GROUNDWATER DEPENDENCE AND DROUGHT WITHIN THE SOUTHERN AFRICAN DEVELOPMENT COMMUNITY

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ABSTRACT

A groundwater situation analysis of the SADC region has been undertaken as part of the World Bank GEF Programme as a basis for ensuring equitable use of groundwater resources, particularly during periods of drought, both for human needs and for sustaining ecosystems. Much of the groundwater in the region occurs in weathered crystalline rocks suitable for dispersed supply to rural communities, although there are several aquifers capable of sustaining urban demand that contribute to the supply of several major cities and towns. A number of SADC Member States, such as Botswana, Namibia and South Africa, are very dependent on groundwater, whereas the Democratic Republic of Congo is least dependent. Groundwater dependence and groundwater demand, together providing an indication of drought vulnerability, have been assessed from the availability and coverage of groundwater data, but it is very apparent that reliable and comprehensive groundwater data are major deficiencies throughout the SADC region. Few attempts have thus been made to calculate renewable groundwater resource volumes or develop optimum use of groundwater, despite the fact that susceptibility of many Member States to drought requires them to consider mitigation strategies to lessen the hardships imposed largely on their rural population. Such strategy requires long-term intervention and not short-term emergency responses, a process that is directly related to availability of comprehensive groundwater datasets. Considerable effort in groundwater assessment and monitoring and the accumulation, evaluation and dissemination of essential datasets will thus be required to maintain population livelihoods in future years when water supply is projected to be in deficit in over half of the SADC Member States.

INTRODUCTION

The Southern African Development Community (SADC) fosters co-operation for mutual benefit between fourteen Member States in southern and eastern Africa. Collectively they account for almost 70% of the gross national product of Sub-Saharan Africa and are home to a third of its people. The region has also been characterised by recent rapid population growth.

Dependence on surface water and groundwater varies between Member States but there are already indications that water will be scarce in nine of the Member States in the next few decades. Comprehensive regional planning and water conservation will be crucial to the region over this period. SADC recognises the importance of water to regional integration and economic development and established its own Water Sector in 1996. A SADC Protocol on Shared Watercourse Systems was adopted to provide guidelines for joint management of resources. A Regional Strategic Action Plan for Integrated Water Resource Development and Management has also been compiled; this is being implemented to address key water management issues for both surface water bodies and major aquifers.

There are significant economic and social values associated with groundwater in most SADC Member States. Groundwater is extensively used for a range of productive and consumptive purposes and during the last few decades the use of groundwater for irrigation and food production has increased considerably; groundwater now accounts for about 14% of the total irrigated area in Namibia, 18% in South Africa, and as much as 56% in Botswana (FAO AQUASTAT database). Apart from agriculture, groundwater is also important for small-scale production activities, such as brick making and brewing, contributing to local employment and income generation.

Extremes of climate bring both frequent drought and substantial flood events that impact livelihoods as well as national productivity. In many Member States rural communities are dependent on groundwater, which is a key element for the alleviation of the hardship drought can inflict upon them. However, policy responses to drought have invariably been based on short-term crisis reactions which generally prove to be inefficient or ineffective. Proactive, sustainable and integrated management of groundwater resources thus needs to be instigated in sympathy with the requirements of the regions ecosystems.

A situation analysis of the region has been undertaken as part of the World Bank GEF Programme (Wellfield Consulting, 2003). The project was part of the Regional Strategic Action Plan for Integrated Water Resources Development and Management and was executed by the SADC Water Sector Co-ordinating Unit (WSCU) with support from the SADC Sub-Committee for Hydrogeology. The project objective was to gather information from which to develop a strategic regional approach to support and enhance the capacity of SADC Member States in the definition of drought management policies, with specific reference to the availability and supply potential of groundwater resources. It also examined the reconciliation of demands for socio-economic development and those of the principal groundwater-dependent ecosystems.

The essential objectives were:

- to undertake a situation analysis of the whole of the SADC Region with respect to groundwater use, water demands and other water related issues in the context of drought preparedness and management,

- to gather information from which to assess the basis for the equitable use of water resources for both human and ecosystem needs.

GROUNDWATER INFORMATION

It is apparent from the results of intensive information search and contact with many different organisations and individuals in the region, as well as resident in-house knowledge, that groundwater information is divided between six overall sources, namely:

Hydrogeological Mapping Programmes: The most recently completed hydrogeological maps are those for Namibia and Lesotho. Mauritius produced a hydrogeological map in 1999 and a series of 1: 500 000 scale maps is now being produced for South Africa (commencing in 1995). All other hydrogeological maps in existence in the region (Botswana, Tanzania) may generally be regarded as ‘first attempts’ often using local formats and legends.

National Water Development Plans: Documents produced as part of National Water Development Plans form a major source of baseline data on hydrogeology and related climatology, hydrology, water use and sanitation. Examples include Zambia (JICA, 1995) Zimbabwe (Norad/Interconsult 1986), Botswana - the National Water Development Plan was completed in 1991-92, Tanzania – Region Water Master Plans were produced on a regional basis during the early 1980’s for all regions except for Dodoma, Arusha, Singida and Morogoro, and Namibia – database produced for the production of the national hydrogeology map dated 2001.

Donor Aid Agencies: Databases from individual projects are normally held within both the donor and recipient countries.

Consultants and Institutions: A variety of consultant organisations have been active in the region. Many have offices in centres such as Harare, Gaborone and in various centres in South Africa. Others are based in Europe and elsewhere. Private sector organisations are beginning to realise the commercial value of their data, especially long-term time series and detailed point source data that would be expensive to replicate. To organise the collection and compilation of effective geo-referenced databases from such sources, could in future, be a relatively expensive undertaking. Some universities in the SADC region are taking an active role in training and ensuring best hydrogeological practice (Waternet).

District Level Institutions: Decentralisation of rural groundwater supply schemes has occurred in a number of Member States. This has created difficulties in countries such as Zambia and Malawi where there are insufficient qualified personnel to take an active role in data collection. City councils are involved in groundwater for urban supply in Windhoek and Lusaka.

National Level Institutions: A number of the most comprehensive national databases are those originally collected by Geological Surveys and, in later years, Water Departments. These databases have suffered from the effects of decentralisation and privatisation of siting and drilling. Archives of Geological Surveys in the then Southern Rhodesia (Zimbabwe), Nyasaland (Malawi), Northern Rhodesia (Zambia), Bechuanaland (Botswana), Tanganyika (Tanzania) and Swaziland include some of the first hydrogeological works undertaken in the SADC region.

GROUNDWATER DEPENDENCE

The role and perception of groundwater in a national water supply strategy is overwhelmingly influenced by availability and access to surface water sources, i.e. by the ‘normal’ meteorological/hydrological regime resultant from the location of the Member State in the region. The relative importance attached to groundwater is also influenced by the decision makers, mostly engineers, whose training conditions them to tap all possible surface water sources (that are both visible and quantifiable) rather than consider groundwater (which is neither visible nor easily quantifiable), as the main component of national water supply.

Botswana, Namibia and Zimbabwe are the most groundwater dependent countries in SADC. DR Congo is the least dependent on groundwater, being well endowed with surface water resources (Table 1). All other SADC nations are dependent to a greater or lesser degree on groundwater especially for rural communities. Irrigation using groundwater, both on a small community garden scale and on more commercial scales for crops such as citrus and sugar, is set to increase in the near future.

Much of the groundwater in the region occurs in weathered crystalline basement rocks that are low yielding but suitable for supply of rural communities (Table 2). There are few groundwater resources capable of sustaining major urban areas, although significant limestone and fractured quartzite aquifers contribute to the supply of some of the major cities, notably Dar es Salaam, Lusaka and Windhoek.

TABLE 1 Groundwater dependency in SADC Member States

Member State	Rural	Urban	Agriculture	Industry	Overall dependency
Angola	**	**	**	*	**
Botswana	***	**	***	***	***
DR Congo	*	*	*	*	*
Lesotho	**	**	*	*	*
Malawi	***	*	**	*	**
Mauritius	*	**	**	**	**
Mozambique	**	**	*	*	**
Namibia	***	***	***	***	***
Seychelles	**	**	*	*	*
South Africa	***	**	**	**	**
Swaziland	**	*	*	*	*
Tanzania	***	**	**	*	**
Zambia	**	**	*	**	**
Zimbabwe	***	**	***	**	***

Scale *** major, ** moderate, * minor

The regional situation analysis has revealed that a useful surrogate when examining groundwater dependence is the availability of groundwater data, although data scarcity in general is a widespread problem. In countries where surface sources are plentiful (e.g. DR Congo), groundwater data coverage is almost non-existent and groundwater resources are poorly understood and managed, whereas in countries that have few potential surface water sources (e.g. Botswana, Namibia) groundwater data coverage is good and groundwater resources play a much more important role (Table 2).

Similarly, the availability and coverage of groundwater demand data when viewed in conjunction with the groundwater occurrence information clearly demonstrates the vulnerability of Member States to drought events. Where coverage of both data sets is poor, then vulnerability to drought can be assumed to be low (DR Congo, Angola); where coverage is good then drought vulnerability is high (Namibia, Botswana).

GROUNDWATER DEMAND

An assessment of overall groundwater demand can be based upon the quality and quantity of the nine data types listed in Table 3, which are largely derived from census information and generic water consumption figures. However, demand evaluation is more complex since demand also varies annually with season and climatic regime, as well as periodically with drought which may be severe enough to cause population migrations from dry to wetter areas as has happened in Zambia and Tanzania.

It is apparent that little specific information is available on the interaction between groundwater and surface water (i.e. rivers, lakes) in the SADC region although the hydrological monitoring network used in the region for the FRIEND project ought, by means of modelling, enable the relative contributions of groundwater to surface water systems to be determined (Hughes et al., 2002). However, recent river basin studies that looked at ecological and hydrogeological factors have been undertaken in the Usangu and Pangani river basins of south-eastern Tanzania, as well as in wetlands of Kwazulu-Natal Province of South Africa, and with the establishment and strengthening of major River Basin Organisations (Limpopo, Zambezi, Orange, Okavango etc) greater knowledge of this component of the water cycle may be expected.

With respect to the role of groundwater in the maintenance of various ecosystems of the region, and in particular, wetlands, it is apparent that although information is available in the scientific literature (e.g. RAMSAR publications) and in national reports and studies (general country/region specific reviews), data are patchy, even to the extent of definitions of what actually constitutes a wetland. Unfortunately, many of these studies are established from a wildlife/vegetation/environmental perspective with the result that there is generally very limited reference to groundwater and its role in the particular ecosystem.

DROUGHT VULNERABILITY

Of the fourteen SADC Member States, eleven are directly and periodically affected by drought events (Table 3). Of the other three, current information would indicate that DR Congo is not affected, and that although Seychelles and Mauritius as island states may be affected to some degree, they are partly isolated from the rigours of continental drought. Meteorological drought is endemic in those Member States that straddle the Tropic of Capricorn, and it is apparent that increasing climatic variability attributed to *El Nino* variations is increasing the periodicity and severity of drought occurrence throughout the SADC region.

Since the definition of ‘drought’ is both ‘sector-specific’ (i.e. defined by climatic changes as well as sectoral impacts) as well as ‘nation-specific’ (a perceived ‘drought’ period with reduced rainfall in higher rainfall states would be considered a relatively ‘wet’ event in say Namibia or Botswana), there unfortunately still appears to be reduced level of cooperative understanding and coordinated forward planning for drought occurrence between SADC Member States, with a consequent increase in ‘crisis management’ actions.

Groundwater significantly contributes to rural water supply in many Member States and the natural buffering capacity of groundwater systems during periods of drought provides considerable advantage in terms of reliability of supply. However, the imposition of greater natural and artificial (abstraction) stress on the groundwater system during drought events also creates longer-term problems because groundwater takes longer to recover after drought than surface sources. There is, therefore, a need for careful management and continuous monitoring of groundwater resources since specific drought monitoring and assessment programmes may fail to pick up these significant longer-term impacts on groundwater, with the result that potentially predictable and manageable problems become emergencies.

Quite frequently anecdotal evidence about how groundwater systems perform during drought is all that is available. For example, it is known that in southern Zambia at the time of the 1984 drought, ponds and ephemeral rivers that were formerly the main supply dried up and hand dug wells had to be sunk. During the 1990-92 drought it appears that these wells dried up and were deepened and new boreholes were drilled. Little recorded data actually exist, while this same pattern of crisis intervention with resultant poor documentation has been observed in Zimbabwe, Malawi, Tanzania and elsewhere in the region. In all cases critical data sets that will be of future use to those who depend upon drought prone aquifer systems clearly were not identified or gathered, and no water table or borehole yield monitoring was implemented from which to gather these data in the future.

UNICEF (1995) reported that reliable information on the status of rural water supplies was unavailable at the onset of the recent drought periods in southern Africa. Reliable and timely information on the status of rural water supplies is fundamental to any form of groundwater drought planning and mitigation. The lack of this information, at least in an accessible and useable form, has been a serious and continuing constraint on sector planning and management during recent drought events, a situation exacerbated by the fact that data holdings that do exist are usually dispersed amongst a range of different organisations (government, NGOs) at different administrative levels (national, regional, local) with little relationship or coordination between them.

From the study undertaken it has become very apparent that the need for a clear understanding of the groundwater resource base is essential if increased use of groundwater during drought periods can be undertaken in an appropriate and sustainable fashion.

With respect to the acquisition of appropriate information on groundwater systems and for drought planning it is thus a matter of priority that Member States should:

- recognise the importance of establishing (and maintaining) a sound hydrometeorological database that can be used and updated routinely both for the planning of new groundwater projects as well as for instituting groundwater drought prevention and mitigation measures.

- establish drought monitoring systems which extend beyond rainfall, surface water and food security indicators to groundwater and groundwater supply status, recognising that antecedent conditions (e.g. river flows and groundwater levels of the previous year) are essential guides for predicting future hydrological and hydrogeological (not meteorological) conditions.

- Acknowledge the shortcomings in data gathering and information dissemination systems that make evaluating the impact of past droughts on groundwater resources and those dependent on them difficult and unreliable.

CONCLUSIONS

For the most part groundwater in the SADC region is available within shallow aquifers contained in the weathered basement rocks which characterise the region. More productive aquifers occur in some areas but groundwater is mainly used to sustain rural communities and less used for urban centres. The availability of groundwater data on a country basis is a useful surrogate for groundwater dependence, and likewise groundwater demand data are a useful indicator of drought vulnerability. The southern and eastern African SADC Member States are most dependent on groundwater, whereas the DR Congo is least dependent. All the groundwater dependent states are vulnerable to drought which is now considered to be endemic in the east and south of the region.

Groundwater resources are difficult to quantify in terms of useable volume and replenishment or sustainability. This contributes to a lower level of importance being ascribed to groundwater in the financial decision making process related to national water supply. In turn this perception inhibits the release of funding for groundwater monitoring, exploration and data gathering programmes, with the inevitable consequence that the nature and reliability of the resource remains poorly understood when in times of drought it may contribute the only reliable source of water to large, mainly rural, sections of the population.

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TABLE 2 Availability of groundwater occurrence data

Member State	Data Type	Format	Department/ Agency	Coverage	Comments
Angola	Dpwa, Bhdp, Bhyd, Bhlc	HC, D	DW, DGS, DRA	*	Weathered crystalline basement (Pre-Cambrian), coastal sedimentary (Cretaceous to recent) and recent alluvial sand aquifers. DNA - 3618 bh. records country-wide. Hidromina - 2546 southern 3 regions.
Botswana	Gwlv, Dpwa, Bhdp, Bhyd, Bhlc, Bhgl	HC, D	DW, DGS, DRA, WSO	***	Weathered crystalline basement (Pre-Cambrian), sedimentary (Cretaceous) and recent alluvial sand aquifers. DGS and DWA >20 000 bh. records in National bh. Archive.
DR Congo	Gwlv, Dpwa, Bhdp, Bhyd, Bhlc, Bhgl	HC, D	DW, DGS, DRA, WSO	*	Sedimentary (Cretaceous) and non-consolidated alluvial (Recent) aquifers. AIDR - about 800 bh. records, REGIDSO - 210 digitised bh. records, SNHR – 838 bh. records.
Lesotho	Gwlv, Dpwa, Bhdp, Bhyd, Bhlc, Bhgl	HC	DG, DW, DRA, WSO	**	Crystalline basement (Pre-Cambrian), volcanic and sedimentary (Cretaceous) aquifers. Hydrocon - 206 digitised bh. records, Monitoring - 89 digitised monitoring bh. records, IGP-1047 bh. records, TAMS-8070 bh. Records.
Malawi	Gwlv, Dpwa, Bhdp, Bhyd, Bhlc, Bhgl	HC	DW, DGS, DRA, NGO	*	Crystalline basement (Pre-Cambrian), sedimentary (Cretaceous) and non-consolidated alluvial (Recent) aquifers. MWD - ~6000 digitised bh. records, 15288-bh records in project files, MASAF - 2200 bh. records, CPAR - bh. records.
Mauritius	Gwlv, Dpwa, Bhdp, Bhyd, Bhlc, Bhgl	HC	DW, DGS, DRA	***	Volcanic (Cretaceous) and non-consolidated alluvial (Recent) aquifers. Unknown number of bh. records with WRU and CWA.
Mozambique	Gwlv, Dpwa, Bhdp, Bhyd, Bhlc, Bhgl	HC	DW, DGS, DRA,NGO, WSO	*	Crystalline basement (Pre-Cambrian), coastal sedimentary (Cretaceous) and non-consolidated deltaic and fluvial (Recent) aquifers. Sdg - 12000 digitised bh. records, GEOMOC - 9000 bh. records.
Namibia	Gwlv, Dpwa, Bhdp, Bhyd, Bhlc, Bhgl	HC, D	DW, DGS, DRA, WSO	***	Crystalline basement (Pre-Cambrian), sedimentary (Cretaceous) and non-consolidated alluvial (Recent) aquifers. 42500 bh. records of which 32000 contain useful data.
Seychelles	Gwlv, Dpwa, Bhdp, Bhyd, hlc, hgl	HC	DW, DGS, DRA, WSO		Crystalline basement (Pre-Cambrian), and non-consolidated alluvial (Recent) aquifers. PUC - 27 digitised monitoring bh. records.
South Africa	Gwlv, Dpwa, Bhdp, Bhyd, hlc, hgl	HC, D	DW, DGS, DRA, NGO, WSO, DA	***	Crystalline basement (Pre-Cambrian), sedimentary (Cretaceous) and non-consolidated alluvial (Recent). DWAF – NGDB - >220 000 digitised bh. records, WMS - >55 000 digitised bh. records.
Swaziland	Gwlv, Dpwa, Bhdp, Bhyd, Bhlc, Bhgl	HC, D	DW, DGS, DRA, NGO, WSO	**	Crystalline basement (Pre-Cambrian), and sedimentary (Cretaceous) and non-consolidated alluvial (Recent) aquifers. DGSM–SWAZIDAT- >2,600 digitised bh. records.
Tanzania	Gwlv, Dpwa, Bhdp, Bhyd, Bhlc, Bhgl	HC	DW, DGS, DRA, NGO, WSO	**	Weathered crystalline basement (Pre-Cambrian), sedimentary (Cretaceous) and non-consolidated alluvial (Recent) aquifers. MWLD - ~7000 bh. records
Zambia	Gwlv, Dpwa, Bhdp, Bhyd, Bhlc, Bhgl	HC	DW, DGS, DRA, NGO, WSO	**	Crystalline basement (Pre-Cambrian), sedimentary (Cretaceous) and non-consolidated alluvial (Recent) aquifers.
Zimbabwe	Gwlv, Dpwa, Bhdp, Bhyd, Bhlc, Bhgl	HC,D	DW, DGS, DRA, NGO, WSO	**	Crystalline basement (Pre-Cambrian), sedimentary (Cretaceous) and un-consolidated alluvial (Recent) aquifers. ZNGD - ~15 000 bh. records.

Data Type:
Gwlv – Groundwater Level
Dpwa – Depth to Water
Bhdp – Borehole Depth
Bhyd – Borehole Yield
Bhlc – Borehole Location
Bhgl – Borehole Geological Log

Format:
HC – Hard copy
D – Digital

Department/Agency:
DW – Dept of Water
DGS – Dept Geological Survey
DRA – District/Regional Authorities
WSO – Water Supply Organisations
NGO – NonGovernmental Organisations
DA – Department of Agriculture

Coverage
*** - Good
** - Moderate to patchy
* - Poor to non-existent.

TABLE 3 Groundwater demand information

Member State	Data Type	Format	Department/ Agency	Coverage	Comments
Angola	Popc, Rrwd, Lvst, Crtp, Urwd, Ldus,	HC	DW, ID, DRA, WSO, DA, NSO	*	Affected by drought and economic situation
Botswana	Popc, Rrwd, Lvst, Idtp, Urwd, Hdcn	HC, D	DW, ID, DRA, WSO, DA, NSO	***	Affected by drought and economic situation
DR Congo	Popc, Rrwd, Lvst, Irar, Crtp, Idtp, Urwd, Ldus, Hdcn	HC	DW, ID, DRA, WSO, DA, NSO	*	Little groundwater used
Lesotho	Popc, Rrwd, Urwd, Hdcn	HC	DW, DRA, WSO, DA, NSO	**	Groundwater supplies peri-urban and rural communities
Malawi	Popc, Rrwd, Irar, Crtp, Ldus, Hdcn	HC, D	DW, ID, DRA, WSO, DA, NSO	**	Affected by drought and economic situation
Mauritius	Popc, Rrwd, Irar, Crtp, Urwd, Ldus, Hdcn	HC, D	DW, ID, WSO, DA, NSO	***	
Mozambique	Popc, Rrwd, Lvst, Irar, Crtp, Urwd, Ldus, Hdcn	HC	DW, ID, DRA, WSO, DA, NSO	**	Affected by drought and economic situation
Namibia	Popc, Rrwd, Lvst, Crtp, Idtp, Urwd, Ldus, Hdcn	HC, D	DW, DRA, WSO, DA, NSO	***	Affected by drought
Seychelles	Popc, Rrwd, Urwd, Ldus, Hdcn	HC	DW, DA, NSO	***	
South Africa	Popc, Rrwd, Lvst, Irar, Crtp, Idtp, Urwd, Ldus, Hdcn	HC, D	DW, ID, DRA, WSO, DA, NSO	***	Affected by drought and increased demand from former homeland areas
Swaziland	Popc, Rrwd, Irar, Crtp, Urwd, Ldus, Hdcn	HC	DW, ID, WSO, DA, NSO	**	
Tanzania	Popc, Rrwd, Lvst, Irar, Crtp, Urwd, Ldus, Hdcn	HC	DW, DRA, WSO, DA, NSO	*	Affected by drought and economic situation – demand for groundwater difficult to assess
Zambia	Popc, Rrwd, Lvst, Irar, Crtp, Idtp, Urwd, Ldus, Hdcn	HC	DW, ID, DRA, WSO, DA, NSO	**	Affected by drought and economic situation
Zimbabwe	Popc, Rrwd, Lvst, Irar, Crtp, Idtp, Urwd, Ldus, Hdcn	HC	DW, ID, DRA, WSO, DA, NSO	**	Affected by drought and poor economic situation

Data Type:
Popc – population census
Rrwd – Rural water demand
Lvst – Livestock distribution
Irar – Irrigation area
Crtp – Crop type/distribution
Idtp – Industry type/distribution
Urwd – Urban water demand
Ldus – Land use
Hdcn – hydrocensus

Format:
HC – Hard copy
D – Digital

Department/Agency:
DW – Dept of Water
ID – Irrigation Department
DRA – District/Regional Authorities
WSO – Water Supply Organisations
DA - Department of Agriculture
NSO – National Statistics Office

Coverage
*** - Good
** - Moderate to patchy
* - Poor to non-existent.