25th WEDC Conference Addis Ababa, Ethiopia, 1999

INTEGRATED DEVELOPMENT FOR WATER SUPPLY AND SANITATION

Geophysics locates water in Dar es Salaam

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THE CITY OF Dar es Salaam is located on the Indian ocean coast of Tanzania, at around latitude 6°°50' south and longitude 39°°15 East. Temperature in the city ranges between 17°°C and 33°°C. Humidity is high reaching up to about 100 per cent.

The city is characterized by rainfall of between 1000 and 1400 mm per annum, the wet season is usually between March and May. The average evaporation rate is 2100mm per annum.

Topography and drainage

Dar es Salaam is built on low lying terrain with increasing altitudes of about 20m a.s.l around city centre to about 260m a.s.l on the Pugu/Kisarawe hills to the south west. The city is drained by three main river systems:

- The Mzinga and Kizinga river system to the south,
- The Msimbazi river system in the centre and
- The Mbezi river system to the north.

Both the Mzinga and Kizinga and Msimbazi river systems emanate from Pugu/Kisarawe hills which have catchment forest reserves.

Geology

The nature of geology is characterized by various episodes of sea transgression and regression that led to both erosion and deposition of various layers of sands and clays. The evaluation of the rock, supported by existing data indicate that sandstone and limestone are two dominant type of rocks typical of the bedrock of Dar es Salaam region. The overburden is classified by their geological age, into two major periods:

- Quaternary Deposits

This consist of three subgroups as follows:

- Alluvial deposits,
- Coastal plain deposits and
- Limestones.

The coastal plain deposits and alluvial deposits are mostly of Pliocene to recent age and are found mainly moving from the coast towards the mainland. These consist of sands, clay and sometimes clay bound sands, gravels and pebbles.

Fine to coarse grained sand occur widely within valleys creeks, deltas and mangrove sites. The main deltas are situated at the mouth of river Mzinga, Kizinga and Msimbazi.

Limestones are mainly coralliferous and are found along the coastal strip. They are generally weathered and normally covered on the surface by white buff sands or reddish brown soils. They are found in Kurasini and Kigamboni areas.

- Neogene Deposits

Neogene deposits are of Miocene and Pliocene period. Two types of formation characterize these deposits as follows:

- Undifferentiated Deposits

The undifferentiated sedimentary deposits consist of inter-bedded sandy clay and clayey sand with some lenses of pure sand and clays. They occur in upper reaches of Mzinga and Kizinga catchments.

- Pugu Hills Kaolinitic sandstone

The Pugu Hills Kaolinitic sandstone consists of fine to medium grained quartz, sand and sandstone, soft richly Kaolinitic and sometimes Feldspathic, occasionally bedded with red and green partings. Locally they have channel structures.

Structure

The coastal area of Dar es Salaam region has tentatively been divided into three main blocks namely Wazo, Dar es Salaam and Kimbiji.

Generally the blocks lie within an area traversed by a series of lineaments and faults. The lineaments are classified into regional, intermediate and local faults. Furthermore, the strike directions of the lineaments tend to form two recognizable sets NNE and NNW.

Geophysical investigations

Geophysical investigations formed the basis of borehole siting methods. As the programme was an Emergency one, only rapid or no Hydrogeological study was done prior to actual Geophysical survey.

Gephysical investigation, thus comprised of resistivity method in form of vertical electrical sounding (VES). VES probes were taken by using three sets of resistivity meters:

Table 1. VES results and borehole parameters

Location	Apparent resistivities (Ohm.m)			Thicknesses (m)		Bh.No.	Yield m^3/hr	EC (us/cm)	Aquifer
	ρ_1	ρ_2	ρ_3	h_1	h_2				
Muhimbili (MMC)	270	27	70	2.8	42	13/97	12.0	1900	Sand/limestone
Fire Brigade	185	18.5	Apprx 0	2	49	19/97	15.9	8000	Sand
TTC Chang'ombe	130	13	Apprx 0	3.6	36	22/97	19.8	650	Sand
Kinondoni P.S	65	16	Apprx 0	1.8	27	37/97	22.6	1690	Sand
Kigogo mwisho	3	30	3	2.3	34.5	39/97	26.4	1210	Sand
Temeke Hospital	310	31	15.5	5.4	54	42/97	22.6	650	Sand
Kigogo P.S	44	5	44	1	3	66/97	12.5	1900	Sand
Tandika Mabatini	900	270	18.5	1	8	132/97	28.3	924	Sand
Dar Tech.	400	20	80	2	30	30/97	26.4	1350	Weath limestone + sand
Mwnanyamala NHC	148	3.7	12	5.6	27.9	108/97	52.8	1050	Sand + weath limestone
Mwnanyamala Hosp	1000	150	8.5	2.3	6.2	32/97	8.8	1100	Sand
Amana	2600	260	30	1.7	8.5	56/97	14.4	1000	Sand
MMC (Matenity)	300	15	7	1.4	35	38/97	6.0	3050	Sand
Ikulu	500	150	Apprx 0	1	11	69/97	1.0		
Uhuru G.P.S.	850	21.3	70	4.8	48	31/97	26.4	820	Sand + weath limestone
Magomeni C.G.	270	27	270	2.5	62	29/97	26.4	1000	Sand + weath limestone
Maji Temeke	360	72	15	3.2	32	53/97	14.4	720	Sand
Buguruni D.S.	560	28	56	1.2	18	95/97	DRY BOREHOLE		

- ABEM AC Terrameter which measures and records resistance values, R
- ABEM SAS C Terrameter which also measures and records, resistance values, R
- OYO Mc OHM which records, current, change of voltage, and resistance values, R.

The obtained resistance values were multiplied by an electrode spacing K to get apparent resistivities.

Schlumberger array of configuration was deployed with maximum AB/2 = 200m and MN/2 = 25m. Due to salinity and / or presence of clayey layers in the area of investigation measurements were stopped when values of less than 1 Ohm m of resistivities were noted.

Interpretation of VES curves were carefully done by complete curve matching techniques using Standard Graphs for Resistivity Prospecting.

A table of selected VES out of the many taken is shown in table 1 where respective successful boreholes and their yields, EC and aquifer characteristics are indicated.

The relationship between aquifer resistivity and EC is indicated in table 2.

Most of all the VES carried out had a 3 - layer geoelectric section. The first normally is a top layer consisting of sand of varying content of clay, its resistivity decreasing with increasing clay content. The intermediate layers mainly is a formation which is an aquifer i.e. sand or weathered limestone, while the last layers is either limestone or formation with highly saline water. These are easily distinguished from their different resistivity values.

Hydrogeological aspects

Out of over 200 boreholes drilled, all had water of yields in the range between 1.3 to 52.8 m^3/hour. It is important to

Table 2. Relationship between aquifer resistivity and EC

Bh. No.	Aquifer Resistivity Ohm.m	EC us/cm
13/97	27	1900
19/97	18.5 to appr 0	8000
22/97	13	650
37/97	16	1690
39/97	30	210
42/97	15.5	650
66/97	44	1900
132/97	18.5	924
30/97	20	1350
108/97	12	1050
32/97	8.5	1100
56/97	30	1000
38/97	15 to apprx. 7	3050
31/97	21.3	820
29/97	27	1000
53/97	15	720

Table 3. Boreholes with excessive salinity

Location	Bh.No.	Yield m^3/hr	EC Us/cm
Fire Brigade	19/97	15.9	8000
Kijitonyama	94/97	2.1	8000
Tabata Kimanga	292/97	9.0	6500
Oysterbay Police	41/97	2.6	6100

note that the unique success of geophysical methodology comes from the fact that only six boreholes were completely dry. Four other boreholes were abandoned due to excessive salinity as shown in table 3.

From the existing data, it is evident that:

- Groundwater in Dar es Salaam is highly controlled by geological factors such as lithology, type and texture of formation and the structures.
- Sand layers are very important in hydrogeology of the area as they mostly have good water bearing capacity implying that water can be with drawn from it in significant quantities. The texture of sands are generally medium to coarse and sometimes gravels and pebbes exist always in clay matrix. Resistivities of these layers range from 9 - 30 Ohm metres.
- The clay layers mostly do not have good water bearing capacity as they hold water which however cannot be withdrawn easily. Resistivities of clay layers are normally less than 7 Ohm.m.
- Generally the evaluation of groundwater occurrences have indicated that two types of aquifers characterize the area:
  - Sand and gravels
  - Weathered limestone

Concluding remarks

- It must be remembered that originally pumped water to Dar es Salaam came from boreholes within the alluvium of the Gerezani Creek. Overpumping caused increased salinity and hardness leading to abandoning of these wells.
- Dar es Salaam, being a coastal position, is characterised by coastal aquifers. These aquifers are highly vunerable to saline intrusion. Thus, development of these water resources is possible through carefully controlled pumping and a well development survellance programme, which currently is being established by the Dar es Salaam Water and Sewerage Authority.
- From the ongoing Dar es Salaam Water Supply Task Force more boreholes have since been drilled, currently (May, 1999) under the UNDP funding where the highest yielding 40m borehole is located at Mwananyamala with a tested yield of 120 m^3/hour. This borehole is 8m away from bh. 108/97. Its aquifer is weathered limestone and sand from 10-36m.
- Based on carefully interpreted VES data and the borehole results, it is now possible to establish groundwater potential zones within the city of Dar es Salaam
- Geophysics, in form of VES has indeed proved that abundant ground water of good quality is available in Dar es Salaam.

References

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