The Use of Vertical Electrical Sounding (VES) for Groundwater Exploration around Nigerian College of Aviation Technology (NCAT), Zaria, Kaduna State, Nigeria.

S.I. Fadele, M.Sc.[1*]; P.O. Sule, Ph.D.[1]; and B.B.M. Dewu, Ph.D.[2]

[1]Department of Physics (applied Geophysics), Ahmadu Bello University, Zaria, Nigeria.
[2]Center for Energy Research and Training, Ahmadu Bello University, Zaria, Nigeria.

E-mail: fadeleidowu@yahoo.com*

ABSTRACT

Electrical resistivity was carried out at Nigerian College of Aviation Technology (NCAT), Zaria, Kaduna state, Nigeria in order to study the groundwater potential with a view of determining the depth to the bedrock and thickness of the overburden. Vertical Electrical Sounding (VES) using Schlumberger array was carried out at fifteen (15) VES stations. ABEM terrameter (SAS 300) was used for the data acquisition. The field data obtained have been analyzed using computer software (*IPI2win*) which gives an automatic interpretation of the apparent resistivity. The VES results revealed heterogeneous nature of the subsurface geological sequence. The geologic sequence beneath the study area is composed of top soil (clayey-sandy and sandy-lateritic), weathered layer, partly weathered (fractured basement) and fresh basement. The resistivity value for the topsoil layer varies from 20Ωm to 600Ωm with thickness ranging from 0.5 to 7.2 m. The weathered basement has resistivity values ranging from 15Ωm to 593Ωm and thickness of between 2.75 to 33.04m. The fractured basement has resistivity values ranging from 201Ωm to 835Ωm and thickness of between 11 to 20.4m. The fresh basement (bedrock) has resistivity values ranging from 1161Ωm to 3115Ωm with infinite depth. However, the depth from the earth's surface to the bedrock surface varies between 2.5 to 37.75m.

(Keywords: vertical electrical sounding, VES, top soil, TP, weathered basement, WB, partly weathered basement, PWB, fresh basement, FB)

INTRODUCTION

The use of geophysics for groundwater exploration and water quality evaluations has increased over the last few years due to the rapid advances in computer software and associated numerical modeling solutions. The Vertical Electrical Sounding (VES) has proved very popular with groundwater prospecting due to simplicity of the techniques. The electrical geophysical survey method is the detection of the surface effects produced by the flow of electric current inside the earth. The electrical techniques have been used in a wide range of geophysical investigations such as mineral exploration, engineering studies, geothermal exploration, archeological investigations, permafrost mapping and geological mapping.

Electrical methods are generally classified according to the energy source involved, i.e., natural or artificial. Thus, self-potential (SP), telluric current come under natural source methods, while resistivity, electromagnetic (EM), and induced polarization (IP) methods are artificial source methods. The electrical d.c resistivity method used in carrying out the present survey is of artificial source using the ABEM terrameter (SAS 300).

Appraising the hydrogeology in Zaria, Danladi (1985) has confirmed the presence of water bearing fractures, which aquifers are located at a shallow basement area of Zaria. McCurry (1970), who studied the geology of Zaria, has established that the Basement Complex rock is made up of the Older Granite, Biotite granite-gneiss. Farouq (2001), carried out geoelectric investigation of the groundwater potential in the Institute for Agricultural Research Farm, Samaru, Zaria, showed that the thickness of the weathered basement around the area varies from 3.4 to 30.4m and depth to fresh basement was 40m. Similarly, Saminu (1999), carried out a comprehensive geophysical survey over the premises of Federal College of Education, Zaria, showed that the thickness of the top soil of the area ranges between 3.5 and 14m while the thickness of the weathered basement ranges between 9 and 36.5m. The depth to bedrock varies from 5 to 14m. In this study, geoelectrical investigations covering fifteen stations at the Nigeria College of Aviation Technology, Zaria, Kaduna State, Nigeria, have been carried out and interpreted fully in order to evaluate the groundwater potentials with a view of determining the depth to the bedrock and thickness of the overburden.

SITE DESCRIPTION

The Nigerian College of Aviation Technology, Zaria, Kaduna State, Nigeria, is bounded approximately by longitudes $7^0$41'E and $7^0$42'E, latitudes $11^0$07'N and $11^0$08'N within the Zaria sheet 102 SW map (Figure 1). The area falls within the semi-arid zone of Nigeria (Harold, 1970). It lies in the guinea savannah; the woodland vegetation is characterized by bushes generally less than 3m high.

GEOLOGY OF THE STUDY AREA

Nigeria lies in the Pan-African mobile belt which has been affected by Pan-African events through the ages of orogenic, epeirogenesis, tectonic and metamorphic cycles (Oyawoye 1964).The study area is part the Nigerian Basement Complex underlain by crystalline rocks. A thick overburden covers the area with varing thicknesses. Underlying the overburden are crystalline rocks consisting of biotite hornblende granite. The granites belong to the Older Granite suite of the North-Western Nigeria, emplaced during the Pan-Africa Orogeny that took place about 600 million years ago (McCurry, 1970).

METHODOLOGY

Vertical Electrical Soundings (VES) using Schlumberger array were carried out at fifteen (15) stations. A regular direction of N-S azimuth was maintained in the orientation of the profiles. Previous geophysical works, carried out within the northern part of Nigeria, has shown that the overburden in the basement area is not as thick as to warrant large current electrode spacing for deeper penetration, therefore the largest Current electrode spacing AB used was 200m, that is, 1/2AB=100m. The potential electrode separation, MN, was also increased intermittently in order to maintain a measurable potential difference, but it did exceed one-fifth of the half-current electrode separation, 1/2AB, as suggested by Dobrin and Savit (1988). The principal instrument used for this survey is the ABEM (Signal Averaging System, SAS300) Terrameter. The resistance readings at every VES point were automatically display on the digital readout screen and then written down on the field report book.

RESULTS AND DISCUSSION

The geometric factor, K, was first calculated for all the electrode spacings using the formula; $K= \pi (L^2/2b – b/2)$, for Schlumberger array with MN=2b and 1/2AB=L. The values obtained, were then multiplied with the resistance values to obtain the apparent resistivity, ρ_a, values. Then the apparent resistivity, ρ_a, values were plotted against the electrode spacings (1/2AB) on a log-log scale to obtain the VES sounding curves using an appropriate computer software *IPI2win* in the present study.

Some sounding curves and their models are shown in Figure 2. Similarly, geoelectric sections are shown in Figures 3 and 4.

Three resistivity sounding curve types were obtained from the studied area and these are the H ($\rho_1>\rho_2< \rho_3$), A ($\rho_1< \rho_2<\rho_3$) and KH ($\rho_1>\rho_2< \rho_3>\rho_4$) type curves. The results of the interpreted VES curves are shown in Table 1.

The modeling of the VES measurements carried out at fifteen (15) stations has been used to derive the geoelectric sections for the various profiles. These have revealed that there are mostly four and three geologic layers beneath each VES station, and two layer cases at three different VES point. The geologic sequence beneath the study area is composed of top soil, weathered basement, partly weathered/fractured basement, and fresh basement. The topsoil is composed of clayey-sandy and sandy-lateritic hard crust with resistivity values ranging from 20Ωm to 600Ωm and thickness varying from 0.5 to 7.5m. It is however, observed from the geoelectric sections that VES 1, 2, 3 and 4 are characterized with low resistivity values varying between 37Ωm to 84Ωm suggesting the clayey nature of the topsoil in these areas are possibly high moisture content.

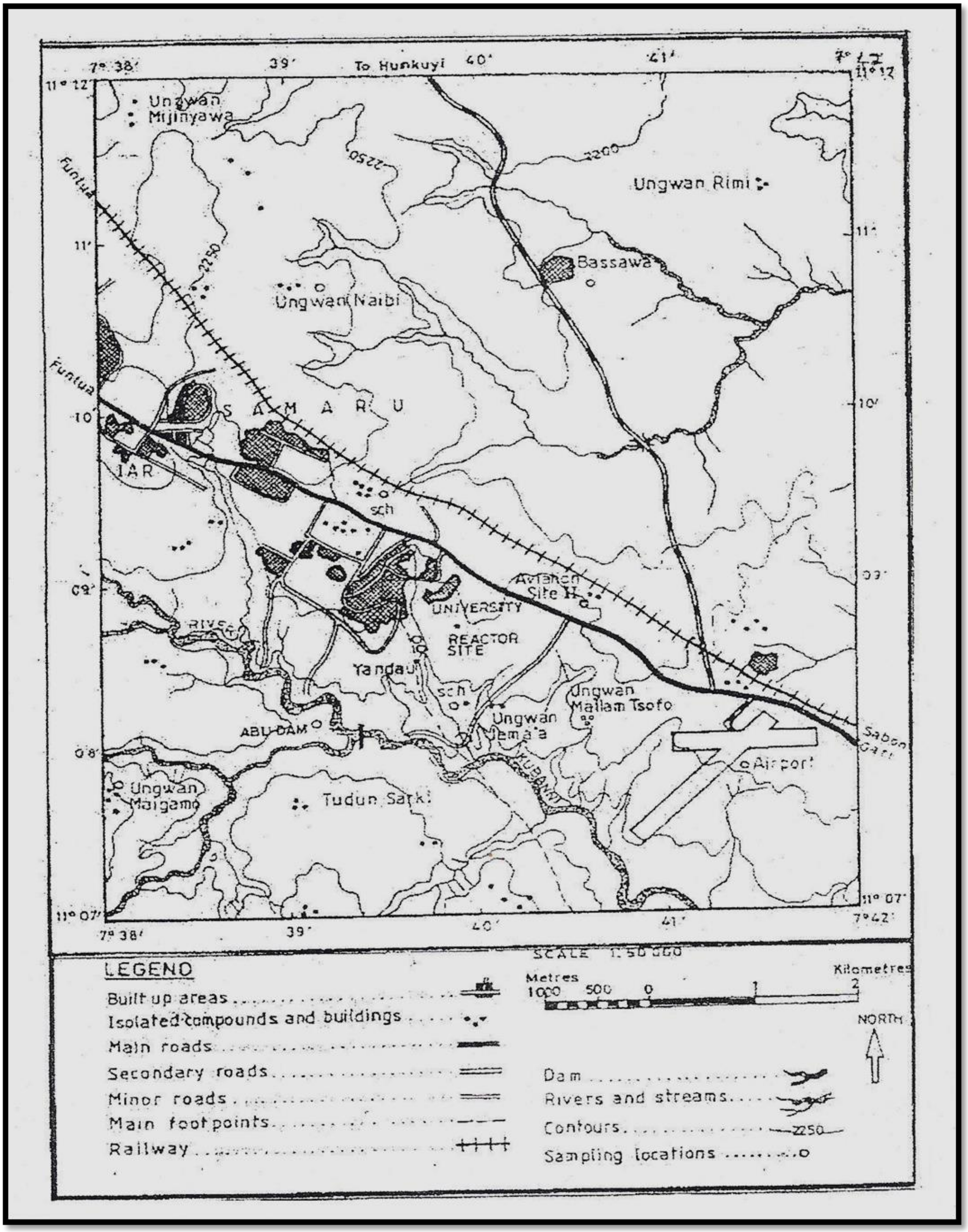
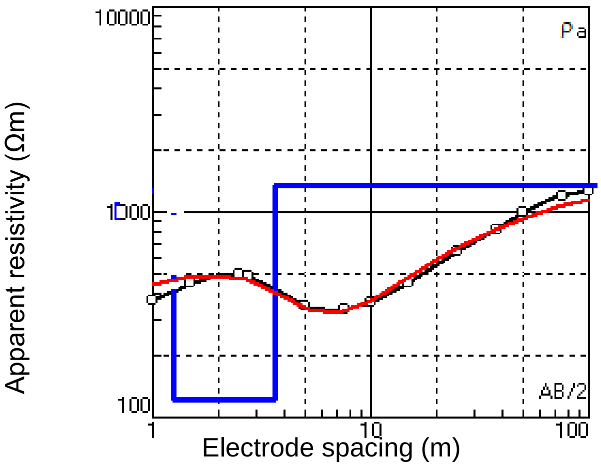


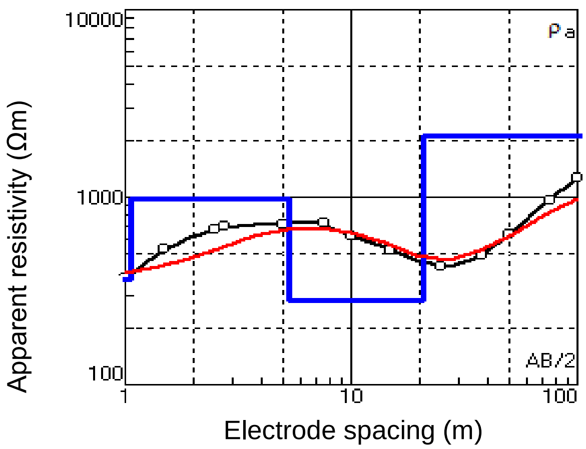
Figure 1: Part of Zaria Sheet 102 Map Showing the Study Area (Drawn from Northern Nigerian Survey Map).



N	ρ	h	d
1	37	1.43	1.43
2	473	6.8	8.23
3	221	17	25.2
4	1251		

Where,
N is the number of layers,
ρ is the apparent resistivity,
h is the thickness and
d is the depth to interface of each layer.

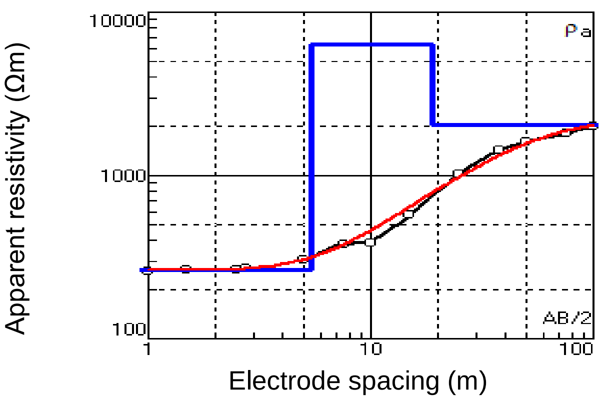
(a) VES Station 1 (TYPE KH CURVE)



N	ρ	h	d
1	40	1.65	1.65
2	503	15.7	17.4
3	210	20.4	37.8
4	1161		

Where,
N is the number of layers,
ρ is the apparent resistivity,
h is the thickness and
d is the depth to interface of each layer.

(b) VES Station 2 (TYPE KH CURVE)



N	ρ	h	d
1	257	2.64	2.64
2	144	32.4	35
3	1410		

Where,
N is the layer number,
ρ is the apparent resistivity in ohm-metre,
h is the layer thickness and
d is the depth to interface of each layer

(c) VES Station 5 (TYPE A CURVE)

Figure 2: Typical Curve Types and Models Obtained from the Study Area.

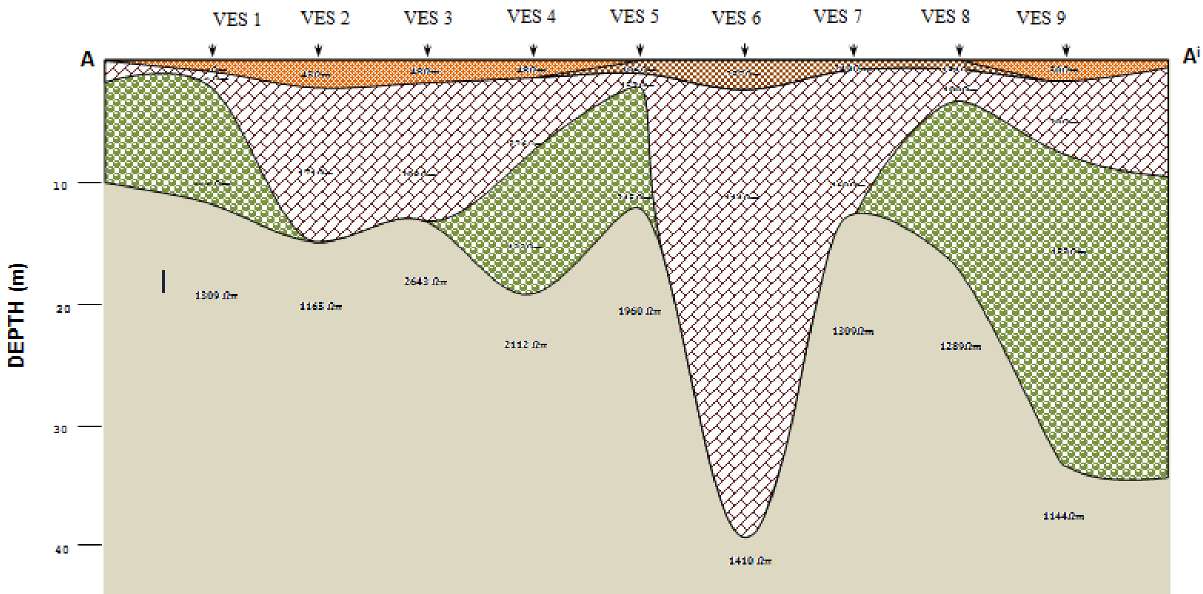


Figure 3: Geoelectric section along profiles A-A^i

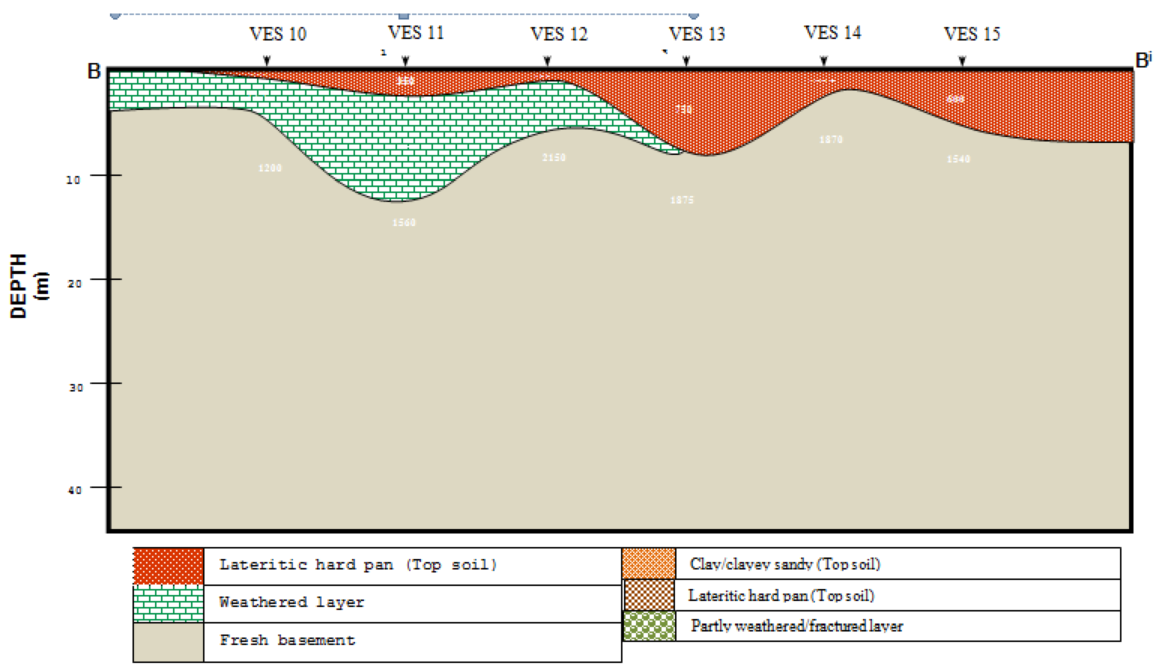


Figure 4: Geoelectric section along profiles B-B^i

The second layer is the weathered basement with resistivity and thickness values varying between 15Ωm and 593Ωm and 2.75 to 33.04m respectively. This layer is thickest at VES station 6, suggesting this point for siting borehole. Other points with probable high water potentials suitable for siting borehole include: VES stations 5, 2 and 8 respectively with appreciable thickness of weathered rock also known as aquifferous zone.

The third layer is the partly weathered and fractured basement with resistivity and thickness values varying between 201Ωm to 835Ωm and 11 to 20.4m respectively. The layer is extensive and thickest at VES station 2 and thinnest at station 3. The fourth layer is presumably fresh basement whose resistivity values vary from 1161Ωm to 3115Ωm with an infinite depth.

Table 1: The results of the interpreted VES curves

VES Stations	Thickness (m)	Layer Resistivity (Ωm)	Remarks	Curve types	Numb of layers
1	1.43 6.80 17.00 -	37 473 221 1251	TP WB PWB FB	KH	4
2	1.65 15.70 20.40 -	40 503 201 1161	TP WB PWB FB	KH	4
3	1.06 12.80 11.00 -	76 350 522 1190	TP WB PWB FB	KH	4
4	2.07 5.60 17.30 -	84 593 835 2020	TP WB PWB FB	KH	4
5	2.65 32.00 -	257 144 1410	TB WB FB	H	3
6	2.98 33.04 -	256 391 1450	TP WB FB	A	3
7	4.14 3.90 -	272 228 1610	TP WB FB	H	3
8	1.87 17.13 -	367 299 1765	TP WB FB	H	3
9	1.54 6.60 -	353 708 3115	TP PWB FB	A	3
10	1.00 2.75 -	20 15 1200	TP WB FB	H	3
11	3.00 9.50 -	350 27 1560	TB WB FB	H	3
12	1.25 4.75 -	180 40 2150	TP WB FB	H	3
13	7.50 -	750 1875	TP FB	2 Layer case	2
14	2.50 -	278 1870	TB FB	2 Layer case	2
15	6.00 -	600 1540	TB FB	2 Layer case	2

However, the depth from the earth's surface to the bedrock surface varies between 2.5 to 37.75m.

CONCLUSION

Geoelectrical investigation using the D.C. electrical resistivity method at Nigeria College of Aviation Technology, Zaria, Kaduna State, Nigeria has revealed two, three and four geologic layers composed of top soil, weathered basement, partly weathered or fractured basement and fresh basement. Based on the qualitative interpretation of the VES data, it is deduced that VES Stations 6, 5, 2 and 8 are potential positions for siting boreholes with appreciable thickness of weathered and fractured basement (aquiferrous zone) ranging from 17.13 to 36.1m, characterized by structural features like fractures that enhance groundwater permeability and storage.

To ensure safe consumption of groundwater in the area, potential sources of contamination site should be sited far away from viable aquifer units because the area is vulnerable to pollution if there is leakage of buried underground septic tank, sewage channels or infiltration of leachate from decomposing refuse dumps in the area as a result of their shallow depth to the aquiferrous zone ranging from 1.43 to 6m. It is also deduced that the area can support low to high engineering structures as a result of the thin clayey nature generally less than 2m, underlain by basement rocks at shallow depth. For massive constructions, structural foundation requires little or no pilling because the basement rocks can serve as pillar supports to the building.

REFERENCES

1. Danladi, G.G. 1985. "Appraisal of Hydrological Investigation in Shallow Basement Area of Zaria". Unpublished M.Sc. Thesis. Department of Geology, Ahmadu Bello University: Zaria, Nigeria.

2. Dobrin, M.B. and C.H. Savit. 1988. *Introduction to Geophysical Prospecting*. *Fourth Edition*. McGraw- Hill Books: New York, NY.

3. Farouq, A.U. 2001. "Geoelectric Investigation of the Groundwater Potential in the Institute for Agricultural Research Farm". Unpublished M.Sc. Thesis. Department of Physics, Ahmadu Bello University: Zaria, Nigeria.

4. Harold, E.D. 1970. *Arid Lands in Transition*. The Hornshafer Company Division of G.D.W. King Printing Co.: New York, NY.

5. Klinkenbera, K. 1970. "Soil of Zaria Area". In: *Zaria and its Region*. M. J. Mortimore (ed). Department of Geography, Occasional Paper No. 4, Ahmadu Bello University: Zaria, Nigeria. 223 – 238.

6. McCurry, P. 1970. "The Geology of Zaria Sheet 21". Unpublished M.Sc. Thesis. Department of Geology. Ahmadu Bello University: Zaria, Nigeria.

7. Oyawoye, P.O. 1964. "Geology of Nigerian Basement Complex". *Journal of Mining and Geology*. 1:110-121.

8. Saminu, O. 1999. "Geophysical Investigation of Federal College of Education, Zaria". Unpublished M.Sc. Thesis. Department of Physics, Ahmadu Bello University: Zaria, Nigiera.

ABOUT THE AUTHORS

S.I. Fadele, M.Sc., is a recent graduate in the Department of Physics (Applied Geophysics option), Faculty of Sciences, Ahmadu Bello, University, Zaria, Nigeria. He specializes in application of geophysical methods in mineral, groundwater explorations and engineering and environmental studies.

P.O. Sule, Ph.D., is a Reader in the Department of Physics (Applied Geophysics option), Faculty of Sciences, Ahmadu Bello, University, Zaria, Nigeria. He specializes in electrical and electromagnetic methods.

B.B.M. Dewu, Ph.D., is a Reader and Director of Centre for Energy Research and Training, Ahmadu Bello University, Zaria, Nigeria. He specializes in electrical and radioactive methods.

SUGGESTED CITATION

Fadele, S.I., P.O. Sule, and B.B.M. Dewu. 2013. "The Use of Vertical Electrical Sounding (VES) for Groundwater Exploration around Nigeria College of Aviation Technology (NCAT), Zaria, Kaduna State, Nigeria". *Pacific Journal of Science and Technology*. 14(1):549-555.

Pacific Journal of Science and Technology