF13).

The above TBAs correspond with the more arid countries of SADC. The highest future groundwater development stress values as well as the largest increases of groundwater development stress of up to 40 percentage points are predicted for TBAs located in Botswana (Riedel and Döll, 2016). Davies et al. (2012) in their analysis of transboundary aquifers identified the Tuli Karoo Sub-Basin (AF9) and the Eastern Kalahari/ Karoo Basin (AF12) as the most likely troublesome in which some form of international collaboration in monitoring, management and apportionment are needed now in order to avoid conflicts in the future should demographics, land use or climate, change. Potentially troublesome TBAs in which there is potential for transboundary degradation of some form or another include the:

- Stampriet Artesian Aquifer System (AF5);
- Zeerust / Lobatse / Ramotswa Dolomite Basin (AF7); and
- Cuvelai and Etosa Basin / Ohangwena Aquifer (AF13).

The classification system for transboundary aquifers proposed by IGRAC (2015) should be used consistently moving forward. The TBAs are identified that require further governance intervention by Member States (Davies et al., 2012, Riedel and Döll, 2016). Already initiatives are underway to understand the Stampriet Artesian Aquifer System (AF5), commonly known as the Stampriet Aquifer System (UNESCO, 2016).

5.2 LEGAL MECHANISMS AND INSTITUTIONAL FRAMEWORKS

Transboundary cooperation in water matters in SADC takes place within the framework of the “*Revised Protocol on Shared Watercourses*” (SADC, 2002), which is supported by an institutional framework for the management of river basins. A number of river basins have been established in SADC: Inkomati Tripartite Permanent Technical Committee, International Commission of Congo-Oubangui-Sangha (CICOS), Kunene Permanent Joint Technical Commission (PJTC), Lake Tanganyika Authority (LTA), Limpopo Water Course Commission (LIMCOM), Orange-Senqu River Commission (ORASECOM), Permanent Okavango River Basin Water Commission (OKACOM), Ruvuma Joint Water Commission and Zambezi Watercourse Commission (ZAMCOM). The commissions are structured along surface water boundaries and no groundwater-related commissions are set-up. At an international level, the “*Law of Transboundary Aquifers*” was adopted by consensus by the United Nations in 2008. The resolution encourages the States concerned to make appropriate bilateral or regional arrangements for the proper management of their transboundary aquifers, regardless of whether they are hydraulically linked to a surface water system or not (UNESCO, 2016). The resolution is non-binding. Its endorsement by States, however, constitutes evidence of their adherence to the basic norms of inter-State behaviour in relation to transboundary aquifers (UNESCO, 2016).

6. CONCLUSIONS AND RECOMMENDATIONS

6.1 WATER MANAGEMENT

Groundwater is increasingly threatened by contamination from agriculture, mining and industrial activities. In urban areas, the indiscriminate use of chemicals and generation of wastes at both domestic and industrial level tend to concentrate potential sources of contamination. Over-abstraction of groundwater is causing declining water levels in some areas of SADC and this is often due to irrigation practices. In many cases, groundwater infrastructure in SADC countries is not maintained resulting in failure to supply communities. There is still a serious backlog in access to an improved drinking water supply for the rural population of most SADC Member States, whereas there is scope for further development of groundwater resources.

Climate change poses a significant risk to the region with an anticipated warming exceeding global average and also the low adaptive capacity of countries to drought. Although groundwater is considered as a buffer during droughts, prolonged drought will cause groundwater levels to decline that result in other water-related problems (also known as groundwater drought). Villholth et al. (2013) highlighted areas across SADC with the highest groundwater drought risk with populations in the order of 39 million at risk. The implications of climate change for groundwater are unknown but may be considerable such as reduced recharge, seawater intrusion due to sea-level rise and increased groundwater over-abstraction.

6.2 WATER GOVERNANCE

Table 3 presents a qualitative analysis of groundwater governance provisions in SADC Member States based on the Foster et al. (2010) groundwater governance assessment approach. These provisions provide a first assessment of the groundwater governance situation in SADC. Each of the identified gaps and institutional barriers was categorised and colour-coded to reflect the magnitude of the gap: (i) green (3) – criteria are met; (ii) amber (2) – criteria partially met; (iii) red (1) – significant gap or absent. In the case of unknowns the field is left blank.

6.2.1 Formal institutional environment: water law and policy

Most SADC countries have legal frameworks in place to support Integrated Water Resource Management principles (Figure 6) but the implementation of legislative provisions is inadequate and requires attention. At SADC-level, the 2002 Revised *Protocol on Shared Water Resources* is an instrument of cooperation between Member States which could be used to support the setting-up of Transboundary Aquifer Commissions.

Attention should also be given to groundwater management that relates to gender issues and impacts on vulnerable communities. Policy strategies aimed to achieve efficiency and sustainability in water use, in order to enhance women's equitable access to water, should be grounded in an understanding of gender relations and unequal power hierarchies as experienced by women in specific local contexts (Derman and Prabhakaran, 2016)

6.2.2 Institutional arrangements

The institutional framework for groundwater management in SADC is weak and there are no explicit groundwater agencies responsible for groundwater management. There is limited coordination between Departments of Agriculture to both control groundwater use and prevent groundwater contamination from agricultural activities. The same lack of coordination applies to government agencies responsible for urban and industrial development. The lack of institutions for groundwater management and coordination with other sectors is increasing the risk of groundwater depletion and pollution.

6.2.3 Information management

There have been numerous efforts to understand and manage groundwater in a SADC context. However, the information systems to manage groundwater data are disparate throughout the region. Significant effort is required to upgrade monitoring systems and at the same time initiate new monitoring campaigns to ensure data collection to take place. Regional datasets are outdated and perhaps do not reflect the true groundwater situation in SADC. There is also an urgent need to capture, process, interpret and report on groundwater data. In parallel, attention should be paid to database development within a GIS environment and on data exchange between Member States.

Table 3: Qualitative indicators for groundwater governance provisions in SADC.

TYPE OF PROVISION	GOVERNANCE PERFORMANCE INDICATOR	CONTEXT FOR APPLICATION	AO	BW	CD	LS	MG	MW	MU	MZ	NA	SC	ZA	SZ	TZ	ZM	ZW
Technical	Existence of Basic Hydrogeological Maps	for identification of groundwater resources	3	3	1	3	3	3	1	3	3	1	3	3	3	3	3
	Groundwater Body/Aquifer Delineation	with classification of typology	2	3	1	2	2	2	2	2	3	1	3	2	2	3	3
	Groundwater Piezometric Monitoring Network	to establish resource status	1	2	1	1	1	2	2	1	3	1	3	2	2	2	2
	Groundwater Pollution Hazard Assessment	for identifying quality degradation risks	1	2	1	1	1	2	2	1	3	1	3	2	2	2	2
	Availability of Aquifer Numerical/Management Models'	at least preliminary for strategic critical aquifers		3	1	1	1	1	1	1	3	1	3	1	2	2	2
	Groundwater Quality Monitoring Network	to detect groundwater pollution	1	2	1	1	1	1	2	1	2	1	2	1	1	1	1
Legal & Institutional	Water Well Drilling Permits & Groundwater Use Rights	for large users, with interests of small users noted		2	1	1	1	1	1	1	2	1	1	1	2	1	2
	Instrument to Reduce Groundwater Abstraction	water well closure/constraint in critical areas		1	1	1	1	1	1	1	2	1	1	1	1	1	2
	Instrument to Prevent Water Well Construction	in overexploited or polluted areas		1	1	1	1	1	1	1	2	1	1	1	1	1	2

TYPE OF PROVISION	GOVERNANCE PERFORMANCE INDICATOR	CONTEXT FOR APPLICATION	AO	BW	CD	LS	MG	MW	MU	MZ	NA	SC	ZA	SZ	TZ	ZM	ZW
	Sanction for Illegal Water Well Operation	penalising excessive pumping above permit	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1
	Groundwater Abstraction & Use Charging	'resource charge' on larger users	1	2	1	1	1	1	1	1	2	1	1	1	1	1	1
	Land-Use Control on Potentially-Polluting Activities	prohibition or restriction since groundwater hazard		2	1	2		2	2	1	2		2	2	2	1	1
	Levies on Generation/ Discharge of Potential Pollutants	providing incentive for pollution prevention	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Government Agency as 'Groundwater Resource Guardian	empowered to act on cross-sectoral basis	1	2	1	1	1	1	1	1	2	1	1	2	2	2	2
	Community Aquifer Management Organisations	mobilising and formalising community participation	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Hydrogeological capacity in public institutions	For effective management of aquifer system	1	2	1	1	1	1	2	1	2	1	2	1	2	2	1
	Vandalism of groundwater infrastructure	Ability to supply communities with water resources	2	2	1	1	2	2	3	1	2	3	2	1	1	1	1
Cross-Sector Policy Coordination	Coordination with Agricultural Development	ensuring 'real water saving' and pollution control	1	2	1	2	2	2	2	2	3	1	2	2	2	2	1
	Groundwater-Based Urban/Industrial Planning	to conserve and protect groundwater resources	1	2	1	1	1	1	2	1	3	1	2	1	2	2	1
	Compensation for Groundwater	related to constraints on	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

TYPE OF PROVISION	GOVERNANCE PERFORMANCE INDICATOR	CONTEXT FOR APPLICATION	AO	BW	CD	LS	MG	MW	MU	MZ	NA	SC	ZA	SZ	TZ	ZM	ZW
	Protection	land-use activities															
Operational	Public Participation in Groundwater Management	effective in control of exploitation and pollution	1	1	1	2	1	2	1	2	3	1	3	2	2	2	1
	Existence of Groundwater Management Action Plan	with measures and instruments agreed		2	1	1	1	1	1	1	2	1	3	1	2	2	2

6.2.4 Hydrogeological capacity and training

There is a serious lack of hydrogeological capacity in Government Departments in SADC, especially at professional (MSc) level and in several countries there is also lack of appropriate hydrogeological capacity in the private sector. In some countries there are only a few hydrogeologists in National Departments. SADC has a number of training institutions that support capacity building. Trained people from these institutions, however, struggle with opportunities in the public sector. There is also the problem of retention of hydrogeological capacity.

6.3 TRANSBOUNDARY AQUIFERS

Twenty-eight transboundary aquifers have been delineated for SADC. A discussion is needed among SADC Member States which of these are truly transboundary and need urgent attention – particularly those that have low transmissivities. TBAs which require further governance intervention by Member States are:

- Karoo sedimentary aquifer (AF1);
- Stampriet Aquifer System (AF5);
- Khakhea/Bray Dolomite (AF6);
- Zeerust / Lobatse / Ramotswa Dolomite Basin (AF7);
- Eastern Kalahari/ Karoo Basin (AF12); and
- Cuvelai and Etosha Basin / Ohangwena Aquifer (AF13).

There are initiatives underway to better understand the Stampriet Aquifer System (AF5) (UNESCO, 2016).

6.4 RECOMMENDATIONS

The following recommendations are made for uptake by the SADC-GMI:

- There is scope for further development of groundwater resources in SADC. Support programmes to characterise groundwater resource are needed to conduct:
 - Regional assessment of Karoo aquifers;
 - Regional assessment of Precambrian basement aquifers;
 - Regional assessment of Karst aquifers; and
 - Regional assessment of Porous-Intergranular aquifers.
- The SADC-GMI must develop a hydrogeological capacity building strategy and operational plan that coordinate training activities already taking place in the region and align this with sector needs. The opportunity to place interns in SADC countries must form part of the plan because of the lack of formal employment opportunities in the public sector.
- The SADC-HGM made a first attempt to establish a regional groundwater database. The development of a Regional Groundwater Monitoring Network and the associated Information Systems are priority.

- Diagnostic reports should be prepared for the following TBAs in line with the diagnostic report prepared for the Stampriet Aquifer System (AF5) :
 - Karoo sedimentary aquifer (AF1);
 - Khakhea/Bray Dolomite (AF6);
 - Zeerust / Lobatse / Ramotswa Dolomite Basin (AF7);
 - Eastern Kalahari/ Karoo Basin (AF12); and
 - Cuvelai and Etosha Basin / Ohangwena Aquifer (AF13)
- Further work is needed to understand and resolve the groundwater governance challenges in SADC.
- More work is critically needed to evaluate groundwater behaviour under different abstraction and climate scenarios and to evaluate groundwater pollution and remedial actions for sustainable groundwater use and management.

7. ACKNOWLEDGEMENTS

This position paper was commissioned by the SADC-GMI. The authors acknowledge Dr Roger Parsons for initiating and supporting this project. The position paper was presented at a workshop and input was provided by groundwater experts from Member States of SADC. The views and opinions expressed in this paper are those of the authors and do not necessarily reflect policies of the SADC and the SADC-GMI.

8. REFERENCES

8.1 PUBLICATIONS USED FOR POSITION PAPER

- AECOM 2015. Data Integrity Assessment Report. Pretoria: Department of Water and Sanitation.
- ALTCHENKO, Y. & VILLHOLTH, K. G. 2013. Transboundary aquifer mapping and management in Africa: a harmonised approach. *Hydrogeology Journal*, 21, 1497-1517.
- ATIBU, E. K., DEVARAJAN, N., LAFFITE, A., GIULIANI, G., SALUMU, J. A., MUTEBA, R. C., MULAJI, C. K., OTAMONGA, J.-P., ELONGO, V., MPIANA, P. T. & POTÉ, J. 2016. Assessment of trace metal and rare earth elements contamination in rivers around abandoned and active mine areas. The case of Lubumbashi River and Tshamilemba Canal, Katanga, Democratic Republic of the Congo. *Chemie der Erde - Geochemistry*.
- AZA-GNANDJI, C. D. R., XU, Y., RAITT, L. & LEVY, J. 2013. Salinity of irrigation water in the Philippi farming area of the Cape Flats, Cape Town, South Africa. *Water SA*, 39.
- BÄUMLE, R. & KANG'OMBA, S. 2013. Development of a Groundwater Information & Management Program for the Lusaka Groundwater Systems: Key recommendations and findings. Lusaka: Ministry of Mines, Energy and Water Development, Department of Water Affairs and Federal Institute for Geosciences and Natural Resources.
- BEEKMAN, H. & SUNGURO, S. 2015. Groundwater Management of the Nyamandlovu Aquifer System with special emphasis on the Nyamandlovu Wellfield : "Nyamandlovu Groundwater Model – Steady State" Harare, Zimbabwe: GIZ.
- BHATTACHARYA, P., LESAFI, F., FILEMON, R., LIGATE, F., IJUMULANA, J. & MTALO, F. 2016. Geogenic fluoride and arsenic contamination in the groundwater environments in Tanzania. *Geophysical Research Abstracts*, 18.
- BRAUNE, E. & ADAMS, S. 2013. Regional Diagnostic Report: Sub-Saharan Africa Region. Pretoria: Water Research Commission.
- CHRISTELIS, G. & STRUCKMEIER, W. 2011. Groundwater in Namibia: an explanation to the Hydrogeological Map. Windhoek, Namibia: Ministry of Agriculture, Water and Rural Development.
- COBBING, J. E., EALES, K., GIBSON, J., LENKOE, K. & COBBING, B. L. 2015. Operation and Maintenance (O&M) and the perceived unreliability of domestic groundwater supplies in South Africa. *South African Journal of Geology*, 118, 17-32.
- DAVIES, J., ROBINS, N. S., FARR, J., SORENSEN, J., BEETLESTONE, P. & COBBING, J. E. 2012. Identifying transboundary aquifers in need of international resource management in the Southern African Development Community region. *Hydrogeology Journal*, 21, 321-330.
- DERMAN, B. & PRABHAKARAN, P. 2016. Reflections on the formulation and implementation of IWRM in Southern Africa from a gender perspective. *Water Alternatives*, 9, 644-661.
- DIPPENNAAR, M. A. 2013. Hydrogeological Heritage Overview: Pretoria's Fountains – Arteries of Life. Pretoria, South Africa: Water Research Commission.
- DIXON-WOODS, M. 2011. Using framework-based synthesis for conducting reviews of qualitative studies. *BMC Medicine*, 9, 1-2.

- DÖLL, P. & FIEDLER, K. 2007. Global-scale modeling of groundwater recharge. *Hydrology and Earth System Sciences Discussions*, 4, 4069-4124.
- DWS 2016. National Groundwater Strategy Draft 4. Pretoria: Department of Water and Sanitation.
- ELISANTE, E. & MUZUKA, A. N. N. 2015. Occurrence of nitrate in Tanzanian groundwater aquifers: A review. *Applied Water Science*.
- FOSTER, S., GARDUNO, H., TUINHOF, A. & TOVEY, C. 2010. Groundwater Governance - conceptual framework for assessment of provisions and needs. Washington DC: World Bank.
- GALE, N. K., HEATH, G., CAMERON, E., RASHID, S. & REDWOOD, S. 2013. Using the framework method for the analysis of qualitative data in multi-disciplinary health research. *BMC Medical Research Methodology*, 13, 1-8.
- HSIEH, H. F. & SHANNON, S. E. 2005. Three approaches to qualitative content analysis. *Qual Health Res*, 15, 1277-88.
- IGRAC 2013. Groundwater Monitoring in the SADC Region Overview. International Groundwater Resources Assessment Centre.
- IGRAC 2015. Transboundary Aquifers of the World. International Groundwater Resources Assessment Centre [online]: http://www.groundwaterportal.org/sites/default/files/TBAmmap_2015.pdf ?
- JUÍZO, D. & MATSINHE, N. 2006. Water services in peri-urban areas of Maputo city with private sector participation. *7th WaterNet-WARFSA-GWP-SA Symposium*. Lilongwe, Malawi.
- KIRSHNER, J. & POWER, M. 2015. Mining and extractive urbanism: Postdevelopment in a Mozambican boomtown. *Geoforum*, 61, 67-78.
- KRUGMANN, H. & ALBERTS, M. 2012. Water demand in the Namibia part of CORB.
- LUSILAO-MAKIESE, J. G., TESSIER, E., AMOUREUX, D., TUTU, H., CHIMUKA, L., WEIERSBYE, I. & CUKROWSKA, E. M. 2016. Mercury speciation and dispersion from an active gold mine at the West Wits area, South Africa. *Environ Monit Assess*, 188, 47.
- MACY, P. 2010. Geology. In: PIETERSEN, K., KELLGREN, N., ROOS, M. & CHEVALLIER, L. (eds.) *Explanatory Brochure for the South African Development Community (SADC) Hydrogeological Map & Atlas*.
- MAHENGE, A. S. 2013. The study on ecological sanitation systems in Dar-es-Salaam (Tanzania). *International Journal of Development and Sustainability*, 2, 2256-2265.
- MATSUMOTO, S., SHIMADA, H. & SASAOKA, T. 2016. The Key Factor of Acid Mine Drainage (AMD) in the History of the Contribution of Mining Industry to the Prosperity of the United States and South Africa: A Review. *Natural Resources*, 07, 445-460.
- MCCARTHY, T. 2006. Groundwater in the wetlands of the Okavango Delta, Botswana, and its contribution to the structure and function of the ecosystem *Journal of Hydrology*, 264-282.
- MENGISTU, H., TESSEMA, A., ABIYE, T., DEMLIE, M. & LIN, H. 2015. Numerical modeling and environmental isotope methods in integrated mine-water management: a case study from the Witwatersrand basin, South Africa. *Hydrogeology Journal*, 23, 533-550.
- MUKUHLANI, T. & NYAMUPINGIDZA, M. T. 2014. Water Scarcity in Communities, Coping Strategies and Mitigation Measures: The Case of Bulawayo. *Journal of Sustainable Development*, 7.
- NHANTUMBO, C. M. C., LARSSON, R., JUÍZO, D. & LARSON, M. 2015. Key Issues for Water Quality Monitoring in the Zambezi River Basin in Mozambique in the Context of Mining Development. *Journal of Water Resource and Protection*, 07, 430-447.
- NUSSBAUMER, D., SUTTON, I. & PARKER, A. 2016. Groundwater Data Management by Water Service Providers in Peri-Urban Areas of Lusaka. *Water*, 8, 135.
- OUEDRAOGO, I. & VANCLOOSTER, M. 2016. A meta-analysis and statistical modelling of nitrates in groundwater at the African scale. *Hydrology and Earth System Sciences*, 20, 2353-2381.
- OWEN, R. 2011. Groundwater needs assessment: Limpopo Basin Commission (LIMCOM). Africa Groundwater Network (AGWNET).
- PARTOW, H. 2011. Water Issues in the Democratic Republic of the Congo: Challenges and Opportunities. Nairobi, Kenya: United Nations Environment Programme.
- PAVELIC, P., GIORDANO, M., KERAITA, B., RAMESH, V. & RAO, T. 2012. Groundwater availability and use in sub-Saharan Africa: a review of 15 countries. Sri Lanka: International Water Management Institute.
- PIETERSEN, K., KELLGREN, N., ROOS, M. & CHEVALLIER, L. 2010. Explanatory Brochure for the South African Development Community (SADC) Hydrogeological Map & Atlas. Southern African Development Community.
- PONCE, V. M. 2007. Sustainable yield of groundwater [Online]. Available: http://ponce.sdsu.edu/groundwater_sustainable_yield.html [Accessed 3 October 2016].
- POURRET, O., LANGE, B., BONHOURE, J., COLINET, G., DECREÉE, S., MAHY, G., SÉLECK, M., SHUTCHA, M. & FAUCON, M.-P. 2016. Assessment of soil metal distribution and environmental impact of mining in Katanga (Democratic Republic of Congo). *Applied Geochemistry*, 64, 43-55.
- REPUBLIC OF BOTSWANA 2016. Botswana Water Accounting Report 2014/15. Gaborone, Botswana: Ministry of Minerals, Energy and Water Resources.
- RIEDEL, C. & DÖLL, P. 2016. Global-scale modeling and quantification of indicators for assessing transboundary aquifers. Frankfurt, Germany: Institute of Physical Geography University of Frankfurt (Main).
- ROBINS, N., DAVIES, J. & FARR, J. 2013. Groundwater supply and demand from southern Africa's crystalline basement aquifer: evidence from Malawi. *Hydrogeology Journal*, 21, 905-917.
- RWIZA, M. J., KIM, K.-W. & KIM, S.-D. 2016. Geochemical Distribution of Trace Elements in Groundwater from the North Mara Large-Scale Gold Mining Area of Tanzania. *Groundwater Monitoring & Remediation*, 36, 83-93.
- SADC 2002. Revised Protocol on Shared Watercourses. In: COMMUNITY, S. A. D. (ed.). Botswana.
- SADC. 2014. *Director of the SADC-Groundwater Management Institute* [Online]. Gaborone, Botswana: Southern Development Community. Available: <http://www.sadc.int/opportunities/employment/employment-archive/director-sadc-groundwater-management-institute/> [Accessed 2 September 2016].
- SORENSEN, J. P., LAPWORTH, D. J., NKHUWA, D. C., STUART, M. E., GOODDY, D. C., BELL, R. A., CHIRWA, M., KABIKA, J., LIEMISA, M., CHIBESA, M. & PEDLEY, S. 2015. Emerging contaminants in urban groundwater sources in Africa. *Water Res*, 72, 51-63.
- SRIVASTAVA, A. & THOMSON, S. B. 2009. Framework Analysis: A Qualitative Methodology for Applied Policy Research. JOAAG, 4.
- STONE, A. E. C. & EDMUNDS, W. M. 2014. Naturally-high nitrate in unsaturated zone sand dunes above the Stampriet Basin, Namibia. *Journal of Arid Environments*, 105, 41-51.

- TAYLOR, R., KELBE, B., HALDORSEN, S., BOTH, G., WEJDEN, B., VAERET, L. & SIMONSEN, M. 2006. Groundwater-dependent ecology of the shoreline of the subtropical Lake St Lucia estuary *Environmental Geology*, 586-600.
- TREDoux, G., VAN DER MERWE, B. & PETERS, I. 2009. Artificial recharge of the Windhoek aquifer, Namibia: Water quality considerations. *Boletín Geológico y Minero*, 120, 269-278.
- UNESCO 2016. Stampriet Transboundary Aquifer System Assessment. Paris, France: International Hydrological Programme of the United Nations Educational, Scientific and Cultural Organization.
- VILLHOLTH, K. G., TØTTRUP, C., STENDEL, M. & MAHERRY, A. 2013. Integrated mapping of groundwater drought risk in the Southern African Development Community (SADC) region. *Hydrogeology Journal*, 21, 863-885.

8.2 KEY DATABASES AND PUBLICATIONS USED FOR SADC COUNTRY REPORTS

Key Databases

- BGS - Groundwater Grey Literature Archive:
<https://www.bgs.ac.uk/sadc/reportsearch.cfm>
 Africa Groundwater Atlas - Earthwise database
http://earthwise.bgs.ac.uk/index.php/Category:Africa_Groundwater_Atlas
- FAO - Aquastat general database:
<http://www.fao.org/nr/water/aquastat/data/query/index.html?lang=en>
 Aquastat dam database:
<http://www.fao.org/nr/water/aquastat/dams/index.stm>
- GEO3- Global Environment Outlook 3
 GEO3 data compendium:
http://geocompendium.grid.unep.ch/data_sets/freshwater/glob_freshwater_ds.htm
- HGM – SADC Hydrogeological Map and Borehole database
- JMP - Joint Monitoring Program on Water and Sanitation WHO-UNICEF
<http://www.wssinfo.org/data-estimates/tables/>
- WB - World Bank database:
<http://data.worldbank.org/indicator>

Key Publications

- BEEKMAN, H.E. AND SUNGURO, S. (eds.), 2008. Freshwater under Threat – Vulnerability assessment of freshwater resources to environmental change – Africa. UNEP-WRCDEW/1104/BA.
- BEEKMAN, H.E. 2010. Compilation of Groundwater Statistics and Data on the SADC Region. UNOPS. Executive summary.
- BEEKMAN, H.E. 2012. Compilation of baseline data and information on the SADC Water Sector - Support to the TWM in SADC Programme, GIZ.
- BRAUNE, E., HOLLINGWORTH, B., XU, Y., NEL, M., MAHED, G. & SOLOMON, H. 2008. Protocol for the Assessment of the Status of Sustainable Utilization and Management of Groundwater Resources with Special Reference to Southern Africa, TT318/08, WRC South Africa.
- DÖLL, P., AND FIEDLER, K., 2008, Global-Scale Modelling of Groundwater Recharge, *Hydrol. Earth Syst. Sci*, 12, 863-885.
- HOLLINGWORTH, BE AND CHIRAMBA, T. (eds), 2005. Implementing the SADC RSAP for IWRM (1999-2004): Lessons and Best Practice. SADC, GTZ, InWEnt.
- KANG'OMBA, S. & BÄUMLE, R. (eds.), 2013. Development of a Groundwater Information and Management Program for the Lusaka Groundwater Systems. Key Recommendations and Findings, Final Report.
- MOLAPO, P., PANDEY, S.K. & PUYOO, S., 2000. Groundwater Resource Management in the SADC Region: A Field of Regional Cooperation; IAH 2000 Conference, Cape Town
- PIETERSEN, K., KELLGREN, N., ROOS, M. & CHEVALLIER, L. 2010. Explanatory Brochure for the South African Development Community (SADC) Hydrogeological Map & Atlas. Southern African Development Community.
- PONCE, V.M., 2007. Groundwater sustainability and utilization. http://ponce.sdsu.edu/groundwater_sustainable_yield.html
- SADC, 2001. Development of a Code of Good Practice for Groundwater Development in the SADC Region. Situation Analysis Report. Final Report 1, Groundwater Consultants (Lesotho), including country reports.
- SADC, 2003 – Regional situation analysis, RFP # WB 1861-571/02, Draft Final Report, 2003. Wellfield Consulting Services Pty Ltd & British Geological Survey.

ANGOLA



INTRODUCTION

Angola, situated in the western part of southern Africa, covers an area of 1 246 700 km². It is bounded to the west by the Atlantic Ocean, the Democratic Republic of Congo (DRC) to the northeast; Zambia to the west and Namibia to the south. The topography changes from west to east from a low coastal plain, extending inland between 50 to 200 km, through a mountainous ridge with the highest mountain of the country of 2 620 m, to a plateau with elevations between 1 000 to 2 000 m. The total population amounts to 25 021 974 with an urban population of 44 per cent and rural population of 56 per cent. The population density is 20 inhabitants per square kilometre (inhab. /km²).

The majority of the country receives good rainfall in excess of 1 000 mm, mainly between September and May. The coastal region and the southeast receive considerably less rainfall, generally less than 600 mm. The extreme southwest of Namibe Province is a true desert with little to no rainfall. The average annual rainfall amounts to 1 010 mm.

WATER MANAGEMENT

Water resources

Surface water

Angola is endowed with substantial surface water resources, with all the major rivers (apart from the Zaire and Chilungo of Cabinda) originating within the country. The majority of rivers rise in the mountainous coastal ridge, with those flowing into the Atlantic being relatively short and those flowing east and north forming longer systems (Cubango and Cuando). The Kunene River forms the border with Namibia.

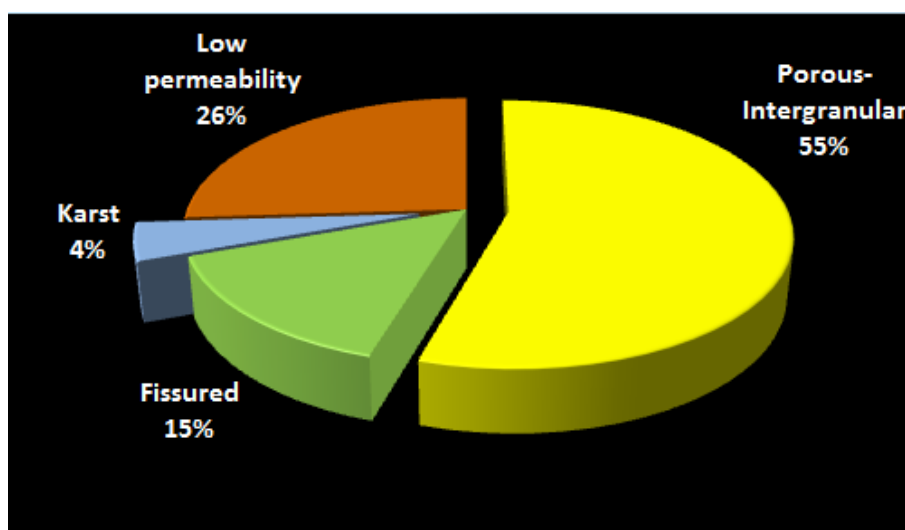
There are 11 major dams (>3 million m³) and the total dam capacity is 9 446 million m³. Angola shares 5 transboundary river basins: Cuvelai, Congo, Kunene, Okavango and Zambezi.

Groundwater

Angola can broadly be divided into three main hydrogeologic regions: eastern, highland and coastal belt. The eastern region of Angola covers approximately two thirds of the country and extends to the mountainous coastal ridge. It is mainly underlain by porous-intergranular, Tertiary to Recent continental deposits of the Kalahari Beds. Yields are commonly low to moderate (1 to more than 5 l/s). The bulk of development in this zone is in the southeastern part. The highland region is underlain predominantly by Precambrian granites as well as

ultrabasic rocks, with lesser sedimentary units in the northwest. Yields are generally low, mostly less than 5 l/s, but, locally yields can be as high as 50 l/s. The coastal belt is underlain primarily by sedimentary deposits, ranging from Carboniferous to Recent ages. The most consistently productive aquifers are present in this zone.

Groundwater availability is estimated at 23 per cent of the total water availability of 5 915 m³/capita/annum.



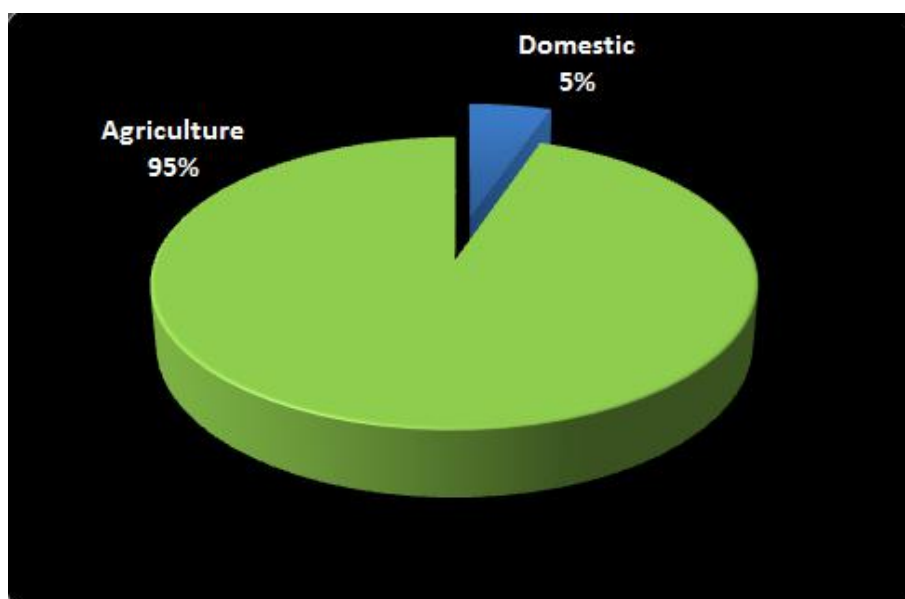
Groundwater occurrence

Groundwater quality in Angola is mostly acceptable although chemical analysis is not conducted regularly, especially in rural areas. Some of the coastal sedimentary formations have a high degree of mineralisation. Although not presently monitored or evaluated, there has been a reported decline in water quality in the coastal portion of Namibe Province, most likely related to salt water intrusion. Other urban and rural water supply schemes using groundwater in the coastal belt have no reported salt-water intrusion at present.

Angola shares 6 transboundary aquifers: Northern Kalahari / Karoo Basin / Eiseb Graben Aquifer (AF10), Cuvelai and Etiosa Basin / Ohangwena Aquifer System (AFS 13), Coastal Sedimentary Basin IV (AF15), Coango (AF23), Dolomitic Basin (AF27) and Aquifere Cotier (AF81).

Water use and water access

The total water use is 2 474 million m³/annum; only 1.4 per cent is from groundwater. The agricultural sector (incl. irrigation) is the largest water user with 95 per cent followed by the domestic (5 per cent) sector. Groundwater use is only a fraction (0.1 per cent) of the total available groundwater resources which leaves tremendous scope for further development.



Sectoral water use

75 per cent of the urban population has access to an improved drinking water supply; 72 per cent of the rural population, however, has no access to an improved drinking water supply and groundwater could play a key role in addressing the urgent water needs.

WATER GOVERNANCE

Formal institutional environment: water law and policy

- Water Act (Law 6/2002)
- Environment Act (Law 5/1998) and Environment Impact Assessment Regulations (Decree 51/2004)
- Water and Biological Resources Act (Law 6-A/2004)
- Land Act (Law 9/2004)
- Town and Country Planning Act (Law 3/2004)
- Corporate Public Law (Law 9/1995) and Regulations (Decree 8/2002)

Institutional arrangements

- The Ministry of Energy and Water (MINEA) was dissolved in 2008 and transformed into the Ministry of Energy and the State Secretariat of Water (SEA). SEA is responsible for water policy development, planning, promotion, coordination, supervision and control of activities related to general use and utilisation of national and transboundary shared water resources as well as activities related to water supply and sanitation
- Department of Energy
- Ministry of Town Planning and Housing
- Department of National Governance (MAT)

- Ministry of Agriculture and the State Secretariat for Rural Development
- Ministry of Health (MINSA)
- Ministry of Environment
- Ministry of Building Works of Public Services (MINOP)
- Ministry of Finance (MINFIN)
- Provincial Governments and Local Authorities
- With regards to transboundary river basins, only the Kunene River has a formal administrative unit: the "Office for the administration of the Kunene River Basin area" (Gabinete para a Administração da Bacia Hidrográfica do Cunene, GABHIC). In the context of international cooperation with Namibia the "Permanent Joint Technical Commission" (PJTC) advises on the sharing of the river's potential. The Office is also responsible for the Cubango River Basin

Information management

- Groundwater information for much of the country is sparse, resulting in considerable uncertainty in terms of hydrogeologic conditions especially for the eastern areas
- The National Water Directorate (DNA) is in the process of setting up an up-to-date database on water supply and sanitation. The project is supported by UNICEF with funding from the European Union. There is a hydrogeological map at the scale of 1:1 500 000 of 1990

Hydrogeological capacity and training

- Only few Angolans have hydrological/hydrogeological qualification
- Groundwater education: there is no academic institution in the country with a full hydrogeology curriculum
- Other resources: water service providers are being established.
 - In Luanda, the company EPAL EP is responsible for water treatment and water distribution in the entire town
 - In Luanda South region this is done by the company EDURB
 - In the cities of Benguela, Lobito and Huambo, water supply is in the hands of institutions that have corporate structures but which are not constituted yet as public law companies
 - For the towns of Cabinda, Malanje, N'Dalatando, Ondjiva, Kuito, Lubango and Uíge, the establishment of water service providers is nearing completion. This task is currently carried out at provincial level by the provincial directorate for energy and water
 - In the peri-urban and rural areas there are countless activities in the field of water supply by private water vendors
 - In addition there are local groups that organise the water supply locally, and projects from non-governmental organisations, which make a significant contribution to the water supply

KEY CHALLENGES AND OPPORTUNITIES

- There is tremendous scope for further development of groundwater resources as only a fraction (0.1 per cent) of available groundwater resources is used
- There is an urgent need to clear the backlog of water supply, especially in rural areas
- The institutional framework of the water sector is weak and is undergoing transformations. There is need for:
 - Professional staff: hydrologists and hydrogeologists at MSc level, water resources managers and management support staff
 - Rehabilitation of the hydrometric network and infrastructure
 - Establishment of river basin management boards for the Zambezi Cubango, Kwanza, Cuvelai, Congo and Cuanza-Dante river basins
 - Establishment of the National water resources institute
 - Approval of various regulation and policy such as: water supply regulation, water resources utilisation, national water resources institute regulation national water resources fund, national water resources board
- The strong economic growth of Angola that is seeing massive development, reconstruction and expansion of infrastructure, as well as institutional development particularly in the water sector (water and waste disposal firms) in all provinces creates strong investment opportunities. The master plans for 16 provincial capitals (exceptions are Luanda and Benguela, which account for 50 per cent of the urban population) describe the need for investment in the region of 1 300 million US \$, with the aim to increase water supply of the urban population from 30 to 105 litres per capita per day. Furthermore, borehole construction and rehabilitation of small water supply and disposal systems in rural communities also provide business opportunities.

BOTSWANA



INTRODUCTION

Botswana is centrally located within southern Africa, primarily on the Central African Plateau. The southern, eastern and a portion of the northern borders of Botswana are formed by rivers: the Molopo, Limpopo and Chobe Rivers and a large wetland: the Okavango Delta is present in the northwest of the country. The majority of the country is characterized by flat savannah and is devoid of major mountains, although more hilly country is present along the eastern border. The total population amounts to 2 262 485 with an urban population of 57 per cent and a rural population of 43 per cent. The population density is 4 inhab./km².

The climate of Botswana is generally semi-arid with rainfall ranging from 250 mm/annum in the southwest to 550 mm/annum in the east up to a maximum of 690 mm/annum in Kasane (north). The average annual rainfall amounts to 416 mm.

WATER MANAGEMENT

Water resources

Surface water

Botswana has relatively limited surface water resources, with major rivers developed only in the eastern and northern regions. The total estimated annual runoff for the country is 705 million m³ or 1.2 mm which is extremely small compared to other countries with a similar climate (e.g. Australia).

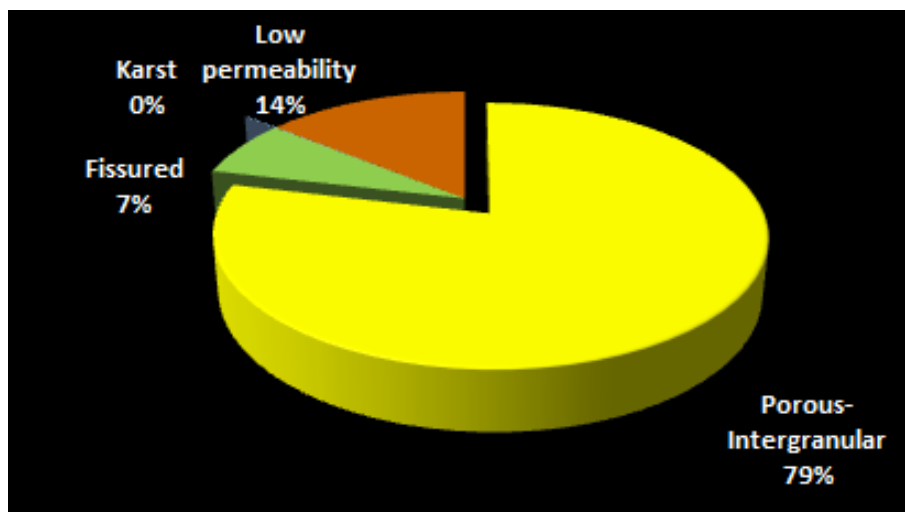
There are 5 major dams (>3 million m³) and the total dam capacity is 447 million m³. Botswana shares 4 transboundary river basins: Limpopo, Okavango, Orange-Senqu and Zambezi.

Groundwater

The geology of Botswana is characterized by a complex association of Archean and Proterozoic cratons overlain by Mesozoic volcano-sedimentary sequences (Karoo Supergroup). These units have been intruded extensively by dykes and sills, including a major dyke swarm in the north of the country and kimberlite pipes. These intrusives are of Triassic to Cretaceous age. Mantling most of the central and western sections of the country is a sedimentary sequence of sand, calcrete, silcrete and clays informally grouped as the Kalahari Beds. The Kalahari Beds occur along an extended belt covering South Africa, Namibia, Zimbabwe, Zambia, Angola and the DRC. In Botswana, the Kalahari Beds attain a thickness of more than 500 m in the northwest of the country.

The majority of the country (79 per cent) is underlain by a sedimentary sequence of porous and intergranular deposits. The Kalahari Beds which form part of this sedimentary sequence also extend into South Africa, Namibia, Zimbabwe, Zambia, Angola and the DRC. The mean blow yield of boreholes in the porous and intergranular deposits is 6.4 l/s. Low permeability rocks cover 14 per cent of the total surface area and boreholes have a mean blow yield of 9.2 l/s. Fissured rocks cover 7 per cent of the total surface area and boreholes have a mean blow yield of 5.7 l/s. The coverage of Karst is less than 0.1 per cent of the total surface area.

Groundwater availability is estimated at 20 per cent of the total water availability of 5 410 m³/capita/annum.



Groundwater occurrence

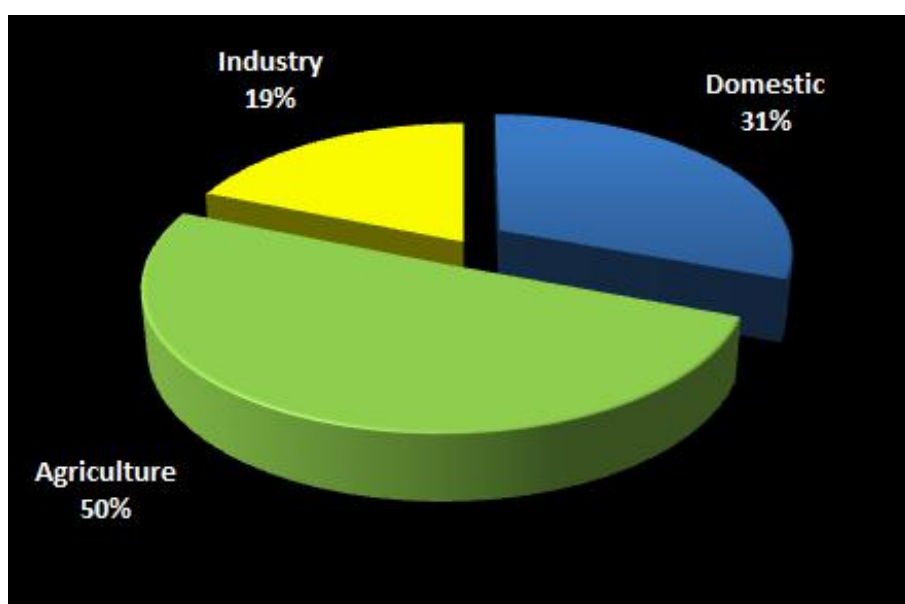
Groundwater quality is highly variable, reflecting the diversity of hydrogeological environments and rainfall-recharge conditions across the country. Groundwater quality over large areas, such as in the southwest of the country, does not meet drinking water standards due to high total dissolved solids (TDS). TDS values vary from < 100 mg/l in basement aquifers to > 60,000 mg/l in brines, which are developed for salt and alkali production. Elevated nitrate and fluoride concentrations in groundwater are reported in a number of locations. High iron content is also occasionally reported, particularly in shallow alluvial aquifers.

Botswana shares 8 transboundary aquifers: Stampriet Artesian Aquifer (AF5), Ncojane Basin (AF71), Khakhea/Bray Dolomite (AF6), Zeerust / Lobatse / Ramotswa Dolomite Basin Aquifer (AF7), Tuli Karoo Sub-Basin (AF9), Northern Kalahari / Karoo Basin / Eiseb Graben Aquifer (AF10), Eastern Kalahari/Karoo Basin (AF12) and Nata Karoo Sub-basin / Caprivi deep-seated Aquifer (AF14).

Water use and water access

Groundwater resources have in the past and continue to play a critical role in water supply. The government takes an active role in developing and managing the resource. Groundwater supply for large towns such as Maun, Tsabong, Jwaneng, Ghanzi and Serowe is provided from wellfields. The Palla Road and Lobatse Wellfields are reserved for emergency supply to the North-South Carrier and the Lobatse Township, respectively. Water supply to the diamond mines at Jwaneng and Orapa is met from wellfields developed for this purpose.

The total water use is 119 million m³/annum; about 64 per cent is from groundwater. The agricultural sector (incl. irrigation) is the largest water user with 50 per cent followed by the domestic (31 per cent) and industry (incl. mining: 19 per cent) sectors. Groundwater use is only 3 per cent of the total available groundwater resources which leaves an opportunity for further development.



Sectoral water use

99 per cent of the urban population has access to an improved drinking water supply; only 8 per cent of the rural population has no access to an improved drinking water supply.

WATER GOVERNANCE

Formal institutional environment: water law and policy

- Water Act, 1968 [and relevant Regulations: Water Regulations, 1976; consolidated version 2008]
- Boreholes Act, 1956 [consolidated version 2008]
- Waterworks Act, 1962 and relevant Regulations [consolidated version 2008]
- Water Utilities Corporation Act, 1970

- National Development Plan 9 (2003/4 – 2008/9) Chapter 9: Water Resources
- National Water Master Plan, 1992
- Botswana National Conservation Strategy; Government Paper No 1 of 1990

Institutional arrangements

- Ministry of Mineral Resources and Water Affairs: coordinate activities related to water and mineral exploration, exploitation and management
- Department of Water Affairs (DWA): providing drinking water to all villages and towns (including groundwater exploration, development and management)
- Department of Geological Survey (DGS): regional scale exploration and resource assessment based on long term development and management plans
- Water Apportionment Board: award water rights to various users
- The government established the Water Utilities Corporation (WUC) in 1970 which is responsible for supplying water to mostly urban areas (mainly using surface water from dams)
- The Joint Permanent Water Commission (JPWC) between Botswana and Namibia (1990)

Information management

- Groundwater resources investigations have over the years received attention with the assistance of international donors
- There are various groundwater databases, such as NIGIS, GEO-DIN, AquaChem, WellMon, etc. The existing hydrogeological map is at a scale of 1:1 000 000 of 1987
- Technical software for processing data is available, e.g. for groundwater modelling, pumping test analysis, hydrochemical analysis, GIS, etc.

Hydrogeological capacity and training

- 3 formally trained hydrogeologists at the DGS, 1 at the WUC and 3 at the Department of Geology of the UB and several geosciences technicians
- Groundwater education: Department of Geology of the University of Botswana has a Master of Science Degree Programme in Hydrogeology
- Other resources: several groundwater exploration and drilling companies.

KEY CHALLENGES AND OPPORTUNITIES

- There is room for further development of groundwater resources: only a fraction, 3 per cent, of available groundwater resources is used. The institutional transformation of Botswana's water sector could provide many investment opportunities
- The hydrogeological capacity in both private and public sectors is reasonable. There is still need, however, for additional qualified hydrogeologists at MSc level to strengthen government institutions (DWA, DGS) due to the high staff turnover

- There is uncertainty in the quality of groundwater data, especially with regards to older data

DEMOCRATIC REPUBLIC OF CONGO (DRC)



INTRODUCTION

The DRC is the largest and most northern member state of the SADC. The country extends across the Congo River basin, which is part of the large central depression that opens in the west towards the Atlantic Ocean. The highest elevations (~5 000 m amsl) are in the east of the country, along the Virunga and Ruwenzori volcanic mountains that form the western boundary of the Rift Valley. The total population amounts to 77 266 814 with an urban population of 42 per cent and a rural population of 58 per cent. The population density is 33 inhab. /km².

The DRC has an equatorial climate with high temperatures and rainfall. In the south-east, rainfall occurs only in the wet season and amounts to 1 250 mm/annum. In the eastern mountain ranges rainfall varies between 1 500 mm/annum to 2 500 mm/annum. The average annual rainfall amounts to 1 543 mm.

WATER MANAGEMENT

Water resources

Surface water

With an average flow rate of 39 000 m³/sec (minimum: 23 000 m³/sec, maximum: 80 000 m³/sec) the Congo River has the largest surface water flow in the world. Surface water is mainly used for the generation of electricity (hydropower).

There are 2 major dams (>3 million m³) and the total dam capacity is 53 million m³. DRC shares 2 transboundary river basins: Congo and Nile.

Groundwater

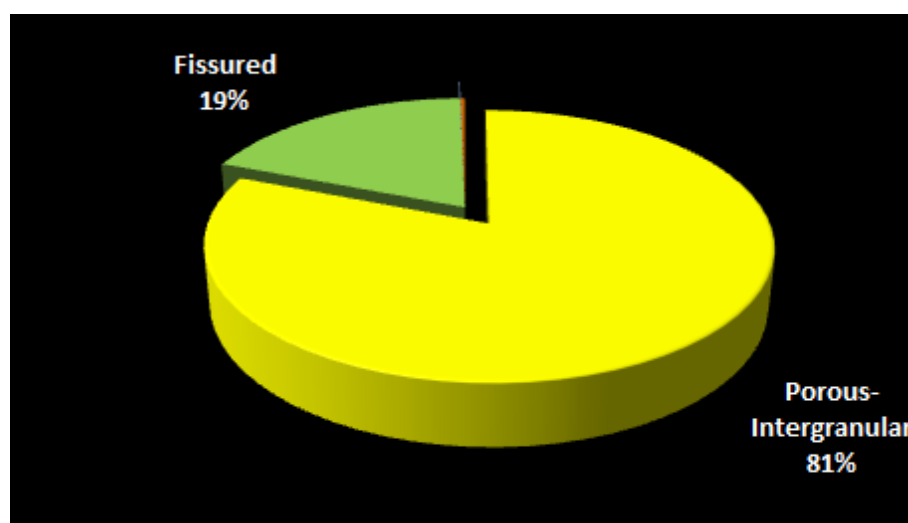
The DRC forms part of the Congo craton, which, together with the Kalahari craton, comprised part of the Gondwana Continent. The DRC territory is underlain by Precambrian metamorphosed sedimentary formations. Uplift, associated with the Cretaceous Rift Valley tectonics and volcanism, resulted in the formation of a closed in-land lake and the subsequent deposition of alluvial and lacustrine sediments. Recent volcanic deposits are associated with the eastern mountains of Virunga and Ruwenzori.

The majority of the country (81 per cent) is underlain by porous and intergranular sedimentary aquifers (Cretaceous; in the south of the central basin) and unconsolidated alluvial aquifers (Recent). The volume of groundwater in these aquifers is considered the

largest in the SADC region. Fissured crystalline basement aquifers (Precambrian) occur mainly in the high relief zone in the east and cover 19 per cent of the total surface area. The coverage of Karst and other Low permeability rocks is very small compared to the porous and intergranular deposits and fissured rock coverages.

Groundwater availability is estimated at 12 per cent of the total water availability of 16 605 m³/capita/annum.

Groundwater quality is generally acceptable for drinking water although in mountainous areas (eastern highland region), high EC values are associated with elevated levels of groundwater mineralisation. Isolated cases of high nitrate and fluoride do occur.

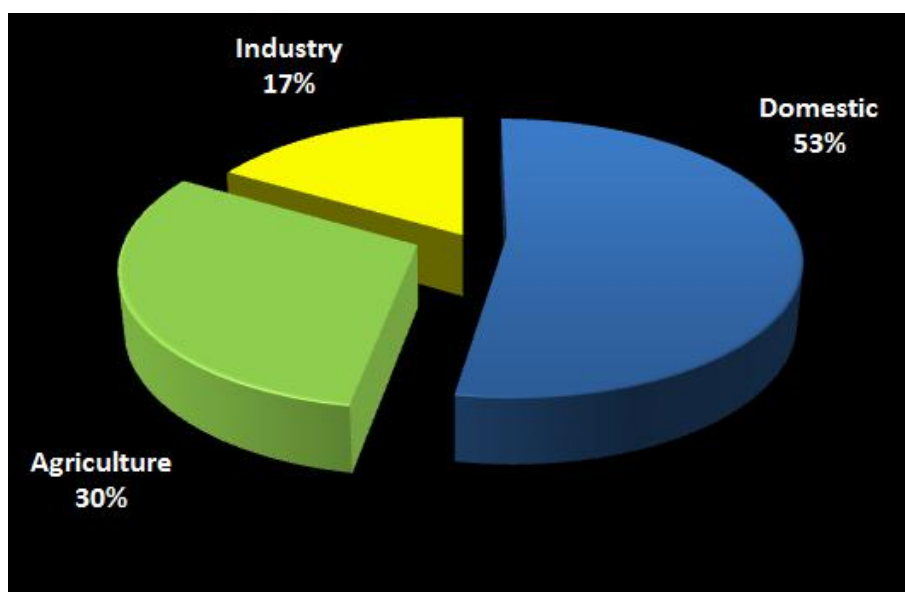


Groundwater occurrence

The DRC shares 5 transboundary aquifers: Kalahari/ Katangian Basin/ Lualaba (AF22), Coango (AF23), Tanganyika aquifer (AF26), Dolomitic Basin (AF27), and Aquifere Cotier (AF81),

Water use and water access

The total water use is 360 million m³/annum; about 13 per cent is from groundwater. The domestic sector is the largest water user with 53 per cent followed by the agricultural (incl. irrigation: 30 per cent) and industry (incl. mining: 17 per cent) sectors. Groundwater use is fraction of the total available groundwater resources which leaves great opportunity for further development.



Sectoral water use

81 per cent of the urban population has access to an improved drinking water supply whereas 69 per cent of the rural population has no access to an improved drinking water supply.

WATER GOVERNANCE

Formal institutional environment: water law and policy

- Article 48 of the DRC's Constitution guarantees access to drinking water whereas Article 54 prohibits polluting inland waters or maritime spaces; it is considered a crime to discharge radioactive or other dangerous substances into inland waters or maritime spaces
- A comprehensive water management law geared towards national development goals was adopted in September 2010 and the government also formulated an action plan for the further development of the drinking water sector by 2020
- Two pioneering policies for drinking water supply and sanitation have been elaborated based on the water management law and the action plan

Institutional arrangements

- Ministry of Energy (MINE) – Department of Water and Hydrology (DEH): responsible for water supply to urban communities, ranging from potable water to the provision of hydro-electric power
- Ministry of Environment, Nature Conservation and Forestry (MECNE): responsible for water resource management and forestry
- Ministry of Health and National Water and Sanitation Committee (CNAEA): responsible for water and sanitation

- Ministry of Agriculture and Livestock with its Directorate of Agricultural Engineering and National Rural Water Service (SNHR): responsible for water supply to rural communities
- Ministry of Planning: responsible for the water distribution infrastructure and coordination of water resource planning
- Ministry of Scientific Research: responsible for the research and analysis of groundwater through the institute of CRGM (Centre de Recherches Géologiques et Minières)
- Ministry of Transport: responsible for navigation
- National Company for Water Supply in Urban Areas (REGIDESO): controls and manages urban water supply
- National Sanitation Program (PNA)
- National Directorate of Hygiene (DNH)
- International Commission of the Congo-Oubangui-Sangha basin (CICOS)

Information management

- Groundwater information systems are basic (at REGIDESO and CNAEA: in MS-Excel) and there is a general lack of information on groundwater. The existing hydrogeological map is at a scale of 1:5 000 000 of 1957

Hydrogeological capacity and training

- There is inadequate hydrogeological capacity and training facilities;
- Other resources: there is insufficient drilling capacity

KEY CHALLENGES AND OPPORTUNITIES

- There is a general lack of information on groundwater in the DRC. Based on the information available, there is room for further development of groundwater resources to meet urgent demands as only a fraction of available groundwater resources is used. Increasing the contribution of groundwater to the urban water supply network would free more surface water for economical exploitation, e.g. for the industry in general and hydropower generation. Groundwater could also play a key role in clearing the backlog of water supply in rural areas
- The Congolese water sector, however, does not yet have a comprehensive policy or legal framework for water governance in place and lacks coordinated planning, functional governmental institutions, efficient water providers and well-qualified personnel
 - The institutional framework of DRC's Water Supply and Sanitation (WSS) sector is weak as result of overlapping jurisdictions, and technical, managerial and financial inadequacies. Sector activities are poorly coordinated and responsibilities are spread among at least twelve ministries and public bodies;

- The hydrogeological capacity in both private and public sectors is inadequate and there is need for additional qualified hydrogeologists at M.SC. level and geoscience technicians
- Water infrastructure is degraded or under-utilised
- The private sector is critically needed for expansion of services to meet DRC's overwhelming need for water access points and sanitation facilities. An area where investment is needed is the drilling of boreholes as there is insufficient drilling capacity in the country. Business opportunities do exist in the medium to long term. Note, however, that only 40 per cent of the required funding necessary to meet the DRC's water and sanitation goals is available through planned public investments each year

LESOTHO



INTRODUCTION

Lesotho is a mountainous, landlocked, country surrounded by the Republic of South Africa. The physiography comprises lowlands, along the Caledon River and in the Senqu river valley, highlands in the east and central parts of the country, and foothills that form a divide between the lowlands and the highlands. Lesotho is the only independent state in the world that lies entirely above 1 000 m in elevation; over 80 per cent lies above 1 800 m with the highest point at an elevation of 3 482 m. The total population amounts to 2 135 022 with an urban population of 27 per cent and a rural population of 73 per cent. The population density is 70 inhab. /km².

Lesotho has a continental climate, with hot summers and cold winters. The yearly precipitation varies from 600 mm in the lowland valleys to 1 200 mm in areas of the northern and eastern escarpment bordering South Africa. 85 per cent of the annual precipitation (including snow) falls from October to April. The average annual precipitation amounts to 788 mm.

WATER MANAGEMENT

Water resources

Surface water

The bulk of the water in Lesotho is surface water. Total availability of surface water resources is 170 m³/s, with much of the highland resources in the process of being developed through the Lesotho Highlands Development Authority (LHDA). The Lesotho Highland dams are developed primarily as a water transfer scheme for South Africa.

There are 4 major dams (>3 million m³) and the total dam capacity is 2 820 million m³. Lesotho shares 1 transboundary river basin: Orange-Senqu.

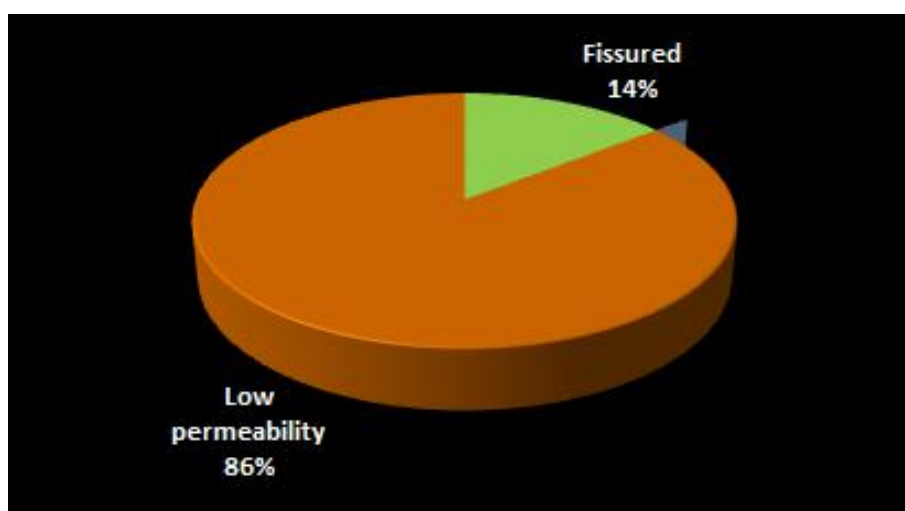
Groundwater

The geology of Lesotho is characterized by horizontally layered basalts (comprising approximately two thirds of the country) and underlying sedimentary formations of the Karoo Sequence. Structure is limited with only very gentle folding and limited faulting.

The majority of the country (86 per cent) is underlain by low permeability rocks and boreholes have a mean blow yield of 1.2 l/s. Fissured rocks cover 14 per cent of the total surface area and boreholes have a mean blow yield of 0.8 l/s.

Groundwater availability is estimated at 4 per cent of the total water availability of 1 415 m³/capita/annum.

Groundwater quality is generally good. TDS for borehole water averages 260 mg/l and for springs 112 mg/l. In some areas, however, high levels of fluoride can be measured (up to 15 mg/l).



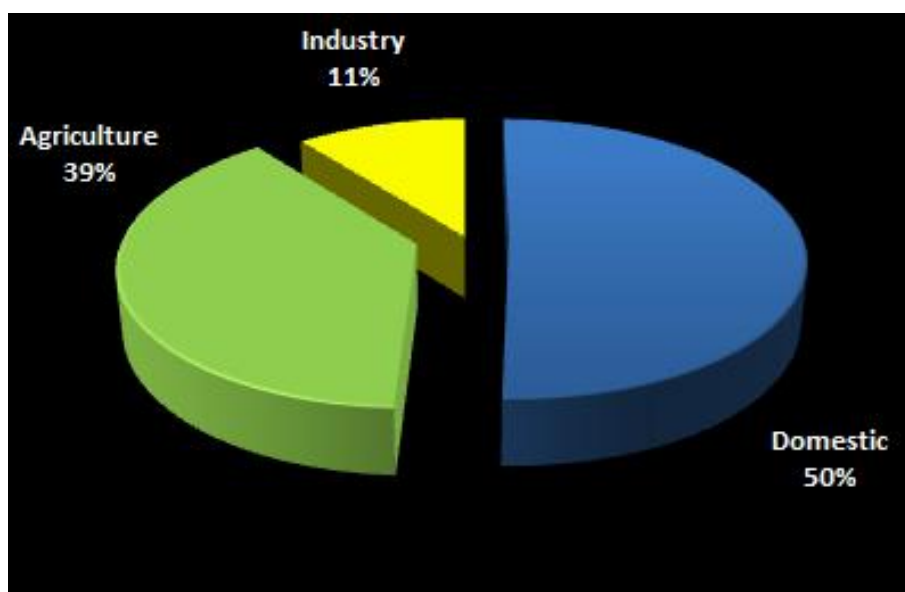
Groundwater occurrence

Lesotho has 1 transboundary aquifer: Karoo sedimentary aquifer (AF1).

Water use and water access

Groundwater from both springs and boreholes is the predominant source of supply to the rural areas. Groundwater also plays an important role in water supply to many urban centers, either through high capacity boreholes or through boreholes and wellpoints in alluvium. Particularly during the dry seasons and recurrent drought periods, groundwater provides an effective means of water supply. At present only two of the 16 urban centers are supplied entirely through surface water schemes (Maseru and Mafeteng).

The total water use is 37 million m³/annum; about 41 per cent is from groundwater. The domestic sector is the largest water user with 50 per cent followed by the agricultural sector (incl. irrigation: 39 per cent) and industry (incl. mining: 11 per cent) sectors. Groundwater use is 30 per cent of the total available groundwater resources which leaves an opportunity for further development.



Sectoral water use

95 per cent of the urban population has access to an improved drinking water supply; 23 per cent of the rural population has no access to an improved drinking water supply.

WATER GOVERNANCE

Formal institutional environment: water law and policy

- Lesotho Water Act, 2008 (No. 15 of 2008)
- Water Resources Regulations 1980
- Lesotho Highlands Development Authority Order 1986
- Lesotho Highlands Development Authority (Amendment) Act 2000
- Environment Act, 2008 (No. 10 of 2008)
- National Water Resources Management Policy 1999
- Lesotho Water and Sanitation Policy, 2007

Institutional arrangements

- The legal framework for the transformation of the water sector was established only when Lesotho's King Letsie III signed the new Water Act of 2008. The institutional framework for an efficient water sector is being established
- Ministry of Natural Resources: coordinates development and operational activities in the energy, water and minerals sector
- Department of Water Affairs (Incl. Groundwater Division): responsible for water sector administration, policy and data collection
- Department of Rural Water Supply: responsible for supply of water to rural communities

- Water Tribunal: to adjudicate over disputes arising under the Water Act or any other law in relation to or in connection with the management of water resources
- Local Authorities: responsible for developing and implementing catchment management plans for the protection and use of water resources in line with water and sanitation strategies
- Water and Sewerage Company (WASCO): takes care of water treatment and distribution. Note that the Water and Sewerage Authority (WASA) was transformed into WASCO

Information management

- Several groundwater investigations have been carried out over the years
- There are various groundwater databases, such as TAMS and Hydrocom in Dbase IV and MS Excel is also used for monitoring, pumping tests and drilling data. The existing hydrogeological map is at a scale of 1:300 000 of 1994

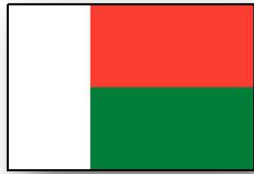
Hydrogeological capacity and training

- There is a shortage of well qualified hydrogeologists and geoscience technicians;
- Groundwater education: some training takes place at the Department of Geography of the National University of Lesotho
- Other resources: several groundwater exploration and drilling companies

KEY CHALLENGES AND OPPORTUNITIES

- There is room for further development of groundwater resources to clear the backlog in access to an improved drinking water supply for the rural population
- The extent and threat to groundwater contamination is an important issue, especially considering the shallow and fractured nature of aquifers
- The hydrogeological capacity in both private and public sectors is weak; there is need for additional qualified hydrogeologists and geoscience technicians
- A lot of development money goes to water infrastructure projects but there is limited funding for groundwater

MADAGASCAR



INTRODUCTION

Madagascar comprises a large main island in the Indian Ocean off the coast of southeast Africa and numerous smaller peripheral islands. Along the length of the eastern coast of the main island runs a narrow and steep escarpment with to the west in the center of the island a plateau ranging in altitude from 750 to 1 500 m amsl. Highest peaks rise up to 2 876 m amsl. These central highlands are the most densely populated part of the island. To the west of the highlands, increasingly arid terrain slopes down to the Indian Ocean. The total population amounts to 24 235 390 with an urban population of 35 per cent and a rural population of 65 per cent. The population density is 41 inhab. /km².

In Madagascar, the climate ranges from semi-arid to tropical forest conditions with less than 400 mm/a in the southwest to 3 000 mm/annum in the mountainous eastern part of the island. The country experiences extended dry seasons with periods of heavy rain. The island is affected by tropical storms or cyclones from November to May each year. The average annual rainfall amounts to 1 513 mm.

WATER MANAGEMENT

Water resources

Surface water

Madagascar can be divided into two major river basins - one draining to the west into the Mozambique Channel: the Anjobony River Basin and the other draining to the east into the Indian Ocean: the Antanambelana River Basin. Surface water is most abundant along the east coast and in the far north and is the main source for most of the economic activities. In the south and west some rivers are ephemeral.

There are 9 major dams (>3 million m³) and the total dam capacity is 493 million m³.

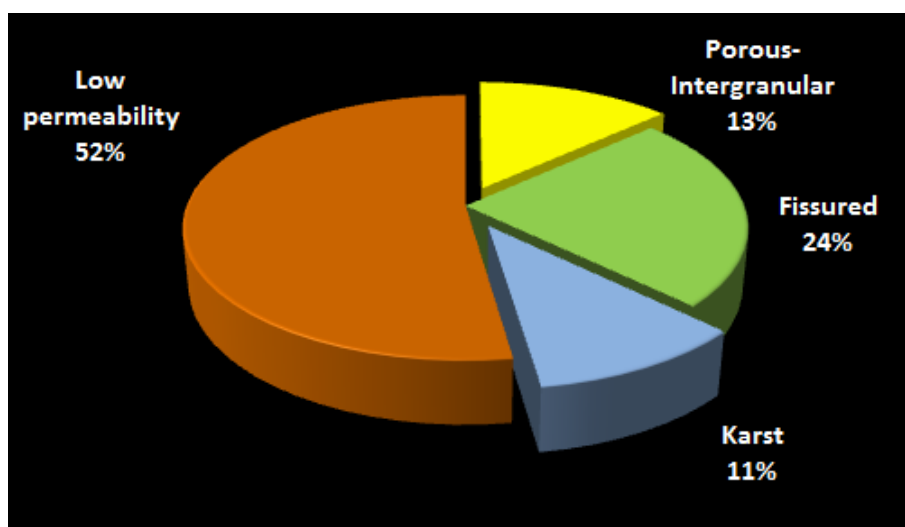
Groundwater

The geology of Madagascar comprises a variety of rocks of Precambrian age which make up the larger part of the east and centre of the Island. They are intruded by basalts and rhyolites of Mesozoic to Cenozoic age. The western part of the island is formed by sedimentary rocks of Carboniferous to Quaternary age.

The majority of the country (52 per cent) is underlain by low permeability sediments/rocks. The mean blow yield of boreholes in these sediments/rocks is 14 l/s. Fissured rocks cover 24 per cent of the total surface area and boreholes have a mean blow yield of 6.4 l/s.

Porous-intergranular sediments cover 13 per cent of the total surface area and Karst covers 11 per cent of the area. Boreholes in these deposits have a mean blow yield of 7.6 l/s and 8.6 l/s respectively.

Groundwater availability is estimated at 10 per cent of the total water availability of 13 905 m³/capita/annum.

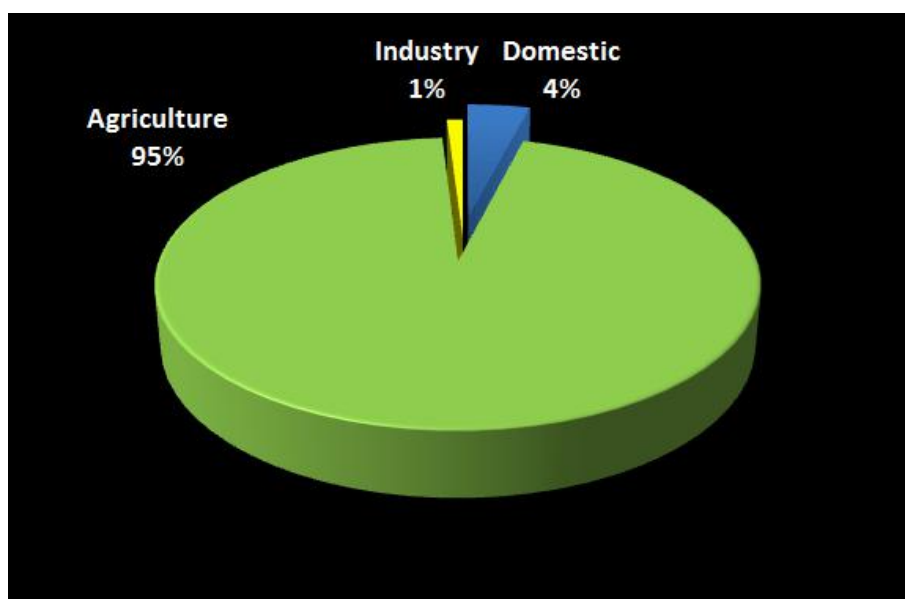


Groundwater occurrence

Groundwater quality varies considerably across the island and with depth, especially in the distinct sediment formations of the coastal basins. Groundwater is generally soft in the silicate rock types. Where carbonate rock types occur, groundwater is generally harder. Groundwater is typically fresh (low salinity) in the crystalline rocks and in areas away from the coast. Salinity is a particular problem in some of the coastal aquifers where affected by saline intrusion and by infiltration of salt water from near-coastal rivers. Little information is available with which to assess the pollution status of Madagascar's groundwaters, but surface water is noted to be polluted in places with raw sewage and other organic wastes.

Water use and water access

The total water use is 20 000 million m³/annum (S.J. Hamelo – Ministry of Water, Sanitation and Hygiene). The agricultural sector (incl. irrigation) is by far the largest water user with 95 per cent followed by the domestic (4 per cent) and industry (incl. mining: 1 per cent) sectors. 25% of the domestic water supply from 40 production centers is from groundwater, whereas 75% of the domestic water supply from 26 production centers is from surface water.



Sectoral water use

82 per cent of the urban population has access to an improved drinking water supply; 65 per cent of the rural population has no access to an improved drinking water supply.

WATER GOVERNANCE

Formal institutional environment: water law and policy

- Water Law (1999; Law No. 98-029 concerning the Water Code), and all related by-laws (by 2005)
- 13 regulations accompanying the Water Code
- Decree No. 2003-940 of 9 September 2003 on protection areas;
- Sanitation Policy (2006) and National Sanitation Strategy
- National Strategy for water, sanitation and hygiene: 2013-2018;
- Sanitation and Hygiene Sector Guidelines: 2015-2019

Institutional arrangements

- One of the most important changes of recent years was the creation of the Ministry of Water, Sanitation and Hygiene in 2008 with the key priority of access to drinking water for all. Institutions directly responsible to the ministry are:
 - L'APIPA (Protection Agency for the Flood Plain of Antananarivo)
 - Le SAMVA (Protection Agency for Autonomous Maintenance Service of the City of Antananarivo)
 - La JIRAMA (Jiro sy Rano Malagasy: responsible for electification and drinking water)
 - Le CNEAGR (National Center for Water and Sanitation of the Genie Rural)
 - L'ANDEA (National Authority for Water and Sanitation)

- L'AES (Water Supply in the South)
- L'OREA (Regulation Agency for Water and Sanitation; study phase of implementation. The Department of Sanitation (DA) provides services to the urban population in the areas of solid and liquid waste and excreta; the Directorate for the Promotion of Health (DPH) is responsible for the safety of the city and well-being of the population and coordination of players in terms of hygiene promotion; and the Directorate of Water Resources Management (DGRE) is responsible for the rational use of water resources and for drinking water supply
- Water services in urban areas are primarily provided by JIRAMA, while local community based service providers (Collectivites Decentralisees or CDs) and user associations provide water services in rural areas

Information management

- The first hydrogeological studies were carried out in 1910 and from 1929 the first synthesis on the geology of Madagascar was published which included information on groundwater. From 1960 and onwards, hydrogeological studies were systematically conducted by the Hydrogeology Department of the Ministry responsible for Geology, Mines and Energy in Madagascar, e.g. a study of groundwater resources for water supply of cities in Madagascar (1971) and studies in the more arid southern and western basins
- The first hydrogeological map of Madagascar was produced in 1972. As part of the geological mapping of the northern and central parts of Madagascar (BGS), a series of 7 hydrogeological reconnaissance maps at 1:500 000 scale were produced in 2008

Hydrogeological capacity and training

- Capacity building in various areas from planning to implementation and maintenance of infrastructure, service provision and training of young people forms part of the Department's strategy. There are academic institutions in the country providing training in the field of hydrogeology and hydrology whereas Malagasy students also obtain formal degrees abroad.
- There is hydrogeological capacity in Madagascar.

KEY CHALLENGES AND OPPORTUNITIES

- Except for hydrogeological maps and few reports there is a general lack of information on groundwater
- Madagascar's institutional framework is weak
- High poverty rates and poor functioning institutions increase vulnerability to the climatic hazards the country faces, including floods, droughts, cyclones, extreme temperatures and sea level rise
- Groundwater could play a role in clearing the backlog in access to an improved drinking water supply, especially in rural areas

- There is need for qualified hydrogeologists at MSc level to strengthen government institutions and private sector and there is need for further studies on the development of existing groundwater resources.

MALAWI



INTRODUCTION

Malawi is a landlocked country and bordered by the United Republic of Tanzania to the north and northeast, Mozambique to the east, south and southwest, and Zambia to the west. Its physiography is characterized by the highlands of Mulanje, Zomba and Dedza in the southern part of the country, the plateau in the central and northern regions, the rift valley escarpment and the rift valley plains along Lake Malawi, the Upper Shire and the Lower Shire Valleys. The total population amounts to 17 215 232 with an urban population of 16 per cent and a rural population of 84 per cent. The population density is 145 inhab./km².

The climate of Malawi is tropical continental and largely influenced by the huge water mass of Lake Malawi, which defines almost two thirds of Malawi's eastern border. There are two distinct seasons: the dry season from May to October and the rainy season from November to April. Annual rainfall in Malawi ranges from 700 to 2 400 mm with an average annual rainfall of 1 181 mm. Its distribution is mostly influenced by the topography and proximity to Lake Malawi.

WATER MANAGEMENT

Water resources

Surface water

Malawi has abundant water resources. There are two major drainage systems: the Lake Malawi system which is part of the Zambezi basin, with the Shire River as the only outlet of the Lake (note that ~91 per cent of the country is located in the Zambezi basin) and the Lake Chilwa system which is shared with Mozambique. Lake Chilwa is an endorheic basin draining rivers originating from the eastern slopes of the Shire Highlands, the Zomba Plateau and the northern slopes of the Mulanje Massif.

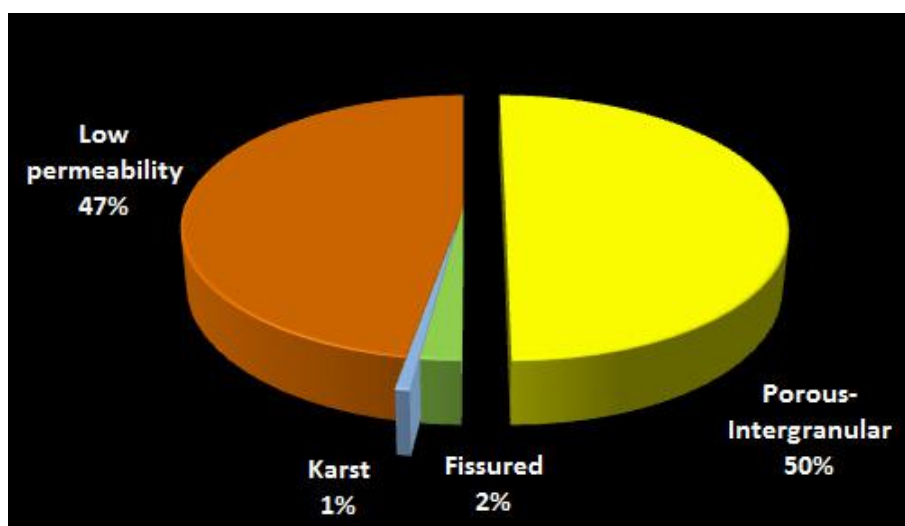
There are 6 major dams (>3 million m³) and the total dam capacity is 42 million m³. Malawi shares 2 transboundary river basins: Rovuma and Zambezi.

Groundwater

The majority of the country (50 per cent) is underlain by a sedimentary sequence of porous intergranular deposits: Quaternary alluvial aquifers that are situated along the lakeshore and the river flood plains which have yields up to 20 l/s. The mean blow yield of boreholes in these deposits is 0.7 l/s. Low permeability rocks cover 47 per cent of the total surface area and comprise Precambrian weathered basement rocks that occur on the low relief plateau

areas and at the base of the escarpments where a well-developed transition zone between the bedrock and the top argillite layer constitutes the main groundwater-bearing horizon. Yields are up to 2 l/s with a mean blow yield of 0.6 l/s. Fissured rocks cover 2 per cent of the total surface area with a mean blow yield of 0.5 l/s and Karst covers 1 per cent of the total surface area with boreholes having a mean blow yield of 1.1 l/s.

Groundwater availability is estimated at 17 per cent of the total water availability of 1 004 m³/capita/annum.



Groundwater occurrence

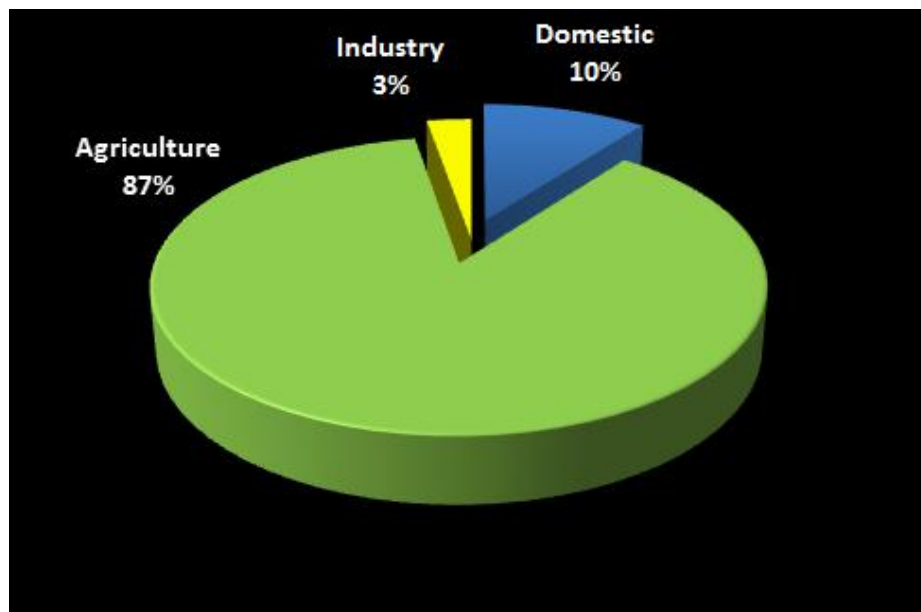
Groundwater quality is generally good with the exception of the following areas:

- In the Lilongwe West area there are high levels of Iron
- In the Nkhota Kota, Chiradzulou and Karonga areas there are high levels of Fluoride associated with extrusive igneous formations and alluvial formations. Fluoride in the alluvial formations is assumed to originate from the extrusive igneous formation associated with the rift
- High salinity levels in the south of Malawi in the Lower Shire area, Chowe, Chikwawa and Nsanje areas

Malawi shares 3 transboundary aquifers: Shire Valley Alluvial Aquifer (AF17), Sand and Gravel aquifer (AF19) and Weathered basement (AF24).

Water use and water access

The total water use is 1 161 million m³/annum; the contribution of groundwater to domestic water supply is 29 per cent. The agricultural sector (incl. irrigation) is the largest water user with 87 per cent followed by the domestic (10 per cent) and industry (incl. mining: 3 per cent) sectors.



Sectoral water use

96 per cent of the urban population has access to an improved drinking water supply; 11 per cent of the rural population has no access to an improved drinking water supply.

WATER GOVERNANCE

Formal institutional environment: water law and policy

- Water Works Act (No. 17 of 1995)
- Water Resources Act (1996)
- Irrigation Act (2001)
- National Water Policy (1996 & 2005)
- Environmental Management Policy (1996)
- Water Resources Management Policy and Strategies (2000)
- National Irrigation Policy and Development Strategy (2000)

Institutional arrangements

- Ministry of Irrigation and Water Development (MIWD) and Department of Water Resources (DWR): facilitates the development and management of water resources in the country and is responsible for ensuring access to safe water and related sanitation services, collection of hydrological data and catchment protection
- National Water Resources Board: an institution within the MIWD responsible for the granting of water rights for abstractions and discharge of effluents, as well as for monitoring the adherence to the water rights
- Department of Environmental Affairs: to ensure that the implementation of projects does not result in the degradation of the environment
- City and Regional Water Boards

Information management

- 1982-1988 marks the period of the production of the first comprehensive description of the groundwater resources of Malawi, volumes on rural groundwater supply and the production of a series of 1:250 000 scale hydrogeology maps covering the country (1987). From 1986 to 1989 BGS in collaboration with the DWR undertook a study of the groundwater resources and aquifer properties of weathered and fractured Basement. Specific studies were undertaken of the groundwater resources of dambo areas and the application of radial collector well systems to supply water for domestic use and small scale irrigation of gardens
- A project to input borehole information in a database has been running from 2002 to 2009, however in 2009 the hard drive of the computer was damaged and there is no backup of the data and information other than hardcopy data and information

Hydrogeological capacity and training

- There is inadequate hydrogeological capacity and financial resources and training needs are in the areas of GIS, Groundwater Modelling, Databases, Groundwater Engineering, Pumping Test Procedure and Analysis and Wellfield maintenance and Management
- Groundwater education: University of Malawi, Chancellor College - Department of Geography and Earth Sciences has a Masters programme in Integrated Water Resources Management in collaboration with Waternet with modules in Environmental Impact Assessment, Water Quality Management, and Environmental Water Requirements
- Other resources: several groundwater exploration and drilling companies

KEY CHALLENGES AND OPPORTUNITIES

- A major task in the coming years will be the further development of the institutional framework of Malawi's water sector to achieve greater efficiency
- There is room for further development of groundwater resources
- There is need for capacity building in specific hydrogeological topics and need for additional qualified hydrogeologists at MSc level and geosciences technicians to strengthen government institutions and private sector
- Capturing of hydrogeological data and information in a database, data processing and interpretation and report production for identified priority areas should be given high priority

MAURITIUS



INTRODUCTION

Mauritius is an Island country in the Indian Ocean. The republic includes the islands of Rodrigues, Agalega and the Chagos Archipelago. Mauritius is encircled by a broken ring of mountain ranges, varying in height from 300–800 m amsl. The land rises from coastal plains to a central plateau where it reaches a height of 670 m; the highest peak of 828 m is in the southwest. The total population amounts to 1 262 605 with an urban population of 40 per cent and a rural population of 60 per cent. The population density is 619 inhab./km².

The climate of Mauritius is sub-tropical to mild maritime with two seasons: a warm humid summer from December to April and a relatively cool dry winter from May to November. Occasional tropical cyclones occur between January and March. Most of the rainfall occurs in summer months. The north and west of the island are the driest regions of the island, with an annual precipitation of 1 200 mm and 900 mm respectively. The Central Plateau at an altitude of 500 m receives an annual average of 4 000 mm. The average annual rainfall amounts to 2 041 mm.

WATER MANAGEMENT

Water resources

Surface water

Most rivers of Mauritius are perennial, originating from the central plateau, and flow radially to the sea. Discharge to the sea is estimated to be 0.5 km³/annum.

There are 8 major dams (>3 million m³) and the total dam capacity is 93 million m³.

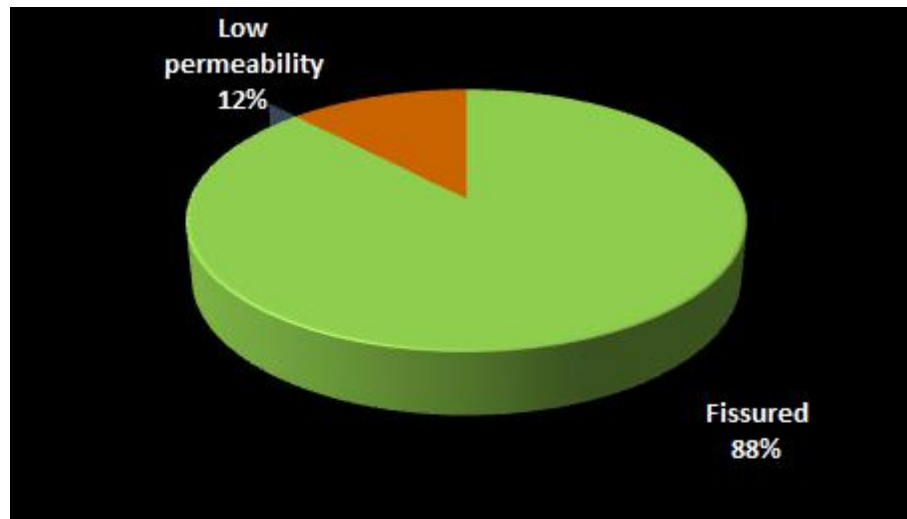
Groundwater

The island of Mauritius is relatively young geologically, having been created by volcanic activity some 8 million years ago (mainly basaltic rocks/lavas). It has emerged from the abysses as a result of gigantic underwater volcanic eruptions that happened thousands of kilometres to the east of the continental block made up of Africa and Madagascar.

The majority of the country (88 per cent) is underlain by fissured rocks. Low permeability rocks cover 12 per cent of the total surface area. The maximum recorded yield from a single borehole is 93 l/s (8 000 m³/d).

Groundwater availability is a very small fraction of the total water availability of 2 179 m³/capita/annum.

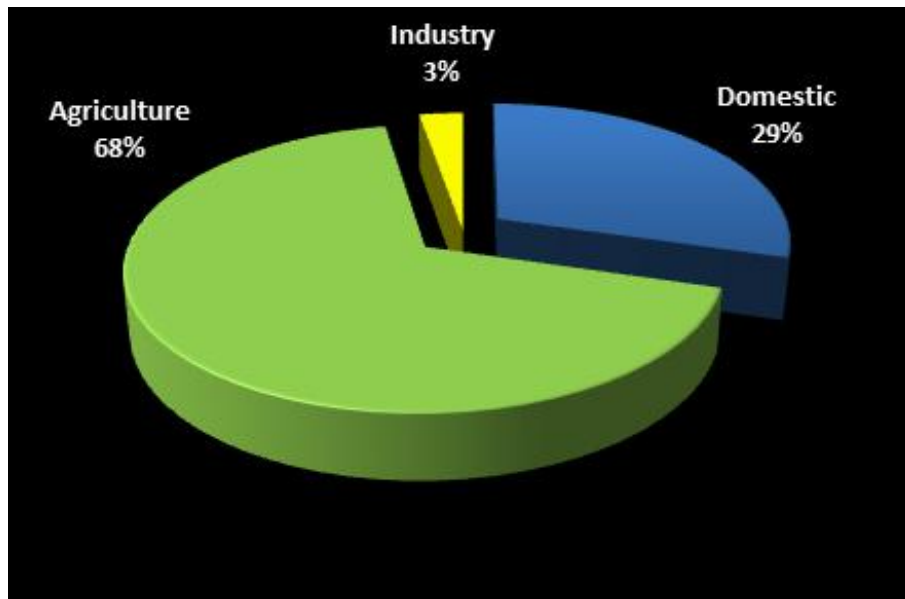
The quality of water resources in Mauritius is within the acceptable limits. Intensive agriculture and industrialisation, however, has led to pollution of water resources, especially within the coastal areas.



Groundwater occurrence

Water use and water access

The total water use is 725 million m³/annum; about 20 per cent is from groundwater. The agricultural sector (incl. irrigation) is the largest water user with 68 per cent followed by the domestic (29 per cent) and industry (3 per cent) sectors. Groundwater use is only 1.8 per cent of the total available groundwater resources which leaves an opportunity for further development.



Sectoral water use

100 per cent of the urban and rural population has access to an improved drinking water supply. Groundwater plays a key role in drinking water supply: in both urban and rural areas it contributes to almost half (46 per cent) of the water supply.

WATER GOVERNANCE

Formal institutional environment: water law and policy

- Environment Protection Act 2002
- Wastewater Management Authority Act 2000
- Irrigation Authority Act 1979
- Central Water Authority Act, 1971
- Ground Water Act, 1970
- Rivers and Canals Act, 1863
- Environment Protection (Amendment) Act 2008

Institutional arrangements

- The Central Water Authority (CWA) is responsible for the water supply in Mauritius and is placed in the Ministry of Renewable Energy & Public Utilities
- Six regional water boards answer to the CWA
- Water supply is separated from wastewater disposal for which the Waste Water Management Authority (WWMA) is responsible. The WWMA is placed in the Ministry of Renewable Energy & Public Utilities

Information management

- Mauritius has a good groundwater monitoring network which has been in existence for over 30 years. 350+ boreholes, spread over the country are monitored on a monthly basis for groundwater levels, abstraction rates and other basic physical and chemical parameters. Water sampling for water quality monitoring is carried out regularly for drinking water and pollution control and analyses are carried out by two qualified laboratories
- There is a computerised database and GIS (GEOLAB) and a hydrogeological map of the country at a scale of 1:50 000 of 2005

Hydrogeological capacity and training

- No information was found on the hydrogeological capacity in the private sector and government institutions
- Groundwater education: Department of Civil Engineering – University of Mauritius has course work and research projects in application of GIS in water resources and environment, water quality and groundwater modelling
- Other resources: several groundwater exploration and drilling companies

KEY CHALLENGES AND OPPORTUNITIES

- Long term pressure on water resources and meeting demand especially during periods of drought. Freshwater availability is expected to further decline in the coming years mainly due to rising demand as a result of growing population (and urbanisation) and expansion in tourism and other industrial sectors
- Threats to groundwater quality due to pollution from agrochemicals, waste and waste water disposal
- Degradation of water sheds and salt water intrusion from the sea – rising sea level due to climate change
- There is also the issue of water losses from domestic water distribution systems of over 50 per cent

MOZAMBIQUE



INTRODUCTION

Mozambique is bounded by Zimbabwe, Malawi and South Africa in the west, by Tanzania in the north, and South Africa and Swaziland in the south. Its physiography comprises a coastal belt: most of the areas south of the Save River and the lower Zambezi area, a middle plateau, ranging from 200 to 1 000 m in elevation, and a plateau and highland region with average elevations of around 1 000 m to the north of the Zambezi River. The total population amounts to 27 977 863 with an urban population of 32 per cent and a rural population of 68 per cent. The population density is 35 inhab. /km².

Mozambique has a tropical and sub-tropical type of climate with a dry season from April to October. Average annual rainfall decreases from 1 422 mm in the north to 762 mm in the south. There are extremely dry arid to semi-arid areas with average rainfall around 350 mm/a mostly in the interior of the Gaza and Inhambane provinces in the south. The average annual rainfall amounts to 1 032 mm.

WATER MANAGEMENT

Water resources

Surface water

Mozambique has abundant surface water resources. The mean annual runoff (MAR) is estimated to be 216 000 million m³ /annum. The Zambezi River Basin is the main source of runoff and contributes 50 per cent of the MAR.

There are 25 major dams (>3 million m³) and the total dam capacity is 79 730 million m³.

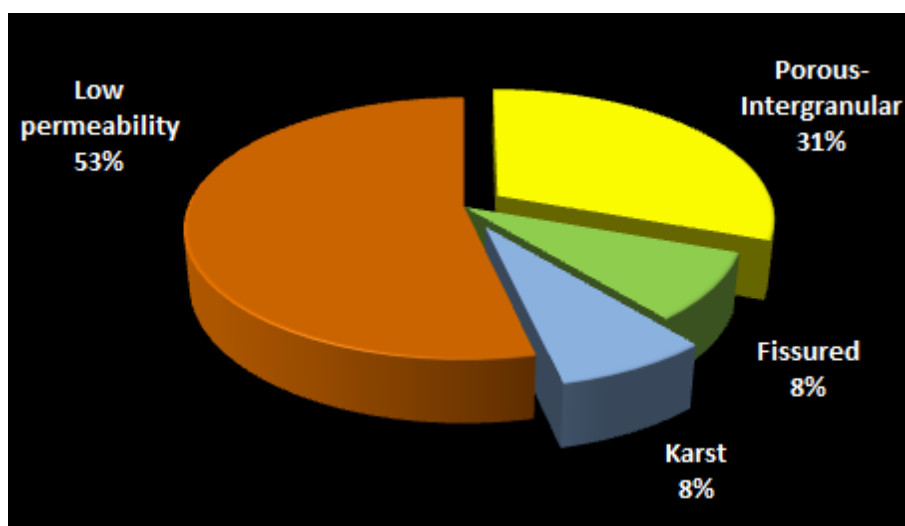
Mozambique shares 9 transboundary river basins: Buzi, Incomati, Limpopo, Maputo-Usutu-Pongola, Pungwe, Rovuma, Save, Umbeluzi and Zambezi.

Groundwater

Precambrian basement rocks underlie over half of Mozambique, mainly in the north and northwest of the country; Karoo sediments occur in small areas of north and northwestern Mozambique; Karoo volcanics are exposed in the Lebombo Mountains, close to the border with South Africa; and Mesozoic to Cenozoic sediments underlie large parts of southern and central Mozambique. The groundwater potential of Mozambique is considerable and lies mainly in the alluvial formations of the various rivers.

The majority of the country (53 per cent) is underlain by low permeability formations. The mean blow yield of boreholes in these formations is 1.2 l/s. Porous-intergranular deposits cover 31 per cent of the total surface area and boreholes have a mean blow yield of 2.6 l/s. Fissured rocks and Karst cover each 8 per cent of the total surface area and boreholes have a mean blow yield of 1.8 l/s and 1.4 l/s respectively.

Groundwater availability is estimated at 10 per cent of the total water availability of 7 760 m³/capita/annum.



Groundwater occurrence

The groundwater quality is generally good. Poor water quality (high salinity) is common in areas like the interior of Gaza and Inhambane which are more arid areas. High concentration of nitrates in the surroundings of Maputo can be found due to a high density of houses and pit latrines. Iron and manganese are reported to be a problem in a few alluvial aquifers. The most noted case is the Pemba Wellfield at Muaguide Valley, where high iron concentration is aggravated by iron bacteria activity which poses a serious engineering problem to wellfield operation. In some areas of coal exploitation, aquifers may be polluted by mining activities.

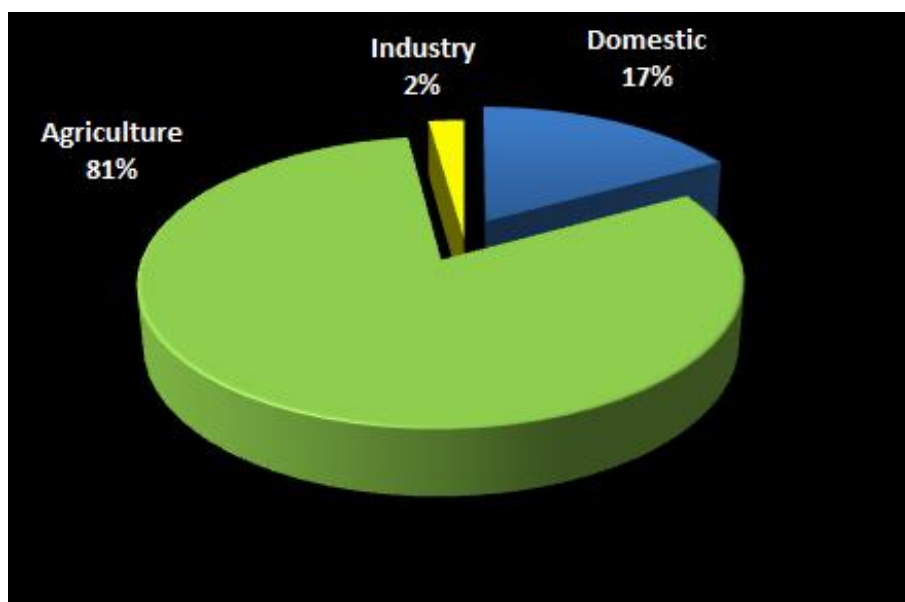
Mozambique shares 9 transboundary aquifers: Coastal Sedimentary basin VI / Coastal Plain Sedimentary Basin Aquifer (AF3), Rhyolite-Breccia aquifer (AF4), Limpopo basin (AF8), Save alluvial aquifer (AF11), Medium Zambezi aquifer (AF16), Shire Valley Alluvial Aquifer (AF17), Arangua Alluvial (AF18), Coastal Sedimentary Basin III (AF20) and Karoo-Sandstone aquifer (AF21).

Water use and water access

Groundwater is almost the only source of water supply for the rural population and is becoming increasingly important for the urban population. Two factors greatly hinder the use of groundwater. Firstly, almost 60 per cent of Mozambique is covered by crystalline rocks (where groundwater occurrence is limited to shallow weathered zones) and secondly, in

some areas of the southern and central regions, groundwater is highly mineralized. Agriculture relies mostly on surface water.

The total water use is 630 million m³/annum; groundwater contributes 34 per cent to the domestic water supply. The agricultural sector (incl. irrigation) is the largest water user with 81 per cent followed by the domestic (17 per cent) and industry (incl. mining: 2 per cent) sectors.



Sectoral water use

81 per cent of the urban population has access to an improved drinking water supply; 63 per cent of the rural population has still no access to an improved drinking water supply.

WATER GOVERNANCE

Formal institutional environment: water law and policy

- Law on Waters No. 16 of 3 August 1991 ("Ley de Aguas")
- National Irrigation Policy (2002)
- National Water Policy (2007; review of the National Water Policy of 1995)
- National Water Resource Management Strategy (2008)

Institutional arrangements

- National Water Council (NWC)
- National Directorate of Water (DNA) of the Ministry of Public Works and Housing (MoPWH): responsible for water supply, sanitation and water resources management

- Regional Water Administrations (ARAs): under DNA subordination with the mandate to promote a rational utilisation of water resources towards preservation of the environment and services satisfaction
- Establishment of River Basin Committees (e.g. Ruvuma Basin Committee)
- Since March 2009, the FIPAG (Fundo de Investimento e Património do Abastecimento de Água) is responsible for the water supply in several cities, e.g. Lichinga and Cuamba (both in the Niassa Province), and Nacala and Angoche (both in the Nampula Province)

Information management

- Groundwater resources investigations have over the years been carried out with the assistance of international donors
- A groundwater database is with the DNA with data and information up to 1990. The existing hydrogeological map is at a scale of 1:1 000 000 of 1987

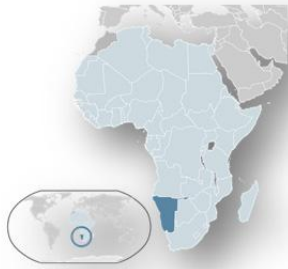
Hydrogeological capacity and training

- Hydrogeologists at MSc level have been trained generally overseas
- Groundwater education: Faculty of Sciences of the University Eduardo Mondlane in Maputo offers a postgraduate Master course in hydrogeology and water resources
- Other resources: several groundwater exploration and drilling companies

KEY CHALLENGES AND OPPORTUNITIES

- Since the water infrastructure in Mozambique is managed more strictly and efficiently through the FIPAG, investment opportunities are rising
- There is an urgent need for further development of groundwater resources to clear the backlog of access to improved drinking water supply, especially for the rural population
- There is also need for strengthening the hydrogeological capacity in both private and public sectors as well as strengthening the training capacity. Specific topics for training include drilling and borehole construction and post-graduate training in hydrogeology
- There is furthermore need to reduce flood and drought vulnerability

NAMIBIA



INTRODUCTION

Namibia shares its borders with Angola in the north, Zambia and Zimbabwe in the northeast, Botswana in the east and South Africa in the south. The physiography of Namibia comprises the Namib Desert along the entire Atlantic coast in the west which rises to an elevation of about 800 m at the foot of the escarpment in the east with mountains up to and in excess of 2 000 m altitude; a central plateau between very flat and mountainous terrain with altitudes between 1000 and 2000 m; to the north and northeast the semi-arid Kalahari Basin; and in the east the Kalahari Sandveld. Extensive wetlands occur along the Okavango, Zambezi and Kwando-Linyanti-Chobe river systems in the northeast. The total population amounts to 2 458 830 with an urban population of 47 per cent and a rural population of 53 per cent. The population density is 3 inhab. /km².

Namibia is the most arid country in Sub-Sahara Africa with annual rainfall ranging from less than 20 mm in the Namib Desert in the west to more than 700 mm in the eastern Caprivi region. The average annual rainfall amounts to 285 mm.

WATER MANAGEMENT

Water resources

Surface water

Namibia has relatively limited surface water resources, with perennial rivers developed along the borders: Kunene, Okavango, Zambezi and Kwando - Linyanti -Chobe in the north and the Orange River in the south. Internal rivers are ephemeral, flowing only for a short period after good rains and most of them flowing towards the Atlantic Ocean.

There are 15 major dams (>3 million m³) and the total dam capacity is 709 million m³. Namibia shares 5 transboundary river basins: Cuvelai, Kunene, Okavango, Orange-Senqu and Zambezi.

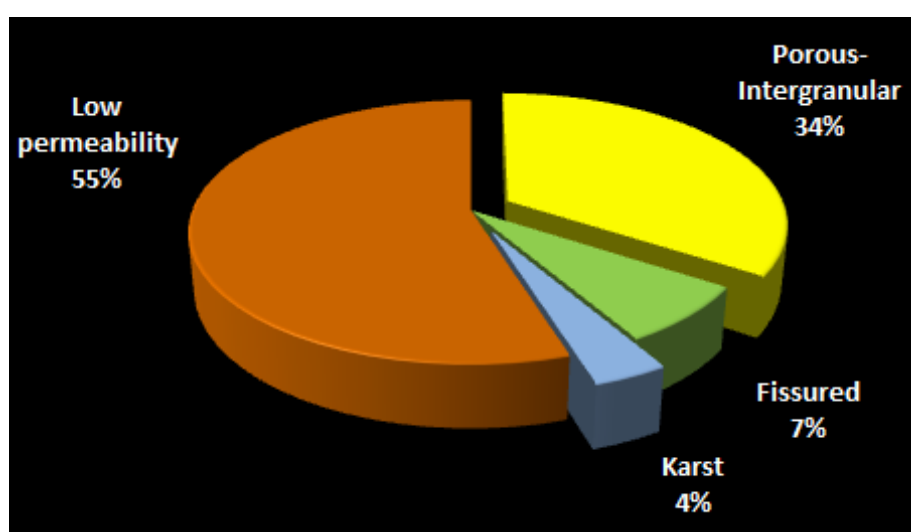
Groundwater

Namibia has very diverse geology, with rocks from Archaean to Cenozoic age. Bedrock is exposed at the ground surface across nearly half of the country, while the remainder, across the Kalahari and Namib Desert, is covered by unconsolidated superficial deposits. Aquifers (porous and fractured) underlie 42 per cent of the country and borehole yields exceed 4 l/s (15 m³/h) only over some 14,000 km² or 3 per cent of the total territory, making these highly

productive aquifers important targets for groundwater supply. Most of these areas have been declared groundwater control areas.

The majority of the country (55 per cent) is underlain by low permeability formations with a mean blow yield from boreholes of 1.6 l/s. Porous-intergranular sediments cover 34 per cent of the total surface area and boreholes have a mean blow yield of 2 l/s. Fissured rocks cover 7 per cent of the total surface area and boreholes have a mean blow yield of 1.7 l/s. The coverage of Karst is 4 per cent of the total surface area with a mean blow yield from boreholes of 3.5 l/s.

Groundwater availability is estimated at 11 per cent of the total water availability of 7 207 m³/capita/annum.



Groundwater occurrence

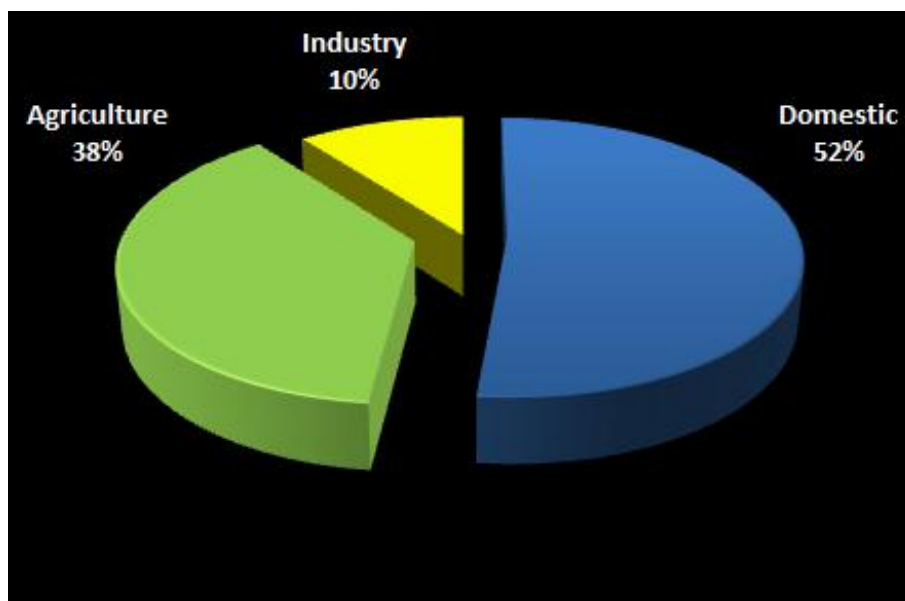
Natural groundwater quality in the country is very dependent on the area where it is found, mainly due the different rock types. There is little anthropogenic contamination of groundwater in general, but untreated waste water in some communities causes degradation of quality. There are some cases of increased nitrate concentration linked to cattle farming, and some natural occurrences of elevated nitrate. The main groundwater quality problem is naturally high TDS and fluoride.

Namibia shares 7 transboundary aquifers: Coastal Sedimentary basin V (AF2), Stampriet Artesian Aquifer (AF5), Ncojane Basin (AF71), Northern Kalahari / Karoo Basin / Eiseb Graben Aquifer (AF10), Cuvelai and Etosha Basin / Ohangwena Aquifer System (AF13), Nata Karoo Sub-basin / Caprivi deep-seated Aquifer (AF14) and Coastal Sedimentary Basin IV (AF15).

Water use and water access

In rural areas, groundwater is mainly used for domestic purposes and livestock watering. In urban areas, groundwater is used for domestic and industrial purposes. Cities which are 100 per cent reliant on groundwater are Walvisbay, Swakopmund, Otjiwarongo, Tsumeb, Luderitz, Grootfontein and Usakos. Major industries that are highly dependent on groundwater are the Rössing Uranium Mine, Husab Mine and Langer Heinrich Mine, the Otjikoto Gold Mine and the Scorpion zinc mine. In the agricultural sector, groundwater is largely used for livestock. Groundwater use for irrigation is not encouraged by Government, but is used in some areas, particularly the Otavi karst area, the Stampriet artesian basin, and along west-flowing ephemeral rivers.

The total water use is 278 million m³/annum; about 50 per cent is from groundwater. The domestic sector is the largest water user with 52 per cent followed by the agricultural (incl. irrigation; 38 per cent) and industry (incl. mining: 10 per cent) sectors. Groundwater use is only 7 per cent of the total available groundwater resources which leaves an opportunity for further development.



Sectoral water use

98 per cent of the urban population has access to an improved drinking water supply; 15 per cent of the rural population has no access to an improved drinking water supply.

WATER GOVERNANCE

Formal institutional environment: water law and policy

- Namibian Constitution, Article 100: "Land, water and natural resources below and above the surface of the land....shall belong to the State...."

- Act No 54 of 1956 (sections of South African Water Act made applicable to Namibia)
- The Namibia Water Corporation Act, Act No 12 of 1997
- The Namibia Water Resources Management Act No 24 of 2004 – which was never commenced, and was subsequently revised
- The Revised Namibia Water Resources Management Act, which was gazetted in December 2013
- Water Supply and Sanitation Policy (1993)
- National Water Policy for Namibia (2000)

Institutional arrangements

- The Ministry of Agriculture, Water & Forestry (MAWF): responsible for the entire water sector incl. waste water; Directorate Resource Management: general observation and management; Division of Geohydrology: groundwater investigations and groundwater management (incl. monitoring water quality and quantity); Directorate Rural Water Supply and Sanitation: coordination for rural usage
- NamWater: a parastatal responsible for bulk water supply throughout the country; Urban water supply is the responsibility of the regional or city councils except for the cities of Oranjemund, Tsumeb, and Grootfontein, where water supply is developed and managed by the private sector
- Permanent Joint Technical Commission (JPTC) between Angola and Namibia on the Kunene River
- Joint Permanent Water Commission (JPWC) between Botswana and Namibia (1990)
- Permanent Water Commission (PWC) between South Africa and Namibia on the lower Orange River
- Permanent Okavango River Basin Water Commission (OKACOM) between Angola, Botswana and Namibia

Information management

- Groundwater resources investigations have over the years been carried out with the assistance of international donors
- The Division of Geohydrology of the MWAFF is hosting the national groundwater database GROWAS II. The database features a GIS based graphical user interface (GUI) with a vast range of query functions, a modular system including time series tools, hydrochemistry, licenses for abstraction application and groundwater status reporting functions among others. The existing hydrogeological map is at a scale of 1:1 000 000 of 2001
- Technical software for processing data is available, e.g. for groundwater modelling, pumping test analysis, hydrochemical analysis, GIS, etc.

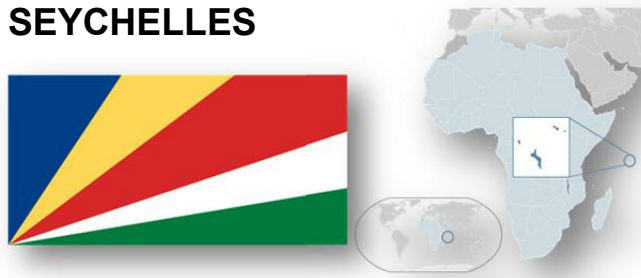
Hydrogeological capacity and training

- Hydrogeologists are trained within the region and overseas and technicians are also trained in South Africa; there is hydrogeological capacity present in the Division of Geohydrology and NamWater
- Groundwater education: the Department of Geology of the University of Namibia has a module in basic hydrogeology
- Other resources: several groundwater exploration and drilling companies

KEY CHALLENGES AND OPPORTUNITIES

- Several new institutions are to be established under the new Water Resources Management Act. They include a Water Advisory Council, Basin Management Committees, a Water Regulatory Board and a Water Tribunal
- Aquifer management is often uncoordinated and water supply planning does not sufficiently include future developments
- Namibian groundwater resources cannot sustain larger agricultural irrigation projects. These should be developed in areas with surface water supply, such as along perennial rivers or near water supply reservoirs
- Groundwater over-abstraction occurs regularly in dry periods, and often results in water restrictions. A lack of monitoring and alternative water supply options contributes to this problem
- A single borehole or well is often the only available water supply, especially in rural areas
- The hydrogeological capacity in both private and public sectors is reasonable. There is still need, however, for additional qualified hydrogeologists at M.Sc. level to strengthen government institutions. Specialised training is also needed in GIS, groundwater modelling, pumping test data analysis, groundwater monitoring and database management.

SEYCHELLES



INTRODUCTION

Seychelles is located in the Indian Ocean, northeast of Madagascar and about 1 600 km east of Kenya. The archipelago consists of 115 islands. Some of the larger granitic islands (40 islands are granitic) have fairly high plateaus and hills (up to 900 m) with narrow coastal plains, while others consist of nearly flat carbonate atolls. Mahe, Praslin and La Digue are the three main islands, inhabited by 99 per cent of the population. The total population amounts to 92 900 with an urban population of 54 per cent and a rural population of 46 per cent. The population density is 204 inhab./km².

The climate of Seychelles is wet tropical (equatorial). Rainfall ranges from 2 900 mm annually to 3 600 mm on mountain slopes. The dry season is from May to September. The average annual rainfall amounts to 2 330 mm.

WATER MANAGEMENT

Water resources

Surface water

The granitic islands have many small, steep, watercourses and most of them have only ephemeral flows. The total dam capacity is 0.97 million m³. The Rochon Dam, which collects its waters from the Rochon River, has a storage capacity of 0.05 million m³. Surplus water is forwarded to the La Gogue Dam, which has a storage capacity of 0.92 million m³.

Groundwater

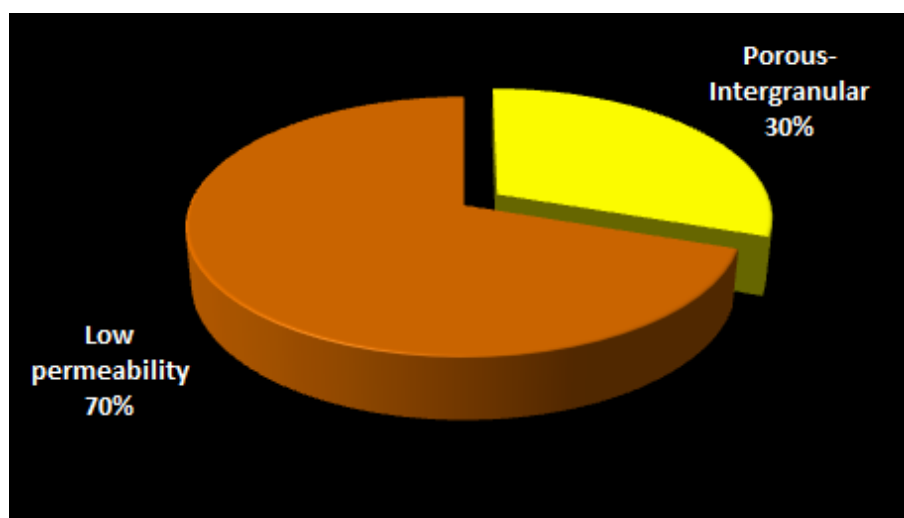
The geology of Seychelles is characterized by granitic islands, the world's only oceanic islands of granitic rock and coralline outer islands. Groundwater resources are limited as not much water is stored at the foot of the hills and the water available is often hard and contains traces of salt.

The majority of the country (70 per cent) is underlain by low permeability formations and porous-intergranular sediments cover the remaining part of the country (30 per cent).

Groundwater availability is estimated at 106 m³/capita/annum.

Groundwater quality is in general excellent on the main islands but tends to be hard. Although there is a clear potential for seawater intrusion under abstraction or reduced

recharge, particularly for the unconsolidated coastal terrace aquifers, there has been no indication of this yet. On La Digue, where production boreholes have been in operation continuously since 1987, there has been no consistent increase in electrical conductivity.

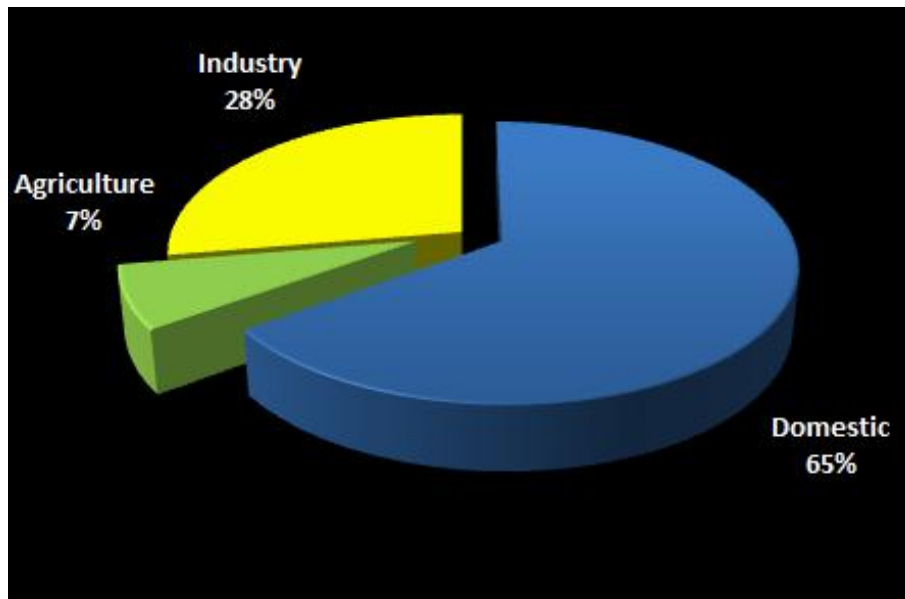


Groundwater occurrence

Water use and water access

In Seychelles, groundwater plays a minor role compared to surface water and desalination plants for water supply (only 2 per cent during the dry season). The only boreholes used for domestic water supply are present on the island of La Digue (2 boreholes which provide approximately 57 per cent of the water supply to the island). About 1 million m³/annum of desalinated water is produced for potable use to compensate for the water shortage that occurs during the dry period.

The total water use is 11.3 million m³/annum; only 2 per cent is from groundwater. The domestic sector is the largest water user with 65 per cent followed by the industry (28 per cent) and agricultural (incl. irrigation: 7 percent) sectors.



Sectoral water use

96 per cent of both urban and rural population has access to an improved drinking water supply.

WATER GOVERNANCE

Formal institutional environment: water law and policy

- Public Utilities Corporation Act, 1985
- Environmental Protection Act, 1994
- National Wetland Conservation and Management Policy, 2005

Institutional arrangements

- Public Utilities Corporation – Water and Sewerage Division: responsible for all water resources
- Rivers Committee: responsible for water abstraction rights
- Ministry of Environment and Natural Resources: responsible for wastewater and water pollution control
- Ministry of Agriculture and Marine Resources: administers a number of small reservoirs and communal irrigation schemes

Information management

- Groundwater data is kept in a hydrology database hosted by the Public Utilities Corporation
- Some groundwater monitoring for water levels and basic physical and chemical parameters of about 60 boreholes is carried out on a fairly regular basis

Hydrogeological capacity and training

- Groundwater education: there is no formal training in hydrogeology

KEY CHALLENGES AND OPPORTUNITIES

- The hydrogeological capacity in both private and public sectors could be strengthened
- Climate variability and change: there is an urgent need for an integrated system of protection to the impact of extreme weather events
- Water availability: up to 98 per cent of the rainwater is lost to the sea or through evaporation. Investments in water infrastructure are needed for storage enhancement (incl. groundwater storage) as well as public awareness and education on effective and efficient water use and on water conservation techniques. There is also need for additional investment in alternative water sources, e.g. water recycling, desalinisation and (rain)water harvesting

SOUTH AFRICA



INTRODUCTION

South Africa is the southernmost country on the African continent. Its topography is dominated by a plateau which drops from 2 400 meters in the Lesotho region in the east to 600 m in the sandy Kalahari in the west. The plateau comprises the Highveld in the center and is separated from the surrounding areas of generally lower elevation by the Great Escarpment, reaching nearly 3 300 m. On both sides of the Great Escarpment, the topography tends to be relatively broken, with common mountains and deeply incised valleys but little genuine coastal plain. South Africa's coastline is characterized by fairly steep slopes rising rapidly inland. South of the Orange River lies the Great Karoo region. Cape Fold Mountains – between 1 000 and 2 500 meters – lie in the southwest of the country. The total population amounts to 54 956 920 with an urban population of 65 per cent and a rural population of 35 per cent. The population density is 45 inhab. /km².

South Africa is a semi-arid country with an average annual rainfall ranging from less than 100 mm/annum in the western deserts to about 1 200 mm/annum in the eastern part of the country. Only 35 percent of the country has a precipitation of 500 mm or more; 21 percent has a precipitation of less than 200 mm. Except for the Western Cape, with a Mediterranean climate and winter rainfall, the rest of the country has summer rainfall. Summer is from October to March. The average annual precipitation amounts to 495 mm.

WATER MANAGEMENT

Water resources

Surface water

South Africa drains into four major systems:

- The Orange river, rising in the Lesotho Highlands and draining ~48 per cent of the country to the Atlantic Ocean: mean annual runoff is 11 100 million m³
- The Limpopo river basin, draining the plateau north of the Witwatersrand ridge, ~14 per cent of the country, to the Indian Ocean: mean annual runoff is 5 100 million m³
- All other rivers draining into the Indian Ocean, ~29 per cent of the country: mean annual runoff is 28 000 million m³
- Rivers draining the Fold mountains of the south-western Cape into the Atlantic and Indian Oceans, ~9 per cent of the country: mean annual runoff is 5 000 million m³

River flows reflect the rainfall pattern. Rivers that have their origin on the eastern great escarpment and in the Fold Mountains of the Western Cape normally have perennial flows. Rivers that originate in the immediate adjoining areas have periodic flows, whereas rivers that originate on the western great plateau have highly episodic flows.

There are 216 major dams (>3 million m^3) and the total dam capacity is 31 022 million m^3 . South Africa shares 4 transboundary river basins: Incomati, Limpopo, Maputo-Usutu-Pongola, Orange-Senqu.

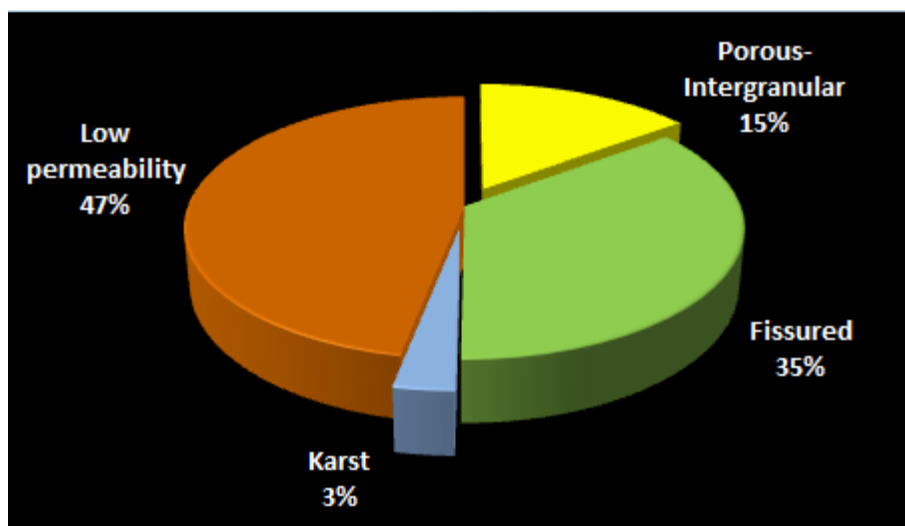
Groundwater

The geology of South Africa is characterized by the Archean Kaapvaal Craton surrounded by younger Proterozoic orogenic belts comprising deformed metamorphic rocks and granites and overlain by Phanerozoic cover sequences. The Pan-African belts fused the older cratons together during the amalgamation of the last supercontinent Gondwana forming a Precambrian basement to extensive Gondwanide sedimentary basins, most notably the Cape and Karoo Supergroups. The break-up of Gondwana in the mid- to Late Mesozoic was associated with extensive outpourings of lava and the intrusion of sills and dyke swarms throughout the Karoo Basin as well as the development of on- and off-shore sedimentary rift grabens. Cenozoic deposits of unconsolidated sand of littoral marine, estuarine, fluvial, lacustrine and aeolian origin are developed extensively along the coastal plains of South Africa.

Groundwater is limited due to the geology of the country and large porous aquifers occur only in a few areas.

47 per cent of the country is underlain by low permeability formations. The mean blow yield of boreholes in these formations is 2.6 l/s. Fissured rocks cover 35 per cent of the total surface area and boreholes have a mean blow yield of 2.5 l/s. Porous-intergranular sediments cover 15 per cent of the total surface area and boreholes have a mean blow yield of 1.7 l/s. The coverage of Karst is 3 per cent of the total surface area and boreholes have a mean blow yield of 5.3 l/s.

Groundwater availability is estimated at 10 per cent of the total water availability of 910 $\text{m}^3/\text{capita}/\text{annum}$.



Groundwater occurrence

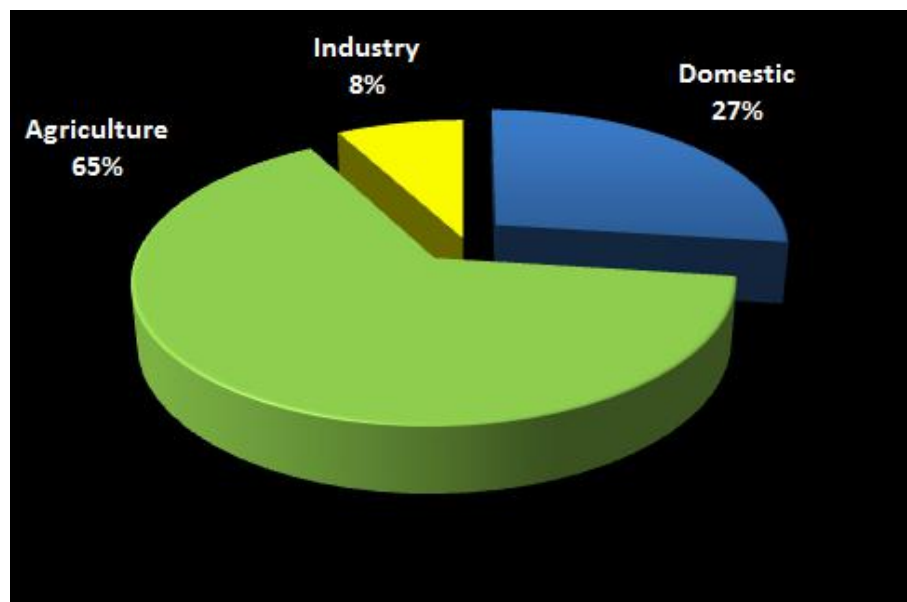
Coastal and inland arid areas, such as Namaqualand and the Kalahari, are characterized by NaCl type groundwater; the Karoo is characterized by CaMg/ClSO₄ type groundwater, while the rest of the country is mainly characterized by CaMg/HCO₃ type groundwater. In terms of potability, TDS ranges from 10 mg/l in mountainous areas of the Table Mountain Group Aquifer in the Western Cape to >1500 mg/l in Namaqualand and the Kalahari. Most of the Karoo Aquifer groundwater is <500 mg/l dropping to <300 mg/l over the rest of the east-central, eastern and northern parts of the country. Nitrate and fluoride levels are a problem in the arid north-western, north-central and north-eastern parts of the country. Many gold and coal mines in South Africa have closed, and dewatering operations have ceased. In the abandoned mining areas the consequent rebounding water table has led to significant pollution of groundwater by acid mine drainage (AMD). AMD is a result of the oxidation of metal sulphides, and is characterized by elevated heavy metal concentrations, high sulphate contents, an increased electrical conductivity and a lowering of the pH of the water in the mining area. It can also lead to pollution by radioactive materials.

South Africa shares 9 transboundary aquifers: Karoo sedimentary aquifer (AF1), Coastal Sedimentary basin V (AF2), Coastal Sedimentary basin VI / Coastal Plain Sedimentary Basin Aquifer (AF3), Rhyolite-Breccia aquifer (AF4), South Stampriet Artesian Aquifer System (AF5), Khakhea/Bray Dolomite (AF6), Zeerust / Lobatse / Ramotswa Dolomite Basin Aquifer (AF7), Limpopo basin (AF8) and Tuli Karoo Sub-Basin (AF9).

Water use and water access

Groundwater is often the primary source in the rural and more arid areas, as well as for many towns. More than 100 towns in South Africa depend on groundwater and about 7.5 per cent of the water supply to Pretoria is from groundwater. It also supplies water to large irrigated areas, livestock and many mines and industries. It is expected that groundwater use for human consumption will further increase, especially in the western part of the country which lacks perennial rivers.

The total water use is 18 965 million m³/annum; about 15 per cent is from groundwater. The agricultural sector (incl. irrigation) is the largest water user with 65 per cent followed by the domestic (27 per cent) and industry (incl. mining) 8 per cent. Groundwater use is 56 per cent of the total available groundwater resources which leaves an opportunity for further development.



Sectoral water use

100 per cent of the urban population has access to an improved drinking water supply; 19 per cent of the rural population has no access to an improved drinking water supply.

WATER GOVERNANCE

Formal institutional environment: water law and policy

- The Constitution of the Republic of South Africa (1996)
- Water Services Act (No. 108 of 1997)
- National Water Act (1998)
- National Environmental Management Act (1998)
- National Disaster Management Act (No. 57 of 2002)
- National Water Amendment Act - 1999 (No. 45 of 1999)
- Water Services Amendment Act - 2004 (No. 30 of 2004)
- National Water Amendment Act, 2014 (Act No. 27 of 2014)
- National Water Resource Strategy – second edition, 2013

Institutional arrangements

- Department of Water and Sanitation (DWS)
- Catchment Management Agencies (CMAs)

- Water Research Commission (WRC)
- Water Boards
- Treaty on the Lesotho Highlands Water Project with Lesotho (1986)
- The Permanent Water Commission between SA and Namibia (1992)
- The Development and Utilisation of the Komati River Basin (KOBWA) with Swaziland (1992)
- Joint Water Commission with Swaziland (1992)
- Tripartite Interim Agreement on the Incomati and Maputo watercourses with Swaziland and Mozambique (2002)
- Trans-Caledon Tunnel Authority (TCTA)

Information management

- There are various groundwater databases, such as the National Groundwater Archive, Water Use Authorisation Registration Management System and Hydstra
- Many hydrogeological and groundwater resource maps are available including the Hydrogeological Map Series of 21 hydrogeological maps at 1:500,000 scale produced by the Department of Water and Sanitation (DWS), which covers the whole country
- Technical software for processing data is available, e.g. for groundwater modelling, pumping test analysis, hydrochemical analysis, GIS, etc.

Hydrogeological capacity and training

- There are many trained hydrogeologists at the DWS, CGS and CSIR. The number of vacant posts in the DWS is around 47 per cent and 53 per cent for geotechnicians and this is compounded by its inability to attract staff. More than 50 per cent of the current groundwater personnel in DWS have fewer than 5 years' experience and do not have experienced mentors to guide them
- Groundwater education: the main academic institutions for groundwater are the University of the Free State and University of the Western Cape. Approximately 600 students graduated in the last 10 years from these two institutions alone, 127 with a Masters or PhD (DWS, 2016). In addition, several other Universities offer groundwater modules, particularly Universities of Pretoria, Witwatersrand and KwaZulu Natal
- Other resources: several groundwater exploration and drilling companies

KEY CHALLENGES AND OPPORTUNITIES

- There is room for further development of groundwater resources:
 - 44 per cent of available groundwater resources are not yet used
 - Groundwater could also play a key role in clearing the backlog in improved drinking water supply to the rural population
- The hydrogeological capacity in the private sector is reasonable. There is still need, however, for additional qualified hydrogeologists at MSc. and PhD level to strengthen

government institutions (DWS, CGS, etc.). Also, water institutions at various levels must be strengthened, e.g. the Department of Water and Sanitation being responsible for water infrastructure and water management

- The institutions to manage groundwater at a local level have not yet been set-up. There are no regulations in place to protect groundwater
- The water infrastructure needs to be massively expanded and renewed at local, provincial and national levels. Particularly operation and maintenance (O&M) of groundwater infrastructure is required in South Africa. Frequently the failure of groundwater supply systems is due to poor O&M rather than resource failure
- Verification of groundwater use is a key challenge which requires a considerable effort

SWAZILAND



INTRODUCTION

Swaziland is located between the Republic of South Africa and Mozambique. Its physiography comprises the Highveld along the western side of the country with a mountainous topography; the Middleveld east of the Highveld with more rolling hilly topography and a landscape of open plains and small hills; the Lowveld (~37 per cent of the country) which is characterised by generally flat bush country and the Lubombo Plateau, adjacent to Mozambique. The total population amounts to 1 286 970 with an urban population of 21 per cent and a rural population of 79 per cent. The population density is 74 inhab. /km².

The climate of Swaziland is subtropical with summer rains. About 75 per cent of the precipitation falls from October to March. The climatic conditions range from sub-humid and temperate in the Highveld to semi-arid in the Lowveld. The average annual precipitation amounts to 788 mm.

WATER MANAGEMENT

Water resources

Surface water

There are four main river systems in the country: the Komati and Lomati systems, in the north of the country; the Mbuluzi River which rises in Swaziland; the Usuthu River, which originates in South Africa and forms the border between Mozambique and South Africa; and the Ngwavuma, in the south of the country, which rises in Swaziland.

There are 7 major dams (>3 million m³) and the total dam capacity is 585 million m³. Swaziland shares 3 transboundary river basins: the Incomati, Maputo-Usutu-Pongola and the Umbeluzi.

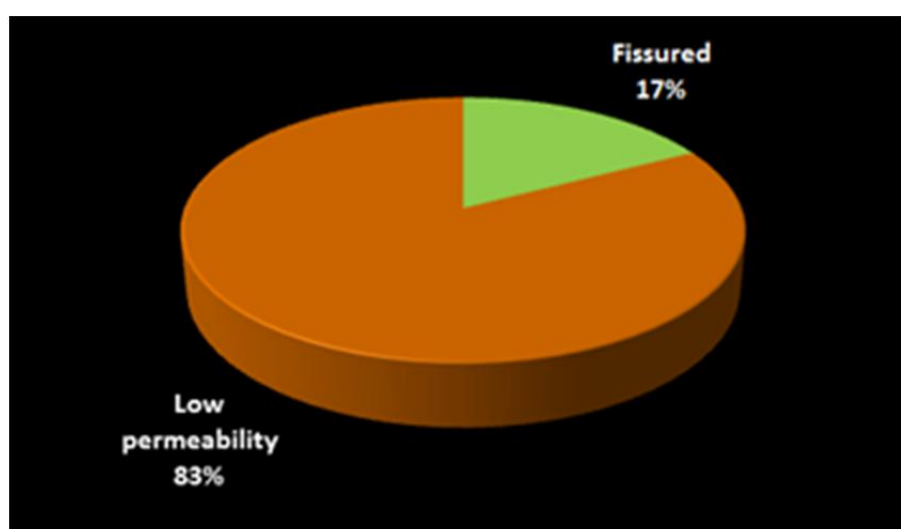
Groundwater

The western two-thirds of Swaziland are underlain by igneous and metamorphic rocks of the Archean Basement Complex. Karoo Sequence sedimentary rocks are present in a narrow band in the eastern Lowveld region and post-Karoo igneous intrusives in the Lubombo region. The Karoo units primarily include the upper formations of deltaic sandstone/mudstone and aeolian sandstone. Recent alluvial deposits are present in small areas along the major river valleys.

There are no laterally extensive aquifers. Groundwater flow is primarily in zones of deep, continuous weathered bedrock (Ezulwini, Malkerns and Manzini areas) or predominantly through either fractured or jointed bedrock, or shallow, discontinuous weathered zones.

The majority of the country (83 per cent) is underlain by low permeability formations. The mean blow yield of boreholes in these formations is 1.7 l/s. Fissured rocks cover 17 per cent of the total surface area and boreholes have a mean blow yield of 1.3 l/s.

Groundwater availability is estimated at 9 per cent of the total water availability of 3 504 m³/capita/annum.



Groundwater occurrence

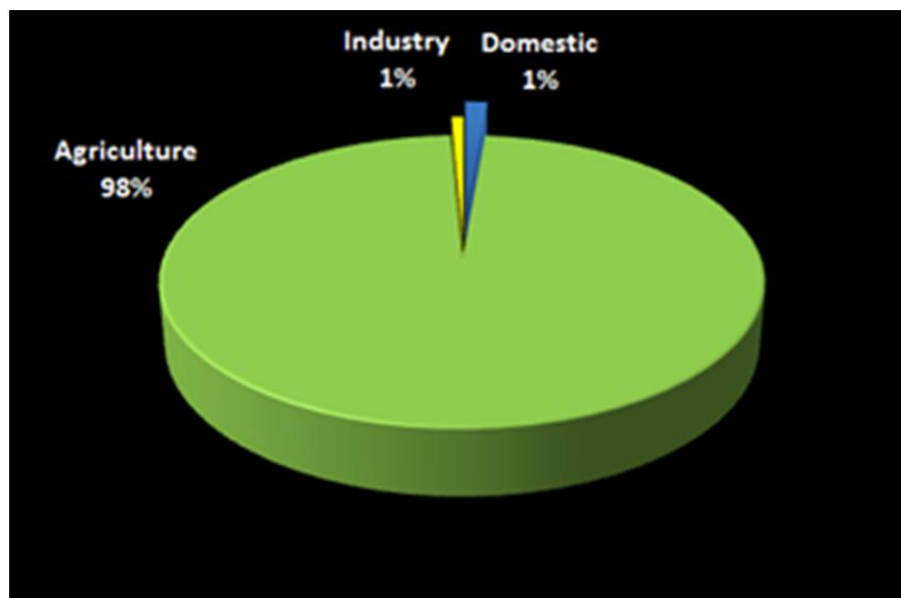
Groundwater quality in Swaziland varies considerably considering the small size of the country. Water quality in the western Highveld and Middleveld is quite good, but higher levels of mineralization make groundwater quality in the Lowveld commonly poor. TDS values for the western section of the country, with basement complex aquifers, is predominately < 800 mg/l while in the Karoo basalts, average TDS is > 1 000 mg/l. Fluoride and nitrate concentrations above accepted water quality levels have also been noted in some locations. The fluoride problem does not appear to be associated with any specific aquifer lithology but there does appear to be a positive correlation between high levels of fluoride and nitrate in groundwater. High levels of nitrate in groundwater are generally attributed to natural sources within the aquifer materials.

Swaziland has 1 transboundary aquifer: Rhyolite-Breccia aquifer (AF4).

Water use and water access

Groundwater resources play a major role (90 per cent of total water use) in (domestic) rural water supply. Major abstraction areas are Nyakeni, Efosini, Mpolojeni, Siphocosini, Nhlanguyavuka, Mangweni, Tributini and KaMfishane.

The total water use is 1 716 million m³/annum; only 2 per cent is from groundwater. The agricultural sector (incl. irrigation) is the largest water user with 98 per cent followed by the domestic (1 per cent) and industry (incl. mining: 1 per cent) sectors. Groundwater use is only 10 per cent of the total available groundwater resources which leaves an opportunity for further development.



Sectoral water use

94 per cent of the urban population has access to an improved drinking water supply; 31 per cent of the rural population has no access to an improved drinking water supply.

WATER GOVERNANCE

Formal institutional environment: water law and policy

- Water Act (2003)
- Water Services Corporation Act, No. 12 of 1992
- National Water Policy (2009; final draft)

Institutional arrangements

- National Water Authority: responsible for policy and legislation and water resources planning
- Department of Water Affairs within the Ministry of Natural Resources and Energy: responsible for water sector administration, policy and data collection
- River Basin Authority: responsible for regulation (water permits)

Information management

- Groundwater resources investigations have over the years received attention with the assistance of international donors
- There is a groundwater database (MS-Access). The existing hydrogeological map is at a scale of 1:250 000 of 1992
- Technical software for processing data is available

Hydrogeological capacity and training

- The Department of Water Affairs is manned by 2 Hydrogeologists; research into groundwater resources is carried out by the Department of Geological Survey and Mines
- Groundwater education: University of Swaziland does not have a course in geology nor hydrogeology
- Other resources: several groundwater exploration and drilling companies

KEY CHALLENGES AND OPPORTUNITIES

- Groundwater could play a key role in clearing the backlog in access to improved drinking water supply for the rural population
- Swaziland urgently needs funds to expand and maintain its water infrastructure; in several cities, water demand can only be met occasionally and investments are needed to improve the situation
- There is need for strengthening the hydrogeological capacity: e.g. postgraduate training for hydrogeologists and training of drillers

TANZANIA



INTRODUCTION

Tanzania consists of the mainland and Zanzibar and Pemba islands. The country is bordered in the north by Kenya and Uganda, in the east by the Indian Ocean, in the south by Mozambique and in the west by Rwanda, Burundi, the Democratic Republic of the Congo and Zambia. Its physiography comprises plains along the coast, a plateau with an average elevation of 1 220 m in the central part of the country, and highlands in the north and south. The northeast border with Kenya has Mt. Meru (4 565 m) and Mt. Kilimanjaro (5 895 m) as highest mountains. Southwards is the Central Plateau reaching elevations above 2000 m. The mountain range of the Southern Highlands separates the Eastern plateau from the rest of the country. The total population amounts to 53 470 420 with an urban population of 32 per cent and a rural population of 68 per cent. The population density is 56 inhab./km².

The climate of Tanzania varies from tropical along the coast to temperate in the highlands. Annual rainfall varies from 500 mm to 1 000 mm over most of the country. The highest rainfall of 1 000 mm to 3 000 mm occurs in the northeast of the Lake Tanganyika basin and in the Southern Highlands. The dry season is from June to October. The average annual rainfall amounts to 1 071 mm.

WATER MANAGEMENT

Water resources

Surface water

Tanzania has nine major river/lake basins that are draining to the Mediterranean, Indian Ocean and Atlantic Ocean, or draining internally (endorheic). River regimes follow the rainfall pattern with river discharge and lake levels rising in November-December and generally reach their maximum in March-April with a recession period from May to October/November. Many of the larger rivers have flood plains, which extend far inland with grassy marshes, flooded forests and ox-bow lakes.

There are 4 major dams (>3 million m³) and the total dam capacity is 104 196 million m³. Tanzania shares 4 transboundary river basins: Congo, Nile, Rovuma and Zambezi.

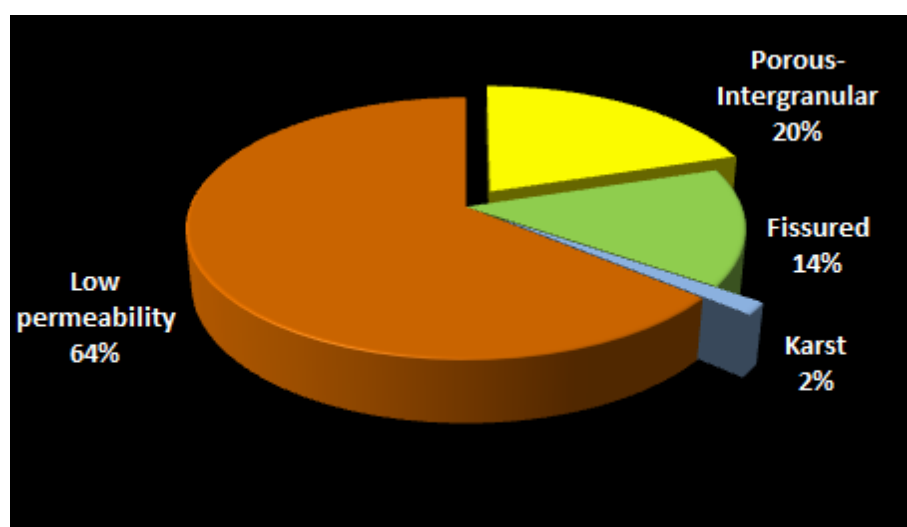
Groundwater

The geology of Tanzania is characterized by a Precambrian Basement complex covering 75 per cent of the country, a Karoo Sequence, Post Karoo Sedimentary Formations and Volcanic and Alluvial deposits. Series of horsts and grabens, the rift valley, are concentrated

in northwest-southeast and northeast trending belts. Groundwater occurrence in the Basement Complex rocks is largely limited to secondary features such as weathered zones, joints, fractures, faults or solution features.

The major part of the country (64 per cent) is underlain by low permeable formations with a mean borehole blow yield of 2 l/s. Porous-intergranular sediments cover 20 per cent of the total surface area and boreholes have a mean blow yield of 3 l/s. Fissured rocks cover 14 per cent of the total surface area and boreholes have a mean blow yield of 3.4 l/s. The coverage of Karst is 2 per cent of the total surface area and boreholes have a mean blow yield of 2.7 l/s.

Groundwater availability is estimated at 22 per cent of the total water availability of 1 800 m³/capita/annum.



Groundwater occurrence

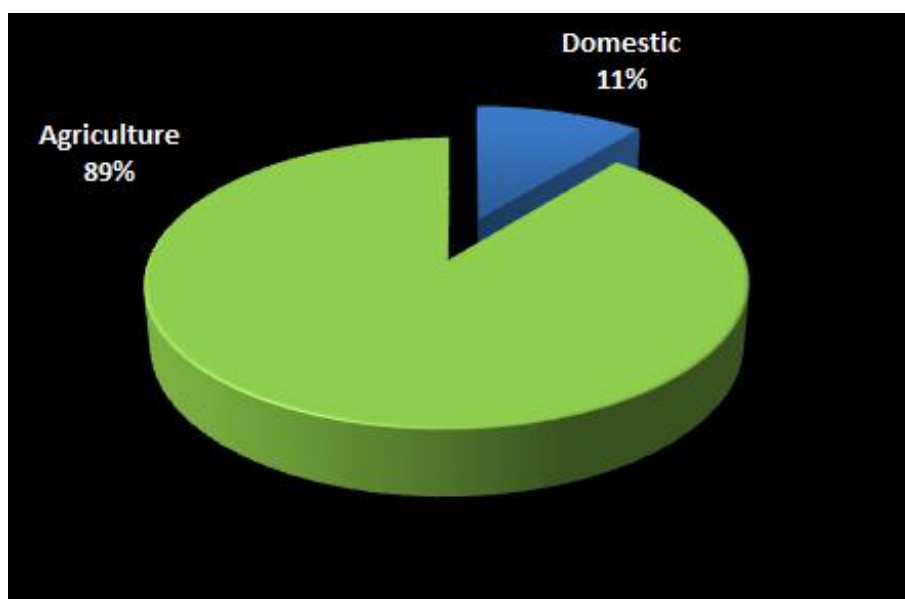
Groundwater quality in Tanzania is generally acceptable for most uses, with only isolated cases of high salinity, fluoride and iron content. Along the coastal areas, the salt content of water is high at places (at times exceeding 1 300 mg/l) due to saline water intrusion. High salinity is also encountered in inland areas due to evaporation in some depressions along the lakes. In the central part of the country, high levels of groundwater mineralization and fluoride are a problem in Basement Complex rocks. Fluoride levels above 8.0 mg/l have been recorded in borehole water in the north-eastern regions within the Precambrian volcanics and metamorphics surrounding the Rift Valley System. The groundwater quality of Zanzibar and Pemba islands is predominantly a calcium bicarbonate type of low to moderate salinity.

Tanzania shares 4 transboundary aquifers: Coastal Sedimentary Basin III (AF20), Karoo-Sandstone aquifer (AF21), Weathered basement (AF24) and Tanganyika aquifer (AF26).

Water use and water access

Several towns, such as Singida, Mtwara, Lindi and Dodoma rely for 70-80 per cent on groundwater for their water supply. Also Dar es Salaam significantly relies on groundwater.

The total water use is 2 423 million m³/annum; 4.5 per cent is from groundwater. The agricultural sector (incl. irrigation) is the largest water user with 89 per cent followed by the domestic sector (11 per cent). Groundwater use is only 0.5 per percent of the total available groundwater resources which leaves great opportunity for further development.



Sectoral water use

77 per cent of the urban population has access to an improved drinking water supply; 54 per cent of the rural population has no access to an improved drinking water supply.

WATER GOVERNANCE

Formal institutional environment: water law and policy

- Water Utilisation Act, 1974
- Waterworks Act, revised edition, 1993
- Water Laws Act, 1981 and 1997
- Water Resources Management Act No. 11, 2009
- Water Supply and Sanitation Act No. 12, 2009
- National Water Policy, 2002
- National Water Sector Development Strategy, 2008

Institutional arrangements

The water sector reform is taking shape in Tanzania with new water acts in place and new institutions being established for water resource management and water supply and sanitation, devolving responsibilities to the lowest appropriate level:

- Central Government: Ministry of Water and Irrigation (MoWI) and other line Ministries
- National Water Board (NWB)
- Basin Water Boards
- Local Government Authorities (LGA)
- Energy and Water Utilities Regulatory Authority (EWURA)
- Water Supply and Sanitation Authorities (WSSAs)
- Community-owned Water Supply Organisations (COWSOs)

The Water Resources Management Act No 11 (2009) provides for the following institutional framework for the development and management of water resources:

- Establish a National Water Board (NWB) as an advisory board to the Minister of Water and Irrigation on all matters relating to multi-sector coordination in integrated water resources planning and management as well as the resolution of national and international water conflicts. NWB replaces the Central Water Board that had no such mandate
- Statutorily establish the office of the Director of Water Resources for coordinating the activities of basin water boards; conduct national water resources planning management, and implementation of strategy; oversee water basin planning and management; and integrate inter-sector coordination and planning aspects that have an impact on water resources
- Establish Basin Water Boards as corporate bodies with the power to sue and to be sued - previously Basin Water Boards had no such powers
- Establish Catchment and Sub-Catchment Water Committees to coordinate and harmonize catchment/sub-catchment integrated water resource management plans and to perform other functions as delegated by Basin Water Board(s)
- Register Water User Associations at the water basin instead of Ministry level

Information management

- Groundwater resources investigations have over the years been carried out with the assistance of international donors
- The borehole database is maintained by the MoWI, Directorate of Water Resources in Dodoma. However, the data entry is not consistent; many boreholes have no data recorded and for others the data are incomplete and lack coordinates. The existing hydrogeological map is at a scale of 1:1 500 000 of 1990
- Technical software for processing data is available

Hydrogeological capacity and training

- There is inadequate hydrogeological capacity in both public and private sectors
- Groundwater education: College of Engineering and Technology, University of Dar es Salaam has a Masters programme in Integrated Water Resources Management in collaboration with Waternet with modules in hydrogeology, remote sensing and GIS and river engineering
- Other resources: several groundwater exploration and drilling companies

KEY CHALLENGES AND OPPORTUNITIES

- There is room for further development of groundwater resources. The development of groundwater resources should be preceded by detailed studies on recharge and available groundwater resources, including the potential of using groundwater for irrigation
- Groundwater should play a key role in clearing the backlog in access to improved drinking water supply to both urban and rural population
- The hydrogeological capacity in both private and public sectors is inadequate including equipment and monitoring infrastructure. There is need for additional qualified hydrogeologists at M.SC. level to strengthen government institutions and the private sector. There is also need for further training in groundwater development and management and groundwater modelling
- There is a need for transforming the existing database into a Management Information Systems (MIS) that is integrated into a Geographic Information System (GIS) for enhanced information sharing. Key information like borehole location, groundwater quality, amounts of abstraction, and other hydrogeological information should be maintained in the database
- Financial support from Development Partners to Tanzania's Water Sector is through general budget support, the water sector basket, earmarked funds and direct and indirect technical assistance. The Private Sector is encouraged to invest in the provision of services and goods, consultancy, contractors, management and supply of water related equipment; there are many investment opportunities in water related projects

ZAMBIA



INTRODUCTION

Zambia is situated on the interior of the central African plateau. The plateau is at an elevation of 1 000 m amsl and is incised by large rift valley related river systems. The Zambezi valley and Luangwe valley escarpments are mountainous and rocky, while the rest of the country is a level to gently sloping plateau with slopes rarely exceeding 3 to 5 per cent. The total population amounts to 16 211 767 with an urban population of 41 per cent and a rural population of 59 per cent. The population density is 22 inhab. /km².

The climate of Zambia is subtropical with two seasons. The dry season is from May to October and can be divided into a cool dry season from May to July and a hot dry season from August to October. The average annual rainfall amounts to 1 020 mm.

WATER MANAGEMENT

Water resources

Surface water

Zambia lies between two large river basins, the Zambezi and the Congo River basins. The total renewable water resources of Zambia amount to 105 km³/annum of which about 80 km³/annum is produced internally.

There are 5 major dams (>3 million m³) and the total dam capacity is 101 133 million m³. Zambia shares 2 transboundary river basins: Congo and Zambezi.

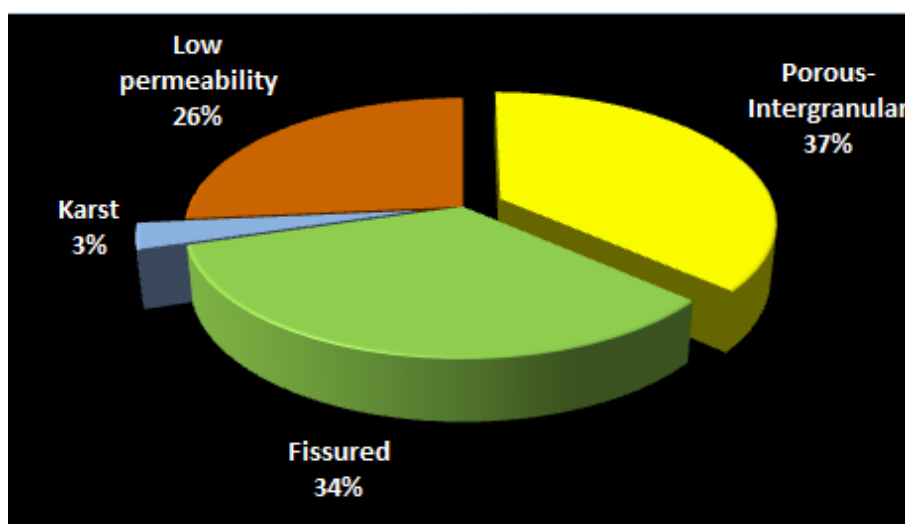
Groundwater

The geology of Zambia comprises (predominantly) crystalline basement rocks (Precambrian), metamorphosed sediments of the Katanga System (upper Precambrian to Lower Cambrian), sandstone, shale limestone and conglomerate of the Karoo System (Upper Carboniferous - Jurassic), Karoo basalts and Kalahari sediments (the latter up to 150 m thickness in the west and southwest of the country). Extensive alluvium has been deposited in the Banweulu depression and along the Kafue and Luangwe valleys. Most productive aquifer systems in Zambia occur within limestones and dolomites of the Katanga system (e.g. Lusaka and surroundings). These aquifers can yield 35 to 50 l/s in karstic sections.

37 per cent of the country is underlain by porous-intergranular sediments with a mean borehole blow yield of 1.3 l/s. Fissured rocks cover 34 per cent of the total surface area and boreholes have a mean blow yield of 1.9 l/s. Low permeability formations cover 26 per cent

of the total surface area and boreholes have a mean blow yield of 0.8 l/s. The coverage of Karst is 3 per cent of the total surface area and boreholes have a mean blow yield of 2.6 l/s.

Groundwater availability is estimated at 18 per cent of the total water availability of 6 489 m³/capita/annum.



Groundwater occurrence

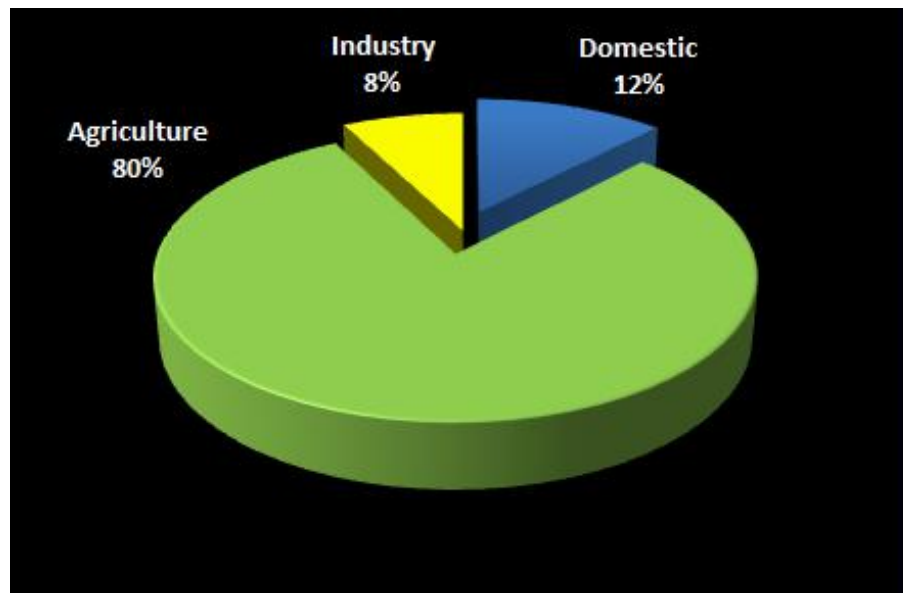
Groundwater quality is generally good. Main quality issues are: Salinity, Iron, Fluoride and contamination due to anthropogenic sources such as pit latrines and mining. High salinity is mostly confined to the south of the country in Kalahari sediments. Elevated Iron contents are mostly associated with the Kundelungu formation of the Katanga Group in the northwestern part of the country and in the Luapula Province. Fluoride levels above WHO guidelines have been found in areas associated with the East African rift. Contamination of groundwater, mainly due to poor sanitation, is the biggest threat to Lusaka's drinking water supply and contamination of groundwater due to mining activities occurs in the Copperbelt and other regions associated with metal mining.

Zambia shares 6 transboundary aquifers: Northern Kalahari / Karoo Basin / Eiseb Graben Aquifer (AF10), Medium Zambezi aquifer (AF16), Arangua Alluvial (AF18), Sand and Gravel aquifer (AF19), Kalahari/Katangian Basin/Lualaba (AF22) and Weathered basement (AF24).

Water use and water access

Groundwater plays a major role in the water sector in Zambia, both in rural and urban water supplies, irrigation and mining. Similar to many southern African countries, the bulk of water supply in rural villages is supplied through hand pumps, open wells and pumped boreholes. But even large urban centres, including Lusaka and Ndola, receive a large proportion of their water from groundwater. In Lusaka, groundwater contributes ~55 per cent to the water supply and is abstracted from a limestone plateau of ~25,000 km² extending from Lusaka to the northwest.

The total water use is 2 221 million m³/annum; 8.5 per cent is from groundwater. The agricultural sector (incl. irrigation) is the largest water user with 80 per cent followed by the domestic (12 per cent) and industry (incl. mining: 8 per cent) sectors. Groundwater use is only 1 per cent of the total available groundwater resources which leaves an opportunity for further development.



Sectoral water use

86 per cent of the urban population has access to an improved drinking water supply; 49 per cent of the rural population, however, has no access to an improved drinking water supply.

WATER GOVERNANCE

Formal institutional environment: water law and policy

- Constitution of Zambia, 1991
- Constitution of Zambia (Amendment) – Act (No. 2 of 2016)
- Environmental Management Act (No. 12 of 2011)
- Water Act, 1948 (amended in 1994)
- Water Resources Management Act (No. 21 of 2011)
- National Water Supply and Sanitation Act (No. 28 of 1997)
- National Water Policy, 2010
- Agreement between the Republic of Zimbabwe and the Republic of Zambia concerning the utilisation of the Zambezi River, 1987

Institutional arrangements

- Department of Water Resources Development (to replace the Department of Water Affairs - DWA) in the Ministry of Mines, Energy and Water Development: responsible

for water resources infrastructure development related to dams and groundwater exploration as well as International Waters

- Water Resources Management Authority (WARMA): responsible for the implementation of the Water Resources Management Act and the allocation and management of all water resources of Zambia
- National Water Supply and Sanitation Council (NWASCO): national regulator for urban and peri-urban water supply and sanitation (WSS)
- Two types of Water Supply and Sewerage service providers: Commercial Utilities (formed by joint ventures among Local Authorities) and Private Schemes (companies supplying water and sewerage services as a fringe benefit to employees)
- Zambezi Watercourse Commission (ZAMCOM)

Information management

- Groundwater resources investigations have over the years been carried out with the assistance of international donors
- NWASCO as the regulator has the legal obligation to monitor the sector, to advise stakeholders on issues related to WSS, to inform the public and to encourage the providers to improve efficiency, accessibility and customer services
 - To monitor performance of providers and to use information for benchmarking NWASCO had to establish an information system comprising key data from all management areas of the providers as well as socio-economic data
 - The regulator was also obliged to put in place a system of regular updating through data submitted by the providers. To fulfil its obligation to inform the public and to offer advice to decision makers, NWASCO also had to put in place a system of reporting to the stakeholders
 - NWASCO requires providers to make annual submissions of information of both technical and non-technical nature about their activities. Besides submitting their financial statements, providers are required to submit an annual report
- Through the GReSP programme, DWA with the assistance of the German BGR established a groundwater information system as part of a national system encompassing a Groundwater Database and a Geographical Information System for mapping of groundwater resources. As of December 2012 over 12 000 water points were captured. The database and information management system was established using the GeODin software package with special adaptations and is based on a Microsoft Access database. The existing hydrogeological map is at a scale of 1:1 500 000 of 1994 and there is a hydrogeological map and a vulnerability map of Lusaka and surroundings at a scale of 1:75 000 of 2013
- Technical software for processing data is available, e.g. for groundwater modelling, pumping test analysis, hydrochemical analysis, GIS, etc

Hydrogeological capacity and training

- Hydrogeological capacity is available in both the public sector and the private sector. Hydrogeologists at MSc level were and are being trained abroad / overseas
- Capacity building was implemented under the GReSP Programme through on-the-job training, training courses at the IWRM-Centre of the University of Zambia (UNZA), training courses for government personnel and researchers in groundwater database and information management targeting district administration, members of staff at the Lusaka Water and Sewerage Company (LWSC) and MSc students at UNZA, and through international bursaries for hydrogeological studies at MSc level
- Groundwater education: School of Mines, Geology Department, University of Zambia – BSc Geology with some hydrogeological research
- Other resources: several groundwater exploration and drilling companies

KEY CHALLENGES AND OPPORTUNITIES

- There is room for further development of groundwater resources; only a fraction of available groundwater resources is used;
- Groundwater could play a key role in clearing the backlog in access to improved drinking water supply for the rural population
- The hydrogeological capacity in both private and public sectors is limited. It is recommended to continue to implement hands-on training measures at relevant institutions in the fields of groundwater information management, development and protection. Furthermore, it is essential to develop and implement a Human Resources Development Strategy for the WARMA and subordinate authorities on catchment and sub-catchment levels that explicitly considers capacity requirements of the new institutions with respect to groundwater. It is also recommended to look into possibilities to develop and install an undergraduate/diploma course in the field of hydrogeology in Zambia
- The biggest threat to Lusaka's groundwater is pollution and requires urgent attention and intervention. Highest priority for intervention to ensure water security for Lusaka relates to sustainable groundwater management (in particular groundwater protection) and improved sanitation (pollution control). Furthermore, new wellfields may need to be established hand in hand with water demand management measures to meet Lusaka's future water demand
- Zambia's water sector also urgently needs investments. The sector is looking for other sources of financing, e.g. through public-private partnerships and more recently through water stewardship programmes with the public sector, private sector and civil society (e.g. GIZ-IWaSP's Lusaka Water Security Initiative – LuWSI)

ZIMBABWE



INTRODUCTION

Zimbabwe is centrally located within southern Africa, primarily on the Central African Plateau. The physiography ranges from low-lying bushveld along the Limpopo Valley and generally flat areas of the central plateau to highlands in the eastern Chimanimani area. The total population amounts to 15 602 751 with an urban population of 32 per cent and rural population of 68 per cent. The population density is 40 inhab. /km².

Similar to other southern African countries, rainfall occurs in the summer months, primarily between November to April. Annual rainfall is generally consistent (between 600 and 1 000 mm) over much of the country, apart from the eastern highlands where it increases considerably (more than 1 200 mm). The average annual rainfall amounts to 657 mm.

WATER MANAGEMENT

Water resources

Surface water

Two major rivers systems are present along the borders of Zimbabwe: the Zambezi River, which forms the international border to the west and north, and the Limpopo River in the south. Although major rivers are present within the country there is only one major body of water, the man-made impoundment of Lake Kariba.

The Zambezi is developed extensively, primarily through the major hydro-electric dam forming Lake Kariba. Smaller rivers are also locally developed by small dams and used for water supply and irrigation.

There are 113 major dams (>3 million m³) and the total dam capacity is 110 070 million m³. Zimbabwe shares 6 transboundary river basins: Buzi, Limpopo, Okavango, Pungwe, Save and Zambezi.

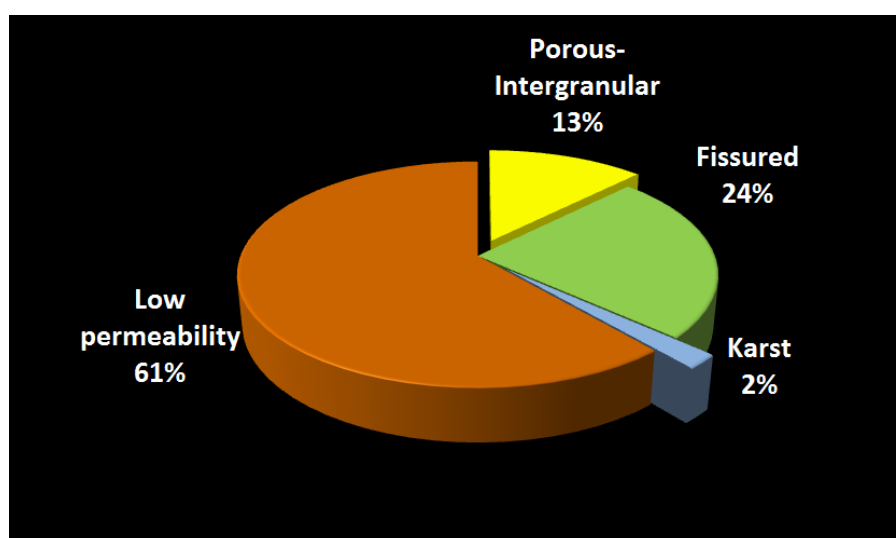
Groundwater

The majority of the country (61 per cent) is underlain by low-permeable Archaean igneous and metamorphic bedrock, primarily granites and gneisses and contains groundwater in

weathered and/or fractured zones. Yields are generally low 0.1-0.6 l/s (10-50 m³/d), but where weathering is well-developed, yields of 0.6 – 1.2 l/s (50 to 100 m³/d) are possible.

The main productive aquifers are developed in the porous and intergranular Forest Sandstone (Nyamandhlovu) and Save Alluvium and in the karstified Lomagundi Dolomite. Yields from the Nyamandhlovu aquifer vary between 1.2-3.5 l/s (50-300 m³/d) and yields from the Save aquifer range from 1.2- 58 l/s (100 to 5000 m³/d). The Lomagundi aquifer has yields between 6-23 l/s (500 to 2000 m³/d).

Groundwater availability is estimated at 8 per cent of the total water availability of 1282 m³/capita/annum.



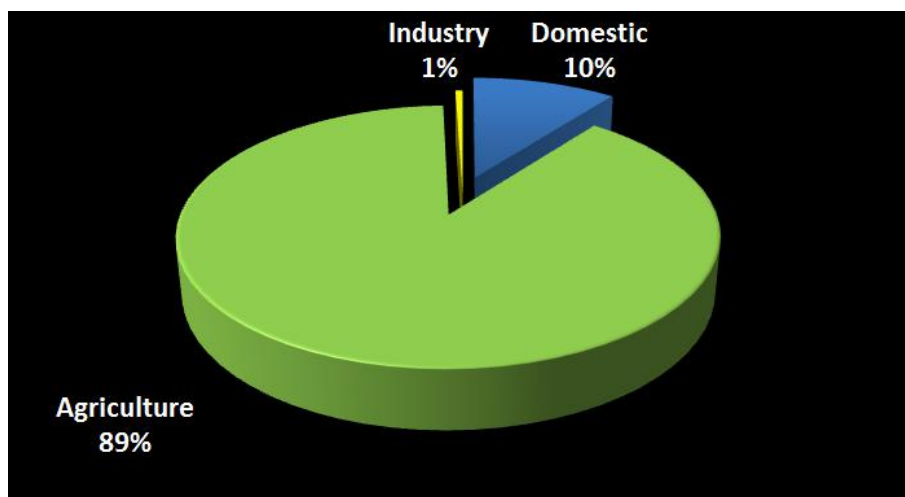
Groundwater occurrence

Groundwater quality in Zimbabwe is generally good, with minor areas of quality unacceptable for human consumption related primarily due to salinity and fluoride. In most of the areas underlain by the basement complex, water quality is good due to the shallow nature of aquifers with active recharge, although they are more vulnerable to pollution. As yet no large-scale problems with contamination of aquifers have been identified.

Zimbabwe shares 6 transboundary aquifers: Limpopo basin (AF8), Tuli Karoo Sub-Basin (AF9), Save alluvial aquifer (AF11), Eastern Kalahari/Karoo Basin (AF12), Nata Karoo Sub-basin / Caprivi deep-seated Aquifer (AF14) and Medium Zambezi aquifer (AF16).

Water use and water access

The total water use is 3 930 million m³/annum; about 10 per cent is from groundwater. The agricultural sector (incl. irrigation) is the largest water user with 89 per cent followed by the domestic (10 percent) and industrial (incl. mining: 1 per cent) sectors. The groundwater use is 25 per cent of the total available groundwater resources which leaves room for further development.



Sectoral water use

97 per cent of the urban population has access to an improved drinking water supply; 33 per cent of the rural population, however, has no access to an improved drinking water supply and groundwater could play a key role in addressing the urgent water needs.

WATER GOVERNANCE

Formal institutional environment: water law and policy

- Water Act (Chapter 20:24), 1998
- Zimbabwe National Water Authority Act (Chapter 20:25), 1998
- Water Resource Management Strategy (2000)
- Zimbabwe National Water Policy, 2013

Institutional arrangements

- The Ministry of State for Water Resources & Infrastructural Development is mandated with the assessment, planning, development and management of Zimbabwe's water resources, and has delegated these responsibilities to ZINWA, a parastatal under the ministry. ZINWA also manages water resources on behalf of the ministry
- Catchment Councils
- Sub-Catchment Councils
- Water User Boards

The government of Zimbabwe is committed to improve the country's coverage of water supply and sanitation (both rural and urban), with the objective of:

- Establishing a common platform of operation in the water and sanitation sector
- Defining sector leadership, sub-sectoral roles and responsibilities, and key coordination and financing mechanisms for the water and sanitation sector

- Establishing key sector and sub-sectoral requirements for sector recovery, including developing policy, legislation, institutional development, and capacity-building
- Drafting the sector agenda and time scales for implementation in the short to medium term, including preparation of a Cabinet Memorandum on the water supply and sanitation sector

Information management

- Groundwater resources investigations have over the years not received focused attention despite close to 70 per cent of the population (mostly rural) depending on it
- Monthly groundwater level monitoring is carried out of the three main aquifers of Lomagundi, Nyamandhlovu and Save
- Groundwater data from boreholes is available in the HydroGeoAnalyst (Waterloo) database and there is a hydrogeological map at the scale of 1: 500 000 of 1986
- Limited technical software for processing data is available; e.g. for groundwater modelling, pumping test analysis and hydrochemical analysis

Hydrogeological capacity and training

- 1 formally trained hydrogeologist in ZINWA, 2 BSc Geology graduates and 1 Hydrologist with practical experience in groundwater who received several trainings in basic groundwater modelling and pumping test analysis
- Groundwater education: National University of Science and Technology (department of civil and water engineering) and University of Zimbabwe (Geology and Civil Engineering Departments)
- Other resources: several groundwater exploration and drilling companies

KEY CHALLENGES AND OPPORTUNITIES

- There is room for further development of groundwater resources: only 25 per cent of available groundwater resources is used
- However, there is a lack of financial resources and financial allocation to (ground)water management in Zimbabwe is minimal; Assistance of external support agencies is desperately needed to implement the most urgent measures. Should the political situation improve, ample capital is expected to flow into the water sector, thus opening up huge investment opportunities
- The hydrogeological capacity in both private and public sectors is weak. There is need for additional hydrogeologists at M.Sc. level to strengthen both ZINWA HQ and catchment management offices. Training needs of the current ZINWA staff are in the areas of intermediate to advanced hydrogeology: groundwater modelling, hydrochemistry, GIS, database management, and further training up to MSc level
- In the meantime, the government with the assistance of donors and NGOs has come up and is implementing an emergency rehabilitation programme for water and sanitation services