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Geoelectrical Investigation of Subsurface Structures for Mapping Groundwater Potential of Joseph Ayo Babalola University Campus Environment, Ikeji Arakeji, Osun State, Southwestern Nigeria

O. E. Odeyemi[1*], O. M. Odeyemi[2], S. A. Owolabi[2], E. A. Mamukuyomi[3] and R. A. Salako[1]

[1]*Department of Science Laboratory Technology, Federal College of Animal Health and Production Technology, Ibadan, Nigeria.*
[2]*Department of Physical Sciences, Joseph Ayo Babalola University, Ikeji, Arakeji, Nigeria.*
[3]*Department of Applied Geophysics, Federal University of Technology, Akure, Nigeria.*

Authors' contributions

This work was carried out in collaboration among all authors. Author OEO designed the study, carried out the field survey, processed the field data, wrote the protocol and wrote the first draft of the manuscript. Authors OMO and SAO managed the analyses of the study and managed the literature searches. Author EAM carried out the field survey and processed the field data and Author RAS managed the analyses of the study. All authors read and approved the final manuscript.

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ABSTRACT

Owing to fast increase in number of staff and students of Joseph Ayo Babalola University, Ikeji Arakeji, Southwestern Nigeria, it is therefore very important to carry out this research in order to recommend the actual locations where boreholes can be sunk for good potential yields of groundwater when the time comes. The aim of this research is to carry out vertical electrical sounding geophysical survey at study area with a view to determining good aquifers that are good

**Corresponding author: E-mail: evasanmi2@gmail.com;*

for the accumulation of groundwater. The study area is located between latitude 0820225 m to 0820345 m (UTM) Northings and longitude 717320 m to 717450 m (UTM) Eastings. Schlumberger electrode array was employed for the study using Ohmega Resistivity meter for the data acquisition. The geoelectric survey of the study area comprised of twelve vertical electrical soundings, with maximum current electrode spacing (AB) of 100 m. The modeled curves are mainly KH-type. The geoelectric sections generated from the sounding curves revealed 4 major layers earth models. The topsoil is made up of clay, clayey sand/lateritic sand with resistivity and thicknesses varying from 54.7 – 210.1ohm-m and 0.2 –0.8m respectively. The second layer is the lateritic clay with resistivities and thicknesses varying from 334 – 963ohm-m and 1.5 – 10.8m respectively. The third layer constitutes the clay / sandy fractured quartzite and it serves as the aquifer unit. The resistivity values lie between 71.7 and 498 ohm-m while the thicknesses vary from 2.1 – 76.3 m. The fourth layer is the fractured/presumably fresh basement bedrock with the resistivity varying from 1879 – 13991.8 ohm-m. Areas characterized with fractured basement of low resistivity with appreciable thickness are therefore recommended for the siting of boreholes. It is concluded that the vertical electrical sounding points of the study area are good aquifers for groundwater accumulation.

Keywords: Aquifers; Vertical Electrical Sounding (VES); schlumberger electrode array; resistivity.

1. INTRODUCTION

Groundwater constitutes the major source of domestic, industrial and agricultural water supply in most parts of the world. Thus, there is a need for information related to the exploration, protection, qualitative and quantitative evaluation of groundwater resources.

Groundwater occurrence and accumulation in the basement complex environment like Ikeji-Arakeji in Oriade Local government area of Osun State could be very irregular owing to abrupt discontinuities in lithology, overburden thickness, their electrical properties, weathered/fractured basements [1,2,3,4]. Exploiting groundwater in sedimentary terrains is less difficult compared to basement terrains which pose some challenges [5,6,7,8].

The study area, Joseph Ayo Babalola University, Ikeji-Arakeji, falls within the basement complex rocks of Southwestern Nigeria. The Institution depends mainly on boreholes drilled by private individuals as their sources of water for drinking, domestic and agricultural needs. However, following the tremendous expansion of the Institution, emergence of new courses and increase in population of students recently, the available water facilities in the area has been stretched to their limits, hence, a growing demand for more water. Based on this, there is need to carry out comprehensive hydrogeologic and geophysical evaluation of the groundwater prospect in the study area for further groundwater development.

Presence of aquifers in crystalline rocks are commonly restricted to features produced by weathering and tectonic processes [9]. To ensure maximum and perennial yields, it is important that a borehole be located where it can penetrate the greatest possible thickness of both the regolith and the fractured zone before hitting the fresh bedrock. A ground geophysical survey is often carried to locate these groundwater aquifers accurately.

Electrical Resistivity techniques have been used in recent times as complementary methods for hydrogeologic and geologic mapping [10-13]. In the last four decades, the electrical resistivity method has become increasingly popular in the search for groundwater [4,14,15]. The method has also been used widely in groundwater investigation in the basement complex terrains [13,15-18].

Electrical resistivity method has been used in the siting of productive borehole in the basement complex terrain [13,19]. Vertical Electrical Sounding was employed using Half Schlumberger array configuration in order to provide a more quantitative information on the geoelectric sequence through the weathered and fractured zone as an aid in siting productive borehole.

Investigation for groundwater requires an in-depth understanding of the information concerning the lithology, stratigraphical sequence, geological structures and the hydrogeological characteristics of the subsurface materials. Also, of importance is knowledge of the position of the water table, the piezometric levels and their fluctuations [18,20].

This study presents the hydrogeologic and geophysical investigation of the groundwater potential of academic areas (College of Natural Sciences, College of Humanity, College of Social Sciences, College of Agricultural Sciences and College of Environmental Sciences) using Electrical resistivity method to delineate the subsurface geoelectric sequence, to determine variations in regolith thickness and subsurface geologic structures and to map the aquifer units in the area.

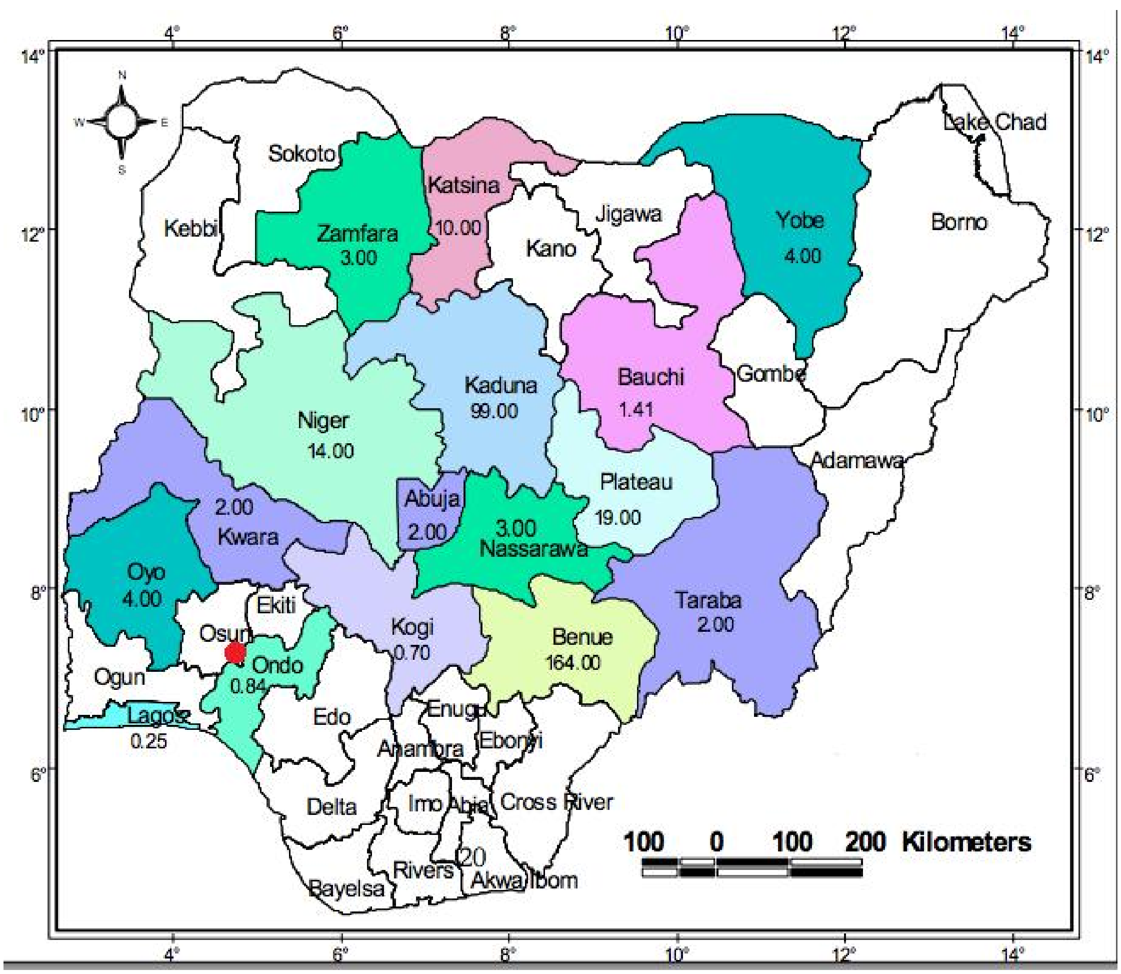
2. MATERIALS AND METHODS

2.1 Site Location and Description of the Study Area

The study area is located in Joseph Ayo Babalola University, Ikeji-Arakeji, along Akure, Ilesa road, Osun State, Southwestern Nigeria. It is situated between Eastings 717320 m to 717450 m (UTM) and Northings 0820225 m to 0820345 m (UTM) as shown in the base map of the study area (Fig. 2). Fig. 1 is the map of Nigeria showing the study area.

2.2 Data Acquisition and Analysis

A total number of twelve (12) vertical electrical soundings were conducted between laboratories and the college buildings and in front of college buildings using Ohmega Resistivity meter. The sounding was conducted along roads and any other available spaces within the study area. Schlumberger array was employed with the minimum current electrode spread of (AB/2) 2.0 m while the maximum current electrode spread (AB/2) used was 100.0m. The maximum (AB/2) of 100 m was chosen because at this spacing the bedrock would have been reached and mapped.



● Study area

Fig. 1. Map of Nigeria showing the location of the study area

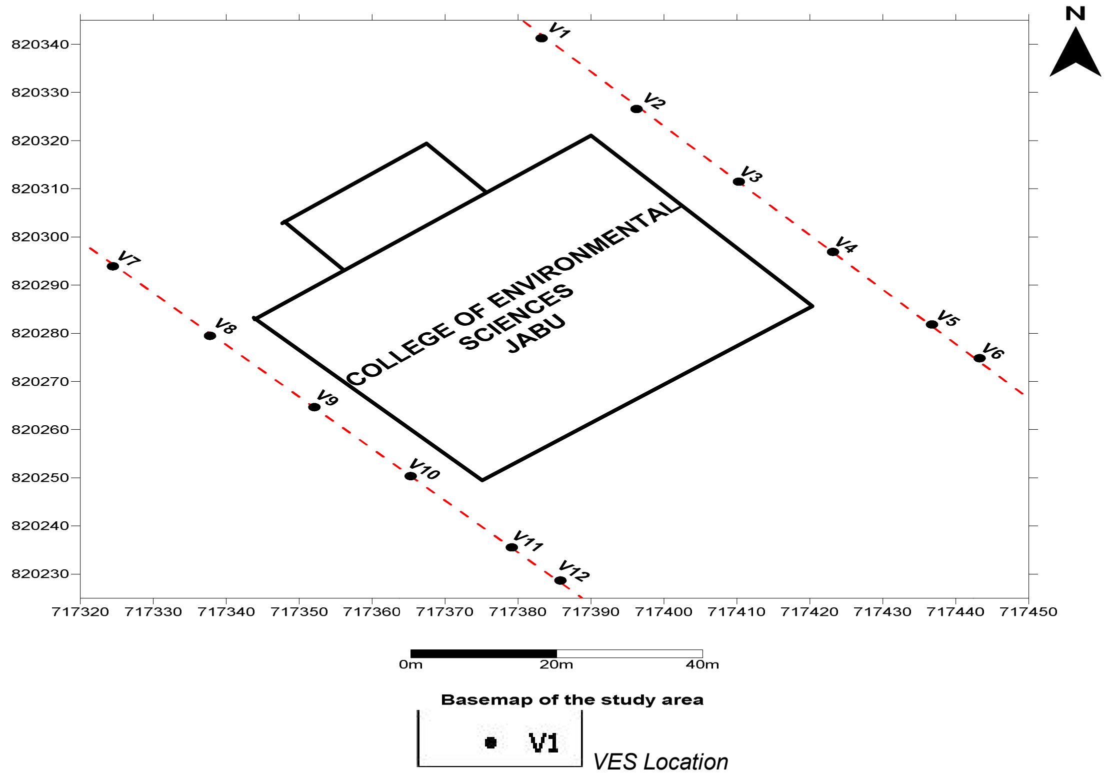


Fig. 2. Base map of the study area showing VES points

The apparent resistivity measurement obtained at each station was plotted against electrode spacing (AB/2) on a bi-logarithmic graph sheets. The curves were inspected visually to determine the number and nature of the layering. For the quantitative interpretation of the curves, partial curve matching was carried out. The geoelectric parameters obtained were fed into the computer as a starting modeling parameter using Win RESIST version 1.0 [21].

3. RESULTS AND DISCUSSION

The typical sounding curves obtained in the study area are shown in Fig. 3a to 3l. Table 1 shows the quantitative analysis of Vertical Electrical Sounding locations with their curve types and their numbers of occurrence in the study area. The depth sounding curve types obtained in the study area were classified as KH and HKH curve types with geo-electric layers

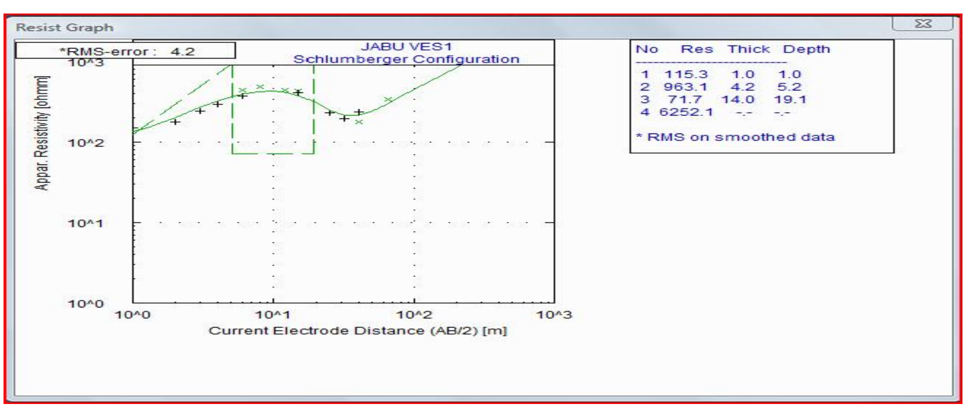


Fig. 3a. The modeled curve for VES 1

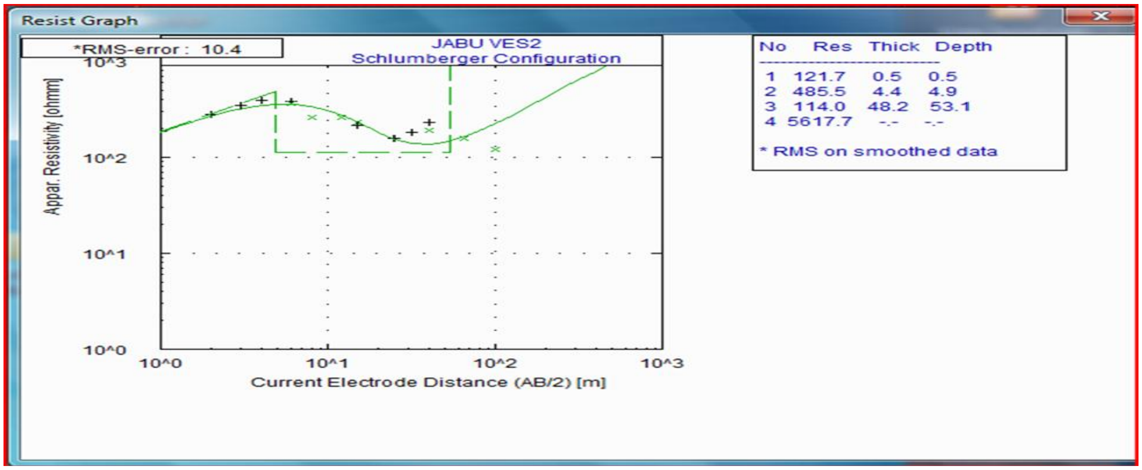


Fig. 3b. The modeled curve for VES 2

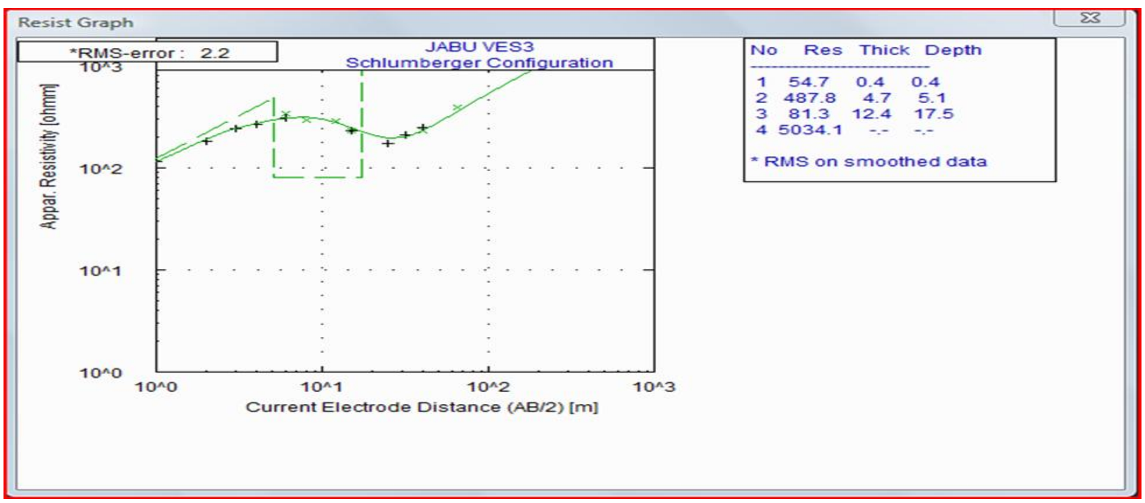


Fig. 3c. The modeled curve for VES 3

ranging from four and five layers. The KH is the most predominant curve type in the area. According to Olayinka and Olorunfemi [15], the expected well yield at a particular location is not necessarily dependent on the number and type of geo-electric layer, but may be related to the degree of weathering.

The geoelectric survey comprised of twelve vertical electrical soundings, with maximum current electrode spacing (AB) of 100 m. The geoelectric sections (Figs. 4 and 5) obtained from the sounding curves revealed four major layers earth models. The topsoil is made up of clay, clayey sand/lateritic sand with resistivity and thicknesses varying from 54.7 – 210.1 ohm-m and 0.2 – 0.8 m respectively. The second layer is the lateritic clay with resistivities and thicknesses varying from 334 – 963 ohm-m and 1.5 – 10.8 m respectively. The third layer constitutes the clay / sand, fractured quartzite and it serves as the aquifer unit. The resistivity values lie between 71.7 and 498 ohm-m while the thicknesses vary from 2.1 – 76.3 m. The fourth layer is the fractured, presumably fresh basement bedrock with the resistivity varying from 1879 – 13991.8 ohm-m. The large root means square error in VES 2 and VES 4 of Fig. 3b and Fig. 3d respectively could be due to erratic behavior of the quartzite and probably as a result of the systematic errors generally encounter during survey such as poor contact between soil and electrodes or noise averaging.

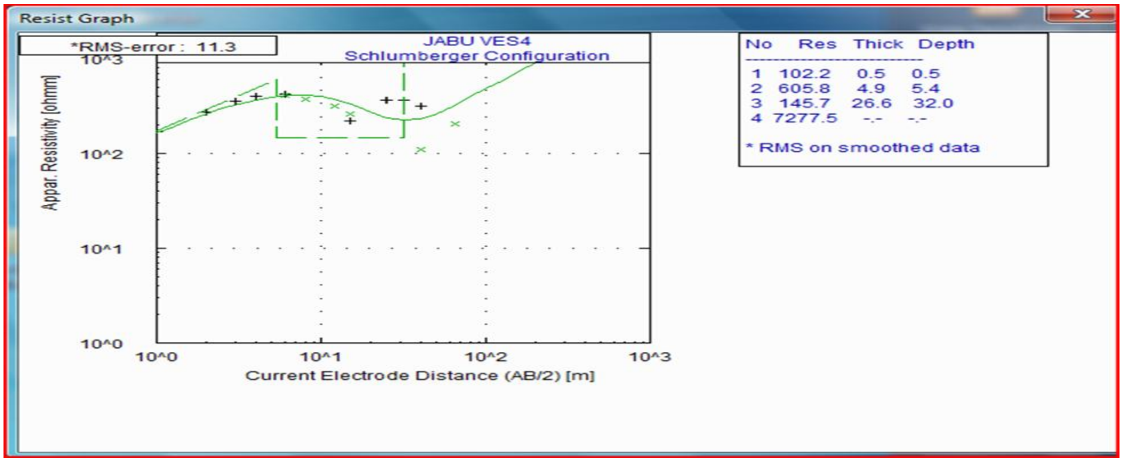


Fig. 3d. The modeled curve for VES 4

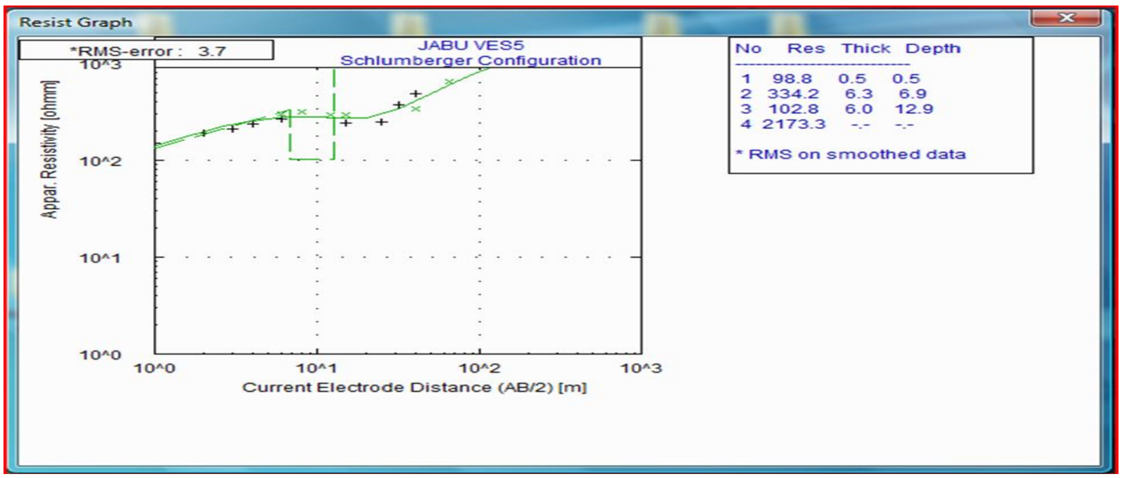


Fig. 3e. The modeled curve for VES 5

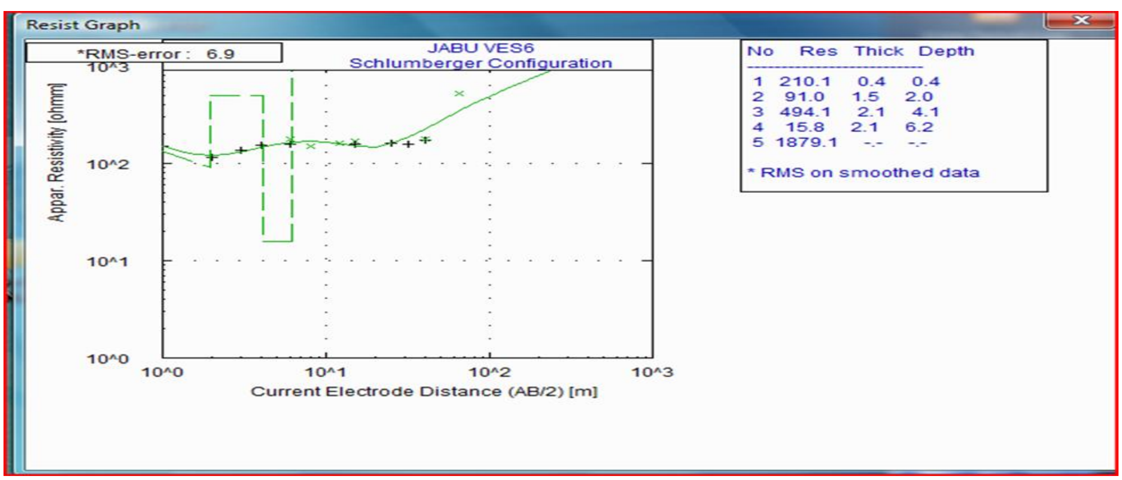


Fig. 3f. The modeled curve for VES 6

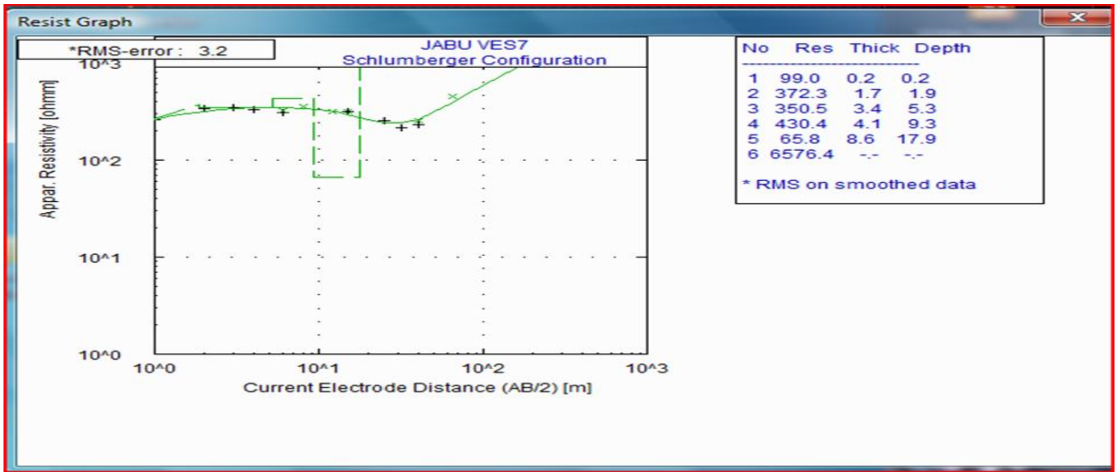


Fig. 3g. The modeled curve for VES 7

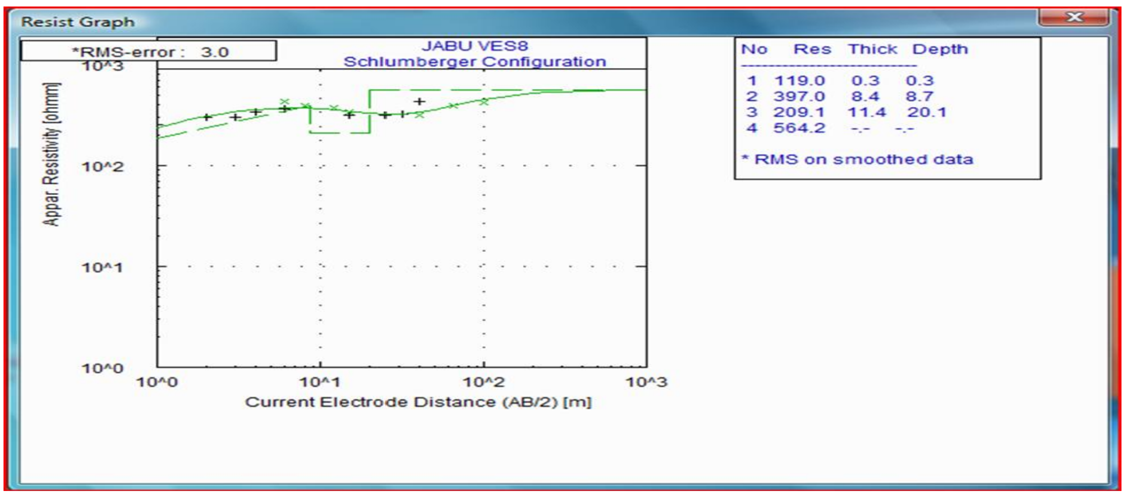


Fig. 3h. The modeled curve for VES 8

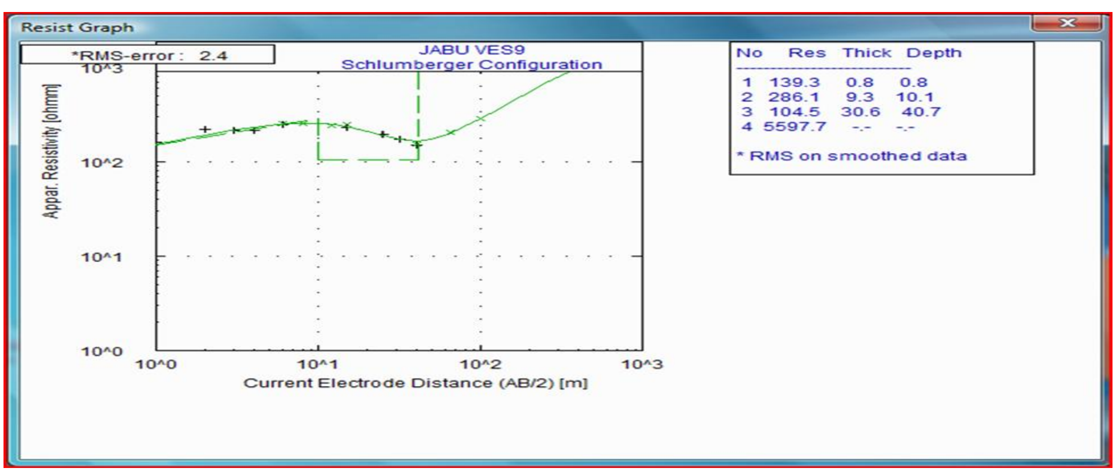


Fig. 3i. The modeled curve for VES 9

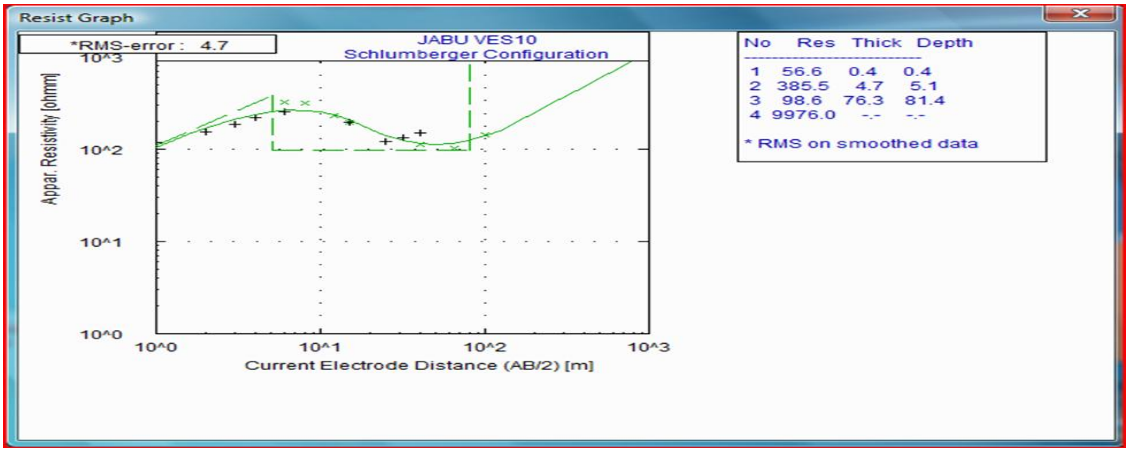


Fig. 3j. The modeled curve for VES 10

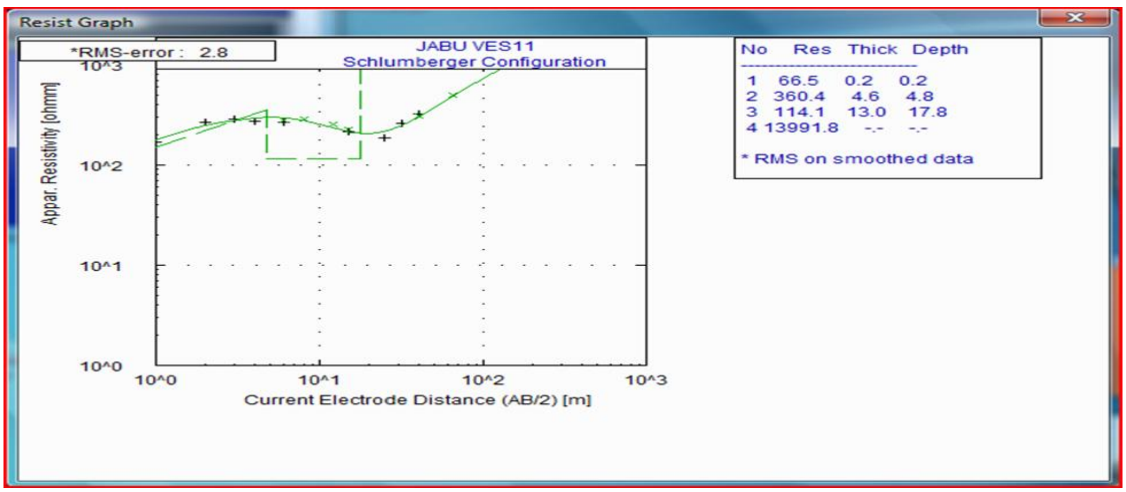


Fig. 3k. The modeled curve for VES 11

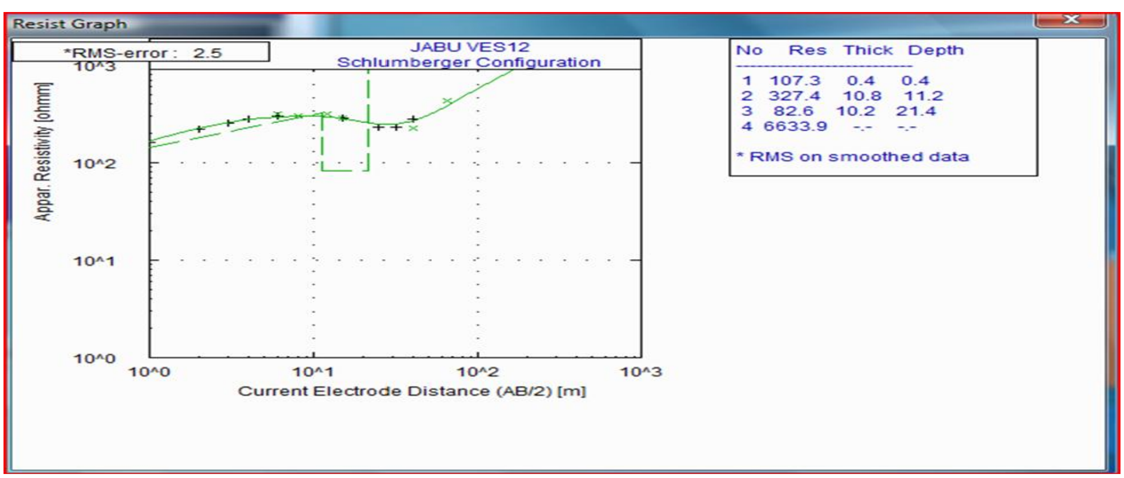


Fig. 3l. The modeled curve for VES 12

Table 1. Vertical electrical sounding quantitative interpreted results

VES no	Layer no	Resistivity (Ohm-m)	Thickness (m)	% RMS error	Curve type	Lithology
1	1	115.3	1.0	4.2	KH	Topsoil
	2	963.1	4.2			Laterite
	3	71.7	14.0			Fractured Basement
	4	6252.1				Fresh Basement
2	1	121.7	0.5	10.4	KH	Topsoil
	2	485.5	4.4			Laterite
	3	114.0	48.2			Fractured Basement
	4	5617.7				Fresh Basement
3	1	54.7	0.4	2.2	KH	Topsoil
	2	487.8	4.7			Laterite
	3	81.3	12.4			Fractured Basement
	4	5034.1				Fresh Basement
4	1	102.2	0.5	11.3	KH	Topsoil
	2	605.8	4.9			Laterite
	3	145.7	26.6			Fractured Basement
	4	7277.5				Fresh Basement
5	1	98.8	0.5	3.7	KH	Topsoil
	2	334.2	6.3			Laterite
	3	102.8	6.0			Fractured Basement
	4	2173.3				Fresh Basement
6	1	210.1	0.4	6.9	HKH	Topsoil
	2	91.0	1.5			Clay
	3	494.1	2.1			Fractured Basement
	4	15.8	2.1			Badly weathered basement
	5	1879.1				Fresh Basement
7	1	99.0	0.2	3.2	KH	Topsoil
	2	372.3	1.7			Laterite
	3	350.5	3.4			Weathered basement
	4	430.4	4.1			Fractured Basement
	5	65.8	8.6			Fractured Basement
	6	6576.4				Fresh Basement
8	1	119.0	0.3	3.0	KH	Topsoil
	2	397.0	8.4			Weathered
	3	209.1	11.4			Fresh Basement
	4	564.2				Partly fractured basement
9	1	139.3	0.8	2.4	KH	Topsoil
	2	286.1	9.3			Laterite
	3	104.5	30.6			Clay
	4	5597.7				Fresh Basement
10	1	56.6	0.4	4.7	KH	Topsoil
	2	385.5	4.7			Laterite
	3	98.6	76.3			Fractured Basement
	4	9976.0				Fresh Basement
11	1	66.5	0.2	2.8	KH	Topsoil
	2	360.4	4.6			Laterite
	3	114.4	13.0			Fractured Basement
	4	13991.8				Fresh Basement
12	1	107.3	0.4	2.5	KH	Topsoil
	2	327.4	10.8			Laterite
	3	82.6	10.2			Fractured Basement
	4	6633.9				Fresh Basement

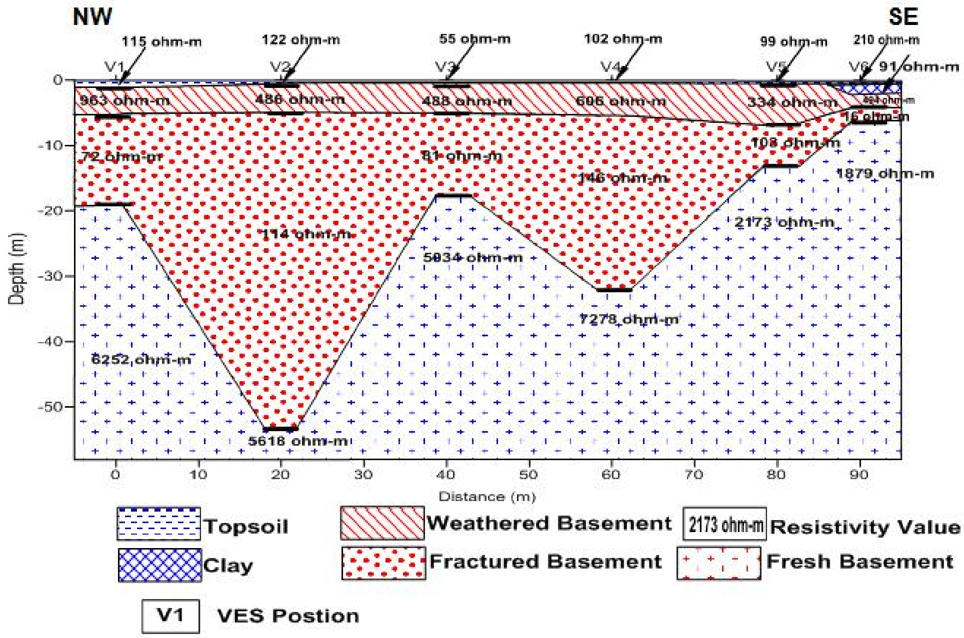


Fig. 4. Geoelectric section along traverse 1 showing VES location 1-6

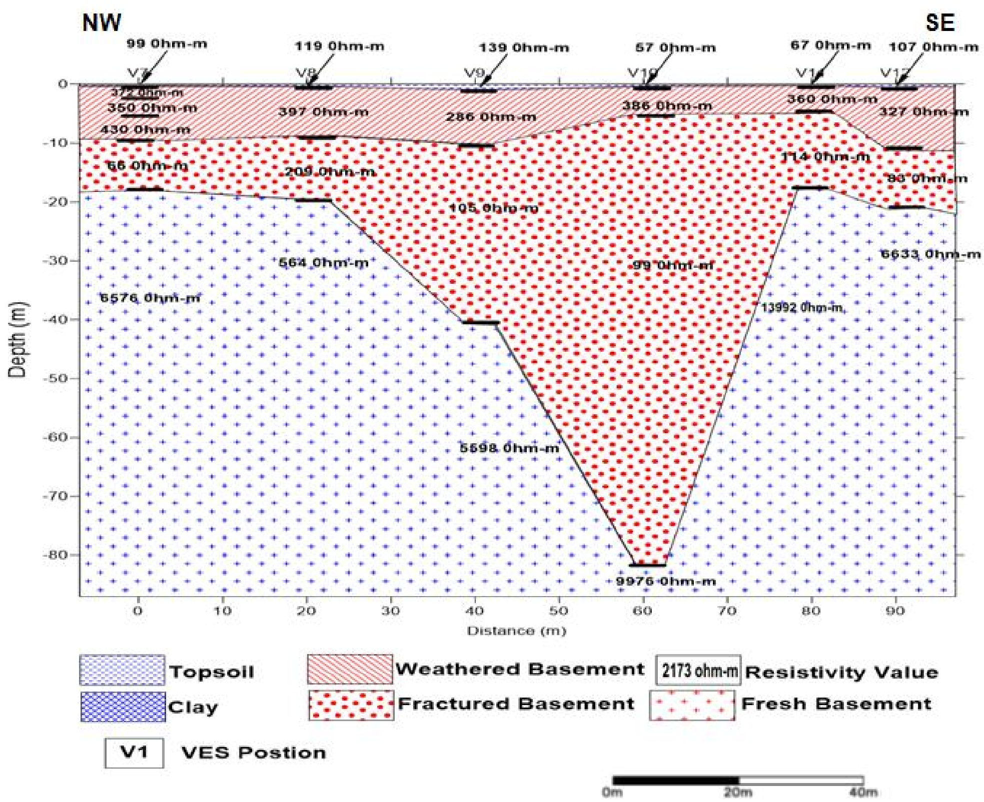


Fig. 5. Geoelectric section of traverse 2 showing VES 7 – 12

3. GEOELECTRIC SECTIONS

The interpreted results of the VES are presented as geoelectric sections in Fig. 4 and Fig. 5 along traverses 1 and 2 respectively, which show the subsurface sequence in 2 – dimensional form. A maximum of four major subsurface layers were delineated beneath these sections. These are topsoil, lateritic clay, clay/sandy clay and the fractured/presumably fresh basement bedrock.

Based on the relation between geology and the resistivity values [22], the topsoil is probably made up of clay, clayey sand/lateritic sand with resistivity and thicknesses varying from 54.7 – 210.1 ohm-m and 0.2 – 0.8m respectively. The second layer is the lateritic clay with resistivities and thicknesses varying from 334 – 963 ohm-m and 1.5 – 10.8m.

The third layer probably constitutes the clay/sand, fractured quartzite and it serves as the aquifer unit. The resistivity values lie between 71.7 ohm-m and 498 ohm-m while the thicknesses vary from 2.1 – 76.3 meters. The fourth layer is the fractured/presumably fresh basement bedrock with the resistivity varying from 1879 – 13991.8 ohm-m. The basement relief is undulating along the two traverses

.

The groundwater yield potential of the area studied was categorized into high, medium and low potentials. In this study, zones where the thickness of the overburden (which constitutes the major aquifer unit) is greater than 25 m and are of low clay content with average resistivity values ranging between 200 and 300 ohm-m are considered to be zones of high groundwater potentials. Areas where the thickness of aquifers ranges between 10 m and 25 m with less clay contents are categorized as medium groundwater potential while the areas where the aquifer thickness is less than 10 m are generally considered to have low groundwater potential.

4. CONCLUSION

In this study area, the VES survey has greatly contributed to the better understanding of the hydrogeology of the basement complex of the area. The geoelectric layers are found to comprise of the topsoil, lateritic clay, clay/sandy clay and the fractured/presumably fresh basement bedrock. Generally, the area was zoned into high and medium groundwater potential and about 45% of the area falls within the high groundwater potential rating, while about 55% constitutes the medium groundwater potential rating. Hence the groundwater potential of the area was generally rated to be moderately high based on the aquifer characteristics. Therefore, all the VES stations or locations under this study area are envisaged to be viable for groundwater development. But, VES 2, VES 4, VES 9 and VES 10 are considered to be the best points for borehole siting for maximum yield of groundwater. Areas which have been characterized by low resistivity values of the weathered and fracture zones with appreciable high thickness of the fractured/weathered layer have been successfully identified as groundwater potential targets for siting boreholes. One major limitation to this study is the lack of drilling information to test the locations identified for borehole siting. Thus, further work is recommended in the study area.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Badmus BS, Olatinsu OB. Aquifer characteristics and groundwater recharge pattern in a typical basement complex, Southwestern Nigeria. African Journal of Environmental Science and Technology. 2010;4(6):328-342.
2. Olorunfemi MO, Fasuyi SA. Aquifer types and the geoelectric/hydrogeologic characteristics of part of central basement terrain of Nigeria (Niger State). Journal of Afr. Earth Sciences. 1993;16(3):309-317.
3. Offodile ME. The occurrence and exploitation of groundwater in Nigerian basement rocks. J. Min. Geol. 1983;20(1-2):131-146.
4. Satpathy BN, Kanugo BN. Groundwater exploration in hard rock terrain. Geophysical Prospecting. 1976;24(4):725–736.
5. Abdullahi MG, Toriman ME, Gasim MB. The application of vertical electrical sounding (VES) for groundwater exploration in Tudun Wada Kano State, Nigeria. J. Geol Geosci. 2015;4:186. DOI: 10.4172/2329-6755.1000186
6. Fadele SI, Sule PO, Dewu BBM. The use of vertical electrical sounding (VES) for groundwater exploration around Nigerian College of Aviation Technology (NCAT), Zaria, Kaduna State, Nigeria. Pacific

Journal of Science and Technology. 2013;14:549-555.
7. Nwankwo LI. 2D resistivity survey for groundwater exploration in a hard rock terrain: A case study of MAGDAS observatory, UNILORIN, Nigeria. Asian J. Earth Sci. 2011;4:46-53.
8. K'Orowe MO, Nyadawa MO, Singh VS, Ratnakar D. Hydrogeophysical parameter estimation fo aquifer charaterization in hard rock environments: A case study from Jangaon Sub-watershed. India. J. oceanogr. Mar. Sci. 2011;2:50-62.
9. Ensline JF. Secondary aquifers in South Africa and the scientific section of boring sites in them. Inter-Africa Conference on Hydrology, Nairobi. 1961;379–389.
10. Palacky GJ, Ritsema IR, Dejong SJ. Electromagnetic prospecting for Groundwater in Precambrian Terrains in the Republic of Upper Volta. Geophysical Prospecting. 1981;29:932–925.
11. Mullern CF, Eriksson I. Analysis of VLF anomalies encountered when prospecting for groundwater in rock. Geological Survey. Sweden, Development Report. 1982;80–151:30.
12. Poddar M, Rathor BSS. VLF survey of the weathering layers in Southern India. Geophysical Prospecting. 1983;31:524–537.
13. Adiat KAN. Integrated geophysical evaluation of groundwater occurrence in Igbara –Oke, Southwestern Nigeria, Unpublished M.Tech. Thesis. Applied Geophysics. Federal University of Technology, Akure; 2004.
14. Worthington PF. Hydrogeophysical properties of the British trias. Geophysical Prospecting. 1976;24(4):672–695.
15. Olayinka AI, Olorunfemi MO. Determination of geoelectrical characteristics in Okene Area and implications for borehole siting. Journal of Mining and Geology. 1992;28(2):203–312.
16. Barongo JO, Palacky GY. Investigation of electrical properties of weathered basement aquifer in malawi in relation to rural water supplies, IAHS publication. 1991;144:57–72.
17. Olorunfemi MO, Olanrewaju VO, Alade O. On the electrical anisotropy and groundwater yield in a basement complex area of S.W. Nigeria. Journal of African Earth Sciences. 1991;12(3):467–472.
18. Ajayi O. Geophysical and geographical information system assessment of groundwater potential of Iju, in Ondo State, Southwestern Nigeria. Unpublished M. Tech. Thesis. Applied Geophysics, Federal University of Technology, Akure; 2006.
19. Ohams EA, Onuoha KM. Geophysical investigation for groundwater in hard – rock terrain. Experience from Fabur Area of the Jos Plateau, Nigeria. Journal of Mining and Geology. 1998;24(1-2):45–50.
20. Hamill L, Bell FG. Groundwater resource development: Butterworths, London; 1986.
21. Vander Velpen BPA. Resist Version I. O M.Sc. Research Project, ITC, Delft Netherland; 1988.
22. Keller GV, Frischknecht FC. Electrical methods in geophysical prospecting. Pergamon Press, Oxford. 1996;523.

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