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Groundwater assessment in sedimentary basins of eastern Kenya, Africa

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ABSTRACT

Finding and developing sources of groundwater is becoming an increasing urgent need in many parts of Kenya. This is particularly critical in the arid and semi-arid lands which forms nearly two-thirds of the total area of the country. Most of this area is underlain by sediments ranging in age between Paleozoic to Quaternary periods. The entire region is drained by seasonal sandrivers except in the coastal best in the souther portion in which rivers Tana, Athi, Voi and other small perennial streams are found. The mean fainfail decreases eastwards and northwards while the potential evaporation rate is high. Aridity, therefore, results from high temperatures accompanied by lack of vegetative cover. Flash floods are frequent in the area.

Analysis of environmental and geological data has been done for the entire area in order to assess the potential of groundwater resources. The result of this analysis shows that the water bearing zones in the consolidated sedimentary rocks range in depth between 50 and 150 metres and the average yield is about 1 - 5 m^3 per hour. The aquifers in the Tertiary - Quaternary deposits are influenced by the seasonal drainage pattern of the area. One of the largest known aquifers in the region extends from northeast of Habaswein. towards Somalia Border on the east. Aquifers adjacent to major laghas have yielded water of good quality from relatively shallow wells.

The chemical analysis of more than 150 samples demonstrate the influence of the depositional palaoenvironment and distance from recharge zones. Although this investigation is still going on, it has been found that the groundwater occurs in the sufficient quantity to reverse the current trend from famine and drought stricken to a region exporting food surpluses to the rest of the country.

INTRODUCTION

The present paper discusses the hydrogeology of the semi-arid and arid area underlain by sedimentary deposits in Eastern Kenya. The aquifer characteristics and recharge features are examined with a view to assessing groundwater potential in the area and also suggesting management options. Although there is no single groundwater basin in the study area data from geological reports supplemented with borehole geophysics and resistivity analysis have been found to be useful tools for identifying aquifer characteristics.

The major water sources in the area includes the perennial Tana River that starts in the eastern Kenya highlands and flows into the Indian Ocean South of Lamu, the Ewaso Ngiro and Daua rivers. The Ewaso Ngiro waters tend to become sub-surface from Habaswein easterwards while the flows of River Daua, an international river running along the border between Kenya and Ethiopia, has low flows during the dry seasons.
In addition there are several seasonal (dry) rivers called laghas, and these supply considerable amount of water during the wet seasons. Most of the water supply is from boreholes, shallow wells and pans. These, probably, supply more than 95 percent of the total water supply in the project area. The water supply is generally interrupted by breakages of

water pumps and bursts of pipes and siltation of pans and dams. There is a need to improve the designs of water projects and plan conjunctive water use of both groundwater and surface water.

The sedimentary rocks underlie nearly one-third of the country covering the north east and eastern Kenya which has low and variable rainfall. The area of the present study is approximately 180,000 Km^2 constituting of Northeast, Coast and Eastern Provinces. The table 1 below gives a breakdwon of the districts covered in the discussion. The geology of the area determines the distribution and occurence of both surface and and groundwater resources in the area. However, the geology of the area has been mapped using air photo reconnaissance survey method only. It it only recently that geophysical methods have been used by petroleum prospecting and groundwater exploration firms.

Table 1: The Districts that comprise the study area

Province	District	Area Km^2	Population (1979)
North eastern	Mandera	26,470	105,610
	Wajir	56,501	139,319
	Garissa	43,931	128,857
Coast	Tana River	38,694	92,401
	Lamu	6,506	42,299
	Kilifi	12,523	430,986
Easter	Kitui	31,099	464,283
	Isiolo	26,605	43,478
	Marsabit	78,078	96,216

GEOLOGY

The geology of the area is comprised of Sedimentary deposits ranging in age from Jurassic to Quaternary periods. These deposits include the Triassic, Mansa Guda Formation, Daua limestone series and the Jurassic Mandera series and Cretaceous Marehan series.

The Dua limestones, measuring about 1200m in thickness near Melka Murri, outcrop in the northeast corner of eastern Kenya in Mandera and Wajir Districts. They were laid in a Jurassic Sea probably of a depth of 2400m as evidenced by the deposition sequence (Ayers, 1952). Overlying the Daua limestones are marine - deltaic - deposited Cretaceous sediments of the Marehan Series, and are confined around El Wak and Finno. The rest of the remaining portion of eastern Kenya comprisesof Tertiary and Quaternary deposits consisting of the Merti Beds of Late Pliocene composed of red, white gray, tan colour friable to semi-consolidated gravel, grif, sand, silt and clay generally intercalated in lenticular beds. These beds extend beneath the plains of Southern Wajir and most of Garissa Districts. Apart of Merti Beds constitute the Wajir Beds that forms a discontinous aquifer around Wajir town. Quaternary deposits consists mainly of soils and alluvial accumulation with patches of limestone, gypsum, sandstones, ironstones and conglomerates.

HYDROLOGY

The mean monthly rainfall was compiled from the records that exist at the Ministry of Water Development's Hydrology Section. The mean annual rainfall range between 700 mm and 200 mm. The rainfall is low, variable and usually occurs in the form of short duration storms. The high evaporation rate, about 2300 mm per annum accompanied by unreliable rainfall makes the study area prone to droughts. The frequency of such droughts range between 4 and 7 year intervals (cf. Ogallo, 1983). The major short coming is lack of adequate hydrometeorological data in the study area. Table 2 shows the distribution of rainfall stations in the area. The well-watered areas have more stations than the areas most affected by drought. The most important stations for our present analysis are those whose records are longer than 20 years. There are two distinct rainy seasons in north eastern Kenya. The long rains start in March and ends in May except in exceptional wet years when the rain ends in June. The short rains start from mid-October to mid-December.

Sources of surface water are limited in eastern Kenya. Most of the rivers originate from outside the study area. Amongst these streams, River

Table 2: The distribution of rainfall stations in the study area

District	Stations	Km^2/Station
North Eastern		
Mandera	13	2036
Garissa	7	6276
Wajir	15	3766
Eastern		
Isiolo	17	1565
Kitui	107	291
Coast		
Kilifi	69	181
Tana River	27	1433
Lamu	18	362
TOTAL	301	1061

Source: Various records at the Meteorological Department and the Ministry of Water Development, Nairobi.

Tana is the largest, transecting through the study area from northeast to southern direction before flowing into the Indian Ocean. The drainage basin covers 132,000 km^2, about 22.7 percent of the total area of the republic.

The average rainfall for the basin is 535 mm. Tana River basin contributes nearly 25 percent of the total runoff of the country. The other important surface water body of interest is River Ewaso Ngiro which has its headwater from Mt. Kenya and Aberdare Range, flows northwards, then eastwards before making a debouch south eastwards. The surface flow, however, disappears at the Lorian Swamp. Only during exceptional floods does Ewaso Ngiro and Lagh Dera, as it is known towards the east, reach the Somalia border. The Ewaso Ngiro river has an area of more than 15,000 km^2 at Archer's post where the annual average discharge is about 1.5 million m^3 A small area in the northwest lyging between Finno and Derkali drains east and northwards to River Daua. Although Daua River is large, it has a seasonal flow and forms an international boundary with Ethiopia. The water supply to Lamu, Mandera town and Army barracks are from the river.

GROUNDWATER RESOURCES

The potential of groundwater resources in the north and north eastern parts of Kenya is not well known. The present sources of water supply in the area includes pans, shallow wells and boreholes, However, the extent and characteristic of the aquifers and the nature of recharge have not been determined. Although lack of such information limits any rational economical development and management of groundwater resources, attempt has been made in the present paper to evaluate the state of knowledge in the area.

The distribution of boreholes by area in eastern Kenya is not limited to the area that is underlain by sedimentary deposits only, but it covers the provinces that are situated in eastern Kenya (Table 4). The distribution of boreholes reflect the effect of water availability as well as the influence of demand. The data based on the borehole physical characteristics are rather more telling than that of the distribution (Table 5). The number of boreholes that were reported dry ranges from 70 percent in Tana River District to about 22 percent in Isiolo. Most of these dry boreholes locate in the Mansa Guda formation but the picture from other series cannot be

Table 4: The distribution of Boreholes by Area and Population

District	Area	Pop.	Boreholes	Km^2 Borehole	Persons B/h
North Eastern					
Mandera	26,470	105,601	52	509	2031
Garissa	43,941	128,857	88	499	1464
Wajir	56,501	139,319	127	445	1097
Eastern Prov.					
Isiolo	26,605	43,478	59	451	767
Kitui	31,099	464,283	39	797	11,905
Marsabit	78,078	96,210	85	918	1,131
Coast Prov.					
Kilifi	12,523	430,986	182	69	2,368
Tana River	38,694	92,401	10	3,869	9,240
Lamu	6,514	22,401	12	543	1,867

Sources: Various District Development Plans, Statistical Abstract (1984) and files in the Ministry of Water Development.

Table 5: ASSESSMENT OF GROUNDWATER RESOURCES IN SEDIMENTARY BASINS - EASTERN KENYA

SUMMARY OF BOREHOLE PHYSICAL DATA

TD: Total Depth; W. S. Water Struck; W.R.L. Water Rest Level

DISTRICT	TOTAL NO B/H	DRY NO B/H	SUCCESSFUL													
			NO. B/H	TD.			W.S.			W.R.L.			YIELD/m/hr		
				MAX	MIN	MEAN	MAX	MIN	MEAN	MAX	MIN	MEAN	MAX	MIN	MEAN
Marsabit	85	39	46	356	19	100	261	4	72	246	7	65	33	0.1	5.6
Isiolo	59	13	46	233	11	93	198	12	61	150	7	52	26	0.5	4
Mandera	52	13	39	300	19	142	277	19	95	144	14	49	10	0.01	4
Wajir	127	47	80	304	14	114	216	6	84	180	3	72	80	0.02	10
Garissa	88	32	56	231	8	118	158	4	103	151	3	98	22	0.07	4
Tana River	10	7	3	135	6	94	-	-	-	94	5	67	3	2	2
Lamu	12	3	9	82	30	56	34	24	28	32	22	26	15	0.5	4
Kilifi	182	58	124	311	4	69	206	1	49	140	2	34	88	0.01	6
Kitui	39	12	27	197	26	102	133	3	32	78	1	22	45	0.04	7

established well because of paucity of data. In comparison the Marehan Series yield groundwater of acceptable quality at relatively shallow depths. Some of the highest yielding boreholes have been drilled around Finno area, along the road from El Wak to Mandera. The yields range between 40 and 90 litres per minute, basically from the upper sandstone unit of the series. The other areas that have promising yields include Asahaba and War Gedud area that is associated with faultline. In some cases reported dry boreholes were not drilled deep enough to tap the lower aquifers.

The Merti Beds around Wajir forms one of the best known productive aquifer in eastern Kenya. It extends from the north east of Habaswein to Somalia border at Liboi and beyond, approximately in line with the Ewaso Ngiro drainageway. The lateral extent of the aquifer is not definitively known but it is believed to be limited by the adjacent saline water bodies. The aquifer extends for about 200 km long and lies between 20 and 90 km wide. The extent of the area in which sweet water occurs range between 10,000 and 20,000 km^2. The depth of the aquifer is approximately 90m in lowlying areas but may exceed 140 m in areas of high attitudes. The yields range between 30 litres per minute to 180 litres per minute. Swarzenski and Murdoff (1977), assuming a saturated thickness of 60m calculated that about 10,800m^3 per day flowed underground past Liboi.

A generalised picture of the aquifer near Wajir town shows that the zone above 2 metres of depth is covered with sandy soil. Below this is covered by limestone series, very hard and dense near the surface, softer below, of 2 to 10 metres thickness. Further below the limestone series is an alluvial deposit(course to clayey sands) of about 10 m thickness. This represents a shallow aquifer. Below this aquifer lies a series of dense clay layers and a few thin sandy and silty beds to a depth of of between 80 and 150 metres. The sandy and silty beds have been found to contain some water at depths between 35 and 40 metres. However salinity increases with depth. The Mansa Guda formation is thought to underkie the area of study.

Preliminary investigation on the characteristics of the lithological logs shows that there are three types of geologic terranes in which potable water is obtained in the sedimentary basin. First is the Quaternary and Pliocene deposits of unconsolidated or poorly consolidated sand and gravel commonly interbedded with clay. The others consists of semi-consolidated and consolidated conglomerate, sandstone or shale formations of which are often jointed and posses intergranular and fracture porosity and permeability. The third geologic terrane is the limestone and gypsum beds which generally contain saline water (C3850), largely calcium sulfate.

THE WATER RECHARGE

Average rainfall, monthly or annual, data do not represent the water balance of the area. Rainfall occurs generally in the form of violent storms, convectional in genesis producing rain that covers areas of only 20 to 50 km^2 (Swarzenski and Murdorff, 1977). The highest rain occurs in the north,west and south of the study area. The influence of rainfall on recharge is determined by the rates of infiltration and evapotranspiration. On the other hand the rate of infiltration is generally influenced by the geology and antecedent conditions. Bestow (1941) suggests that moisture deficiency in northern part of the country is generally met by about32.5mm of rainfall after which infiltration is possible. It is possible that such infiltration recharges shallow aquifers only and therefore have little impact on the total groundwater resources of the area.

Recharge may occur also as a result of imported water from the Eastern Highlands and Marsabit mountain. Approximately 180,000 m^3 per day passes as underground flow at Serich along the Ewaso Ngiro drainageway via several laghas including Lagh Bor, Lagh Bogal, Lagh Dima and these laghas may recharge perched aquifers in the region. Permeable volcanic lavas that are located in Marsabit area and stream bed deposits allow high infiltration rates to occur and as a result they account for localized recharge. Besides channelised seepage that accounts for underground flow in the area, occasional floodwater especially on the Lorian Swamp - Lagh Dera drainageway is probably responsible for recharging the aquifers of Merti and Wajir Beds. Other physiographic features that are in the area such as alluvial fans, ponds and dams store water and allow infiltration to increase are yet to be identified and mapped. Although clay plugs that generally occur along abandoned channels and swamps may be counterproductive in enhancing infiltration, many of such plugs become eroded during large floods. Such clay plugs at depths of 0.5 to 1.0 m and 7.0 to 20.0 m can be identified in lithological data of boreholes from the area.

There is high rate of evapotransipiration. For recharge to occur, the rate of infiltration need to exceed that of evapotranspiration in order to obtain net gain in storage. Presently, it is impossible to isolate the parameters of recharge because perennial recharge through faultlines, erratic rainfall and seepage all combine to recharge the area.

WATER QUALITY

The groundwater chemistry in Eastern Kenya depends on the hydrochemical character of recharge waters and the aquifer matrix.

This zone is referred to as the zone of chloride waters (Ongwenyi, 1973), extending from Lake Rudolf southwards through Samburu, Isiolo, Kitui, Taita Taveta districts and eastwards to the borders, except for a narrow strip running in a northwest – southeast trend.

Fresh groundwater containing less than 1000 mg/l of dissolved solids is rare in the region. Except for the Merti Beds with low salt content and pH values ranging between 7.2 and 7.8, most of the groundwater in the area is below the recommended limits (cf. U.S. Public Health Service, 1962). The salinity increases towards northeast and southwest in amounts of sodioum, chloride, bicarbonate and sulfate. Concentrations of flouride is sometimes high, and this is partly due to volcanic rocks around Merti area. The temperatures of the water range from 34° to 39.2° slightly in excess of average air temperatures by 8° to 9°C.

Groundwater tapped from consolidated Mesozoic sedimentary rocks contains 2,000 to 4,000 mg/l of dissolved solids (Swarzenski and Mundorff, (1977) and is marginally suitable for human consumption. High nitrate concentration has been reported in various areas within the region (Joubert, 1963). Such high nitrate concentration would be explained from two sources, namely from biological pollution or from buried palaesals.

CONCLUSION

The present paper has examined the aquifer characteristics of the sedimentary basins of eastern Kenya. Knowledge of the physical character of rocks and climate, the two main factors that determine the occurrence of groundwater, is patch and fragmentary at best. Aquifers in the area can be distinguished by depth or by lithological composition.

Three types of aquifers were distinguished according to depth namely shallow aquifers (depth less than 10 metres deep), deep aquifers (between between 35 to 40 metres) and deep and fractured aquifers (of depth from 80 to 120 metres). These types of aquifers are represented by sandy to clayey deposits except the latter one.

From lithological logs, it was possible to identify three types of aquifers namely unconsolidated and consolidated sand and gravel commonly interbedded with clay; semi-consolidated and consolidated conglomerate, sandstone or shallow formations often with joints or fractures- and finally limestone or gypsum beds. The water chemistry of each group of aquifers differs considerably from each other.

REFERENCES

1. Ayers, F. M. (1952): Geology of the Wajir - Mandera District, Northeast Kenya. Government Printers.

2. Bestow, T. T. (1960): Northern Province Groundwater Survey. Explanatory note on Shee 13 - Lower Ewaso Ngiro.

3. Government of Kenya (1962): An Investigation into the Water Resources of the Ewaso Ngiro Basin, Kenya. Ministry of Works, Hydraulic Branch Report 5. Government Printers.

4. Government of Kenya (1977): The National Water Master Plan of Kenya. Government Printers.

5. Government of Kenya (1973): Sectional Study and National Programming for Community and Rural Water Supply, Sewerage and Water Pollution Contr Report 7. Groundwater Resources in Kenya WHO, Brazzaville.

6. Jonbert, P. (1963), Geoloy of Wajir - Wajir Bor Area. Geol. Survey of Kenya, Report No. 57, 34 p.

7. Krhoda, G. O. (1986): The Groundwater Resources in semi-arid and arid parts of Eastern Kenya, in Geoly-drology of Drought - Prone Areas of Africa Commonwealth Science Council, Technical Publication Series No. 202, London.

8. Krhoda, G. O. (1987): Assessment of Groundwater Resources in Sedimentary Basins, Eastern Kenya: Progress Report.

9. Krhoda, G. O. , Water Supply in Kenya Today and the Year 2000 AD, in S. H. Ominde (ed.), Issues in Population Growth and Resources in Kenya by the year 2000 AD, chapter 16, in press.

10. Krhoda, G. O. (1987): Water Resource Constraints and Prospects for Agricultural and Industrial Development Towards the Year 2000 Ad. Paper presented at the Workshop on Kenya's Industrial and Agricultural Strategies Towards 2000 A.D.Kenya Economic Association, September 21 -25, 1987.

11. Mason, P. (1955): Geology of the Meru - Isiolo Area. Government Printers.

12. Matheson, F. J. (1971) : Geology of Garba Tula Area Geol. Survey of Kenya, Report No. 88, 30 p.

13. Ogallo, L. (1983) Rainfall trends in Arid regions. The Kenya Geographer, V. 5, No. 1 and 2 p. 26 - 32, 1982.

14. Ongwenyi, G. S. (1973): The Significance of the geographic and geologic groundwater chemistry in Kenya. Unpublished M.Sc. thesis, University of Nairobi.

15. Swarzenski W.V. and M. J. Mundorff (1977). Geohydrology of Northestern Province, Kenya, USGS, Water Supply Paper 1757 - N.