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APPLICATION OF RESISTIVITY SOUNDING TO GROUNDWATER PROSPECTING IN GUDUMA TOWN PART OF KEFFI SHEET 208 NE, NASARAWA STATE, NIGERIA

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ABSTRACT

Electrical resistivity sounding using the Schlumberger electrode configurations was done with the aim of prospecting for ground water at Guduma Town, part of Keffi sheet 208 NE, Nasarawa State, Nigeria. The area is underlain by the Basement Complex rocks, mainly Schists, Gneisses and Charnockites. A total of twenty (20) VES points were sounded with a maximum AB/2 of 100m. The data were processed using the Win Resist Software which allowed for curve matching. The curves obtained in the study area are the H, Q, and KH and AH type. The area is characterized by 4 and 6 geoelectric layers including: top soil (70-1475 Ωm) up to 1.5m below ground surface; lateritic layer (80-1700Ωm) from 1.4m to 2.9m; weathered basement (46-132Ωm) from 6m to 19m; fractured basement (161-457Ωm) from 4.8m to 30m and finally, fresh basement (600-1691Ωm) from 30m below ground surface. The weathered and fractured basement forms the aquiferious unit in the area, as such depth to aquifer ranges between 4m and 6m and corresponding thickness between 25 and 28m. Contour plots of depth to basement, aquifer resistivity and corresponding aquifer thickness were compared to produce a groundwater potential map of the study area for abstraction of sustainable and resilient Farming System Intensification.

***Keywords**: Apparent resistivity, thickness, depth, curve type, basement complex, Resistivity, Quantitative and Qualitative, groundwater.*

INTRODUCTION

Groundwater is the most preferred and effective source of water for agricultural and domestic uses. Given that the use of contaminated surface water for domestic purposes engenders several endemic health problems resulting from water-borne diseases (e.g., guinea worm, cholera, dysentery viral hepatitis); we have undertaken this study to contribute to the investigation for additional good quality water resources. A geophysical investigation of the earth's interior involves taking measurements near the earth's surface that are influenced by internal distribution of its properties whose measurements can reveal how the physical properties of the earth's interior which may vary vertically in the sub-surface. The study area under the observation is underlain by the basement rocks consisting of Mica schist, augengneiss, charnockite, garnet mica schist and biotite gneiss. The need for potable water in the area is becoming unbearable due to the increasing population of the study area, and "Sustainable Resilient Farming System Intensification and "Dry-season Agriculture project" without depletion of the aquifers. This led to the decision to carry out the present study in order to assess the quantity and quality of the groundwater. Ground water is protected from surface pollutants as the earth's media composing of different sub-surface layers act as natural filter to infiltrating water.

Electrical resistivity techniques have been applied to groundwater prospecting in many areas underlain by Basement Complex rocks. Offodile, (2002), saw that despite the poor hydrogeological response of the Basement Complex rocks of Nigeria, the Basement Complex still remains an important source of water since more than half of the country seats on it. He further explained the need of adequate hydro-geophysical surveys and improved drilling techniques to harness better results or more productive boreholes within the Basement Complex terrains. Ariyo *et al.,* (2003), worked on the hydro-geophysical evaluation of Groundwater potentials of Awa-Ijebu, south-western Nigeria using electrical resistivity survey. They successfully identified the presence of aquifers in the Basement Complex rocks, where water level and ranged between 1.82 to 9.04m. the study was also able to delineate high, medium and low zones for groundwater exploration. Jatau and Bajeh (2007), carried out a hydrogeological appraisal of parts of Jemaa Local Government Area, Kaduna State where they employed both Horizontal Electrical Profiling (HEP) and Vertical Electrical Sounding (VES) to assess the thickness of regolith aquifers. Interpretation of VES suggest that the subsurface layering ranges from 3-4 layers; borehole yield showed good correlation with the actual drilling, pumping test data and geophysical data. Jatau *et al.,* (2013), carried out geoelectrical sounding in parts of Abaji Area Council, Federal Capital Territory of North-Central Nigeria. Seventy-two (72) Vertical Electrical Sounding points were established at various stations. The results obtained from the field data were interpreted using the IXID and IPI2WIN software for quantitative analysis, while the GIS software was used for the qualitative analysis. The study area shows four units of water system in some places at 30m, 60m, 90m and 120m. The apparent resistivities value ranges from as low as 56Ωm to as high as 3000Ωm. The study area revealed 5-7 lithologic sequences consisting of top soil, laterite, clay, siltstone, fine sand and sandstone of various thicknesses. The water bearing zones are within the fourth to sixth lithologic layers as a result of the moderate resistively values obtained which ranges between 50Ωm to about 650Ωm. The results correlated well with existing geology.

The geophysical investigation involved carrying out Vertical Electrical Sounding (VES) techniques applying Schlumberger electrode configuration. Data collected were analysed using both Quantitative and Qualitative interpretation to produce the geoelectric sections in the study area in determining aquifer potential of Guduma and environ part of Keffi sheet 208 of north central Nigeria.The main aquifer potential in Guduma are located weathered/fractured bedrock.

GEOLOGY OF THE STUDY AREA

The study area is part of Keffi sheet 208 NE (Fig.1.0) is situated on the Pre-Cambrian Basement Complex of North-Central Nigeria; rock outcrops are Mica schist, augen gneiss, charnockite, garnet mica schist and biotite gneiss. Structures such as fractures, joints, veins, pinch and swell, foliation, and xenoliths were observed with their direction of trend taken into account.

MATERIALS AND METHOD

Schlumberger Configuration was used to carry out vertical electrical sounding for the determination of the depth to bedrock and the thickness of layers because of its sensitivity to signal response as asserted by Ozebo (2011). Twenty (20) vertical soundings were carried out on the field. This was done by changing the distance between the current electrodes so that the depth range to which the current penetrates changes, (Telford *et al*., 1976). A succession of apparent resistivity reading was taken for increasing electrode spacing. The half electrode spacing of the current electrode (AB/2) and its corresponding potentials were recorded.

The instrument used for this survey is ABEM SAS 1000 Terrameter and its accessories (the connecting cables and clips, four Reels of long electronics cables, hammers, battery which is inbuilt power source and Global positioning system (GPS))**.** The electrodes used are made of steel, that is stainless which are driven into the surface of the earth for few centimeters with the aid of hammer for good electrical contact. The electrodes were connected to their reels (current and potential) by wire from the reel of long cable. Four reels were used on the field, two of which are reels with cables of about 70 -100 meters in length in connecting current electrodes. These parameters were then used for the computer iteration technique using the win Resist software to give the actual resistivities, depths and thicknesses of the layers.

Reconnaissance field mapping exercise was carried out in order to have a picture of the geology of the area.

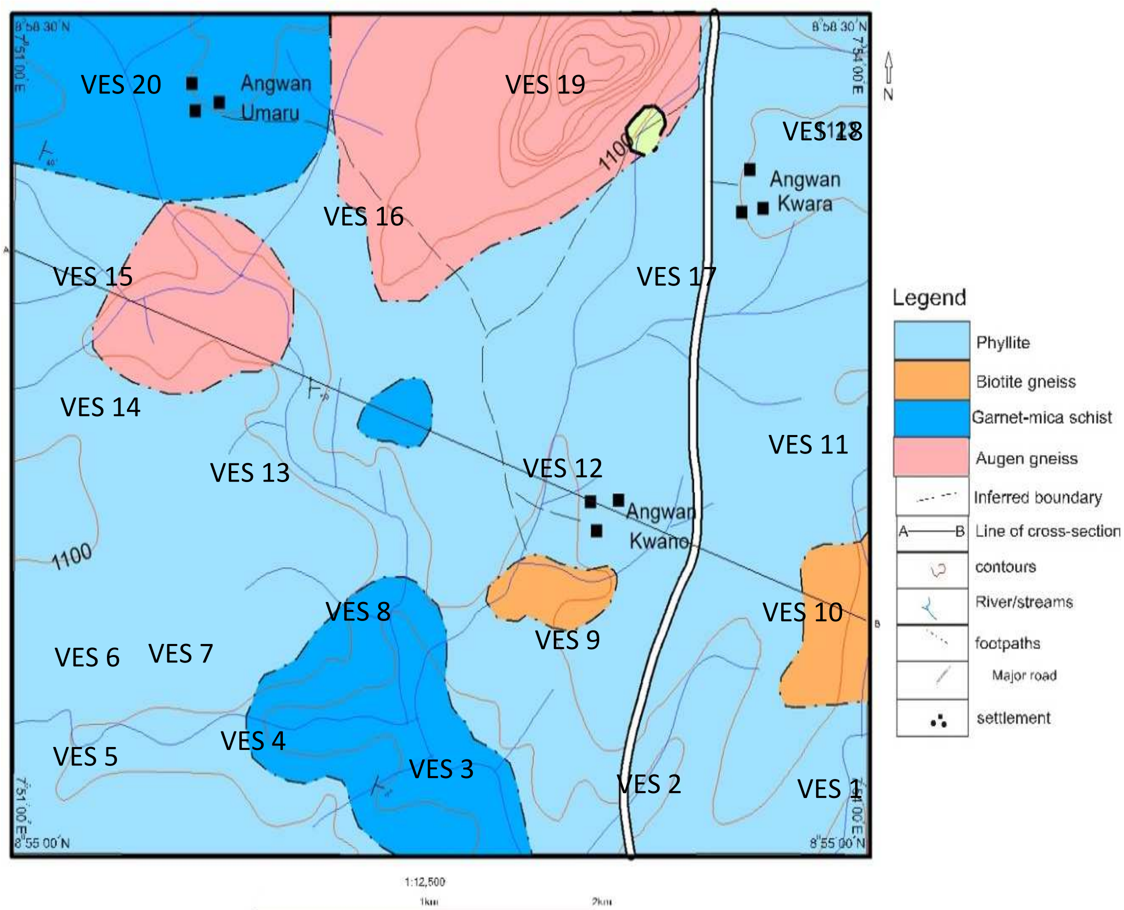


Figure 1. Geological map of Gunduma and environs showing distribution of rock and VES points

RESULTS AND DICUSSIONS

Quantitative Interpretation of VES

In quantitative interpretation of VES data, the aim is to determine the number of layers represented by the curves of individual layer resistivity and thickness. The procedures for the quantitative interpretation are as follows:

Curve matching

Using the available albums of theoretical curves computed for mathematical model with four or six layers

Partial curve matching

The auxiliary point method is an empirical method by which a multi-layer problem is progressively reduced to a simple two or more-layer case. Two and three layer curves are used in conjunction with one or more of the charts that represent the families of auxiliary curves.

Complete curve matching: This involves the computation of theoretical curves, which are then compared and fitted to the observed field data. In this method, one must start off with reasonable approximation to the number of layers' thickness and resistivities of the geoelectric sections using above methods.

Direct Interpretation: Interpretation of the VES curve in terms of layer thickness and resistivity was carried out with aid of computer programs without an initial approximate geoelectric sections.

Computer Iteration Technique

Computer iteration involves the input of field data and model parameters obtained from curve matching. Also, the VES curve had to be smoothened prior to iteration. Iteration makes interpretation of many layers, which appears cumbersome on curve matching to be easier. An iteration process then commences until a good fit is obtained between the field and computer curves, Win Resist. The best smooth curves through the set of data points were interpreted quantitatively by a method of partial curve matching using 2-layer master curves and auxiliary curves (Orellana and Mooney, 1966, 1972). The number of iterations depends to a large extent upon the complexity of the geological structure. Moreover, any available supplementary information, such as from electrical soundings and drilling thus possibly reduces the number of iteration. The interpreted data was presented in form of VES curves, geoelectric sections and geophysical maps. The types of sounding curves identified in the area are shown below. The number of layers varies between 4 and 6. The visual inspection of the sounding curves based on their distinct geo-electric characteristics has been used to classify the curves as shown in Table 1. records, often helps in constraining the modeling, and thus possibly reducing the number of iteration.

Table 1: Quantitative Interpretation Showing Geoelectric Parameters

VES	Curve type	No of layer[s]	Resistivity [ohm-m]	Thickness [m]	Depth [m]	Lithological Units
1	H	4	751	1.2	1.2	Topsoil
			327.6	3.8	5.0	Lateriate
			262.6	11.9	16.9	Weather/fractured basement
			805.2			Fresh basement
2	H	5	135.1	0.7	0.7	Topsoil
			364.5	1.1	1.9	Lateriate
			46.0	4.2	6.0	Weather basement
			58.4	19.6	25.7	Fractured basement
			231.8			Partial fresh basement
3	H	5	1475.2	0.6	0.6	Topsoil
			707.5	2.9	3.5	Lateriate
			91.4	5.0	8.5	Weather basement
			130.1	14.0	22.5	Fractured basement
			481.0			Partial fresh basement
4	H	4	1208.6	1.0	1.0	Topsoil
			188.3	1.5	2.5	Lateriate
			58.5	12.3	14.8	Weather/fractured basement
			688.2			Fresh basement
5	H	6	867.1	1.0	1.0	Topsoil
			702.5	1.0	1.9	Lateriate
			217.3	3.9	5.8	Sandy/clay
			45.0	8.9	14.7	Weather basement
			161.0	15.1	29.8	Fractured basement
			1143.4			fresh basement
6	AH	5	104.0	1.4	1.4	Topsoil
			235.5	1.6	2.9	Lateriate
			50.8	7.7	10.6	Weather basement
			151.0	8.2	18.8	Fractured basement
			1691.6			fresh basement
7	H	4	688.9	1.4	1.4	Topsoil/Lateriate
			124.4	3.4	4.8	Weather/fractured
			747.8	11.3	6.2	partial fresh basement
			1107.7			Fresh basement

Table 1: Quantitative Interpretation Showing Geoelectric Parameters continued

VES	Curve type	No of layer[s]	Resistivity [ohm-m]	Thickness [m]	Depth [m]	Lithological Units
8	H	5	254.1	0.7	0.7	Topsoil
			80.5	0.7	1.4	Lateriate
			44.9	2.3	3.6	Weather basement
			50.5	16.9	20.5	Fractured basement
			644.6			fresh basement
9	AH	4	228.5	1.2	1.2	Topsoil
			547.7	3.2	4.2	Lateriate
			148.9	13.7	18.1	Weather/fractured basement
			644.4			Fresh basement
10	QH	5	622.3	0.9	0.9	Topsoil
			660.4	2.6	3.6	Lateriate
			227.3	4.9	8.6	Lateritic
			98.7	10.9	19.4	Weather basement
			187.6			Fractured basement
11	H	5	545.1	0.5	0.5	Topsoil
			91.2	1.0	1.6	Lateriate
			114.0	3.1	4.6	Lateritic
			54.1	14.9	19.5	Weather basement
			151.5			Fractured basement
12	KH	5	69.7	0.6	0.6	Topsoil
			339.2	1.0	1.5	Lateriate
			297.3	2.4	3.9	Lateritic
			80.6	6.1	10.0	Weather basement
			149.9			Fractured basement
13	H	5	788.7	1.0	1.0	Topsoil
			535.9	1.4	2.3	Lateriate
			75.8	5.3	7.6	Weather basement
			268.5	9.0	16.6	Fractured basement
			513.4			Partial fresh basement
14	QH	5	1232.1	1.0	1.0	Topsoil
			860.8	1.8	2.8	Lateriate
			238.8	6.8	9.8	Weather basement
			264.4	19.4	29.0	Fractured basement
			399.0			Partial fresh basement
15	H	5	900.5	1.1	1.1	Topsoil
			430.7	1.4	2.5	Lateriate
			281.9	1.3	3.8	Weather basement
			96.2	7.0	10.8	Fractured basement
			724.1			Partial fresh basement

Table 1: Quantitative Interpretation Showing Geoelectric Parameters continued

VES	Curve type	No of layer[s]	Resistivity [ohm-m]	Thickness [m]	Depth [m]	Lithological Units
15	H	5	900.5	1.1	1.1	Topsoil
			430.7	1.4	2.5	Lateriate
			281.9	1.3	3.8	Weather basement
			96.2	7.0	10.8	Fractured basement
			724.1			Partial fresh basement
16	Q	5	1151.1	0.9	0.9	Topsoil
			1706	1.9	2.9	Laterite
			816.6	5.7	8.6	Partial fresh basement
			456.9	8.9	17.5	Partial Fractured basement
			184.4			Partial weather/fractured basement
17	H	5	673.4	0.8	0.8	topsoil
			920.3	2.2	3.0	Lateriate
			175.1	9.5	12.5	Weather basement
			325.0	12.5	25.0	Fractured basement
			820.0			fresh basement
18	H	4	598.3	1.3	1.3	Topsoil
			457.0	3.0	4.4	Lateriate
			169.6	14.5	19.0	Weather/fractured basement
			831.0			Fresh basement
19	H	5	696.8	1.0	1.0	topsoil
			549.4	1.6	2.6	Lateriate
			186.7	3.3	5.9	Weather basement
			105.1	11.9	17.8	Fractured basement
			1395.4			fresh basement
20	KH	5	273.5	1.0	1.0	topsoil
			525.9	2.3	3.3	Lateriate
			90.7	4.8	8.1	Weather basement
			91.3	15.3	23.4	Fractured basement
			270.2			Partial fresh basement

DISCUSSION

The field results obtained of the twenty (20) stations carried out with the study area is presented in Table 1. The interpretation of the data identified aquifer layers at various sounding points showing the variation of aquifer resistivity and thickness due to lithologic composition, which revealed that four to six geologic layers, composed of topsoil which have resistivity values varying from 70-1475 Ωm up to 1.5m lateritic with a resistivity value ranging from 80-1700Ωm and 1.4m to 2.9m , weathered basement, with resistivity and thickness value varying between 46-132Ωm and 6m to 19m, fractured basement with resistivity and thickness values ranging from 161- 457Ωm and 4.8m to 30m, and finally, fresh basement whose resistivity vary from 600-1691Ωm with an infinite depth. The aquifer resistivity in the study area ranges from 80 to 457 Ωm with an average value of 120 Ωm. From the results obtained, aquifer thickness ranges from 5 to 35 m having an average value of 15 m. The VES with the greatest thickness of 30 m was observed at VES 14 layouts while VES 12, 13 and 15 have the thinnest of 10m. The main aquifers of the study area are located in VES 2, 3, 5, 6, 8, 10 and11, Angwan Kwano and Angwan umaru showing good water potential in the area. Areas with very low water potential are VES 1, 4, 7, 9, 12, 14 and southern part of Angwan umaru.

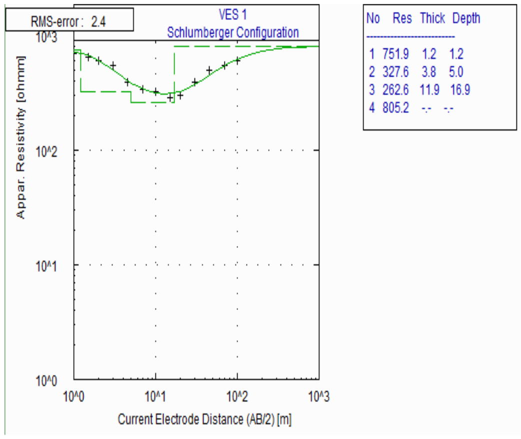
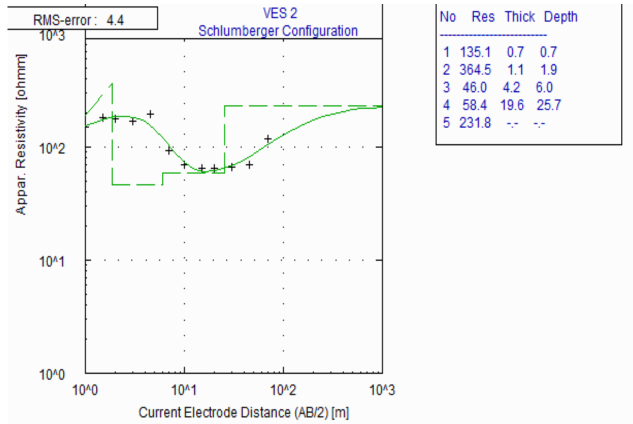


Fig 1.**Curve type H**



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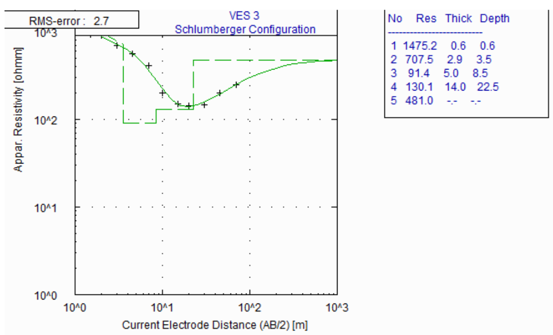

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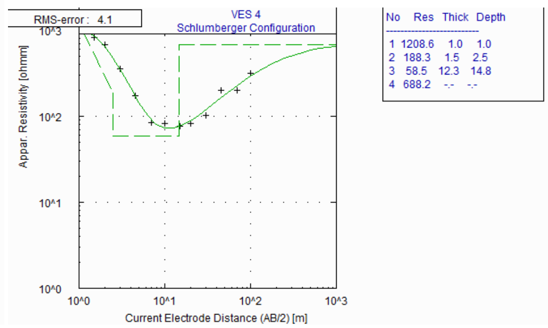

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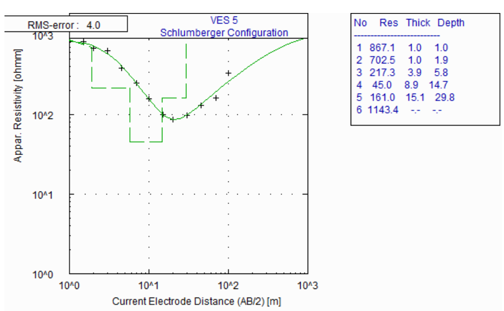

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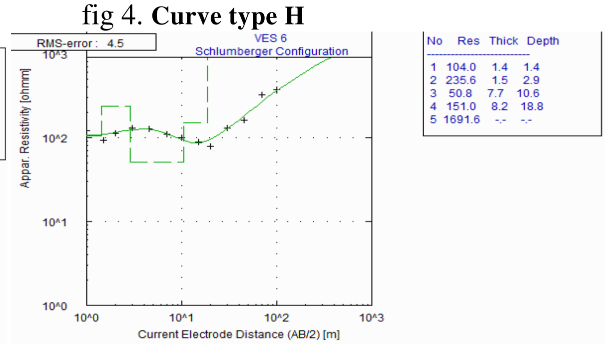
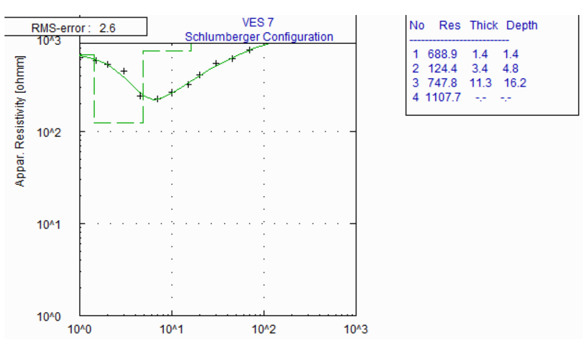


fig 6.**Curve type AH**



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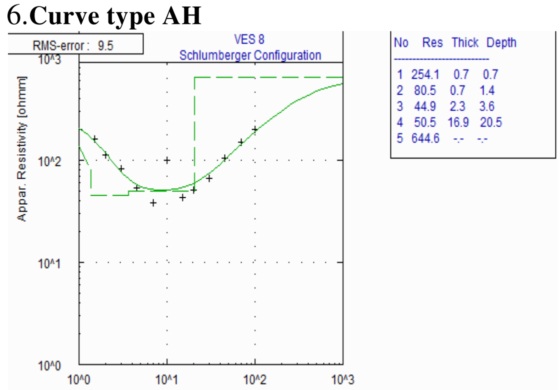

fig 8.**Curve type H**

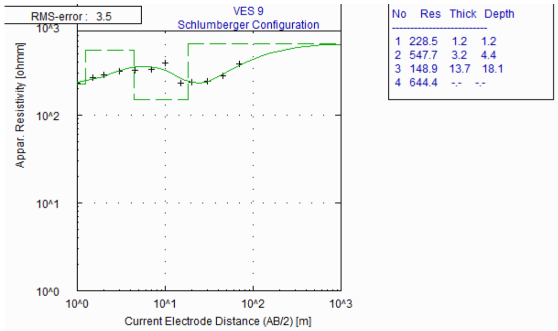

Fig 9.**Curve type AH**

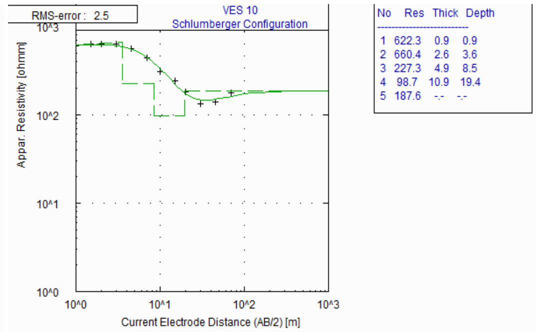

Fig 10. **Curve type QH**

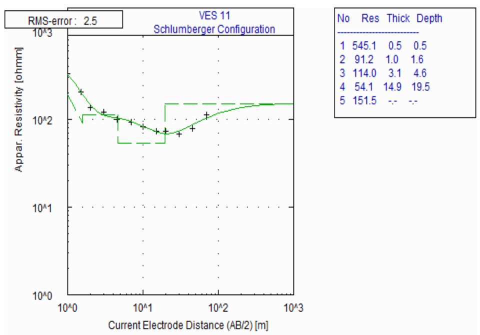

Fig 11.**Curve type** H

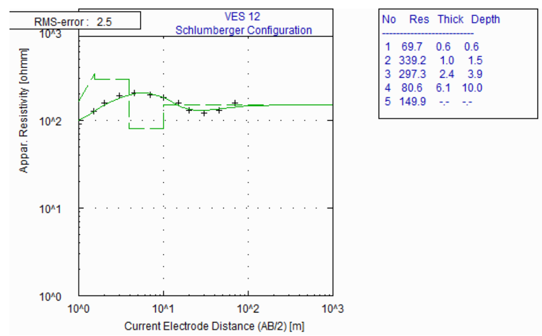

fig 12.**Curve type KH**

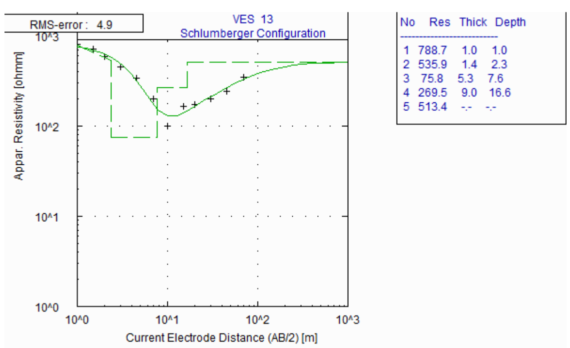

Fig 13.**Curve type H**

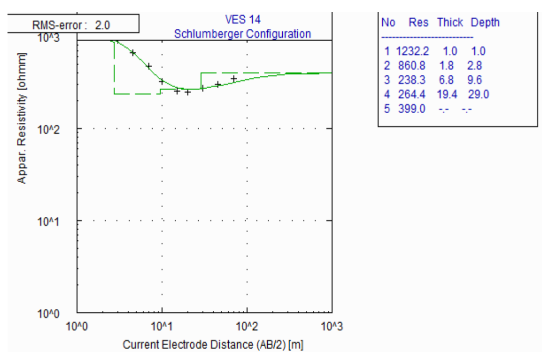

fig 14.**Curve type QH**

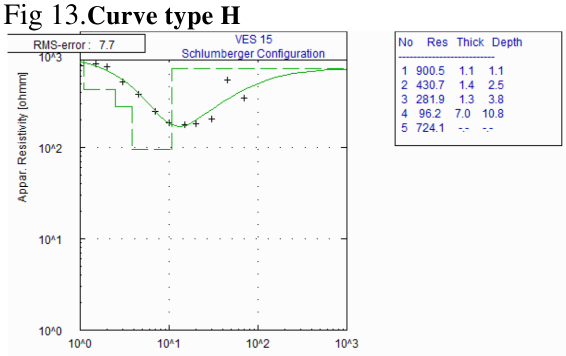

Fig 15.**Curve type H**

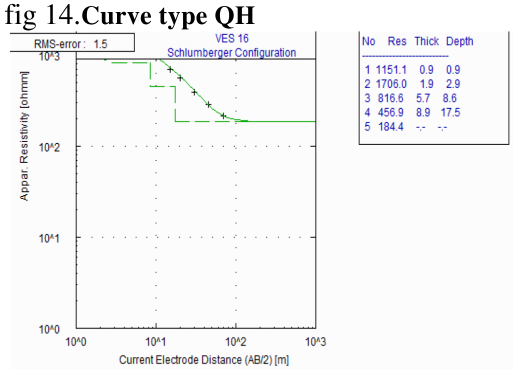

fig 16.**Curve type Q**

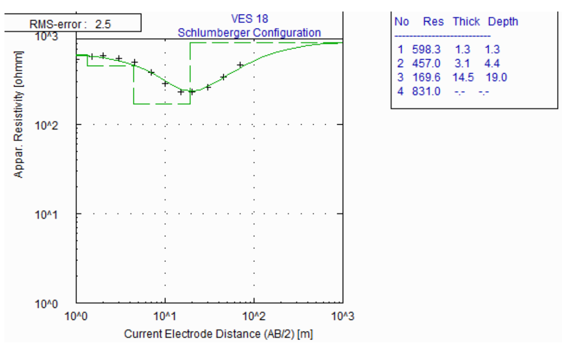

Fig 17.**Curve type H**

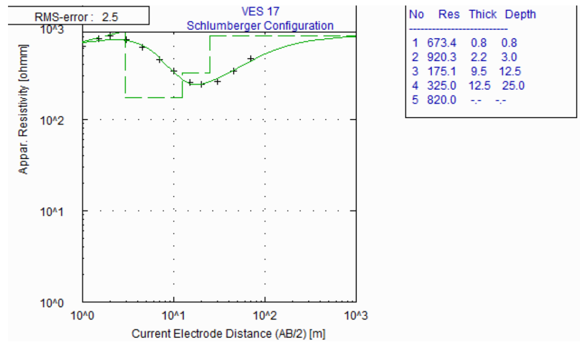

fig 18.**Curve type H**

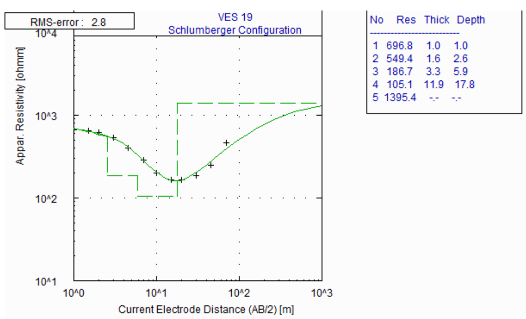

Fig 19.Curve type H

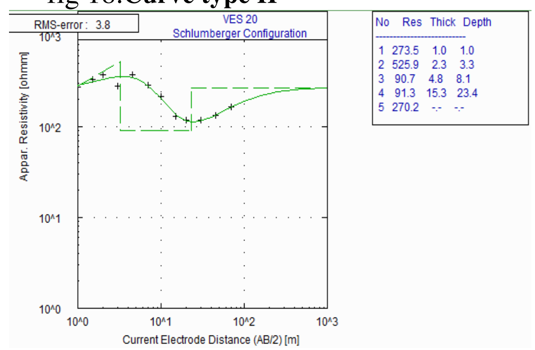

fig 20.Curve type K

CONCLUSION AND RECOMMENDATION

Groundwater investigation at Guduma and its environs part of Keffi sheet 208, in Nasarawa State, Nigeria, involved Vertical Electrical Sounding (VES) technique using ABEM SAS 300C terrameter for the mapping of subsurface geo-electric characteristics, structural features and aquifer units and its characteristics. The geophysical survey revealed 4-6 geoelectric layers comprising of top soil, laterite, weathered basement, partially weathered/fractured basement and fresh basement; which gave rise to the weathered and fractured aquifer that are peculiar to the Basement Complex terrain. Which implies that some area are good for groundwater development, especially places with distinctive weathered/fractured thicknesses. Boreholes drilled through these stations; yield will be productive. Also the investigation was carried out to deduce the nature of subsurface and for proper description of relationship between yield and other parameters and to improve our knowledge of the variable of interest. It is hereby recommended that further geophysical methods should be carried out in the study area to fully ascertain viable aquifer zones which serves as the limitation of the study.

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