L: TANZANIA

L.1 INTRODUCTION

Gordon Maclear of SRK Consulting conducted the Tanzania country visit from the 11 to 20 March 2002. The two pre-union countries comprising the United Republic of Tanzania, viz Tanganyika and Zanzibar (colloquially referred to as the 'mainland' and the 'island' respectively) were both visited, since they both have their own groundwater maps and they function as separate government entities with respect to water issues. In addition, the visit to Zanzibar was requested at top level in the Ministry of Water and Livestock Development (MWLD) since Zanzibar, highly dependent of groundwater, had been excluded from the previous country visit.

The main institutions and personnel visited are detailed below and summarised in Table 1:

- MWLD, Water Resources Division: Hydrogeology Section (HGS), Dar es Salaam. Mr **Lister Kongola** – Assistant Director, Dr **Samson Mpanda**, Mr **Hamza Sadiki**, Mr **Gerald Maganga** – Senior Hydrogeologists;
- MWLD, Water Resources Division: Dar es Salaam. Mr **Butingo Luhumbika** – Director, Water Resources Division;
- MWLD, Water Resources Division: Dar es Salaam. MR **Faustine Masanja** – Senior Hydrologist.
- University of Dar es Salaam, Department of Geology: Dar es Salaam. Dr **Hudson Nkotagu** – Lecturer in Applied Hydrology and Dr **Crispin Kinabo** – Acting Head of Department;
- Tanzania Natural Resources Information Centre (TANRIC), Institute of Resource Assessment, University of Dar es Salaam: Dar es Salaam. Mr **Simon Mwansasu** and Mrs **Anna Mushi** – Senior Researchers and Cartographers; major producers of maps and derivative maps in Tanzania;
- Ministry of Lands and Human Settlements Development (MLHSD), Surveys and Mapping Division: Dar es Salaam. Mr **Zabron Masele**, Senior Surveyor and Photogrammetrist;
- Ministry of Energy and Minerals, Geological Survey of Tanzania: Dodoma. Mr **Boniface Mcharo** – Acting Principal and Mr **A Minde** – Senior Geologist;
- MWLD, Water Resources Division: Hydrogeology Section, Dodoma. Mrs **Ellen Mcharo** – Senior Hydrogeologist;
- Ministry of Water, Construction, Energy and Land (MWCEL), Department of Water Development: Zanzibar. Mr **Omar Zuberi** – Director, Department of Energy and Minerals, Mr **Said Suleiman** – Former Director, Department of Water Development, Mrs **Mariam Hassan** and Mr **Hamad Bakar** – Professional Hydrogeologists.

Table 1: Contact Details of Persons Interviewed

Name	Title	Designation	Institution	Address	Telephone	Fax	E-mail
Lister Kongola	Mr	Assistant Director	MWLD, Water Resources Division, Hydrogeology Section	PO Box 412, DODOMA, Tanzania	+255 26 42471	+255 26 232 0060 +255 26 232 4825	dwr-maji@intafrica.com
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Hamza Sadiki	Mr	Senior Hydrogeologist	MWLD, Water Resources Division, Hydrogeology Section	PO Box 35066, DAR ES SALAAM, Tanzania	+255 22 245 0792 +255 744 375 801 (cell)	+255 22 245 1457	rbmproject@raha.com
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Hudson	Dr	MHO Programme	University of Dar	PO Box	+255 51 410	+255 51 410	hudson@ucc.udsm.ac.tz

Nkotagu		co-ordinator Senior lecturer	Es Salaam, department of Geology	35091, DAR ES SALAAM, Tanzania	013	514 / 410 078	pmu@udsm.ac.tz
Crispin Kinabo	Dr	Acting Head of Department Environmental engineer	University of Dar Es Salaam, department of Geology	PO Box 35091, DAR ES SALAAM, Tanzania	+255 51 410 013	+255 51 410 514 / 410 078	crispin@uccmail.co.tz
Simon Mwansasu	Mr	Senior researcher	TANRIC, Institute of Resource Assessment	PO Box 35097, DAR ES SALAAM, Tanzania	+255 22 241 0144	+255 22 241 0393	smwansasu@ira.udsm.ac.tz
Anna Mushi	Ms	Senior researcher and Cartographer	TANRIC, Institute of Resource Assessment	PO Box 35097, DAR ES SALAAM, Tanzania	+255 22 241 0144	+255 22 241 0393	tanric@ira.udsm.ac.tz
Zabron Masele	Mr	Surveyor and Photogrammetrist	MLHSD, Surveys and Mapping Division	PO Box 9201, DAR ES SALAAM, Tanzania	+255 22 212 3735	+255 22 213 8962	smd@intafrica.com smd@raha.com
Boniface Mcharo	Mr	Acting Principal	Tanzania Geological Survey	PO Box 903, DODOMA, Tanzania	+255 26 232 4943 +255 741 213 571 (cell)	+255 26 232 4943	madini@africaonline.co.tz http://www.africaonline.co.tz/madini
AB Minde	Mr	Senior Geologist	Tanzania Geological Survey	PO Box 903, DODOMA, Tanzania	+255 26 232 4943 +255 741 213 571 (cell)	+255 26 232 4943	madini@africaonline.co.tz http://www.africaonline.co.tz/madini
Ellen Mcharo	Ms	Senior Hydrogeologist	MWLD, Water Resources Division, Hydrogeology Section	PO Box 412, DODOMA, Tanzania	+255 26 42471 +255 741 213 572 (cell)	+255 26 232 0060 / 4825	madini-lab@africaonline.co.tz

Omar Zuberi	Mr	Director	MWCEL, Department of Water Development	PO Box 460, ZANZIBAR, Tanzania	+255 24 223 3687 +255 741 273 943 (cell)	+255 24 223 6292	-
Said Suleiman	Mr	Executive engineer	MWCEL, Department of Water Development	PO Box 460, ZANZIBAR, Tanzania	+255 24 223 2770 / 3687 +255 741 431 597 (cell)	-	-
Mariam Hassan	Ms	Professional hydrogeologist	MWCEL, Department of Water Development	PO Box 460, ZANZIBAR, Tanzania	+255 24 223 2770	-	-
Hamad Bakar	Mr	Professional hydrogeologist	MWCEL, Department of Water Development	PO Box 460, ZANZIBAR, Tanzania	+255 24 223 2770 +255 747 414 831 (cell)	-	hjbakari@hotmail.com

L.2 BACKGROUND

L.2.1 Physiography and Climate

Mainland Tanzania is generally flat and low-lying along the coast. A plateau with an average elevation of 1,220 m constitutes the greater part of the country. Isolated mountains rise in the northeast and southwest. The highest mountain of Africa, Kilimanjaro rises to an elevation of 5,895 m near the north-eastern border with Kenya.

There are two main seasons in Tanzania: a wet season from November to May and a dry season from June to October. In the northeast of the country, the wet season is divided into the 'short rains' from November to December and the 'long rains' from March to May. Mean temperatures range from around 26°C on the coast to 17°C in the southern mountains. Rainfall patterns largely follow the topography. Mountain areas receive 1,000 to 2,000 mm of precipitation annually, in contrast to the central area that has a low and unreliable rainfall of 800 mm or less. The coastal belt receives rainfall of 1,000 to 1,400 mm.

L.2.2 Water Resources

Three of the great lakes of Africa, Lake Tanganyika in the west, Lake Victoria in the northwest and Lake Nyasa (Malawi), are partially located in Tanzania. Lake Nyasa and Lake Tanganyika lie in the Great Rift Valley of East Africa.

Tanzania has nine major river/lake basins and seven large lakes. Six of Tanzania's rivers and five of its lakes are shared with neighbouring countries. The total available surface water, excluding the lake water, is estimated to be more than 5,200 m^3/sec.

L.2.3 Overall Institutional Framework Of Water Sector

The Ministry of Water and Livestock Development (MWLD) is responsible for the water resource assessment, development and management in Tanzania. The national water resource management policy is under review with significant institutional changes having taken place, most significantly with the role of the ministry changing from implementation to roles of facilitator, regulator and promoter. The Ministry is divided into three divisions:

1. Water Resources Division (WRC), which is responsible for surface and subsurface water resources assessment, exploration and management. The Division is further divided into two sections; Hydrology Section (HLS) and Hydrogeology Section (HGS)
2. Rural Water Supply Division (RWSD) which is responsible for water supply to the rural community, and
3. Urban Water Supply and Sewerage Division (UWSSD)

At the national level, the Hydrogeology Section (HGS) of the Water Resources Division (WRD) is the key institute for groundwater resource assessment, exploration, development and management in Tanzania, with offices in Dodoma and Dar es Salaam. The section is divided into 5 units: the Groundwater Exploration Unit for exploration and geophysical survey, the Groundwater Management Unit, the Groundwater Data Management Unit, the Groundwater Project Preparation Unit and the Groundwater Cartography Unit. There are also some units involved in groundwater-related activities, which fall directly under the Permanent Secretary (PS). These are the Central Water Laboratory and the Central Water Board.

The recently founded Drilling and Dam Construction Agency (DDCA) is a parastatal organisation responsible for the drilling of boreholes. The Central Water Laboratory deals with water quality and wastewater pollution monitoring. The Central Water Board deals with regulatory functions of water resources development and management, including groundwater.

The islands of Unguja (commonly referred to as Zanzibar Island) and Pemba (together forming 'Zanzibar') are independent from the mainland with respect to water issues. The ministry of Water, Construction, Energy and Land's Department of Water Development is responsible for all groundwater related issues, with an office on each island, *viz* Zanzibar on Zanzibar Island and Chake-Chake on Pemba Island.

L.2.4 Role of Groundwater in Water Sector

As per the estimates of 1993, the population of Tanzania was 27.25 million. The present population is estimated as 33.5 million. Of the total population, 21% lives in urban areas and 79% in rural areas. The urban growth rate is 6.4%, while rural population is growing at a rate of 1.4%. Agriculture is the most important economic activity in the country with a 57% share of GDP, followed by the service and industry sectors. The Irrigation sector is the largest user of water (97.3%) followed by the municipal or drinking water sector (2.1%), which includes urban and rural water supplies, and livestock sector shares a meagre 0.6%. Only 3% of the cultivated areas are irrigated, and these are dominated by traditional irrigation methods (Country Situation Report, 1997).

Groundwater developed through boreholes, shallow wells and springs is used all over the country and contributes about 25% of the total domestic water supplies and 4% of overall water uses (Molapo et. al., 2000).

Many of the major urban centres rely heavily on groundwater, in conjunction with surface water resources, for municipal water supply. In Singida, Mtwara, Lindi and Dodoma, groundwater accounts for approximately 70 to 80% of the supply. In Dodoma alone, 6.5 million gallons per day of water is extracted. In 1996 to 1997, Dar-es-Salaam experienced a severe shortage of water due to drought and under an emergency programme 200 boreholes were drilled in and around the city. Of these, about 92 boreholes are presently in operation. Arusha and Moshi are the two other towns where a considerable amount of groundwater is exploited for domestic supplies. In most of the peri-urban areas boreholes are the only source of water. In addition to municipal water supply boreholes, a large number of hand dug wells and shallow wells are also used by private owners for domestic water supply.

At present, rural water supply coverage is in the range of 46% to 48%. Almost 60% of the rural water supply schemes are based on hand-pumps and pumped water systems while the rest are based on springs and small dam sources. Most of the rural water supply systems have not been functioning properly and, accordingly, the emphasis has been on rehabilitation. There has also been a general policy shift towards the involvement of community and demand-driven action. Operation and maintenance of the systems is now gradually being handed to the community.

Mostly inland drainage basins are exploited for groundwater for domestic water supplies. Overall contribution of groundwater to irrigation is fairly limited. Groundwater use for livestock is also common through shallow dug wells and springs, although the extent of use is not yet established. Groundwater is being increasingly used for industrial supplies in isolated areas. Most of the industrial use is in Dar-es-Salaam, where many industries have developed their own independent water supply through boreholes.

The majority of the 'islands'' (Zanzibar and Pemba) water supply is from groundwater, since what few rivers occur on the islands are non-perennial. Groundwater on Zanzibar is exploited mostly by means:

- Hand-dug wells – typically through 20-30 m of unconsolidated formation (sand and shelly sand) and then 1-2 metres into the basal calcrete/limestone formation;
- From collector pools in limestone caves; eg the Dimani Cave with a groundwater yield limited only to the pump capacity;
- Springs: eg two springs, *viz* the Mtoni and Bububu Springs, produce approximately one third of Unguja Island's total water supply, with the springs respectively delivering 2-8 ML/day and 3-5 ML/day depending on the season;
- Boreholes: typically drilled using percussion or percussion rotary 40-70 m and constructed with uPVC casing and slotted casing in unconsolidated formation. Fifteen main production boreholes supply groundwater to the town of Zanzibar.

With the population of Zanzibar at ~1 million, the dependence of the 'island' people on groundwater is highlighted.

L.2.5 Groundwater Development

The majority of the groundwater development and exploration for urban, rural and irrigation water supply is done by the HGS, upon the request of water boards, district offices and other governmental and non-governmental organisations. The HGS, in return, charges the service-receiving department for the services at a fairly nominal rate that is not based on the financial self-sufficiency of the Section. The 20 regional offices in mainland Tanzania, supported by the Head Office in Dodoma, carry out most of the implementation.

In general, co-ordination between HGS and other departments/sections within the ministry (particularly RWSD and UWSSD) is fairly good. HGS is now fully involved in the development of project plans and Terms of Reference relating to groundwater development. However, co-ordination with some other government agencies is not adequate, e.g. Ministry of Children and Women Affairs has also been actively involved in borehole drilling programmes in rural areas without any co-ordination with HGS.

External Support Agencies (ESA) such as the Japanese International Co-operation Agency (JICA), UNICEF, GTZ, DANIDA and CIDA are some of the international agencies that are actively involved in groundwater development at various levels. They implement approximately 30 to 40 boreholes and 200 to 300 shallow wells per year. Most of the ESA's co-ordinate well with HGS on groundwater development and generally involve regional hydrogeological teams of HGS at the implementation stage. JICA has been actively involved in water supply as an integral part of community development projects. They are operating mainly in Singida and Kagera regions.

Water resources development has declined in priority in government plans and the level of funding has been reduced significantly in the last few years compared to that on other infrastructure development. The water sector constitutes only 4 to 5% of all the development sectors' expenditure (WSSR, 1994). Around 70-80% of water sector funding is through grants and loans from ESAs. At present the major funding plans in the pipeline are from KfW, World Bank and EU.

L.3 GEOLOGICAL AND HYDROGEOLOGICAL FRAMEWORK

L.3.1 Geology

Precambrian Basement Complex, Karoo Sequence, Post Karoo Sedimentary Formations and Volcanic and Alluvial deposits are the main formations represented. Most of the country (75%) is covered by Precambrian Basement Complex rocks that include granites, granodiorites, gneisses in association with metasediments, sandstones, shales, basalts and marbles.

Tectonically, the central part of the country has been fairly stable. However, the rift valley extensional system of East Africa has formed a series of horsts and grabens in Tanzania, concentrated in a northwest-southeast trending belt and a northeast trending belt.

L.3.2 Hydrogeology

Groundwater occurrence in Basement Complex rocks is largely limited to secondary features such as weathered zones, joints, fractures, faults or solution features. The potential of weathered zones depends on the degree and depth of saturation and associated fracturing. Higher yields (up to 13 l/s) are encountered in narrow bands of gneisses and metasediments, which are affected by a greater degree of fracturing due to their proximity to fault zones. Such zones occur in Pangani Basin. Higher yields are also obtained where thick weathered zones are associated with fracturing in bedrock, such as in Makutapora Basin in Dodoma, and in fractured quartzite and metasediments in otherwise dense gneisses. General yields in basement complex rocks are about 3 l/s and vary with lithology.

Sandstone and conglomerate of Karoo age are characterised by groundwater occurrence associated with primary porosity and intergranular flow, which may locally be enhanced by the secondary porosity created by fracturing. Yields commonly range between 0.1 to 5 l/s. Yields of up to 15 l/s are also reported from these formations.

In the coastal sedimentary formations, which attain a thickness of more than 200 m, yields vary depending upon the lithology. Limestones have yielded between 1 to 6 l/s, while the sandstones have proved less productive (up to 2.5 l/s). The marls and shales are generally unproductive.

Alluvial deposits are confined to delta regions and along river courses and yield between 0.2 to 2 l/s, depending upon the lithology. The greatest potential lies within the volcano-pyroclastic and volcano-alluvium deposits of the Kahe Basin and Sanya Plain near Kilimanjaro. The average borehole yields are in the range of 11 l/s and are sufficient for irrigation needs.

The main source of groundwater recharge in Tanzania is rainwater, with lesser infiltration from rivers and lakes. Isotope studies have been used to estimate the age of groundwater within the Makutapora Basin in the Dodoma region. The findings of the study suggest that recharge to the Makutapora Basin is 30 years old and occurs at low elevations around the basin and that the swamp water does not percolate to groundwater. Also the recharge in the Kilimanjaro and Singida areas is local and of recent age (Rapid Water Resources Assessment, Main Report, Vol. 1). Groundwater discharge is mainly through springs and some by base flow to rivers. Springs are common in mountain areas and yields of up to 40 l/s have been recorded along the slopes of Kilimanjaro.

L.3.3 Natural Groundwater Quality

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 mineralisation 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, reflecting the effect of the aquifer host rock (limestones, marls) on the water. The eastern and coastal portions of the islands, however, is generally sodium-chloride in character due either to connate conditions, the effect of windblown sea-spray, as well as natural and induced seawater intrusion. In these areas the groundwater is generally too saline for human consumption, although good quality, less saline groundwater occurs as perched (shallow) aquifers.

L.4 DATA ACQUISITION

L.4.1 Institutional Framework for Data Collection

The MWLD is responsible for water resource assessment, development and management in Tanzania. The national water resource management policy is currently being reviewed and associated strategies are being drafted and significant institutional changes are taking place. The role of the MWLD is changing from being an implementer to a facilitator, regulator and promoter. The Ministry is divided into three divisions:

1. Water Resources Division (WRC), which is responsible for surface and subsurface water resources assessment, exploration and management. The Division is further divided into two sections; Hydrology Section (HLS) and Hydrogeology Section (HGS)
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The contributions of each of the institutions contacted with respect to the SADC Map and Atlas project is summarised in Table 2 below:

Institution	General groundwater information	Monitoring / time dependant data	Map production
MWLD, Hydrogeology Section, Tanzania mainland *	X	X	X
University of Dar Es Salaam, Department of Geology	X		

TANRIC, Institute of Resource Assessment			X
Surveys and Mapping			X
MWCEL, Department of Water Development, Zanzibar *	X	X	X
* whilst these Departments are willing to contribute to the SADC project, their capability with respect to map production is limited to non-computerised map production			

L.5 GROUNDWATER INFORMATION SYSTEM

L.5.1 Hardware and Software Set-up

The MWLD Hydrogeology Section is the lead institution in Tanzania with respect to groundwater data collection and management. Since 2001, the HGS has had a computerised database, *viz* the Groundwater Quality and Aquifer Productivity Database run on a Windows operating system under the MS Access software. This database replaces the spreadsheet data storage and retrieval system in place prior to the MS Access system, however, since the database was only recently implemented, there is a massive backlog of data to be entered to upload the paper data that exists since the 1960's.

The main islands of Tanzania (Zanzibar and Pemba) do not, as yet, have a computerised database for hydrogeological information, with paper records only available.

Ministry of Water and Livestock Development – Hydrogeology Section

Within the MWLD there are only 4 PCs available between the Dodoma and Dar es Salaam offices (2 per regional office), running the common applications of MS Office under MS Windows operating system.

The graphical presentation software used is Surfer with very limited access to GIS ArcView within the Ministry. SATEM (Selected Aquifer Test Evaluation Method developed by ILRI) is used for test-pumping interpretation.

Tanzania Natural Resources Information Centre (TANRIC) – Institute of Resource Assessment (IRA)

Whilst TANRIC does not have a groundwater information system, they are the biggest institution in Tanzania that produce derivative and thematic maps, as well as one of Tanzania's leading map producing institutes. As such, they have a well-established research infrastructure and related information system, reference library and GIS facilities that are available on a project basis. TANRIC's major databases comprise the following:

- Meta-database: information about organisations in Tanzania which collect or hold natural resource data;
- Meteorology: information about weather stations in Tanzania together with meteorological data;
- Population: population data at village level, categorised by gender and age group;
- Expertise profile: a directory of individual expertise in the fields of natural resources and environment;
- Bibliography: information about TANRIC's book collection;
- GIS Catalogue: Information about GIS projects undertaken at TANRIC.

TANRIC has completed a wide range of GIS projects, including coverages of the entire country's agro-ecological zones, soils, drainage network, forest and game reserves and mean annual rainfall. In addition, detailed coverages of certain regions exist, eg the geology of Dar es Salaam and the adjacent coastal region.

TANRIC possesses 7 PCs, 5 digitising tables (4 x A1, 1 x A0), 2 A0 plotters and 2 printers (A4 and A3). The Centre has a wide range of software packages, viz ArcInfo, ArcView, MapInfo (with ArcGis on order), and is equipped to read and transform data between all common formats. All data generated from GIS activities are available either in hard copy or digital format.

The hardware and software set-up of the authorities / institutions that are capable of contributing to the SADC project are summarised in Table 3 and 4.

Table 3: Institutional Hardware Set-up (number of units indicated)

Institution	Server	Work-station	PC	Other
MWLD – Hydrogeology Section	-	-	4	
University of Dar Es Salaam – Department of Geology			10-15	
TANRIC – Institute of Resource Assessment		2	5	Digitising tables (4 x A1, 1 x A0), 2 x A0 plotters, printers (A4 and A3)
Surveys and Mapping Division	1	6	8	Scanners (2 x A0 Calcomp, 1 x A4), plotters (2 x A0 HP), digitising tables (3 x A0, 1 x A1)
Geological Survey of Tanzania	1	4	15	

Table 4: Institutional Software Set-up (availability marked with an X)

Institution	Windows	MAC	MS Office	WP Office	GIS	In-house	Other
MWLD – Hydrogeology Section	X		X		ArcView		SATEM
University of Dar Es Salaam – Department of Geology	X		X				
TANRIC –	X		X		ArcView		

Institute of Resource Assessment					ArcINFO ArcGIS MapINFO		
Surveys and Mapping Division	X		X		ArcView ArcINFO ArcGIS		PS Map
Geological Survey of Tanzania	X		X		MapINFO		AutoCAD

L.5.2 Data Saved (Structure of Information System and Graphical Interface)

Approximately 7,000 borehole records are available in Tanzania. Also, there are an estimated 14,000 shallow wells installed with hand-pumps for which completion forms are not required and as such are not available.

Prior to drilling, borehole numbers are supplied by the drilling section in Dodoma and recorded in a Borehole Book, which also summarises the other drilling information. The system was initiated in 1953. The borehole file contains a borehole construction diagram, a location map, pumping test data and chemical analyses. In addition, borehole catalogues are also available in two volumes for the period 1931 to 1966 and contain some extra information that is additional to that registered in the Borehole Books.

Data on shallow wells is not collected. For deep wells, a standard form known as the 'Completion Form' is used for drilling and test pumping data collection. The form incorporates most of the relevant hydrogeological information.

Data collection is mainly the responsibility of regional hydrogeologists who collect data on drilling, pump testing, complete evaluation forms and compile reports. The regional office retains a copy of the data (Completion Form) and another copy is sent to the HGS in Dodoma. Drillers also generally maintain their own copies of information. The Completion Forms are also supposed to be used by private drillers and companies, but only a few follow this procedure. It is reported that about 60 to 70% of private borehole data are not made available to the government. The new proposed regulations are very specific on the issue of data collection and transfer to HGS. Borehole drilling samples have been collected since 1972 and stored, although in recent years the practice has been irregular.

Even where systematic groundwater development is carried out for bigger urban water supply schemes, data are not submitted by private drillers, nor at times by DDCA.

Private owners do not submit data. Some of them report to HGS following drilling to take a borehole number. Private drillers collect the data on DDA forms and then supply it to HGS. It is estimated that private drillers drill about 50% of boreholes.

In Zanzibar, each borehole is assigned a serial number and a 'Borehole Completion Report' form details the borehole position, geology, construction, water strikes, aquifer type and yield, water level, pump installed, and water quality. In addition, water levels and groundwater abstraction volumes are routinely monitored for certain boreholes and these data are entered onto a 'Borehole Monitoring Form' for each selected borehole.

L.5.3 Quality of Data

In general the quality of the data for individual points (boreholes, wells etc), where captured, is acceptable with sufficient detail captured for each point. A manpower shortage, however, results in insufficient resources being available to capture and update the database with all the hydrogeological detail for a large portion of data points. As a result, <25% of data collected are being entered in the database.

In certain areas of strategic groundwater occurrence or high groundwater use, detailed high-quality and high-resolution data are available on geology, boreholes and groundwater. The positioning accuracy of the data points is generally 100 – 1000 m with a backlog of data to be input into the database of >5 years. As a result, there is a delay before the quality of the data can be checked and verified. A further restriction in the quality of the data is the limited analysis of the data (eg test-pumping) due to manpower shortages, resulting in minimal beneficiation of hydrogeological data for aquifer characterisation.

L.5.4 Available Resources for Maintenance

Due to the staff shortage within the Hydrogeology Section of the Water Resources Division (MWLD), the manpower resources for upkeep and maintenance of the groundwater information system is limited. In addition, the lack of adequate hardware and software places restrictions on the maintenance of the database.

Since the groundwater database was only developed in 2001, a phasing in time period will be required to initiate a system of data input and database maintenance, as well as manpower training. Whilst the groundwater monitoring function of the MWLD is well-staffed (70), there are only a limited number of staff available for data management and map production (10 to cover both functions), with only 2 hydrogeologists and 4 technicians that are available for full-time hydrogeological database maintenance, update and groundwater mapping.

Out of a total budget of TSh250M (TSh = Tanzania Shillings), only TSh10M will be made available for hardware upgrades within the next 2 years, TSh5.5M for software and TSh1M for upgrade of the maintenance system. This is considered to be insufficient to adequately address the shortfalls in data management and database maintenance.

A limitation on updating of the existing data set, and hence quality of the data-set, is the fact that both the 'mainland' and 'island' maps were projects done with international donor funding and done by international agencies. As a result, these agencies often end up holding the data-sets, as well as the maps in some cases. A point in fact is that the only copy of the 'mainland' Tanzania map that the MWLD are aware of, is held by the WSCU at their offices in Lesotho.

L.6 GROUNDWATER MONITORING

L.6.1 Institutional and Legal Framework

The existing legal framework for the water sector is covered under the Water Utilisation Act (No. 42 of 1974) and two subsequent amendments of 1981 (Act No. 10) and 1997 (Act No. 8). There is also an Urban Water Supply Act of 1981. Under the legislation the MWLD grants right for withdrawal of water for use in domestic, industrial, hydropower, livestock, irrigation, environment and habitat preservation or mining activities. Groundwater development issues are superficially covered under

these laws and the ministry is planning to review them in this perspective. Two significant aspects of the law relating directly to groundwater are:

- Water abstraction permits are required for abstraction exceeding 22,700 litres per day; and;
- Boreholes cannot be drilled within 230 m of an existing borehole and within 90 m of a surface water body.

It is estimated in the Pangani basin that only about 30% of water abstractions have operation water rights. Drillers are expected to get a drilling permit and registration from HGS, although this is not enforced by law. Most, if not all, of the drilling firms do have permits. In some cases the drillers are registered with HGS without having adequate equipment or no equipment at all. In fact many of the groundwater development issues are dealt with through guidelines and circulars issued by the MWLD. Borehole registration is not required by law. Consultants are not expected to register. A permit cannot be applied for unless a borehole is drilled.

The water policy of Zanzibar contains a Groundwater ordinance (1945). This, however, is outdated and requires urgent revision to accord groundwater the required status of a strategic sustainable water supply to the inhabitants of the islands.

The Tanzania groundwater monitoring networks are detailed in Table 5 below:

Table 5: Monitoring Network Detail – Tanzania and Zanzibar

Name	No of boreholes	Purpose of monitoring	Parameters monitored	Recording method	Monitoring frequency	Monitoring period
?	?	?	?	?	?	?
?	?	?	?	?	?	?

Detail above to be filled in by Dr Samson Mpanda ('mainland') and Ms Mariam Hassan ('island') during July workshop?

L.6.2 Monitoring Network and Frequency

Groundwater monitoring is presently only carried out in a few locations. The monitoring is limited to selected areas and on specific projects where large quantities of water are extracted for municipal water supply. There is no systematic network throughout the country, despite the adequate manpower. A lack of financial resources has been the major limitation.

The only regular water level monitoring is carried out in Makutapora Basin in Dodoma region, where ten automatic water level recorders are installed. Water level monitoring is also performed in observation wells in Arusha by the Urban Water Supply Authority, and in TPC-Moshi by HGS. Most of these measurements are taken manually on a daily basis. Groundwater quality monitoring is more limited and is done on a monthly basis at some places where quality problems are reported. Bacteriological monitoring is performed only in Makutapora. Water abstraction monitoring is also done on the above-mentioned three wellfields. In general flow meters are not installed, so abstraction monitoring is inferred from borehole yield and pump capacity. This indirect method is of limited accuracy. Systematic groundwater water level monitoring is being undertaken in Makutopora and Dodoma. It has been realised that there is a considerable need for monitoring in other towns where large quantities of water is extracted, such as Singida, Dar-es-Salaam and Mtwara.

In most cases low yielding boreholes are converted to observation boreholes (when high yields are required). As such, they are not specifically designed as observation boreholes. Water samples for

chemical analysis are collected immediately after the completion of drilling and the procedure is repeated later.

In the near future it is planned to establish 13 more water level monitoring stations and 10 water quality monitoring stations in priority areas in Pangani and Great Ruaha river basins.

The National Environmental Management Council (NEMC) does the sampling and analysis on request and in problem areas.

In summary, the groundwater monitoring network is random in extent, existing mostly on a regional scale and is carried out by MWLD staff as well as NGOs, with water level and field salinity mostly being measured.

L.6.3 Quality of Monitoring Data

The quality of monitoring data is accurate where data exists for identified monitoring network boreholes, although the positional accuracy is >1000 m in places and thus cannot be used for site-specific studies.

The level of education of staff members responsible for the various hydrogeological tasks of the MWLD is generally high (mostly tertiary university level). The lack of qualified manpower, however, results in insufficient resources available to adequately cross-check all aspects of the data gathering and input phases.

Whilst QA / QC measures are in place, they vary mostly from ad-hoc / random checks during the stages of monitoring / sampling and data management, to basic protocols related to manual drawing and editing in the map production stage, where maps are produced for local reports covering small areas only.

Due to the backlog in data to be entered into the database, the time period between data capture and verification is extensive.

L.7 HYDROGEOLOGICAL MAPPING

L.7.1 Existing Hydrogeological Maps

Tanzania - Mainland

A compilation of borehole catalogues of different regions of the country was carried out to produce a Hydrogeological Map of Tanzania in 1990, at a scale of 1 : 1 500 000. The map was produced by a UK company, viz McDonald and Mott and the chief map author was Allan Randall.

At the time of the country visit, there was no copy of the map available in Tanzania, although it was suggested that the SADC WSCU in Lesotho had a copy. As a result, only limited data could be gathered regarding the map, based mostly on memory of the staff of the Hydrogeology Section of MWLD.

From the 1999 situation analysis report, however, the following information is available: The first and only countrywide hydrogeological map was compiled under the Sub-Saharan Africa Hydrological Assessment Study (McDonald and Mott, 1990). The map was produced at a scale of 1:1,500,000 and

serves rather as a reconnaissance map presenting the available hydrogeological information. The data sources for the map were mainly the Regional Water Master Plans and borehole information compiled on various maps by the Hydrogeology Section. Only proportions of the boreholes drilled are shown. Almost all the spring data are included. The boreholes selected are those considered representative and with good quality data. The borehole locations are indicated with their number, borehole depth, TDS and specific capacity. Three broad categories of aquifers are identified: aquifers dominated by intergranular flow, aquifers dominated by flow in fissure and discontinuities and aquifers of limited regional potential. Further subdivision of these categories is also made to indicate the groundwater potential variations within a particular aquifer type.

In summary, the map was produced as a preliminary representation of the hydrogeology of Tanzania, with only limited hydrological and physical parameters represented on the map, viz locations of selected boreholes and springs shown as circles on the map, with related data. The main map feature is lithology-based showing 3 types of aquifers (colour shaded) subdivided into a total of 7 classes of aquifer productivity shown as hatching. The map legend is based on the international UNESCO 1970 format

Tanzania - Islands

With a population of ~1 million, obtaining all its sustainable water supply from underground water resources, groundwater is a resource of critical importance to the Tanzanian islands of Zanzibar and Pemba. A hydrogeological map of the islands of Zanzibar and Pemba was produced as part of a United Nations Department of Technical Co-operation for Development project (Project URT/80/001). The map was compiled from field data collected from 1981 to 1984 by the Hydrogeological Unit of the Ministry of Water, Power and Minerals, Zanzibar. The chief map author was JH Johnson, a consulting hydrogeologist.

The map is referred to as: *Hydrogeological Map of Zanzibar including the islands of Zanzibar and Pemba, The United Republic of Tanzania, Map No. 3344, United Nations, July 1987.* The map sheet shows the hydrogeology of Zanzibar and Pemba as two separate maps at a scale of 1 : 125 000 and the legend is based on the UNESCO format.

The following features are displayed on the Map:

- Geology and lithology in hatching and time-unit abbreviation;
- Detailed text description of each hydrogeological unit with respect to occurrence of groundwater and related water quality;
- Chemical quality with respect to water types in three colour shades as well as Schoeller diagrams of typical hydrogeological units;
- Topography and Geology, showing boundaries of geological units, roads, faults etc;
- Hydrology, showing rivers, catchment areas, lakes etc;
- Groundwater Features, showing location of eg springs, groundwater contours, water table divides etc;
- Water use and Water Management Features, showing selected wells or boreholes, as well as inset maps, within island map border, of areas of intensive groundwater development.

The map sheet is printed on both sides with the front face shows the Climate and Water Resources maps of the islands together with a text description of the hydrogeology of the islands of Zanzibar and Pemba. The back face of the map sheet comprises the Hydrogeological Map of Zanzibar as two maps, *viz* Zanzibar Island and Pemba Island.

The detail of the hydrogeological map legend is summarised in Table 6 below:

Table 6: Hydrogeological Main Map Summary

Legend	Details of legend
Geological and Lithological Unit	8 units for Zanzibar 3 units for Pemba, shown as a unit letter (Q, P, M) related to the geological period (Quaternary, Pliocene and Miocene). The Quaternary and Miocene Periods divided into sub-units according to variations in the lithology of the main unit. Some sub-units have hatching or patter to further define geology of the unit.
Chemical Type	Shown as shaded polygons of three colours: ➢ Blue: low TDS, $CaCO_3$ type ➢ Green: moderate salinity, chloride type ➢ Orange: high salinity, NaCl type Further description of each geological units' hydrochemistry is given in the legend text
Hydrogeological Characteristics of the various aquifers	Shown as seven colour shades in the Zanzibar Island map: ➢ Dark blue and green: high storativity (25%) and low average seasonal water table fluctuation (1.7 m) ➢ Medium blue and green: medium storativity (15%) and moderate average seasonal water table fluctuation (3.3 m) ➢ Light blue and green (yellow): low storativity (7%) and high average seasonal water table fluctuation (7.9 m) ➢ Orange: marginal coastal areas suitable for small developments only Shown as two shades in the Pemba Island map: ➢ Blue: poor transmissivity and permeability ➢ Orange: poorly transmissive coastal sands vulnerable to seawater intrusion with over-development
Rainfall shown as coloured polygons as well as text detail of climatology of Zanzibar and Pemba in tabular format (temperature, humidity, wind-speed etc)	Three shaded polygons representing MAP ranges: ➢ Dark blue: 2000 – 2500 mm ➢ Green: 1500 – 200 mm ➢ Light green: 1000 – 1500 mm Average direction of surface winds shown as light red arrow
Hydrogeological and Geological Symbols / Features	Symbols / features shown are: ➢ Water table contours: thin red lines with water table figure ➢ Water table divide: thick dashed red line ➢ Hand-dug well: red open circle (well number indicated next to circle) ➢ Borehole: open circle with cross underlay (borehole number indicated next to circle) ➢ Spring: open circle with blue arrow ➢ Pond: filled blue half-circle ➢ Disappearing stream: blue line entering blue 'igloo' shape ➢ Geological boundary: thin black line ➢ Fault: thick black line
Topographical Symbols	Common topographic symbols used are:- ➢ Roads, tracks and footpaths: shown as different dashed black lines; ➢ Areas of congested buildings (towns): brown shaded polygons; ➢ Village: open grey circle; ➢ Drainage feature: solid and dashed blue lines (definite and indefinite respectively);

	➢ Marsh and mangrove swamp: blue and brown polygons with varying pattern in-fills; ➢ Terrain contours: thin brown lines showing elevation figure

L.7.2 Derivative maps

In addition to the main map there are three inset (derivative) maps that provide complimentary information to the main Map. The three inset maps comprise:

- Climate (scale 1 : 420 000) – showing detailed monthly meteorological data such as max and min temperature, evaporation, humidity and wind strength as well as average annual rainfall and prevailing wind direction dependent on season;
- Water Resources – Zanzibar Island (scale 1 : 200 000) – with the island divided into seven hydrogeological units. Each unit is displayed as a separate colour shading representing individual hydrogeological characteristics of storativity, seasonal water level fluctuation and annual groundwater availability;
- Water Resources – Pemba Island (scale 1 : 200 000) – with the island represented as two simplified hydrogeological units delineated as two colours showing areas of similar aquifer transmissivity and vulnerability to seawater intrusion.

L.7.3 Classification and Legend of Maps

On the main map the aquifer type with respect to hydrochemical facies and salinity is represented as three colour shades with text description of the aquifer characteristics for each defined lithological unit in a legend, using a modified UNESCO legend format.

On the inset maps the aquifer type is delineated with colour shading according to areas of similar aquifer productivity using a modified UNESCO legend format. Areas of moderate to high storage (25%) and groundwater availability are shown in dark blue, ranging to areas of low storage (7%) and water availability indicated in light green.

L.7.4 Existing Geological Maps

The head office (and only office) of the Tanzania Geological Survey (the old Mineral Resources Division) is based in Dodoma, roughly centrally located within Tanzania. Some 80% of the geology of Tanzania has been surveyed, of which 34% has been surveyed but not yet published in the form of geological maps. In general, the majority of the geological maps are at a scale of 1 : 125 000, referred to as 'quarter-degree sheets', printed from the early 1960's to the late 1990's.

The geology of Tanzania is published on a single map sheet at a scale of 1 : 2 000 000 and is available, together with the quarter degree sheets, from the Ministry of Energy and Minerals in paper format. This map is an update of the Geological Map of Tanganyika (1959) as printed at a scale of 1 : 3 000 000 in the Atlas of Tanzania (1967), Surveys and Mapping Division, Ministry of Lands, Settlement, and Water Development, Dar es Salaam, Tanzania.

L.7.5 Existing Physiographic Maps

In addition to quarter degree topographic map sheets, Tanzania mainland is divided into blocks to facilitate topographic coverage of 1 : 50 000 mapping. Publishing of these maps dates from 1964 to 1995, totalling 1265 sheets covering most of the country. The most recent mapping of Tanzania took place from 1992 to 1995, comprising 25 sheets, mostly with funding from JICA.

All topographic mapping is based on aerial photography, thereby producing base maps only showing data captured from the aerial photograph. The mapping of Tanzania has been carried out mostly with the aid of international donor funding from agencies such as JICA (mainland) and the UK Directorate of Overseas Surveys (island).

The maps are mostly available in hard copy from the Surveys and Mapping Department of Tanzania (mainland) and Department of Lands and Surveys (island), with some limited maps available in digital (scanned) format. Topographic maps at a scale of 1 : 10 000 are also available for Zanzibar, in addition to the 1 : 50 000 map series.

In addition to the above physiographic maps, maps (at a scale of 1 : 3M) are published in the Atlas of Tanzania (1967, updated in a 2nd edition in 1972) on the following: physical (physical, geological, soils, potential land use, geophysical; climatic (hydrology, mean annual rainfall, rainfall probability); flora and fauna (vegetation, forests, game conservation, fisheries); human geography (regions and districts, population, population characteristics, antiquities, education); medical (medical, tsetse and sleeping sickness, malaria); resources (agriculture, cattle distribution, minerals, water supplies); and statistics (exports and imports, revenue and expenditure, deployment and manpower).

L.8 DATA AVAILABLE FOR SADC HYDROGEOLOGICAL MAP

The availability of the individual data sets / maps for the SADC project map is indicated in Table 7.

Table 7: Data-set / Map availability

Data-set / Map	Source data available	Processed data available	Not available
Boreholes	X	X	
Geology	X	X	
Physiography	X	X	

The Tanzanian Groundwater Quality and Aquifer Productivity Database is created and owned by the MWLD Hydrogeology Section, and its use is restricted to the MWLD. As such, it is protected by a licence agreement, and access to and use of the database is conditional.

L.9 CAPACITY AND COMMITMENT FOR THE PROJECT

L.9.1 Existing Capacity

The Hydrogeology Section of MWLD have limited capacity at a national level for their own mapping programme and information system. From all the interviews held, the major and predominantly identified deficiency related to data collection, management and map production, was a lack of staff, especially qualified staff and insufficient funding.

The manpower resources available to the Hydrogeology Section of Tanzania number less than ten key staff members. Whilst these staff are highly qualified and experienced, they are mostly involved in general MWLD and Divisional duties with lack of available time for other work outside of their main areas of responsibilities.

L.9.2 Commitments on Contribution to Regional Mapping Project

The commitments made by individuals and institutions towards the SADC project are summarised below:

- MWLD – Dar es Salaam – 2 members of staff at senior hydrogeologist level with hydrogeological, hydrochemical and data management experience and 4 hydrogeological technicians for a 100% time commitment for the duration of the project. This is considered to be a genuine commitment and indicative of the Ministry's eagerness to contribute to the project. No funds are available within the Hydrogeology Section of the MWLD budget for the SADC map and atlas project.
- MWLD – Dodoma – 3 members of staff at senior hydrogeologist level with hydrogeological, hydrochemical and cartography / drafting experience for a 40% time commitment; 3 hydrogeological technicians for a 50% time commitment and 5 draftsmen for a 75% time commitment during the project period. This is considered to be a genuine commitment;
- University of Dar es Salaam – Department of Geology – 3 members of staff with geological (sedimentology and structure) and hydrogeological experience available from the University Consultant's Bureau on a consulting basis from US$100 – US$200 / day. In addition, at least 2 students could be made available on a project basis if finances permit. This commitment would require formalising closer to project inception.
- TANRIC - Institute of Resource Assessment – at least 3 permanent members of staff (more can be sub-contracted as required) available on a full time project consulting basis at US$125 / day, irrespective of the number of staff required or employed. This is considered to be a genuine commitment from an institute with very good GIS, data management and information skills. The period of commitment would, however, require confirmation since there may be prior arrangements with respect to other projects;
- Surveys and Mapping Division – 12 members of staff with GIS, cartography, photo-grammetry and survey skills are available to work on the SADC Project for a 30% time commitment. In addition, the full hardware and software resources of the Division (6 GIS work-stations and 8 PCs with ArcView, ArcInfo and ArcGIS can be made available. This is considered to be a feasible commitment, although it would require planning and approval on upper management level;
- Geological Survey of Tanzania – Staff with geological, geophysical, cartographic and GIS experience can be made available on a consulting basis at US$50 to US$60 / day per geologist. In addition the organisation's hardware (15 PCs and 4 GIS work-stations) and software (GIS MapInfo) can be made available to the project as required. This commitment will require planning and communication with the Chief Executive of the Tanzania Geological Survey to obtain firm commitment;

- Department of Water Development – Zanzibar – 3 members of staff with senior hydrogeology, geology and data management experience as well as 4 hydrogeological technicians on a 100% time commitment on request for the duration of the SADC project. This is considered to be a genuine commitment and indicative of the Zanzibar Ministry's eagerness to be a part of and contribute towards the SADC project.

L.9.3 Country Expectations and Policy Concerns with the SADC Project

The following policy issues were highlighted as being important prior to regional application of the SADC map and atlas:

- Issues of access to hydrogeological information and data need to be clarified;
- There must be a commitment by SADC to free access to the project data for all participating countries;
- A decision needs to be taken regarding the responsibility for maintenance of the groundwater database for the project. Who will be responsible for routine updating and maintenance of the database?;
- The status of water policies within each country and differing institutional frameworks within each country need to be taken into account;
- It is considered essential to use local people in each country with the necessary experience to do Phase 2 of the Project (production of the map/s and atlas) in order to satisfy the maxim: "For the people, by the people".

A summary of the major concerns regarding the project in general as well as issues related to Tanzania is given below:

- Will the scale of the base-line information be sufficient to provide ability to zoom in to specific areas of concern / interest?
- The huge backlog of information and groundwater data to be input into the Tanzania groundwater database is a significant limitation to producing a groundwater map of Tanzania, and thus the SADC region, within the time scale available;
- Similarly, the lack of a well populated Tanzania National Groundwater Database is a concern regarding the implementation of the SADC map and atlas;
- Lack of hardware, software, funds and personnel have and will continue to limit the effective development of a representative Tanzania groundwater database;
- The huge backlog in data to be entered into the new groundwater database will hamper the contribution of Tanzania to the SADC region groundwater map and atlas. In essence, a detailed and new groundwater map of Tanzania is considered necessary before even the SADC region project can proceed;
- The Water Utilisation Act 1974 (Act #42, amended 1981) of Tanzania is considered inadequate to protect the country's groundwater resources from over-abstraction / exploitation;
- It was similarly considered necessary to update Zanzibar's outdated (1945) water policy to ensure effective management of Zanzibar's groundwater resources;
- It was stressed that Zanzibar should be included in the SADC region project since they are a member of the SADC states. In addition, it was felt that a Zanzibari hydrogeologist should be included in future SADC meetings and technical committees.

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