Groundwater Monitoring in the SADC Region

Overview prepared for the Stockholm World Water Week 2013

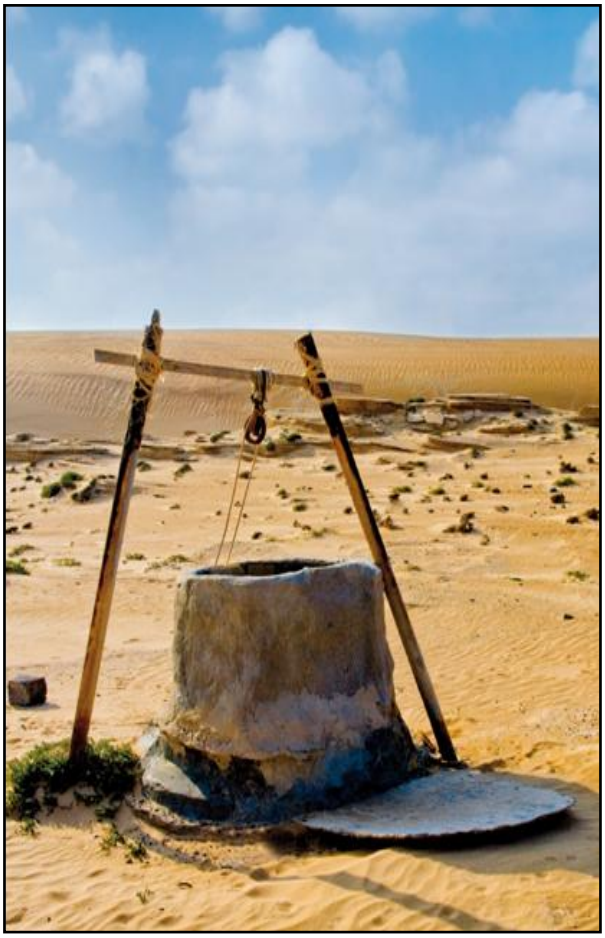
International Groundwater Resources Assessment Centre

This report is a summary on groundwater monitoring practices in the SADC region. A brief overview is made for each country to capture the current state of national monitoring networks in the SADC region and their future challenges. It is a compilation of the information shared during 2nd regional workshop of the Global Groundwater Monitoring Network. We thank the workshop participants for their active participation and their valuable input. This report would not have been possible without their collaboration and timely contributions.

Content

1. Introduction

Groundwater resources are vital for drinking water supply, irrigation and the sustainability of rivers, lakes, and wetlands. However, increased demand, population growth and climate change are increasingly putting pressure on our groundwater resources. Lack of and inappropriate management have already led to contamination and overexploitation of aquifers in some areas and could result in additional water supply problems, land subsidence and deterioration of groundwater dependent ecosystems. Monitoring our groundwater resources is crucial for assessment, prediction and sound groundwater management. There is however, still a lack of groundwater information availability and resistance to share groundwater data. Lack of information, along with the transboundary nature of many of the aquifers, complicates sustainable water management at the national and international levels.



Recognizing the lack of groundwater data around the world, IGRAC took initiative to establish the Global Groundwater Monitoring Network (GGMN). The GGMN is an interactive tool that relies upon contributions from networks of groundwater experts. Its sets up regional workshops to strengthen and expand the community of groundwater monitoring experts. The regional workshops further aim to enhance groundwater management in regional cooperation.

On November 15 and 16, 2012, 16 representatives from the Southern African Development Community (SADC) as well as key representatatives of the Zambian Ministry of Energy and Water and the SADC Water Division attended the GGMN workshop in Lusaka, Zambia. Participating countries were Angola, Botswana, Lesotho, Mozambique, Namibia, South Africa, Tanzania, Zambia and Zimbabwe.

Throughout the workshop, groundwater data and detailed information was shared by the participants on groundwater monitoring in their countries.

This summary report contains the basic information on groundwater monitoring practices in the SADC region. It begins by describing the IGRAC GGMN. Next, a brief overview is made for each country to capture the current state of national monitoring networks in the SADC region and the future challenges.

1.1. The Global Groundwater Monitoring Network

The Global Groundwater Monitoring Network programme has been initiated to improve global groundwater monitoring, increase sharing of information and thereby improve understanding of changes in groundwater resources. The GGMN Programme consists of two components: the GGMN Portal and the GGMN People Network. The GGMN builds a network of networks, structured around national focal points who manage the collection and entry of groundwater monitoring data in the web-portal.

The GGMN Portal

The web-based GGMN application (http://ggmn.un-igrac.org) offers access to aggregated groundwater data in a geographical information system, which detects changes in groundwater levels. Members of the GGMN People Network can access the country-dedicated workspace of the portal. This workspace allows users to upload, interpolate, aggregate and analyse the groundwater data from their country. The simplicity of the application and clear information ownership (it remains with the data supplier) ensures that the global groundwater community can readily participate in the GGMN programme.

The GGMN People Network

The GGMN relies on the participation of groundwater specialists, with knowledge of regional hydrogeology. Regional (spatial) aggregation of groundwater point measurements is much more than a numerical interpolation. It needs to be carried out by regional experts with a clear understanding of local hydrogeological conditions, existing monitoring practices, historic developments, socio-economic changes and other relevant factors.

During GGMN workshops participants become familiar with the GGMN web-application and subsequently continue to collaborate as national focal points of the GGMN People Network.

The GGMN and transboundary water cooperation

When it comes to management strategies for transboundary aquifers, a participatory approach is essential. National groundwater monitoring networks play a key role in transboundary aquifer management. Connecting national, regional and global networks is a first step towards transboundary water management. Within this framework, the GGMN attempts to contribute to the harmonization of transboundary groundwater information and to promote further dialogue for transboundary cooperation.

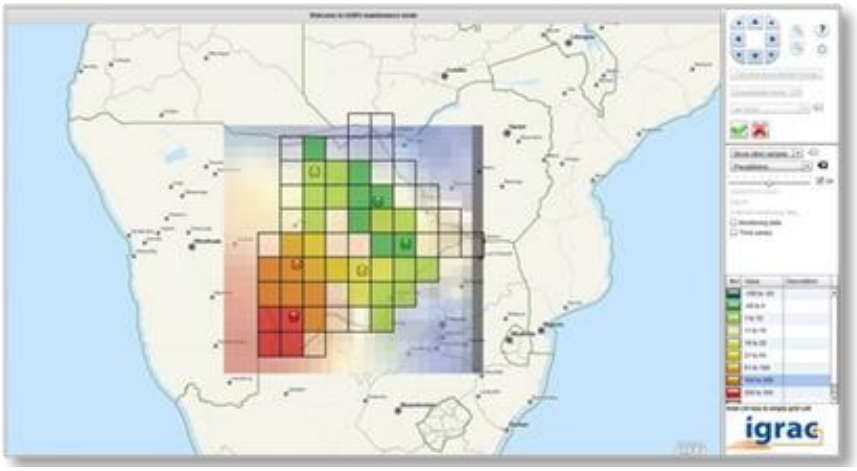


Figure 1. Aggregation of groundwater monitoring data in the GGMN web-

2. Current monitoring and assessment practices in the SADC region

2.1. Southern African Development Community

The Southern African Development Community (SADC) is an inter-governmental organization, with 15 member states: Angola, Botswana, Democratic Republic of Congo, Lesotho, Mauritius, Malawi, Mozambique, Namibia, Madagascar, Seychelles, South Africa, Swaziland, Tanzania, Zambia, and Zimbabwe. Its objective is to increase socio-economic cooperation and integration among the community.

It is estimated that about 70% of the people in the SADC region rely on groundwater as their only source of water [1]. The SADC member states are facing comparable groundwater management challenges. Increasing aridity and limited surface resources are increasing the dependency on groundwater for both domestic and commercial water needs [2]. Recognizing the increasing dependency has resulted in regional strategic approaches to improve groundwater management practices in Southern Africa, such as the Groundwater Management Programme (GMP) [3]. Groundwater management is now an integral part of the Southern African Development community.

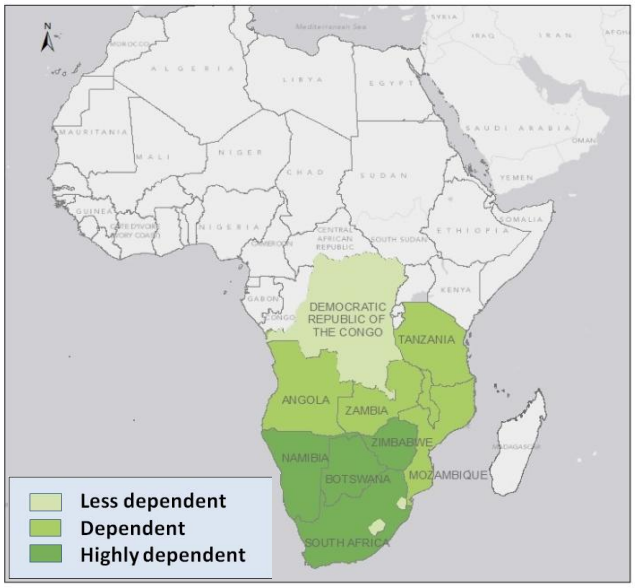


Figure 2. Overall groundwater dependency (for domestic, irrigation and industrial use) in the SADC Region (after Farr et al., 2005 [4]).

2.2. Angola

About 3.5 out of 18.5 million people (approximately 19%) in Angola rely exclusively on groundwater. Groundwater use is concentrated in the southern and coastal portions of the country where conditions are more arid and water less available. Additionally, groundwater is being increasingly developed for local systems to augment urban supply in the rapidly growing peri-urban areas [5]. The economic development of these regions and the well-being of Angola's population largely depend on these groundwater resources.

National groundwater monitoring network

There is no formal institution responsible for data collection related to groundwater. However, Angola's National Department (DNA) carries out annual field surveys of the operational status of water supply systems to assess the level of water supply coverage. The Government has entered into various agreements with UNICEF. Among these agreements, there has been a project which aimed to increase water supply and sanitation in rural areas. From 1977 to late 2007, approximately 4,000 water points were drilled and hand pumps were installated. A groundwater policy has not yet been formulated into a national development strategy. However, the government is committed to strengthening the existing monitoring structure to assure sustainable supply of the water quality and quantity in the future.

Data management and assessment

A groundwater database and data management is lacking. Inter-institutional relationships regarding data sharing and management do not exist.

Challenges

Establishment of a monitoring network is still in its underway. Lack of groundwater management has led to overexploitation of aquifers. At present, about 50% of the constructed hand pumps do not work. Drying out of these wells is the main cause of the non-functional water points.

2.3. Botswana

Groundwater supplies two-thirds of the national water consumption. Groundwater resources are used throughout the country for livestock, municipal supply, and for small areas of irrigation. In most parts of Botswana, groundwater abstraction is depleting limited resources. It is estimated that over 21,000 boreholes exist in the country, but many are not used and capped. Just over half of the registered boreholes in the country are owned by the government, the remainder by private individuals [6].

National groundwater monitoring network

Groundwater level monitoring in Botswana is carried out by the Ministry of Mineral Energy and Water Resources. Natural (undisturbed) areas are monitored by the Department of Geological Survey (DGS) while pumping (disturbed) areas are monitored by the Department of Water Affairs (DWA). The objectives of DGS are to observe long-term groundwater level behaviour under natural conditions and to accumulate data for future economic development and resources management. The DWA focuses on observation of long-term groundwater level behaviour under pumping conditions to observe changes and to see the aquifers' responses to stress.

Figure 3 shows the locations of the most important well fields in Botswana. The first monitoring activities date back to 1971 (Table 1). Monitoring activities include groundwater levels observations, water quality analysis, estimation of abstraction rates, and specialized (project related) monitoring. Most groundwater levels are measured on a monthly basis. Observation wells equipped with digital loggers are measured daily.

Data management and assessment

DGS records the groundwater data into a national borehole archive (NBA). DWA stores their data into WELLMON software. WELLMON is a software package for groundwater monitoring data, meteorological data and other parameters, which produces groundwater hydrographs. Currently, WELLMON only contains groundwater level and abstraction data. In general monitoring data are of good quality [7]; data is graphed to check for consistency and continuity before it is entered into the system.

Challenges

Some government departments do not recognize the need to monitor. However, for proper groundwater resources management, the spatial density of observation wells in Botswana is not yet adequate. Additional challenges stem from lack of coordination. In particular, groundwater quality monitoring is not well coordinated. Delay in data processing has resulted in inconsistent data series, which subsequently has generated time series with numerous data gaps.

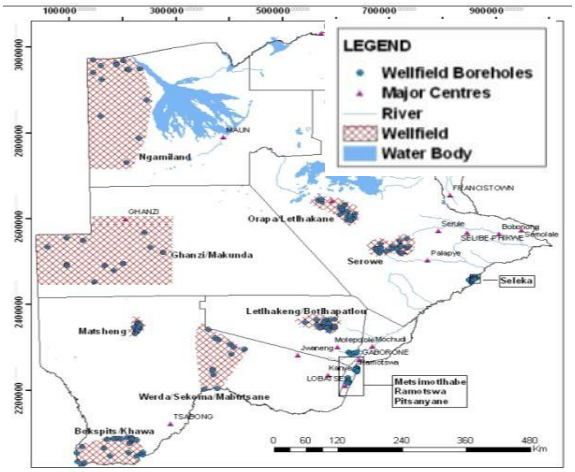


Figure 3. Well fields and the corresponding well field boreholes of Botswana.

Wellfield	Date started
Serowe	December 1971
Pitsanyane	September 1983
Metsimotlhabe	December 1987
Ramotswa	October 1984
Seleka	March 1992
Letlhakeng-Botlhapatlou	October 1993
Matsheng	December 1995
Khawa-Bokspits	April 1996
Ghanzi-Makunda	August 1996
Hunhukwe-Lokalae	December 2000
Orapa-Letlhakane	September 2001
Werda-Sekoma	August 2003
Ngamiland	February 2006

Table 1. Name and start of monitoring of the well fields of Botswana.

2.4. Lesotho

For many rural and some peri-urban communities in Lesotho, groundwater is the only source of potable water. Groundwater is accessed through natural springs and boreholes. The majority of the boreholes are located in the lowlands of the country, whereas the natural springs are distributed throughout. There is limited potential for irrigation with groundwater in Lesotho since most aquifer yields are low [8].

Many households have privately owned boreholes from which they are tapping groundwater. These privately owned boreholes are increasing at an alarming rate. Their number and the amount of groundwater being abstracted are unknown. However, efforts are being made to collect this information and to control and regulate borehole drilling in the country.

National groundwater monitoring network

The Department of Water Affairs (DWA) in the Ministry of Energy, Meteorology and Water Affairs (MEMWA) is the executing agency for the national groundwater monitoring network. Groundwater monitoring started in the early 1990's with only a few springs across the country. Currently the network consists of 162 monitoring springs and 72 observation wells. Both observation wells and springs are monitored every three months. Springs are monitored on their yield and physical parameters, such as pH, temperature, EC, salinity and redox potential. Chemical water quality parameters are measured once a year.

Data management and assessment

Data is stored in spreadsheets that are linked to a Geographical Information System. Data is not publically available online, but can be given out publicly on demand. The groundwater division performs annual groundwater resources assessments. These assessments include determination of the seasonal fluctuations of the water table, determination of groundwater flow direction and sustainability of groundwater abstraction.

Challenges

Due to financial constraints monitoring points and frequency of monitoring is limited. Lesotho needs public awareness on the importance of groundwater. There is a poor understanding of the importance of observation wells among local communities.

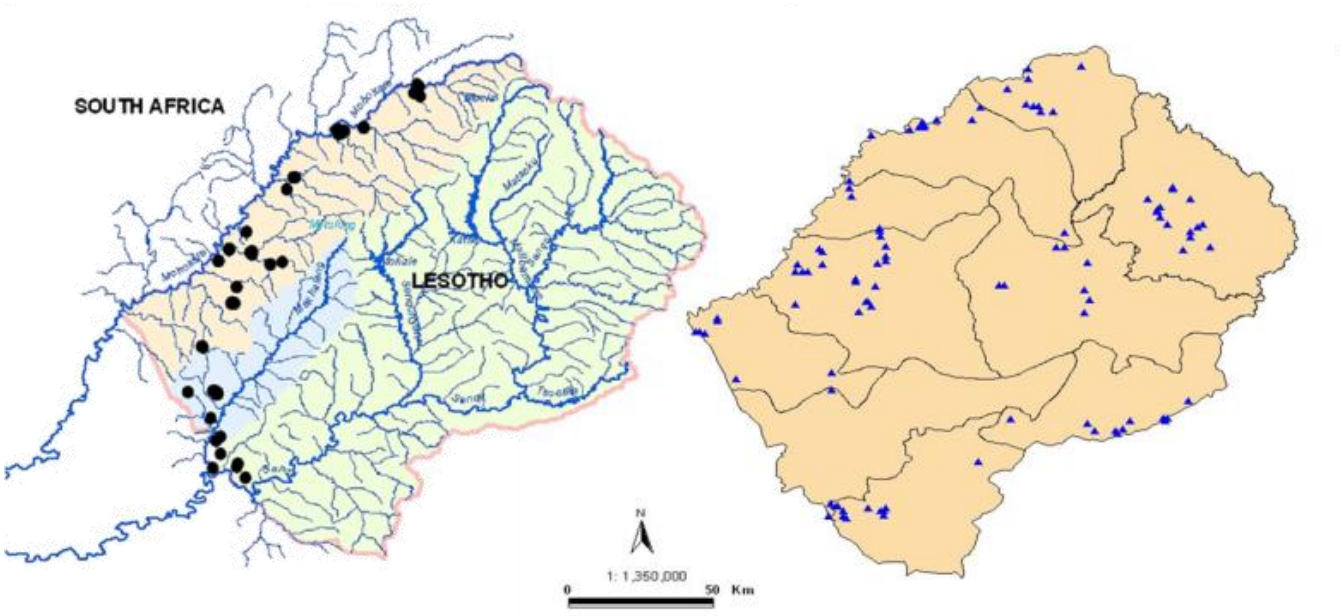


Figure 4. Left figure shows the location of boreholes; mainly located in the lowlands of Lesotho. The blue triangles in the right figure indicate the location of the monitoring springs.

2.5. Mozambique

The main source of water in Mozambique is surface water. However, groundwater is utilized on a large scale in a number of cities for drinking water supply. Groundwater potential is substantial and lies in the alluvial formations of the various rivers [9].

Starting in 1980, data and information on groundwater resources have been collected in many provinces by rural water supply services. Until the late 1990s expatriates supported the system, however very little capacity building of local employees took place. When the National Water Directorate (DNA) initiated the replacement of the expatriates by national staff, the databases at all levels collapsed. This information is in most cases either incomplete or missing entirely [10].

National groundwater monitoring network

The water agency ARA-Sul currently executes a pilot project on groundwater monitoring. This project includes the collection of hydrogeological information of a complete aquifer system (~5000 km²) in the metropolitan area of Maputo. The operational network consists of 25 groundwater level monitoring points and 48 water quality monitoring points. Data collection includes groundwater levels, electro-conductivity (EC) and chemical parameters. Groundwater levels are monitored monthly whereas groundwater samples are taken quarterly.

The staff is trained in drilling, supervision and collection of hydrological data and educated to acquire a better understanding of the aquifer system. The main task of ARA-Sul is the management of the groundwater resources through protection of aquifers from over-pumping and pollution. The experience from this pilot project will be extended to other areas in the future.

Data management and assessment

Groundwater database management in Mozambique is poorly developed. Inter-institutional relationships regarding database management do not yet exist.

Challenges

Mozambique needs professional capacity building on groundwater management and hydrogeological knowledge of aquifer systems. The challenge is to establish a national groundwater monitoring programme. The knowledge of the current pilot project could be of great asset.

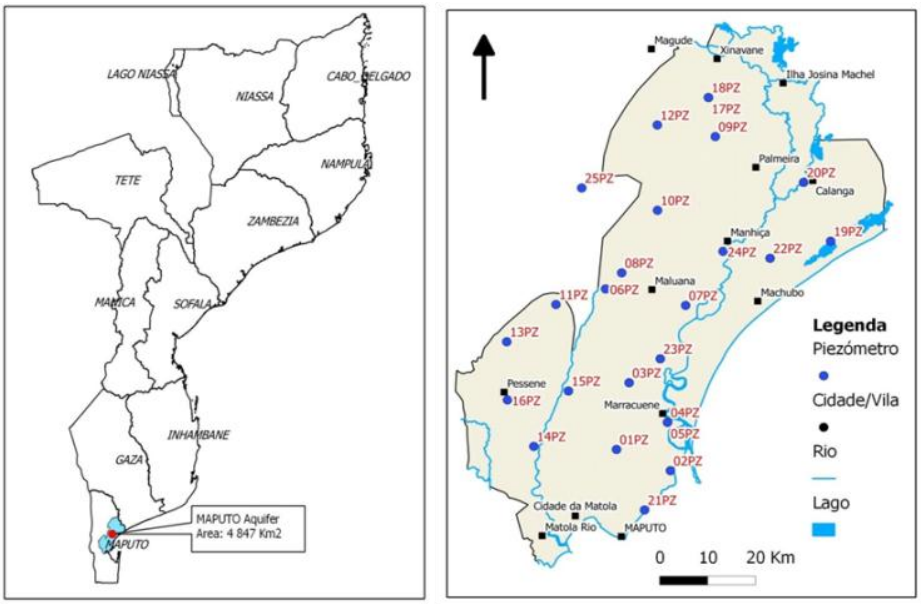


Figure 5. Left figure shows the provinces of Mozambique and location of the Maputo Aquifer. Right figure shows the location of the monitoring points, which are part of the ARA-Sul pilot project.

2.6. Namibia

Namibia is the most arid country in sub-Saharan Africa and depends strongly on its groundwater resources. Rainfall is variable. The western part of the country is a desert, the southern part is arid and the north eastern part receives rain over 700mm/yr [11]. Groundwater is pumped for domestic, livestock and wildlife consumption, as well as for mining, industrial operations and irrigation. More than 50% of land in Namibia is covered by farms that all depend on groundwater; either for watering livestock or irrigation (with more irrigation taking place in the Karst area).

Over 100.000 boreholes have been drilled for groundwater exploration. A large number of these boreholes have either come up dry or dried up over time [12]. It is estimated that there are more than 50,000 production boreholes in use, as the country does not have any perennial rivers within the country apart from those that form the border with neighbouring countries. With the assistance from the BGR, the government has done comprehensive research on the aquifer in northern Namibia, where large amounts of fresh water were discovered at around 300m depth. More boreholes need to be drilled in the area to improve the monitoring network coverage and effective management of this aquifer.

National groundwater monitoring network

The Department of Water Affairs and Forestry is responsible for national groundwater management. Groundwater level monitoring started in Namibia in the 1960s. The network consists of around 650 groundwater level monitoring points. Groundwater monitoring is carried out through manual measurement and downloading of digital loggers. The readings are done on a quarterly basis in all basins. Over the past year, Namibia has invested in advancing groundwater monitoring by purchasing and installing digital loggers in most of the existing observation wells. Strategies have been developed to increase the numbers of observation wells in areas that were previously not monitored. Groundwater quality monitoring is in its elementary stage but is being established.

Data management and assessment

Namibia has a National Groundwater database called GROWAS. The database is used for storing groundwater data such as groundwater levels, groundwater quality, permits for abstraction and all the hydrogeological data in the country. The data is checked and verified before being entered in the database. Currently, the database is being upgraded to improve its use and to link it to ArcGIS. The database is not publically available.

To adopt appropriate management strategies and to ensure the sustainable utilization of the aquifer each major aquifer is operated according to an aquifer management plan. However, the knowledge about the water balance, or recharge versus abstraction, is often insufficient due to short historical records of these aquifers. Regional groundwater reporting has not yet been done in the country but plans are there to start with this.

Challenges

Human capacity is lacking to carry out the groundwater monitoring in all basins. Groundwater quality monitoring is lagging behind as well as data processing. Four of the monitored aquifers in Namibia are of transboundary nature. For transboundary monitoring it is often politically difficult and time consuming to amend legal provisions and make organizational arrangements.

2.7. Republic of South Africa

Groundwater resources in South Africa are limited, since large porous aquifers occur only in a few areas. Despite their limited availability, groundwater resources are extensively utilized in the rural and more arid areas [13]. More than 400 towns and 80% of the rural settlements depend on groundwater. South Africa has several areas of large-scale abstractions for irrigation, which put a lot of pressure on the groundwater resources. It is foreseen that groundwater use for human consumption will increase, especially in the western part of the country which lacks perennial rivers.

National groundwater monitoring network

The National Water Act (Act 36 of 1998) provides the Department of Water Affairs and Forestry with the mandate to protect, use, develop, conserve, monitor, manage and control South Africa's water resources in an integrated manner [14]. South Africa is advanced regarding its groundwater monitoring network. Groundwater is monitored to identify spatial and temporal trends as well as to understand the cause and effect relationship of groundwater changes in affected areas.

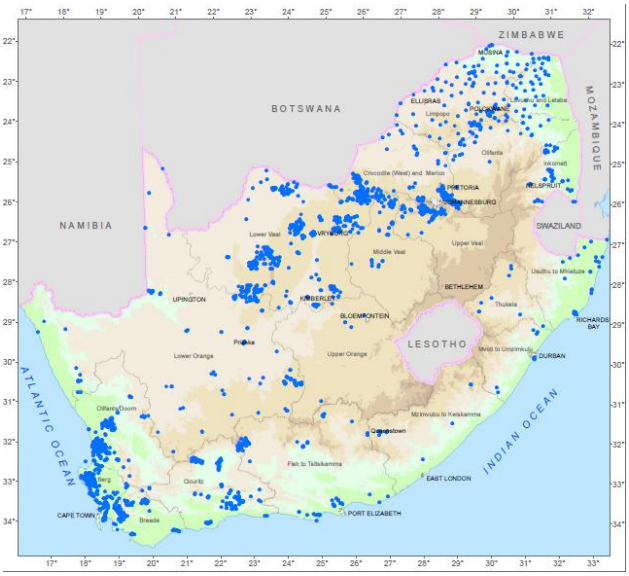


Figure 6. Blue points indicate the active stations used for groundwater level monitoring.

Groundwater levels are monitored on ~2.500 monitoring points. Monitoring consists of electronic real time data while some monitoring points are still measured manually every three months. There are 350 chemical monitoring points, which are sampled twice a year (end of dry - and end of wet season). Samples are analysed on macro elements, trace elements and environmental isotopes.

Data management and assessment

Data is stored in the National Groundwater Archive (NGA). NGA is a centralized web enabled database. People with a direct interest in groundwater can register to search, capture and store data. The database is an ArcGIS geodatabase storing all verified spatial hydrogeological data. Spatial data is available in GIS format.

The Groundwater Resource Assessment and Monitoring (GRAM) is responsible for the assessment of groundwater quantification and quality, as well as for the development of protection requirements in support of groundwater resources management. Groundwater level maps are produced to depict annual, seasonal and monthly groundwater changes. GRAM further works on the on-going provision of technical and scientific support for groundwater development and integrated water resource management at all levels.

Challenges

South Africa would like to audit and optimize its groundwater monitoring programme and network. This includes expansion of the national network coverage and a gradual upgrade to a national real time monitoring network. Furthermore it aims to increase the number of chemical groundwater monitoring points covering the country.

2.8. Tanzania

Groundwater is a vital source of water in the semi-arid areas, while it supplements surface water in the other parts of Tanzania. Groundwater accounts for approximately 70 to 80% of the supply. Mostly inland drainage basins are exploited for groundwater for domestic water supplies. Overall contribution of groundwater to irrigation is fairly limited [15]. There are over 20,000 recorded medium and deep boreholes, and 100,000 shallow wells.

National groundwater monitoring network

In 2009, the water resources management act was established as an instrument to implement the National Water Policy. The act covers various aspects of water resources including the development and management of groundwater resources.

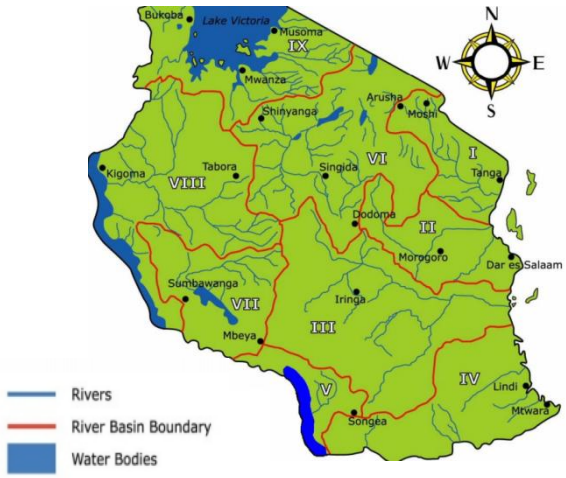
Water resources in Tanzania are managed basin-wise; five river basins and four lake basins (Figure 7). Water monitoring is done by the Ministry of Water. Groundwater monitoring in Tanzania started in 1955 with the Makutapora well field, because of its vital role as the only water source for Dodoma city in Central Tanzania. With the assistance of the World Bank 12 monitoring wells were drilled in Rufiji basin in early 2000s. The World Bank and other development partners are now supporting the drilling of monitoring boreholes in all nine basins. In the Internal Drainage Basin 30 boreholes have been drilled (2007). In the Pangani River Basin 15 out of 35 planned monitoring boreholes have been drilled (2010). In Wami Ruvu Basin 19 boreholes have been drilled by JICA and installed with water level loggers (2011). It is planned to drill another 6 monitoring boreholes in the Ruvuma Basin in 2013 with the assistance of SADC, through the Shared Watercourses Support Project. Furthermore, the regulations for groundwater licensing are being prepared.

Data assessment and management

In general the quality of the data for individual points is accurate with sufficient detail captured for each point. However, due to shortage of manpower, the time period between data capture and verification is extensive. As a result, less than 25% of data collected are being entered in the database [16].

Challenges

There is inadequate public awareness on the importance of groundwater resources, while resources are overexploited and polluted. Monitoring and assessment generally have a low budget. However, as a result of potential climate change impacts, the government is currently establishing a Groundwater Management and Development Centre to strengthen institutional provisions and building institutional capacity for improved groundwater management. Drilling of monitoring wells is part of this groundwater development programme in major aquifers.



I	Pangani Basin
II	Wami and Ruvu Basin
III	Rufiji Basin
IV	Ruvuma and the Southern Coast Basin
V	Lake Nyasa Basin
VI	Internal Drainage
VII	Lake Rukwa Basin
VIII	Lake Tanganyaika Basin
IX	Lake Victoria Basin

Figure 7. The river and lake basins of Tanzania.

2.9. Zambia

Zambia is endowed with relatively abundant water resources predominantly from a distinct rain season, which starts in October and ends in April. The annual rainfall averages between 700 mm in the south to 1400 mm in the north. However the majority of the population still lacks access to good quality drinking water and improved sanitation especially in rural settings and in the unplanned settlements surrounding the major cities and towns.

Groundwater plays a major role in the water sector in Zambia. Both Lusaka and Ndola fulfil approximately half of their supply requirements through groundwater. The city of Kabwe was previously supplied completely by groundwater, but this has since been reduced to approximately 20% due to the increasing presence of lead and zinc in the groundwater. Supplies from groundwater have also been reduced near Lusaka and in the Copperbelt mining area where water pollution and increasing nutrient loads is a growing problem [17].

National Groundwater Monitoring Networks

The Revised National Water Policy of 2010 designated the Ministry of Energy and Water Development (MEWD), through the Department of Water Affairs (DWA) and the Department of Energy, as the main institution responsible for water policy formulation and water resources management activities. This includes the assessment, planning and development of surface water and groundwater [17]. However, most of the monitoring and assessments on both quantity and quality of water in Zambia are not carried out by the institutions mandated to do so because of lack of financial resources and poorly maintained monitoring stations. Hence, groundwater monitoring and assessments are mainly performed by organizations and industries within their areas of operations such as the Zambezi River Authority (Lake Kariba and parts of the Zambezi River), Zambia Electricity Supply Cooperation (on Kafue River) and various mining companies. These data are often proprietary and not accessible to the public [18].

Data management and assessment

DWA maintains paper files for siting and drilling operations. Data from 1970 onwards are present in the files. The project “Groundwater Resource for Southern Province” was carried out to make an assessment of the groundwater resource potential for the southern province and Lusaka and surroundings. This project could be a good example for future network developments. As an integral part of this project, a professional groundwater information system at DWA was developed, consisting of groundwater database and GIS. The database stores information on over 3,000 water points including hand dug wells, boreholes, springs and unsuccessful groundwater exploration drill sites. The database includes the information of all the major hydrogeological investigations carried out since the mid-1970s and combines general information with comprehensive and detailed technical information on groundwater hydraulics, borehole design, geology and groundwater quality. Data has been grouped into four categories, namely groundwater quality (779 water points); groundwater hydraulics (697 water points), lithological description (519 boreholes); and groundwater point information encompassing 3,116 water points, 1,620 drilled boreholes, 1,150 hand dug wells, 13 thermal springs and 159 reported unsuccessful boreholes [18].

At regional level, an information river system for the Zambezi River Basin called Zambezi Water Information System (ZAMWIS) located at Zambezi River Authority in Lusaka, Zambia has been developed. Its purpose is to support planning and management of water resources in the Zambezi Basin. In addition, the future function of ZAMWIS with ZAMCOM is to assist with the collection, valuation and sharing of all data and information on the Zambezi watercourse [17]. Data collected for projects outside of DWA, such as UNICEF or Lusaka Water and Sewerage (LWS) projects, are rarely submitted to DWA. Various levels of data are kept by these institutions in their reports [17]. A major national resource evaluation was completed in 1995 [19] as part of the development of the National Water Master Plan. This study included assessments of surface water and the major aquifer units in the country in terms of factors such as average yields, water quality and development potential.

Challenges

Zambia is coping with a growth in water demand especially for agriculture and hydropower. The rate of urbanization exceeds infrastructure development. The degrading water quality is increasingly undermining the important role of water in the country's economic development. With only a limited legal framework at present for groundwater, control and management of the resource is limited. There is no permitting of groundwater abstraction, no nationalised borehole system and no requirement for groundwater data submission to DWA. Water resources infrastructures are poorly developed or maintained.

The major concerns of government departments are on strategic planning, maintenance of systems as well as political/security [20]. Although there are no statistics, private development of groundwater is notably increasing in many parts of the country. However, the restructuring of DWA and the creation of the new posts generally reflects an increasing emphasis on the groundwater sector.

2.10. Zimbabwe

Overall, groundwater resources are small compared to estimates of surface water resources in Zimbabwe. This is mainly because the greater part of Zimbabwe consists of ancient igneous rock formations where groundwater potential is comparatively low. Four aquifer systems of relatively high groundwater potential are known.

National groundwater monitoring network

Groundwater resources management is carried out by the Groundwater Department of the Zimbabwe National Water Authority (ZINWA). ZINWA is a parastatal under the Ministry of Water Resources Development and Management. Monitoring of groundwater level fluctuation is currently confined to only three major aquifers. These are the Lomagundi Dolomite Aquifer situated in the north western part of the country, the Nyamadlovu Sandstone Aquifer situated in the south western part of the country and the Save Alluvial Aquifer located in the south eastern part of the country. Water levels are measured using data loggers and readings are collected monthly. Chloride deposition has been monitored in six monitoring stations throughout the country but has been discontinued due to lack of funds. The information was used in the assessment of groundwater recharge rates. The Department also used to carry out chemical surveillance on groundwater and surface water but again the programme was suspended due to lack of resources.

Data management and assessment

Groundwater fluctuation levels are recorded on template sheets during the last week of the month by field observers who send the records to the main office in Harare. The data is recorded in Excel and an initial quality control exercise is performed. The data is then reformatted and importated into a national groundwater database called Hydro GeoAnalyst. The software has proven to be quite versatile and meeting the needs of ZINWA. Hydrographs and groundwater maps are produced which assist in overall groundwater development and management.

Challenges

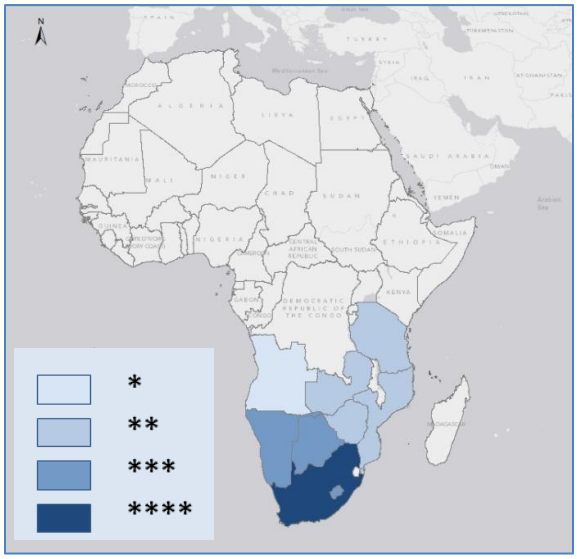
The main challenges encountered relate to lack of financial resources, logistical support and limited staff. Another challenge is related to vandalism of facilities by local communities. In certain instances, monitoring boreholes are clogged with debris making water level recording impossible. Specialised entrances for data loggers and locking mechanisms are currently being manufactured for monitoring boreholes in the Save Alluvial Aquifer. It is desired to revive both the chloride deposition and chemical surveillance programmes and to have telemetric (real time) data collection for the water level fluctuations.

3. Conclusions and recommendations

There is limited groundwater monitoring taking place in SADC-countries. The state of development of national monitoring networks in the SADC region is highly diverse. The groundwater monitoring networks vary in its 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. South Africa has an advanced groundwater observation and data processing system. Various countries emphasized their challenges regarding the lack or inadequate institutional arrangements to regulate groundwater resources while other highlighted importance of (professional) capacity building and public awareness regarding the importance of groundwater resources.

The GGMN programme advocates an improvement of the national groundwater monitoring networks in the SADC region in order to acquire detailed observations of this vital natural resource. The shared information and knowledge during the workshop is a starting point to share groundwater data in the SADC region. Countries that do not have software for groundwater data management can make good use of the GGMN web-application and the statistical tools offered in the GGMN to detect changes in groundwater levels.

The workshop created a platform to discuss groundwater monitoring challenges as well as to exchange knowledge and perspectives on monitoring networks. The regional workshop has supported the development of the GGMN People Network. The participants will continue to serve as the GGMN national focal points, who manage the collection and entry of groundwater monitoring data in the web-portal. This engagement is one of the key developments for a successful GGMN programme. A continuous and collaborative effort will contribute to the assessment and management of the groundwater resources and endorse shared groundwater management among aquifer states.



Country	Development of monitoring network
Angola	*
Botswana	***
Lesotho	***
Mozambique	**
Namibia	***
South Africa	****
Tanzania	**
Zimbabwe	**
Zambia	**

Level of development: * Poorly developed **** Developed

Figure 8. Development of groundwater monitoring networks in the SADC region.

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Appendix I. Participant list

The information in this report is a compilation of the information shared by the participants of the GGMN workshop. This report would not have been possible without the contributions of the participants and their organizations partners who volunteered their efforts. The participants will continue to serve as the GGMN national focal points, who manage the collection and entry of groundwater monitoring data in the web-portal.

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Zambia	Ngosa Howard Mpamb Mpambanh@hotmail.com	Ministry of Energy and Water
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Table 2. Participant lists of the GGMN Workshop

Appendix II. Overview of SADC national groundwater monitoring networks

	National Monitoring Network	Data management	Challenges
Angola	*DNA, Poorly developed*	*None*	*Establishment of network*
Botswana	*Yes, DGS, DWA since 1971*	*National Borehole Archive (NBA)*	*Spatial density of wells, coordination of the work*
Lesotho	*Yes, DWA, since 1990 >150 springs and > 60 wells*	*Database linked to GIS*	*Financial resources, public awareness*
Mozambique	*Pilot Project, Ara-Sul >25 gw monitoring wells >45 gw quality mon. points*	*Poorly developed*	*Establishment of network, professional capacity building*
Namibia	*Yes, DWA, since 1960 > 650 gw monitoring wells*	*GROWAS, database linked to GIS*	*Human capacity, evaluation of data*
South Africa	*Yes, DWA >2500 gw monitoring points >350 gw quality mon. points*	*National Groundwater Archive (NGA) Web-enabled database linked to GIS.*	
Tanzania	*Yes, Ministry of Water, since 1955 >75 gw monitoring wells*	*Database*	*Institutional capacity, Coordination of the work*
Zambia	*Yes, DWA*	*Database linked to GIS*	*Financial resources, coordination of the work*
Zimbabwe	*Yes, ZINWA 3 aquifers are monitored*	*Hydro GeoAnalyst, database linked to GIS*	*Financial resources, human capacity*

Table 3. Overview of the national groundwater monitoring networks per country and the main challenges as indicated by the GGMN national focal points.