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Original Research Article

Geo-electric Sounding for Groundwater Investigation: Case of Umuida and its Environs, Igbo-Eze North Local Government Area, Enugu State, Nigeria

[1]Omali, A.O., *[1]Ugbena, K.G. and [2]Ezeugwu, S.U.

[1]Department of Earth Sciences, Faculty of Natural Sciences, Kogi State University, PMB 1008, Anyigba, Kogi State, Nigeria.
[2]Enugu State Ministry of Water Resources, Government Secretariat, Enugu, Nigeria.
*ugbenakelvins@yahoo.com

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ABSTRACT

The quest to assess potable water for human activities has led to intense subsurface investigation in most parts of the world. In this study, an attempt has been made to evaluate the groundwater potential of Umuida community and its environs in Enugu State, Nigeria. Using vertical electrical sounding (VES), the field survey was carried out at eleven points within the study area. Data analysis and modeling curves revealed five to six geo-electric layers with one aquiferous layer within an average depth of 90 m and average resistivity value of 243.38 Ωm in the area. Correlation of interpreted VES data with data obtained from five existing boreholes in the area indicated slight variation in depth values for the aquiferous layers. Depth to saturated zones from the VES data was within the range of 88.3 m and 125.8 m and shallower within the North-Eastern zone with thickness averaging 60 m. The use of this method has shown that productive boreholes for potable water, can be recommended at locations within Umuida and a benchmark of 110 m depth has been recommended to represent subsurface horizons saturated with water in the area. In spite of the inherent problems encountered using this geophysical method for the subsurface investigation, the use of resistivity method remains an invaluable tool for the investigation of subsurface geology and plays a key role in exploration programmes for water resources.

1. INTRODUCTION

Groundwater is water that is contained in geologic formations beneath the surface that are porous and permeable (aquifer) where the hydro-static pressure is equal to or greater than atmospheric pressure. Increase

A.O. Omali et al. / Nigerian Research Journal of Engineering and Environmental Sciences
7(1) 2022 pp. 298-308

in population in most parts of the developing countries of the world has created serious concerns on providing potable water that can serve this growing populace and the best means of harnessing this natural resource.

In spite of having groundwater in abundance in the earth, it's scarcity at some part of the world has continued to pose threat to humanity caused as a result of geologic implication in some areas and cost of exploitation and distribution to the common people in the hinterland. Problems associated with areas facing groundwater scarcity are perhaps caused by the diversity of geological environments which present unique challenges relating to detailed geological activities such as sediment deposition, mapping, surveying and many others (Camarero and Moreira, 2017; Ijaleye *et al.*, 2020).

Umuida community is one of the most populated areas in Igbo-Eze North Local Government Area of Enugu State Nigeria and its being challenged by scarcity of water. The cause of borehole failure varies in many places within the area arising from natural and/or unnatural causes.

Several geophysical methods are used in studying both surface and subsurface geology of areas in the world. These include seismic method, electromagnetic method, gravity method, geothermal method, magnetic method, radiometric method and electrical method which can provide direct answer and valuable additional data to augment other studies and more invasive means of evaluation such as drilling (Kearey *et al.,* 2002). Many researchers have worked in the Nsukka and Igbo-Eze South axis of Enugu state using geophysical methods with Igbo-Eze North receiving less attention (Umah, 2003; Ofoma *et al.*, 2006; Ezeh and Ugwu, 2010; Onunkwo *et al.*, 2014; Obiora *et al.,* 2015). Reports from previous studies show that regional water table in the area range between 70 m-150 m and depend on topography and time or season of acquiring the data (Umah, 2003). Higher transmissivity values are expected in the areas underlain by the Ajali formation (Ezeh and Ugwu, 2010). Ofoma *et al.*, (2006) reported 6 to 7 subsurface layers for the Nsukka axis. Depth to water table in the area falls within the lower parts of layer 5, at a depth of 110 m. Comparative analysis of quality of shallow and deep aquifer water of Nsukka area showed that water table is very deep at the areas bordering the water divide while it is shallow at the low lying areas (Onunkwo *et al.*, 2014). Obiora *et al.* (2015) presented the same subsurface geo-electric model curve, an indication that the western part of the area is prolific. In the research, hydro-geophysical study was carried out to characterize aquifers in parts of Nsukka and Igbo-Eze South LGA. Result review low value of longitudinal conductance of aquiferous layers but with high transmissivity and permeability which suggest high groundwater potential in the study area.

In this current research, vertical electrical sounding and borehole sampling were carried out at Umuida and its environ to carefully characterize, delineate the saturated and unsaturated zones and explore the potentiality of obtaining portable groundwater in the area to reduce the risk of drilling abortive boreholes.

2. METHODOLOGY

2.1. Location and Geology of the Study Area

The study area, Umuida is situated in Igbo-Eze North Local Government Area of Enugu State Nigeria, and lies within Latitudes 6º 58'0''N and 7º 2'0''N and Longitudes 7º 22'30''E and 7º 30'0''E. It is bounded by Alor-Agu to the Northeast, Unadu to the West, Enugu-Ezike to the East and Ibagwa-Aka to the South (Figure 1). The area falls within the Anambra Basin of Nigeria which was formed during the uplifting, folding and rifting of Santonian sediments of the Benue trough. These tectonic activities were recorded to have started in the early Cretaceous time with the separation of the African plate from the South American Plate which resulted in the opening up of the Atlantic Ocean (Burke *et al.,* 1972). The area is underlain by four geologic Formations. Nkporo Formation, Mamu Formation, Ajali Formation and Nsukka Formation. An interesting geomorphologic characteristic of the study area is that, Nsukka Formation occurs mainly as outliers on the Ajali sandstone. The provenance interpretations of the depositional settings of this area according to different researchers have favored fluvio-deltaic; (Reyment, 1965) fluvial deposit (Murat, 1972; Hoque and Ezepue, 1977) inter-bar channel (Banerjee, 1979; Amajor, 1986). The laterite in the area are permeable particularly those of Ajali sandstone thereby allowing easy water percolation into the groundwater table during the rainy season. The use of mathematical models in the analysis of flow in regional water table aquifers in Nsukka

A.O. Omali et al. / Nigerian Research Journal of Engineering and Environmental Sciences
7(1) 2022 pp. 298-308

area of the state according to Amah (2016) identified three major areas of flow system; the groundwater divide associated with the high head that attained a maximum of 328 m with gradient value of 1/200 or less, which is due east of Nsukka. The through flow or transfer areas of Nsukka plateau with head value of generally less than 300 m and gradient value of 1/150 or less and the discharge or terminating areas of the west and northwest where head are 230 m or less. Depth to water table in the area is within the average range of 106.7 m from recharge areas to 9.15 m at the discharge areas with average transmissivity value of 3.25×10^{-2} m^2. Hydraulic Conductivity value is estimated at 2.3×10^{-3} m/yr (Uzoije *et al.*, 2014).

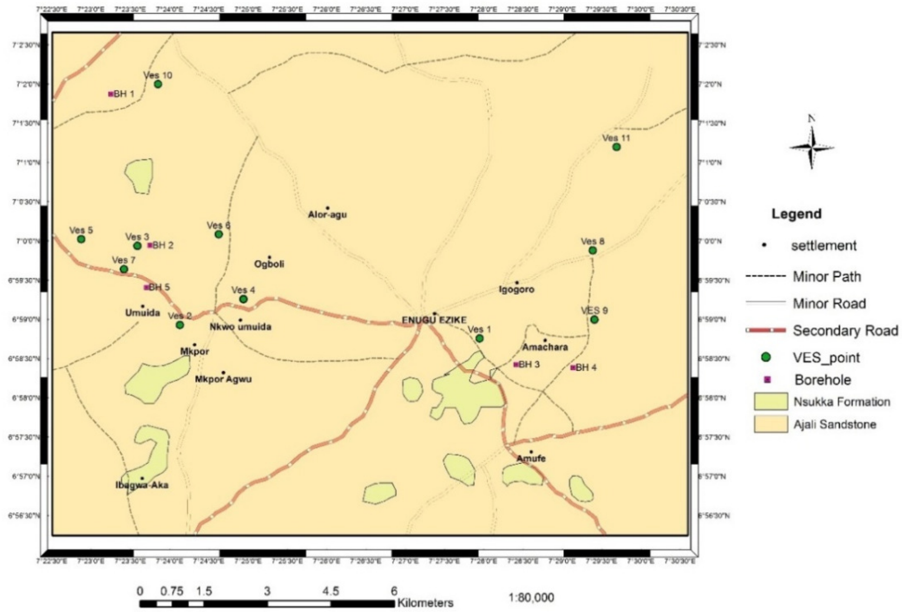

Figure 1: Geological map of the study area, VES and borehole points

2.2. Geological Investigation

Vertical electrical sounding (VES) technique using Schlumberger configuration was adopted. Current (I) was fed into the ground using (1/2) of the two current electrodes A and B placed at a distance ‘2a’ apart. At the center of the two electrodes, the voltage was measured between the half (1/2) of the two potential electrodes M and N placed at a distance ‘b’. The maximum spacing for the current and potential electrode was 5.0 m for MN/2 (potential electrodes) and 150.0 m for AB/2 (current electrodes). A total of 11 VES points were acquired using the versatile ABEM SAS 1000B Model Terrameter (Plate 1). The resultant apparent resistivity calculated from the field resistance values were plotted on the log-log graph against half current electrode spacing AB/2 using a computer algorithm (IP12WIN). The field data were subjected to qualitative analysis using partial curve matching and computer iterations from which the various layer thickness, depth and corresponding resistivity were obtained. Depths to static water level in sampled existing boreholes were determined using a calibrated water level meter.

Plate 1: ABEM SAS 1000B Model Terrameter and electrode configuration during data acquisition

3. RESULTS AND DISCUSSION

Results of the sounding revealed 5 to 6 geo-electric layers in the study area. The first layer at all locations as presented in Figures 2-12 is composed of lateritic soil and known as the topmost layer with resistivity value range of 47.23-4516 Ωm and thickness value range of 0.18-2.00 m as presented in tables 1-11. The second layer is composed of reddish fine grained sandstone (Figures 2, 3, 4, 5, 7, 8, 9, 11 and 12) at most points with resistivity value range of 356.5-65465 Ωm and thickness value range of 0.54-18.30 m (Tables 1, 2, 3, 4, 6, 7, 8, 10, and 11). The third layer is made up of fine-medium grained sandstone at locations (1, 2, 5, 6, 10 and 11) (Figures 2, 3, 6, 7, 11 and 12) with resistivity values ranging from 22-9-143421 Ωm and thickness ranging from 2.74-82.30 m as presented in (Tables 1, 2, 5, 6, 10 and 11). Location 2 and 5 are saturated and serves as the aquiferous zones for the locations found while locations (1, 6, 10 and 11) are not saturated zones. At locations (3, 4 and 9) the fine-medium grained sandstone occurs as the fourth layer (Tables 3, 4 and 9) and both are non saturated zones. The fourth layer at other locations is composed of dry sandstone and forms the saturated zone at VES 6, location 6 (Table 6). These layers had resistivity values ranging from 62.90-121324 Ωm and thickness values ranging from 5.84-70.30 m. The fifth layer is composed of fine-medium grained sandstone and forms the aquiferous zone for VES 4 and 11 (Tables 4 and 11). Some points revealed sandy-claystone. The resistivity values ranges between 84.7-27149 Ωm and thickness of 36.70-55.29 m. The thickness and depth of these layer are however undefined at points where five geo-electric layer are recorded. The sixth layer is composed of sandstone with undefined thickness and depth. The layer shows low resistivity values at all VES points. Layers four and five occur as the saturated zones in the area being encountered at depths of 80 m downwards. Preferably, this depth can be recommended for drillers as a potential water zone in the area. However, five VES points (VES 3, 7, 8, 9 and 10) represented in Tables 3, 7, 8, 9 and 10) shows increasing values of resistivity from the surface down to layer five or six. This is an indication of absence of aquiferous zone within the depth covered in this study. Two curve types dominate in the area; A-Type curve and K-Type curve. VES 1 shows very low resistivity value of 22.9 Ωm at a depth of 53.20 m, an indication of the presence of perched aquifer as reported in literature for works carried out in parts of Enugu state (Nsukka and its environs). The top layer material in the area is believed to be permeable to allow percolation of water from the surface downwards during the rainy season to encounter the water table. Figure 12 compares the computer model for resistivity data obtained for VES 2 (Table 2) within Umuida community and borehole log of an existing borehole (BH5) in the community. Result shows that saturated layer is within deep depth in the area.

Table 1: Resistivity model of VES 1

Layer	Apparent resistivity (Ωm)	Thickness (m)	Depth (m)	Remark
1	47.23	2.00	2.00	Top lateritic soil
2	356.5	18.30	20.30	Reddish fine grained sandstone
3	22.9	32.90	50.20	Saturated fine-medium grained sandstone
4	832	30.26	80.46	Claystone
5	838	Undefined	Undefined	Claystone

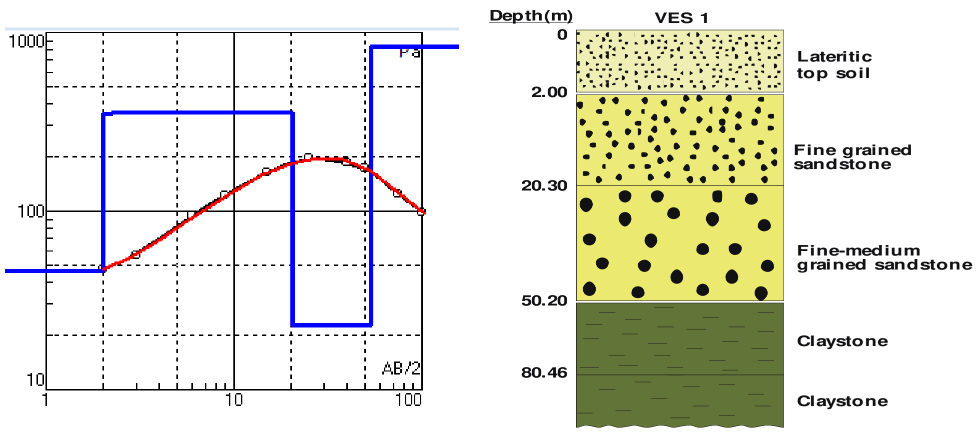

Figure 2: Computer modeling and geo-electric section for VES 1

Table 2: Resistivity model of VES 2

Layer	Apparent resistivity (Ωm)	Thickness (m)	Depth (m)	Remark
1	1419	1.18	1.18	Lateritic top soil
2	45083	9.39	10.57	Reddish fine grained sandstone
3	6081	82.30	92.87	Fine-medium grained saturated sandstone
4	5546	Undefined	Undefined	Saturated sandstone

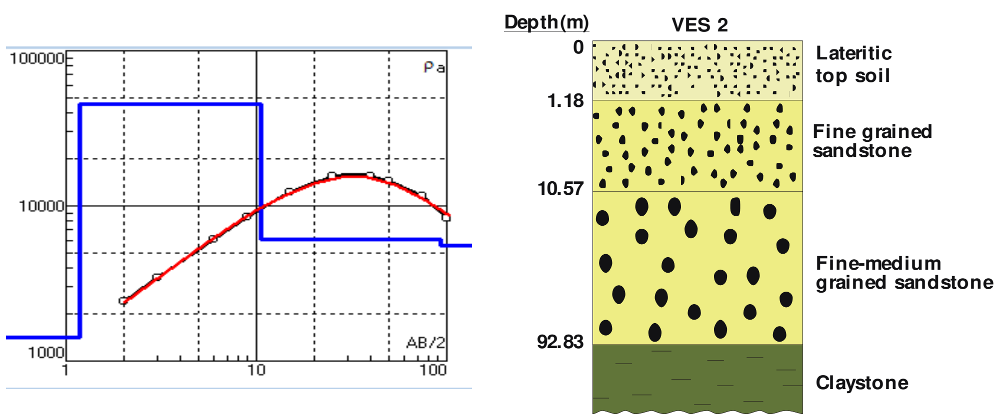

Figure 3: Computer modeling and geo-electric section for VES 2

A.O. Omali et al. / Nigerian Research Journal of Engineering and Environmental Sciences
7(1) 2022 pp. 298-308

Table 3: Resistivity model of VES 3

Layer	Apparent resistivity (Ωm)	Thickness (m)	Depth (m)	Remark
1	4423	1.12	1.12	Lateritic top soil
2	65465	14.20	15.32	Reddish fine grained sandstone
3	91204	30.80	46.12	Dry sand
4	46133	43.40	89.52	Fine-medium grained sandstone
5	21282	Undefined	Undefined	Silty claystone

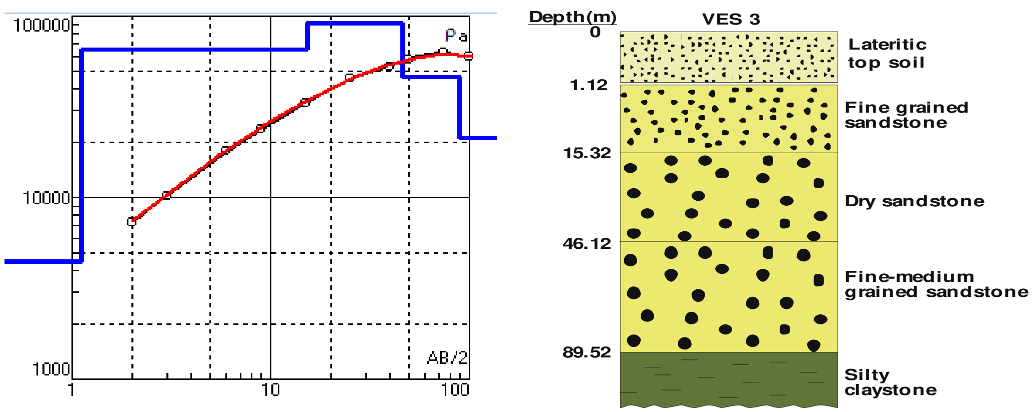

Figure 4: Computer modeling and geo-electric section for VES 3

Table 4: Resistivity model of VES 4

Layer	Apparent resistivity (Ωm)	Thickness (m)	Depth (m)	Remark
1	4516	0.68	0.68	Top lateritic soil
2	15910	6.37	7.05	Reddish fine grained sandstone
3	53458	14.60	21.65	Dry sandstone
4	21677	23.60	45.25	Fine-medium grained sandstone
5	1556	49.30	94.60	Saturated sandstone
6	745	Undefined	Undefined	Saturated sandstone

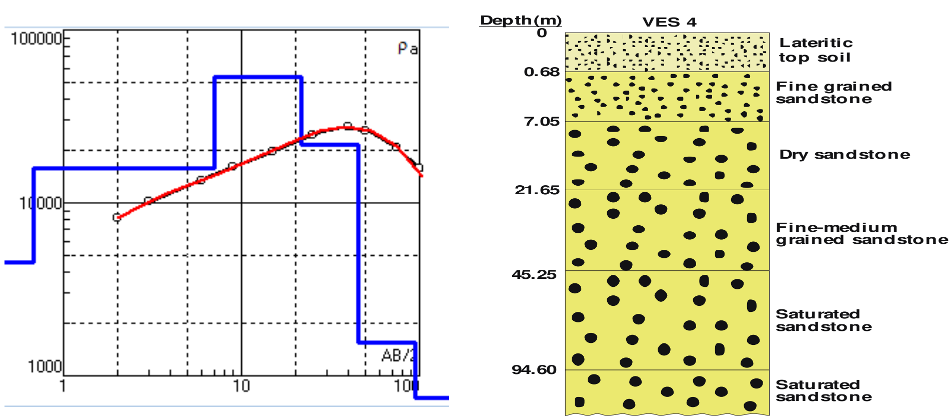

Figure 5: Computer modeling and geo-electric section for VES 4

Table 5: Resistivity model of VES 5

Layer	Apparent resistivity (Ωm)	Thickness (m)	Depth (m)	Remark
1	210	1.46	1.46	Top lateritic soil
2	1418	9.93	11.39	Reddish sandy-clay
3	460	68.90	80.29	Fine-medium grained saturated sandstone
4	62.9	Undefined	Undefined	Saturated sandstone

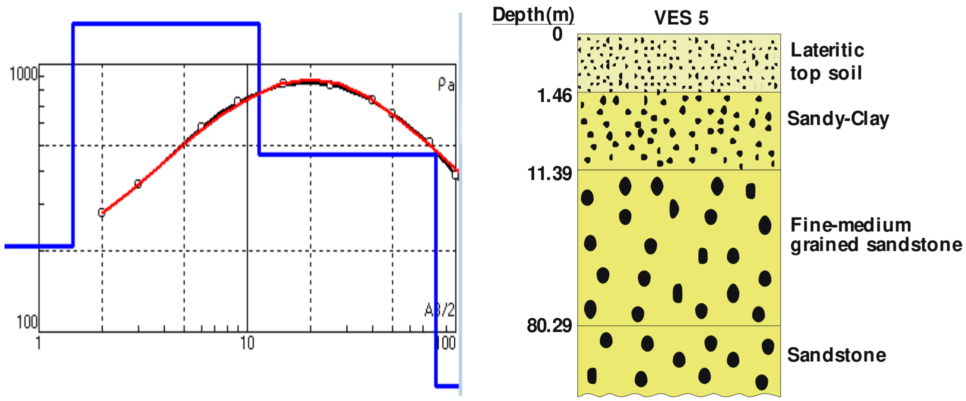

Figure 6: Computer modeling and geo-electric section for VES 5

Table 6: Resistivity model of VES 6

Layer	Apparent resistivity (Ωm)	Thickness (m)	Depth (m)	Remark
1	601	1.12	1.12	Lateritic top soil
2	8954	2.45	3.57	Reddish fine grained sandstone
3	3565	17.30	20.87	Fine-medium grained sandstone
4	150	70.30	91.17	Saturated sandstone
5	84.7	Undefined	Undefined	Saturated sandstone

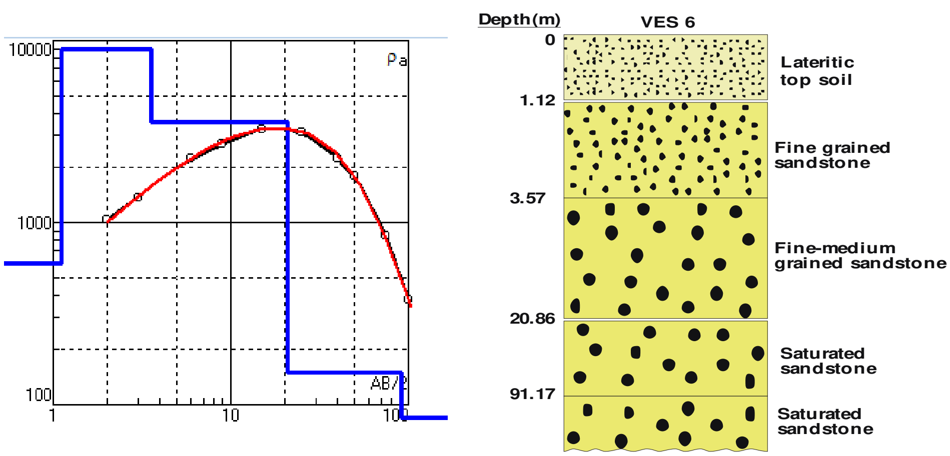

Figure 7: Computer modeling and geo-electric section for VES 6

A.O. Omali et al. / Nigerian Research Journal of Engineering and Environmental Sciences
7(1) 2022 pp. 298-308

Table 7: Resistivity model of VES 7

Layer	Apparent resistivity (Ωm)	Thickness (m)	Depth (m)	Remark
1	4096	0.35	0.35	Lateritic top soil
2	45426	0.60	0.95	Reddish fine grained sandstone
3	73312	33.43	34.38	Dry sandstone
4	97447	59.36	93.74	Dry sandstone
5	14365	Undefined	Undefined	Sandy-claystone

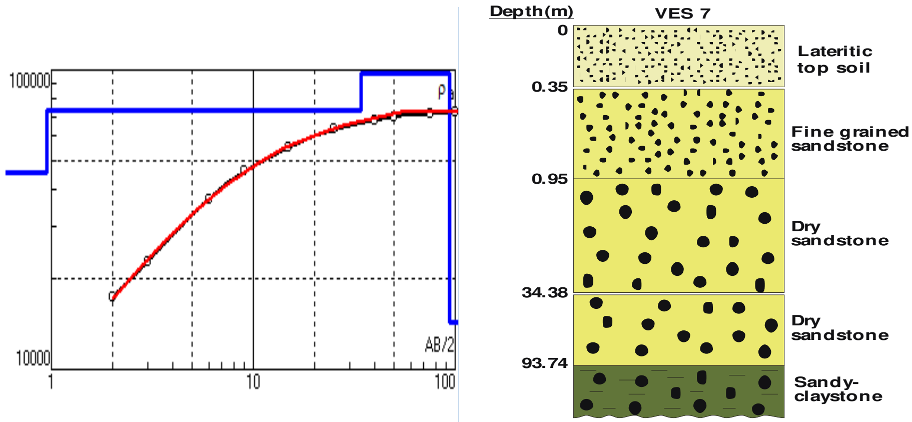

Figure 8: Computer modeling and geo-electric section for VES 7

Table 8: Resistivity model of VES 8

Layer	Apparent resistivity (Ωm)	Thickness (m)	Depth (m)	Remark
1	169	0.18	0.18	Lateritic top soil
2	17061	0.76	0.94	Reddish fine grained sandstone
3	143421	6.03	6.97	Dry sandstone
4	121324	31.81	38.77	Dry sandstone
5	27149	44.90	94.67	Sandy-claystone
6	17061	Undefined	Undefined	Claystone

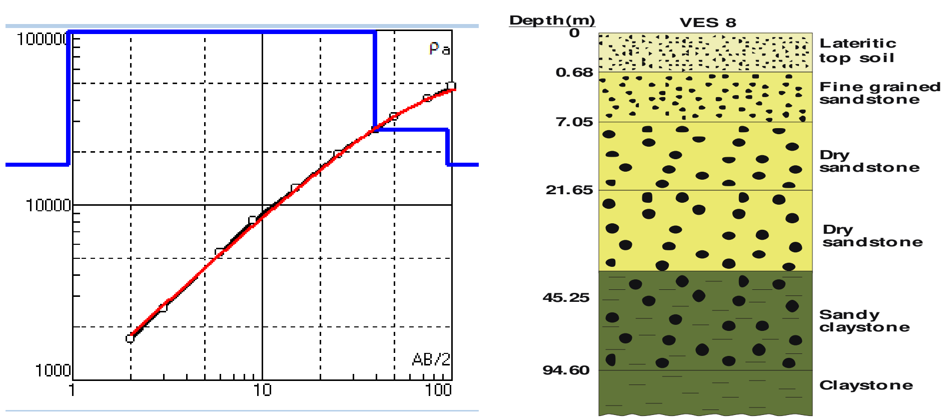

Figure 9: Computer modeling and geo-electric section for VES 8

A.O. Omali et al. / Nigerian Research Journal of Engineering and Environmental Sciences
7(1) 2022 pp. 298-308

Table 9: Resistivity model of VES 9

Layer	Apparent resistivity (Ωm)	Thickness (m)	Depth (m)	Remark
1	1117	0.57	0.57	Lateritic top soil
2	624	1.89	2.46	Reddish sandy-claystone
3	13183	8.10	10.56	Dry sandstone
4	8954	34.70	45.26	Fine-medium grained sandstone
5	7448	47.60	92.86	Sandy-Claystone
6	5546	Undefined	Undefined	Claystone

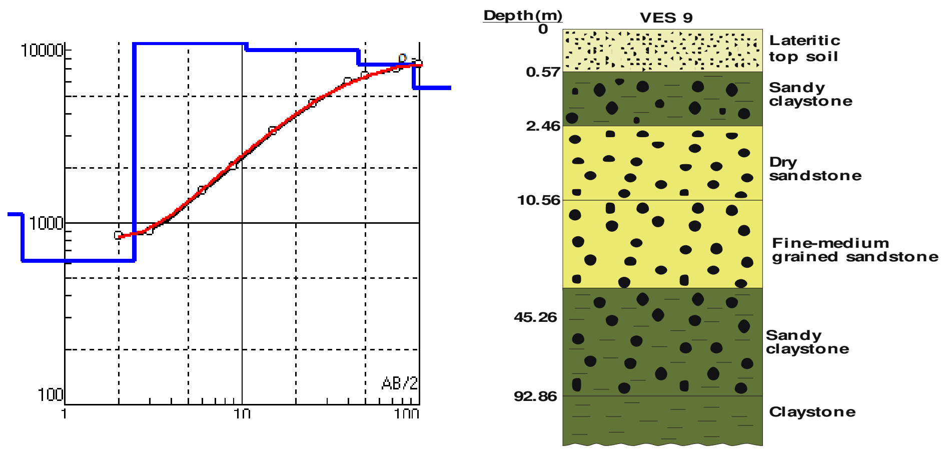

Figure 10: Computer modeling and geo-electric section for VES 9

Table 10: Resistivity model of VES 10

Layer	Apparent resistivity (Ωm)	Thickness (m)	Depth (m)	Remark
1	624	1.44	1.44	Lateritic top soil
2	947	0.54	1.98	Reddish fine grained sandstone
3	10321	2.74	4.72	Fine-medium grained sandstone
4	12045	5.84	10.56	Dry sandstone
5	11542	36.70	47.26	Fine-medium grained sandstone
6	27149	47.30	94.56	Dry sandstone
7	22759	Undefined	Undefined	Dry sandstone

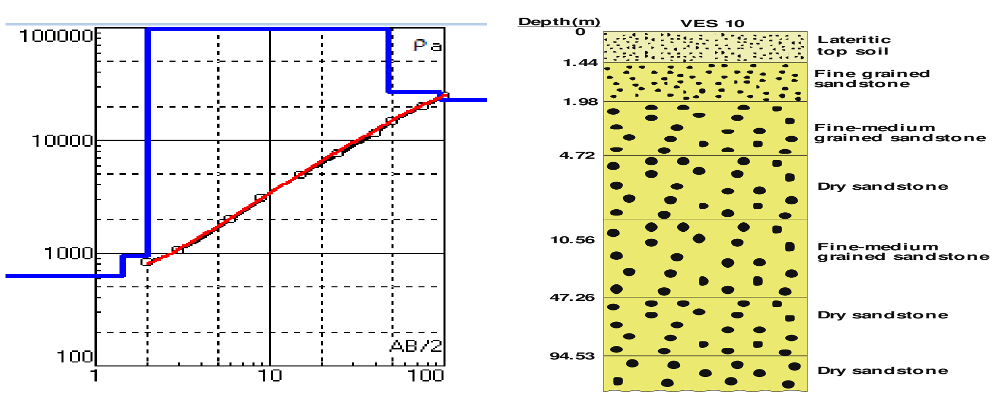

Figure 11: Computer modeling and geo-electric section for VES 10

A.O. Omali et al. / Nigerian Research Journal of Engineering and Environmental Sciences
7(1) 2022 pp. 298-308

Table 11: Resistivity model of VES 10

Layer	Apparent resistivity (Ωm)	Thickness (m)	Depth (m)	Remark
1	288.6	1.36	1.36	Lateritic top soil
2	8962	1.22	2.58	Reddish fine grained sandstone
3	4727	15.52	18.10	Fine-medium grained sandstone
4	11159	21.27	39.37	Dry sandstone
5	236.1	55.29	94.66	Saturated sandstone
6	219.4	Undefined	Undefined	Saturated sandstone

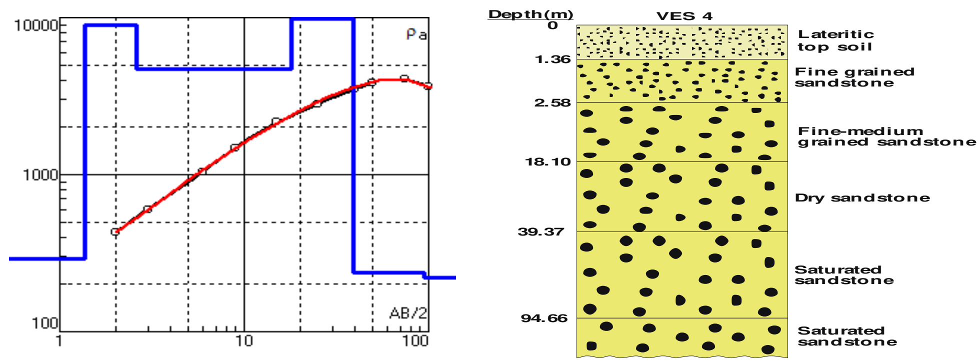

Figure 12: Computer modeling and geo-electric section for VES 11

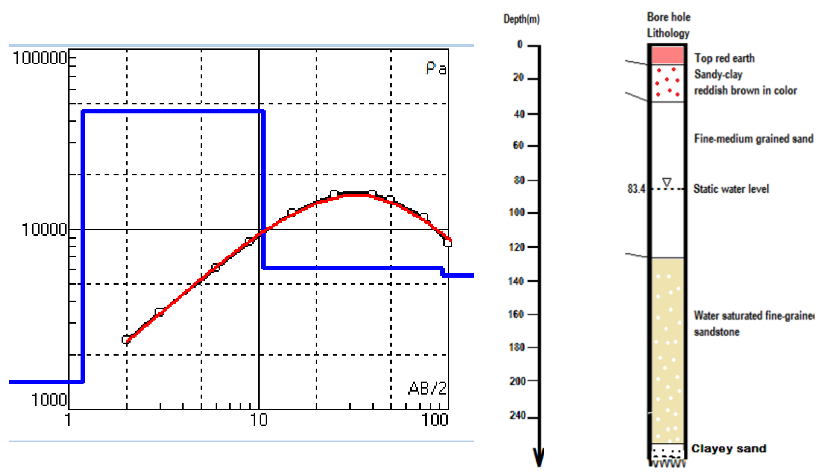

Figure 13: Comparison of computer model for VES 2 and borehole log obtained from BH5 within Umuida community

4. CONCLUSION

In spite of the inherent problems encountered during subsurface evaluation such as characterizing a formation, applying geophysical methods using our knowledge of the earth's resistance to electrical current at various depths remain a veritable tool for such investigations. This is because; results obtained from such investigations shows that the method can image the subsurface for occurrence of natural resources such as the presence of groundwater. In this study results obtained from the VES revealed 5 to 6 delineable geo-electric layers with layers four and five being aquiferous.

A.O. Omali et al. / Nigerian Research Journal of Engineering and Environmental Sciences
7(1) 2022 pp. 298-308

5. ACKNOWLEDGEMENT

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6. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

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