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An assessment of groundwater resources in basement complex terrain Ofgwarinpa-Kafe area of Abuja Metropolis, Central Nigeria

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ABSTRACT

The exploration, exploitation and evaluation of 28boreholesin Gwarinpa and Kafe areas of Abuja metropolis have been used to assess the groundwater potentials of the basement complex terrain.Of the 28 boreholes developed,three (3) were located on weathered basement with overburden thickness of 24 m, 27.0m and 29.5 m while twenty-five (25) were located on fractured basement intercepted at various depthsranging from 20.0 m to 36.0 m. Among the 28 boreholes developed, 14 (or 50%) had yield ranging from 3.33 m^3/hr to 5.0 m^3/hr while 8 (or 28.6 %) had yield from 5.1 m^3/hr to 6.0 m^3/hr whereas 6 (or 21.4 %) had yield between 6.1 m^3/hr and 6.70 m^3/hr.Wells located on weathered overburden had intermediate yield of 5.0 m^3/hr to 5.2 m^3/hr while the high yield are from wells located on northerly trending fractures.Groundwater saturation and yield in the area aretherefore due to a combinationof the factors such as the nature of topography, degree of weathering of the basement rocks, thickness of overburden, degree of fracturing and or the interconnectivity of fractures in the basement rocks. The groundwater resource is largeenough for domestic consumption and supplementsthe limited surface water supply to the area.

Keywords: groundwater, fractures, weathered overburden.

INTRODUCTION

Groundwater accounts for about 98% of the world's fresh water and it is fairly well distributed throughout the world [7]. The exploration and exploitation of groundwater as a major resource to meet the growing population in some urban cities in Nigerialocated on basement complex rocks have been a subject of discussion [4, 5,9,11]. These works involved a combination of hydrogeological and geoelectrical parameters to delineate aquifer characteristics in the Nigerian crystalline basement rocks in Akure[9], Gusau[5] and Lokoja [11]. This work is concerned with the exploration and exploitation of groundwater resources in the basement complex terrain in parts of Abuja, north-central, Nigeria.

Abuja, the Federal Capital Territory of Nigeria, has witnessed exponential growth in physical infrastructures and human development. The major surface water scheme in use within the cityhas been the 'Lower Usman Dam'. A smaller dam built at the Abatcha Barracks' serves its immediate community at the army barracks, also within the territory. Another dam, the 'Gurara Dam', is being constructed from a distance of about 56 km from the metropolis and reticulated to serve the city. Construction of the Gurara Dam is nearing completion and it is anticipated that it should be put to use by 2012. In the meantime, government, private establishments and individuals have had to drill bore holes to supplement discharge from the dam for both domestic and industrial uses. This study assesses groundwater characteristics in Gwarinpa-Kafe area of Abuja metropolis, Federal Capital Territory, Nigeria using geophysical exploration tools and geoelectric parameters of sites whose selection were demand driven. Aquifer characteristics were delineated, drilling exercises were undertaken and yield evaluated to determine the quantity of the water required to meet the domestic needs of the owners.

Physiography and geology
Physiography

The Gwarinpa-Kafe area lies between Latitudes 09°06' N and 09° 07' 30" and longitudes 07° 22'E and 07° 27' 30"E in north central Nigeria (Fig. 1). The average annual rainfall of the area is between 1,200 and 1, 400mm [3]. The vegetation cover consists of shrubs and trees typical of the savannah belt region of north central Nigeria. Abuja city is warm and humid during the dry season and cool during the rainy season. The study area is underlain by Basement Complex rocks outcropping both as low and high hills (Fig. 1). Elevation above sea level varies from 430 m to 540 m. Settlements are concentrated at the low-lying areas at Kafe, Dawaki, and Gwarinpa (Fig. 1). Streams and rivers are sparsely distributed within the area and the flow is from the northeast to the southwest.

Geology of study area

Abuja lies in the basement complex terrain of Nigeria. McCurry (1989) defined the basement complex of Nigeriaas the reactivated ancient crystalline rocks which formed a suit of migmatite, gneiss and granite grouped as a single petrogenetic unit [10].Rahaman (1988) pointed out that the metamorphism of the basement rocks of Nigeria was polycyclic [2, 12].Woakes *et al.* (1989) argued that about 60% of the basement complex rocks in north central Nigeria are made up of migmatite and gneissic rocks which have undergone at least three stages of deformational trends (metamorphism) before their present state [14]. Ekwueme (2004) emphasized the need for the presence of joints and fracture sets in crystalline rocks if the basement rocks are to act as good indicators of groundwater sources and sites of tube-well drilling for potable water supply [8]. Omada *et al.* (2009) indicated that the basement complex rocks in parts of Lokoja metropolis in north central Nigeriaare potential groundwater resources. Field studies of the Gwarinpa-Kafe area indicate that the basement complex rocks are migmatite, gneiss with intrusions of Older Granite suites and pegmatite dykes. Fractures trend northerly in the NNE-SSW, NNW-SSE directions (Fig. 2). In this study, exploration and development of 28 bore holes have been undertaken, the aquifer characteristics outlined, and yield determined.

MATERIALS AND METHODS

Selection of the 28 borehole sites within Gwarinpa-Kafe area of Abuja metropolis was demand driven. Elevations above sea level of bore-hole sites (Table 1) were obtained using Global Positioning System (GPS). Thickness of overburden and fractures were obtained by the use of terameter model 500 for Vertical Electrical Sounding (VES).The measured apparent resistivity values obtained from Schlumberger Array were plotted against the corresponding electrode separation on a logarithmic graph and then compared with theoretical curves prepared (standard data). This process yielded the resistivity and thickness of the various subsurface (geo-electric) layers represented in Figure 2.The 28 boreholeswere drilled using Schramm 900 model Rig with Ingersorrand compressor.The drilling operation was done usually to the bottom (lower limit) of the water-bearing (aquiferous) horizons in order to obtain full utilization of the aquifer thickness and maximum drawdown with resultant well yield.The encountered geo-electric layers were interpreted through direct logging.Static water levels (SWL) of the boreholes were directly measured during pump installations.The bored holes were wide enough to freely accommodate the submersible pump intended for installation and to pump the anticipated water capacity. Sufficient clearance between pump bowl and permanent PVC casing installed was provided to allow for possibility of misalignment in the casing that could cause the pump shaft not to be vertical thereby causing malfunctioning of pump resulting in low well yield or outright well damage. The well screen diameterranges between 4" and 6" (standard) was chosen to meet the required standard and also to ensure good hydraulic efficiency of the borehole.The Schramm model (US made) used in the operation carried 4" and 6" hammer barrel on the power head section.Casing, gravel packing/grouting, pump installation, pump test facility provision andwater quality fittings and assessment were undertaken after each drilling operation.The evaluation procedure used was pumping test of well and in-situ measurements regarding the various hydrogeologic information on aquifer units at subsurface.Length of safety rope (marine rope) was also required to secure the pump with varying capacity from 0.5 to 1.0 HP. Allegro, 0.5 HP was installed forwells with shallow depth and static water level (SWL).The site investigation, drilling and installation took place from April, 2009 to February, 2010**.**

RESULTS AND DISCUSSION

Data obtained from the geophysical exploration exercise of the 28 sites indicate the presence of six geo-electric subsurface layers as:

i. topsoil (loose)
ii. lateritic sand
iii. clayey sand (moist)
iv. weathered basement rock (wet)
v. weathered/fractured basement rock (highly saturated), and
vi. fresh/non-fractured basement rock (dry)

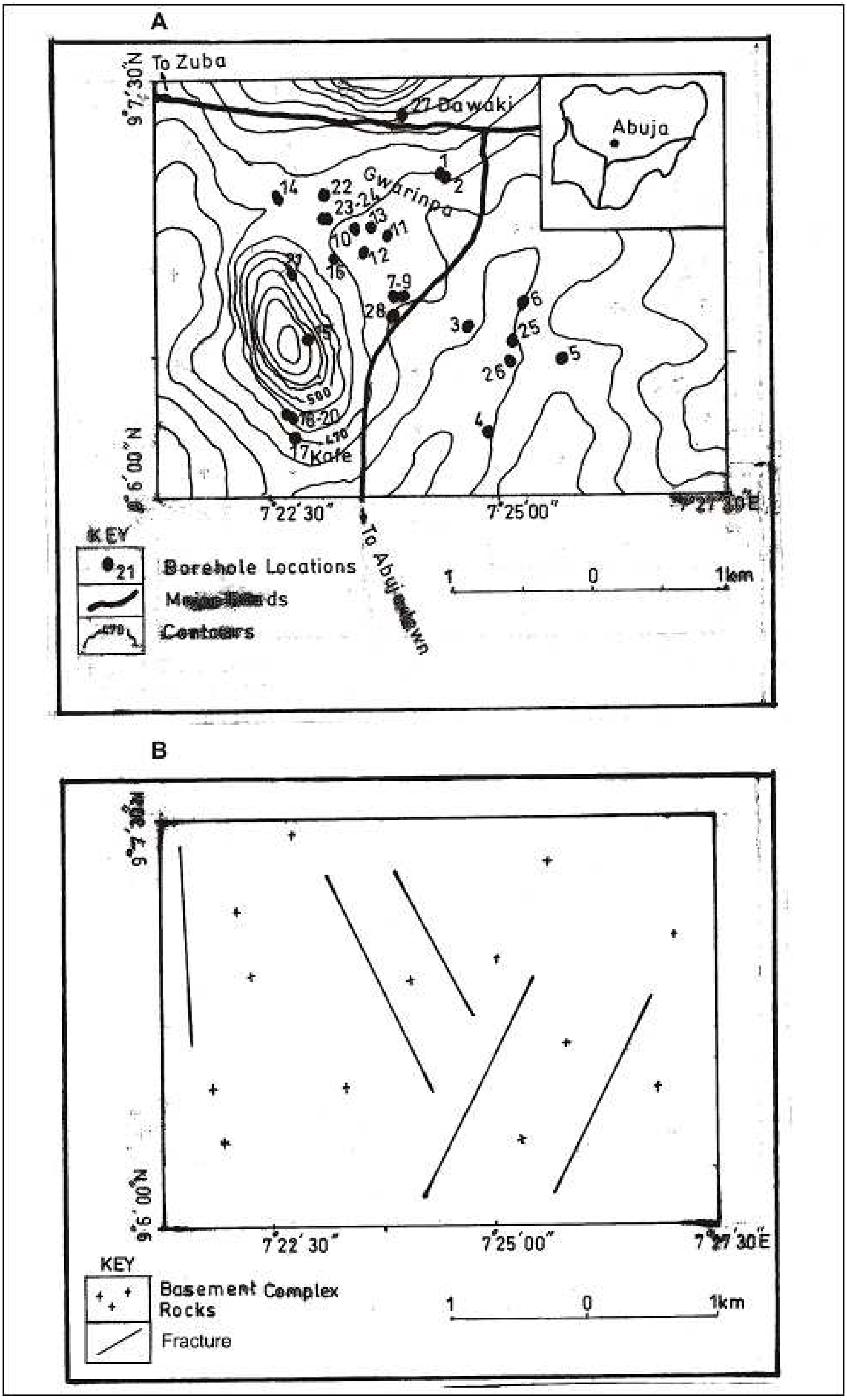

Figure 1. A: Contour map of the Gwarinpa-Kafe area of Abuja Metropolis showing the location of 28 boreholes in the study.Insert: Map of Nigeria showing the location of Abuja.
B: Geologic map showing northerly trending fractures in the Gwarinpa-Kafe area.

Table 1.Locations, Aquifer Characteristics, Yield and Static Water levels of 31 Wells in Gwarinpa-Kafe Area of AbujaMetropolis, Nigeria.

S/No	Location	Latitude	Longitude	Altitude (M)	Thickness Of Weathered Overburden (M)	Thickness Of Fractured Basement Drilled (M)	Borehole Depth (M)	Estimated Yield (M^3/Hr)	Static Water Level (M)
1	Citec Gate, Gwarinpa	09° 07' 08.6" N	07° 24' 07.1" E	480	7.00	14.00	21.00	4.20	7.2
2	Citec Gate, Gwarinpa	09° 07' 07.8" N	07° 24' 08.2" E	483	7.00	19.00	26.00	4.20	7.2
3	54th Road, Gwarinpa	09° 06' 35.0" N	07° 24' 40.2" E	466	9.00	18.00	27.00	5.00	7.5
4	5th Avenue, Gwarinpa	09° 06' 13.7" N	07° 24' 48.8" E	456	15.00	10.00	25.00	5.00	7.1
5	2nd Avenue, Gwarinpa	09° 06' 28.5" N	07° 25' 24.2" E	450	24.00	0.00	24.00	5.20	7.0
6	14th Road, Gwarinpa	09° 06' 41.2" N	07° 25' 28.9" E	465	7.00	13.00	20.00	6.70	3.4
7	Road 371, Gwarinpa	09° 06' 42.5" N	07° 23' 56.8" E	465	9.50	14.00	23.50	6.70	4.0
8	Road 371, Gwarinpa	09° 06' 42.5" N	07° 23' 57.7" E	467	9.50	13.50	23.00	6.70	4.0
9	Road 371, Gwarinpa	09° 06' 42.7" N	07° 23' 56.2" E	466	9.00	13.00	22.00	6.70	4.0
10	7th Avenue, 58 Road Gwarinpa	09° 06' 58.1" N	07° 23' 29.1" E	455	18.00	9.00	27.00	5.40	9.0
11	7th Avenue, 58 Road Gwarinpa	09° 06' 56.9" N	07° 23' 26.8" E	450	14.00	18.30	32.30	5.80	6.1
12	7th Avenue, 58 Road Gwarinpa	09° 06' 52.1" N	07° 23' 31.8" E	454	15.00	8.00	23.00	5.80	5.6
13	7th Avenue, 58 Road Gwarinpa	09° 06' 58.6" N	07° 23' 33.1" E	462	7.00	25.00	32.00	6.25	6.4
14	6th Avenue, Road, 692 Gwarinpa	09° 07' 04.8" N	07° 22' 53.7" E	458	27.00	0.00	27.00	5.20	10.8
15	KingPalace, Lungu Abuja	09° 06' 31.8" N	07° 22' 58.5" E	454	20.40	15.00	35.40	5.40	12.1
16	Team 6b, 6thAvenue, Gwarinpa	09° 06' 49.6" N	07° 22' 47.6" E	436	10.50	14.00	24.50	5.20	6.8
17	Shaara Estate, Kafe District	09° 06' 12.4" N	07° 22' 20.1" E	428	19.00	10.00	29.00	3.33	12.1
18	Shaara Estate, Kafe District	09° 06' 17.3" N	07° 22' 25.7" E	424	19.00	3.00	22.00	3.33	12.0
19	Shaara Estate, Kafe District	09° 06' 17.3" N	07° 22' 20.0" E	431	18.00	3.00	21.00	3.33	12.0
20	Shaara Estate, Kafe District	09° 06' 17.0" N	07° 22' 1.9" E	430	18.00	4.00	22.00	3.33	12.0
21	Team 7b, Gwarinpa	09° 06' 47.2" N	07° 22' 26.3" E	431	7.00	12.20	19.20	5.20	6.3
22	House 12, Team 7, Gwarinpa	09° 07' 13.7" N	07° 22' 43.0" E	467	8.00	21.50	29.50	4.80	11.6
23	House 20, Team, Gwarinpa	09° 06' 59.4" N	07° 22' 40.6" E	438	7.00	23.40	30.40	4.80	10.8
24	Road 69, Team 7, Gwarinpa	09° 06' 58.7" N	07° 22' 43.1" E	462	15.00	18.00	32.00	4.20	12.3
25	Foreign Affairs Quarters, Gwarinpa	09° 06' 32.0" N	07° 25' 24.1" E	457	12.00	13.00	26.00	3.33	7.8
26	Setraco Gate, Gwarinpa	09° 06' 28.4" N	07° 25' 24.2" E	451	10.00	14.00	24.00	4.20	8.4
27	Behind News Engineering, Dawaki	09° 07' 24.8" N	07° 23' 59.5" E	485	29.50	0.00	29.50	5.00	12.6
28	Behind Borno House Gwarinpa	09° 06' 42.9" N	07° 23' 58.3" E	462	16.00	20.00	36.00	6.25	8.0

***Data Source: Source:** This study (1st April 2009 to 28th February 2010).*

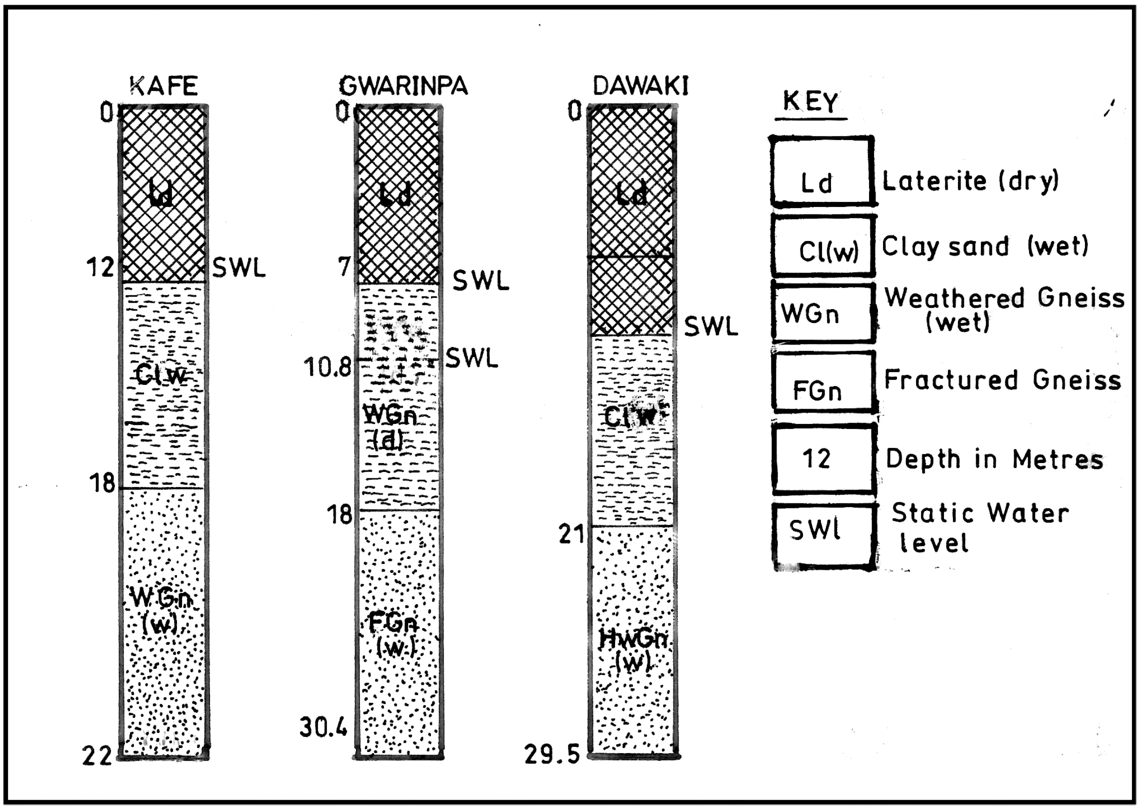

Fig. 2. Geologic logs of representative borehole sites at Gwarinpa-Kafe area of Abuja, Nigeria.

Zones (i) to (iii) may be wet or dry depending on the season in the year but do not transmit water enough for usage. Zones (iv) and (v) are the aquiferous units. Basement rocks such as gneiss, migmatite and granite in the study area show characteristic non-uniformity of weathering profiles of individual rock unitsand therefore non-uniformity in the thickness of the weathered overburden (Table 1, Figure 2). The undulating nature of the topography of the study area also created a non-uniform factor for consideration of direction of water flow at the subsurface. Therefore, lateral groundwater flow within the fractured zones of the basement rocks actually depended on the interconnectivity and size of the fractures in addition to role played by relief.The thickness of overburden on the basement complex of the study area ranges from 7.0 m at Gwarinpa to 29.50 m at Dawaki (Table 1).

Of the 28boreholes developed, three (3)(serial 5, 14 and 27 in Table 1) were developed on weathered basement alonesince geophysical studies indicated absence of fractures but the presence of saturated overburden with thickness of 24 m, 27 m, and 29.5 m, respectively. Subsurface fractures identified by geophysical investigation guided the location of the remaining 25 borehole sites in the study. Thickness of fractured basement penetrated during drilling varied from 3.0 m to 25 m in various locations. Generally, there existed certain peculiarities in the thickness of the overburden and fractures and borehole depths from one site to the other. Borehole depthsrangedfrom 20.0 m to 36.0 m indicatingthat the wells in the study areshallow wells. This istypical of boreholes in basement terrains elsewhere in Nigeria.

Yield of water from the wells varies from 3.33 m^3/hr to 6.70 m^3/hr. Among the 28 boreholes developed:14(or 50% of the wells) had yield of 3.33 to 5.0 m^3/hr,while 8(or 28.6 %) had yield that ranged from 5.1 to 6.0 m^3/hr, whereas6(or 21.4 %) had yield between 6.1 and 6.70 m^3/hr. Wells located on weathered basement alone had yield that range from 5.0 m^3/hr to 5.2 m^3/hr indicating that more prolific wells are associated with saturated fractures within the basement terrain.. Majority of the low yielding wells (> 5.0 m^3/hr) are around the Kafe while the most prolific wells are in Gwarinpa on the undulating plain of between the Dawaki and Kafe ridges.There is therefore a relationship between topography, yield of boreholes and static water level. For example, the wells with the most prolific yield (>6.1 m^3/hr) which are located on the undulating plains have the shallowest static water levels which ranged from 3.4 m to 4.0 m. Static water level in low yielding wells varies from 6.4 m to 12.6 m (Table 1). Topography is one of the major factors that affected the yield. For example, Kafe is on an elevated area of the basement terrain (> 470 m above sea level) while Gwarinpais on the undulating plain (430 m to 460 m).Other factors are the thickness of weathered overburden, existence of fractures and their interconnectivity.

According to Skinner (2003), this yield is sufficient for use in a family of about 120 persons [13]. This means that the yield from most of the wells can support several families and perhaps small scale industries. This result is consistent with those of earlier works in basement areas of Lokoja area,central Nigeria (e.g. Omada *et* al, 2009).It is recommended that government should undertake regional survey of water bearing fractures in metropolis underlain by basement complex rocks and earmark them as reserve areas on which government or individuals could locate boreholes and tap from the ground water resource. The current uncoordinated demands, exploration and drilling of boreholes in homes should be discouraged as it is expensive and less productive..

CONCLUSION

This studyassessed the potentialsof groundwater in basement complex terrain of Gwarinpa-Kafe area of Abuja metropolis for the supply of potable waterfor domestic uses.Results show that groundwater resources are available in both the weatheredoverburden and fractured zones of the basement complex rocks in the area.Subsurface fractures in the study area were at depths ranging from 7.0 m to 36.00 m and they served as good reservoirsfor water. Generally, drilling penetrated both the overburden and the competent basement complex rocks until fractures were encountered.

Yield of water from the shallow wells varies from 3.33 m^3/hr to 6.70 m^3/hr. Among the 28 boreholes developed, 14 (or 50% of the wells) had yield of 3.33 to 5.0 m^3/hr while 8 (or 28.6 %) had yield that ranged from 5.1 to 6.0 m^3/hr whereas 6 (or 21.4 %) had yield between 6.1 and 6.70 m^3/hr. The three (3) wells developed on weathered overburden had yield of 5.0 m^3/hr to 5.2 m^3/hrwhilewells with high yield (> 6.1 m^3/hr) had intersection with saturated fractures within the basement terrain. Basement rocks such as gneiss, migmatite and granite in the study area have non-uniformity of weathering profiles of individual rock units which may have also played a role in the variations of yields of the boreholes drilled. In addition, topography, degree of weathering and the presence of fractures were controlling factors that affected yield from the wells. The yield is however adequate in quantity for domestic consumption and shows that groundwater resource continues to be good alternative to surface water in the provision of potable water.

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