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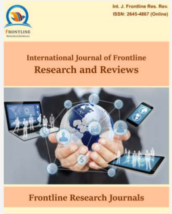


(RESEARCH ARTICLE)

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# Parameter variations for the sandy aquifers in northern parts of Akwa Ibom state, Southern Nigeria

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## Abstract

The subsurface sandy aquifers in the in northern parts of Akwa Ibom State, Southern Nigeria were studied to see how homogenous or otherwise the aquifer parameters could be. The parameters considered in the present study were lithologic composition of the aquifer, depth of occurrence, thickness and aquifer resistivity. Vertical Electrical Sounding (VES) using Schlumberger electrode configuration was the choice array used in data collection. Forty five (45) points were electrically sounded across the study area to obtain information on the electrical signatures of the subsurface layers. Both manual and computer aided methods were used in the analysis of the acquired field data. Interpreted results showed great variability of the aquifer parameters. Aquifer lithological make-up varied markedly from fine/coarse grained sand to clayey sand as one approached the northern parts of the study area. Deep seated/confined aquifers reaching an interpreted drill depth of about 110 m were also found northwards compared to an interpreted drill depth of about 22.7 m inland. Most of the aquifers encountered were prolific with some reaching a thickness of over 60 m. Aquifer resistivity values varying between 71.8 Ωm to 28,413.0 Ωm were also obtained within the study area. The study concluded that, the varied inhomogeneity of the explored subsurface indicated that the area of study is a transition zone between the Pliocene-Pleistocene Benin formation/Coastal plain sand and the Middle Eocene Bende-Ameke Group.

**Keywords:** Aquifer; Resistivity; Thickness; Vertical Electrical Sounding

## 1 Introduction

Groundwater is a universally important and priceless renewable resource for human life and economic growth. It is the major source of water for most uses in Nigeria in particular and the world at large [1, 2]. It constitutes a major portion of the earth's water circulatory system known as hydrologic cycle and occurs in permeable geologic formations called aquifers. It is estimated that about one third of the world's population use groundwater for drinking [3] supplying more than 1.5 billion urban dwellers with water [4] and is extensively used for rural water supply. In pastoral context, groundwater provides the mainstay for agricultural irrigation and is important to providing additional resources for food security. .Itrepresents 30% of the freshwater resources, and as much as 96% of the fraction in liquid form [5] with approximately one third of the world's population depending on it for drinking [6]. The worldwide development of past

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civilizations as well as recent socioeconomic evolution of nations are based and strongly controlled by the availability of this all-important resource [7].

For effective management of groundwater, knowledge of aquifer parameters is essential [8] for quantitative and qualitative description of aquifers in order to address several hydrological and hydro-geological problems. To achieve this, geophysical methods, especially the electrical resistivity method present itself as an effective tool for indirectly mapping the subsurface rock formations and structures [9] and for identification of zones that can serve as potential water bearing formations due to resistivity contrast. Ideally, in a clayey or saline environment, high resistivity anomalies are most probably indicators of potable water; while low resistivity anomalies would be the target for groundwater exploration in basement terrain [10].

The present study evaluates parameter variations for the sandy aquifers in the northern parts of Akwa Ibom State, southern Nigeria.

## 2 Methodology

### 2.1 Geologic setting of the study area

Geologically, the study area is underlain by late Cretaceous to Quaternary sediments. The lowermost sediment is made up of lateritic sandstone with minor shale of the Maastrichtian Nsukka Formation [11,12,13]. During the Paleocene to Early Eocene, a thick shale intercalated with sandstone and limestone (Imo Shale Formation) was deposited while in the middle of the Eocene; semi-consolidated sandstone, siltstone and minor shale (Bende Ameki Formation) was deposited. Since the Miocene-Oligocene, grit and sand with intercalations of clay and lignite beds were deposited constituting the Ogwashi-Asaba Formation. Overlying this formation is a thick sequence of gravel, sand, silt, and clay constituting the Benin Formation also known as the coastal plain sands and alluvial ridges [14].

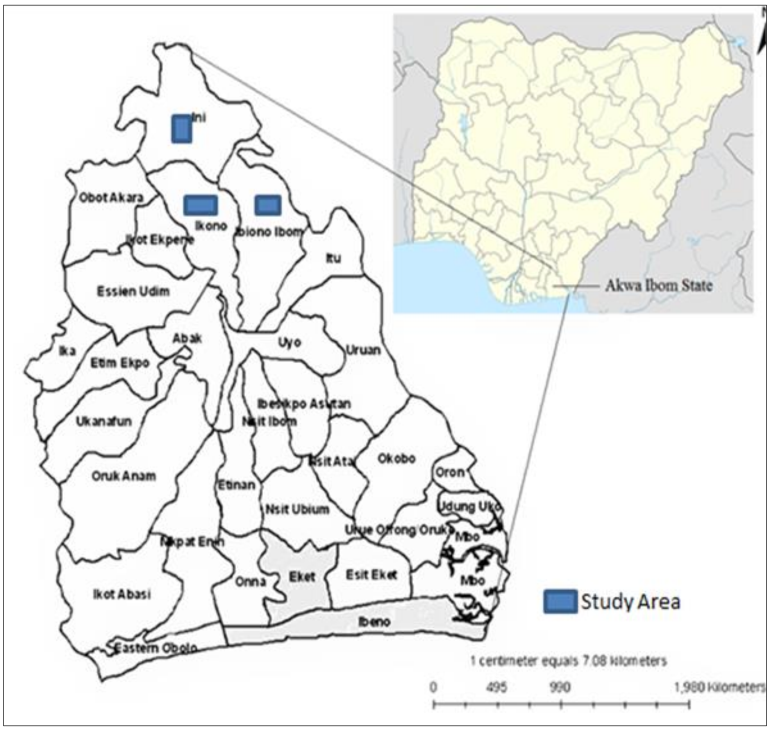


**Figure 1** Map of Akwa Ibom State showing the study area

### 2.2 Field Procedures

The Vertical Electrical Sounding (VES) using schlumberger electrode configuration was used for the electrical resistivity work. This was the choice array because of its high degree of penetration, accuracy, reliability and the use of limited work force [15, 16]. The sounding center was first determined which enabled the electrodes to be deployed along a straight traverse in conformity with the theory. After determining the sounding point, its coordinates were taken using a GPS device. Two potential electrodes $P_1$ and $P_2$ were initially planted at a distance of 0.50 m respectively from the center, giving an initial potential electrode separation (a) of 1.0 m. The two current electrodes $C_1$ and $C_2$ were also planted at a distance of 1.5 m respectively from the center, giving an initial current electrode separation (b) of 3.0 m. These electrodes were connected by the insulated copper cables to their respective terminals as indicated on the resistivity meter. With the equipment on the "ON" mode, the measurement cycle of four was selected and the earth's resistance was automatically measured by depressing the measure button. The current electrode spacing was increased after each reading while the potential electrodes spacing was increased only when deemed necessary and controlled by the relation $\left(\frac{AB}{2}\right) \geq \left(\frac{5MN}{2}\right)$ as required by Schlumberger array [17]. A total of forty five soundings were made across the study area with a minimum current electrode spread of 800 m. In the analysis of the obtained data, both manual and computer modeling techniques were employed to reduce the VES data to their corresponding 1-D geological prototypes. The manual procedure involved plotting the computed apparent resistivity on a bi-logarithmic graph and where necessary, the curves generated were smoothened in order to remove the effects of lateral heterogeneities and other forms of noisy signatures [18, 19]. This was performed by averaging the two readings at the crossover points, or deleting any outlier at the crossover points that did not conform to the dominant trend of the curve. Also deleted were data that stood out as outliers in the prevalent curve trend which could have caused serious increase in root-mean square error (RMSE) during the modeling phase of the work.

## 3 Results and discussion

The geo-electric layer parameters obtained for the study area are presents in Table 1 which shows the Vertical Electrical Sounding (VES) number, the location of the sounding point (longitude and latitude), layer resistivity, thickness and depth to the layer from the sounding surface. The first layer, which represented the top soil, has thicknesses that varied from 0.4 m at VES point 12 to 19.0 m at VES point 4. The top soil in the study area consisted of laterite and coarse grain sand/loam at various point within the area of study. The apparent resistivity values for the top soil varied from 61.5 Ωm at VES point 37 to 4273.7 Ωm at VES point 6. The second layer was interpreted to be gravely sand with varying mixture of silt and clay. The thickness of this layer varied from 2.6 m at VES point 1 to 90.4 m at VES point 16. Apparent resistivity values for the second layer also show great variability which arises as a result of the percentage composition of clay, loam and silt. The minimum value of 44.5 Ωm was recorded at VES point 20, with a maximum of 9508.9 Ωm recorded at VES point 6. High apparent resistivity values were observed at VES point 6, especially for the first and second layers. This was interpreted to be due to the poor compaction of the soil particles in this area and the relative absence of clay and silt/loam in the soils which was evidence from a lithologic log from a nearby drilled well.

**Table 1** Geo-electric layer parameters

| VES NO. | LONG. (°E) | LAT. (°N) | RESISTIVITY (Ωm) | | | | | THICKNESS (m) | | | | DEPTH (m) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | $\rho_1$ | $\rho_2$ | $\rho_3$ | $\rho_4$ | $\rho_5$ | $h_1$ | $h_2$ | $h_3$ | $h_4$ | $d_1$ | $d_2$ | $d_3$ | $d_4$ |
| 1 | 7.818 | 5.267 | 764.3 | 125.4 | 15514.6 | 782.6 | 728.6 | 1.9 | 2.6 | 19.4 | 38.8 | 1.9 | 4.5 | 24.0 | 62.8 |
| 2 | 7.746 | 5.273 | 1149.1 | 1765.3 | 2868.2 | 2092.5 | - | 11.1 | 24.8 | 73.4 | - | 11.1 | 35.8 | 109.2 | - |
| 3 | 7.754 | 5.224 | 266.4 | 1850.5 | 3347.1 | 2394.2 | - | 4.6 | 16.7 | 68.6 | - | 4.6 | 21.3 | 89.9 | - |
| 4 | 7.760 | 5.218 | 1606.9 | 13214.6 | 5279.3 | 2222.1 | 621.4 | 19.0 | 33.7 | 24.6 | 38.1 | 19.0 | 52.6 | 77.2 | 115.2 |
| 5 | 7.763 | 5.219 | 1668.8 | 793.4 | 2242.2 | 20333.7 | - | 1.9 | 34.3 | 25.3 | - | 1.9 | 36.2 | 61.5 | - |
| 6 | 7.705 | 5.171 | 4273.7 | 9508.9 | 2031.0 | 17141.2 | - | 18.5 | 42.8 | 48.3 | - | 18.5 | 61.3 | 109.6 | - |
| 7 | 7.694 | 5.321 | 829.4 | 3411.0 | 3616.8 | 208.5 | - | 4.7 | 11.6 | 47.6 | - | 4.7 | 16.3 | 63.8 | - |
| 8 | 7.735 | 5.280 | 1128.4 | 4042.4 | 744.1 | 7361.0 | - | 7.2 | 21.4 | 63.6 | - | 7.2 | 28.6 | 92.2 | - |
| 9 | 7.721 | 5.290 | 2358.6 | 742.6 | 5335.6 | 6184.7 | - | 1.6 | 13.5 | 53.2 | - | 1.6 | 15.1 | 68.4 | - |
| 10 | 7.723 | 5.299 | 1284.5 | 3346.5 | 1850.0 | 959.2 | - | 12.3 | 30.3 | 63.4 | - | 12.3 | 42.6 | 106.0 | - |
| 11 | 7.713 | 5.347 | 170.6 | 1400.0 | 311.3 | 2908.4 | - | 2.4 | 11.9 | 51.1 | - | 2.4 | 14.2 | 65.3 | - |
| 12 | 7.780 | 5.350 | 939.6 | 5222.1 | 5031.1 | 688.7 | 3768.9 | 0.4 | 24.3 | 9.2 | 49.6 | 0.4 | 24.7 | 33.9 | 83.5 |
| 13 | 7.698 | 5.351 | 834.4 | 1232.7 | 601.1 | 927.3 | 409.1 | 9.0 | 24.0 | 47.5 | 44.2 | 9.0 | 33.0 | 80.5 | 124.7 |
| 14 | 7.665 | 5.396 | 3054.1 | 3502.2 | 6144.9 | 2225.0 | 130.6 | 5.0 | 24.8 | 18.3 | 39.9 | 5.0 | 29.8 | 48.1 | 88.0 |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 15 | 7.657 | 5.405 | 274.8 | 1368.5 | 54.0 | - | - | 1.4 | 47.6 | - | - | 1.4 | 49.0 | - | - |
| 16 | 7.674 | 5.363 | 2544.4 | 1394.7 | 474.4 | - | - | 5.3 | 90.9 | - | - | 5.3 | 96.2 | - | - |
| 17 | 7.714 | 5.274 | 673.5 | 2546.9 | 1725.4 | 361.4 | - | 2.4 | 37.4 | 63.3 | - | 2.4 | 39.8 | 103.1 | - |
| 18 | 7.748 | 5.344 | 1585.5 | 2998.4 | 3942.3 | 1508.2 | 1152.3 | 2.4 | 16.2 | 21.3 | 62.0 | 2.4 | 18.7 | 40.0 | 101.9 |
| 19 | 7.752 | 5.355 | 476.3 | 4665.0 | 882.4 | 77.6 | - | 2.5 | 27.1 | 43.4 | - | 2.5 | 29.6 | 73.0 | - |
| 20 | 7.672 | 5.380 | 539.2 | 44.5 | 794.4 | 2457.1 | 4170.4 | 3.9 | 12.2 | 9.4 | 22.7 | 3.9 | 16.1 | 25.5 | 48.2 |
| 21 | 7.743 | 5.347 | 3226.3 | 2668.1 | 916.5 | 1386.3 | - | 3.6 | 17.2 | 52.8 | - | 3.6 | 20.8 | 73.6 | - |
| 22 | 7.680 | 5.288 | 582.4 | 1586.9 | 1997.5 | 681.9 | 157.4 | 1.0 | 26.9 | 15.1 | 45.6 | 1.0 | 27.9 | 43.0 | 88.6 |
| 23 | 7.687 | 5.288 | 1413.3 | 3350.9 | 2137.2 | 2134.5 | - | 1.3 | 17.0 | 66.2 | - | 1.3 | 18.3 | 84.6 | - |
| 24 | 7.718 | 5.303 | 1502.2 | 2121.8 | 1670.7 | 588.3 | - | 5.9 | 30.4 | 64.1 | - | 5.9 | 36.2 | 100.3 | - |
| 25 | 7.727 | 5.294 | 2174.9 | 735.2 | 24723.6 | 2667.4 | 586.8 | 1.3 | 7.2 | 40.6 | 27.0 | 1.3 | 8.4 | 49.0 | 76.0 |
| 26 | 7.776 | 5.191 | 1519.9 | 672.2 | 1404.8 | 4790.1 | 2102.4 | 2.2 | 5.8 | 21.9 | 66.9 | 2.2 | 7.9 | 29.8 | 96.7 |
| 27 | 7.767 | 5.170 | 185.6 | 87.5 | 2145.8 | 263.1 | - | 1.5 | 6.5 | 43.6 | - | 1.5 | 8.0 | 51.5 | - |
| 28 | 7.788 | 5.174 | 456.9 | 404.2 | 2100.2 | 3213.5 | - | 3.9 | 15.9 | 54.6 | - | 3.9 | 19.9 | 74.4 | - |
| 29 | 7.789 | 5.172 | 1154.4 | 1709.8 | 5722.1 | 1191.2 | 1285.7 | 1.6 | 24.8 | 61.8 | 60.8 | 1.6 | 26.4 | 88.2 | 149.0 |
| 30 | 7.712 | 5.290 | 450.3 | 1529.6 | 1795.6 | 451.8 | - | 6.1 | 19.4 | 62.6 | - | 6.1 | 25.5 | 88.1 | - |
| 31 | 7.743 | 5.280 | 551.7 | 204.3 | 261.1 | 986.3 | 238.9 | 2.9 | 3.8 | 17.9 | 64.4 | 2.9 | 6.6 | 24.5 | 88.9 |
| 32 | 7.784 | 5.283 | 105.0 | 716.6 | 385.2 | 28413.0 | - | 1.4 | 23.3 | 35.0 | - | 1.4 | 24.7 | 59.7 | - |
| 33 | 7.757 | 5.227 | 763.3 | 679.6 | 5156.0 | - | - | 9.7 | 31.2 | - | - | 9.7 | 40.9 | - | - |
| 34 | 7.744 | 5.240 | 189.3 | 939.2 | 5975.9 | 2250.6 | - | 0.7 | 17.5 | 62.9 | - | 0.7 | 18.2 | 81.1 | - |
| 35 | 7.770 | 5.252 | 1122.2 | 3042.9 | 6976.1 | 418.0 | - | 7.1 | 9.9 | 53.9 | - | 7.1 | 17.0 | 70.9 | - |
| 36 | 7.732 | 5.192 | 370.4 | 993.4 | 324.2 | 415.3 | - | 8.1 | 25.2 | 72.0 | - | 8.1 | 33.3 | 105.4 | - |
| 37 | 7.814 | 5.116 | 61.5 | 288.0 | 404.7 | 534.0 | - | 1.7 | 29.3 | 63.1 | - | 1.7 | 31.0 | 94.1 | - |
| 38 | 7.813 | 5.097 | 702.2 | 601.0 | 780.2 | 215.5 | 468.1 | 4.1 | 13.1 | 18.6 | 62.8 | 4.1 | 17.2 | 35.8 | 98.6 |
| 39 | 7.814 | 5.066 | 282.7 | 671.4 | 124.2 | 119.6 | - | 2.5 | 16.8 | 57.5 | - | 2.5 | 19.3 | 76.8 | - |
| 40 | 7.806 | 5.024 | 83.5 | 1161.5 | 187.8 | 176.6 | - | 0.6 | 51.9 | 75.2 | - | 0.6 | 52.5 | 127.7 | - |
| 41 | 7.617 | 5.305 | 244.5 | 794.3 | 327.9 | 71.8 | - | 3.5 | 21.1 | 79.0 | - | 3.5 | 24.5 | 103.6 | - |
| 42 | 7.559 | 5.235 | 209.4 | 200.7 | 457.8 | 987.4 | 202.4 | 4.7 | 4.6 | 16.1 | 49.2 | 4.7 | 9.3 | 25.4 | 74.7 |
| 43 | 7.632 | 5.176 | 639.1 | 1283.9 | 691.1 | 312.0 | 2738.9 | 1.2 | 6.6 | 13.0 | 51.4 | 1.2 | 7.8 | 20.8 | 72.3 |
| 44 | 7.689 | 5.214 | 366.4 | 1552.9 | 962.9 | 1222.6 | - | 2.2 | 32.0 | 78.5 | - | 2.2 | 34.1 | 112.6 | - |
| 45 | 7.933 | 5.140 | 164.1 | 678.7 | 490.2 | 419.4 | - | 4.7 | 34.3 | 69.0 | - | 4.7 | 39.0 | 107.9 | - |

The third layer was interpreted to be fine-coarse grained sand with varying proportion of clay. Its thickness and resistivity also showed great variability within the study area. The thickness of the layer was least at VES point 12 with a value of 9.2 m and extended to 79.0 m at VES point 41; while the measured apparent resistivity values ranged from 54.0 Ωm at VES point 15 to 24723.6 Ωm at point 25. Areas with high resistivity values were interpreted as having a very little composition of clay. In some areas, especially around VES points 15 and 16, the thickness of the third layer was infinite with a low resistivity which implies high clay content. These areas may not be viable for large scale groundwater development at the investigated depth, as the formation porosity will greatly inhibit the rate of groundwater flow. This was evident from an abandoned borehole in the vicinity of VES point 15. The aquifers around these VES points are deep-seated confined aquifers. To tap from them, the drillers should be able to drill through the clay layer which was found to be over 90.9 m thick around VES point 16.

The fourth and fifth layers were interpreted to consist of fine grained sand which essentially constituted the aquifer in most of the locations. The fourth layer thickness was 22.7 m at VES point 20 and increased to 66.9 m at VES point 26. The apparent resistivity of the fourth layer was found to increase from 71.8 Ωm at VES point 41 to 28,413.0 Ωm at VES point 32. At most VES points, the fourth layer was found to be infinitely thick, beyond the depth of investigation. In some areas, a fifth layer was encountered. The layer thickness varied from 24.5 m at VES point 26 to 112.6 m at VES point 44. Apparent resistivity values for the layer also varied from 130.6 Ωm at VES point 14 to 14170.4 Ωm at VES point 20. Generally, there was a relatively high observed apparent resistivity values for the fourth and fifth layers. This shows that the aquifers are generally free of contamination and would constitute a good source of drinking water. Within the study area, the minimum drill depth to the aquifer varied greatly across the study area. From the interpreted result, the minimum drill depth of 24.5 m was encountered at VES point 31 while the minimum drill depth of 112.6 m was encountered at VES point 44. Representatives of modeled curves for some VES points are presented as Figure 1 to 6.

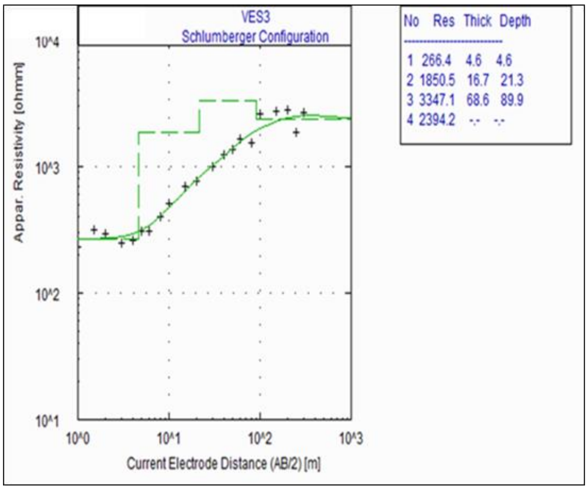


**Figure 1** Modeled curve for VES 3

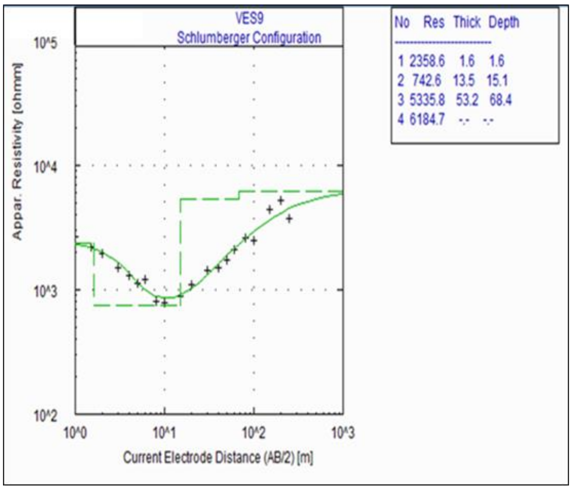


**Figure 2** Modeled curve for VES 9

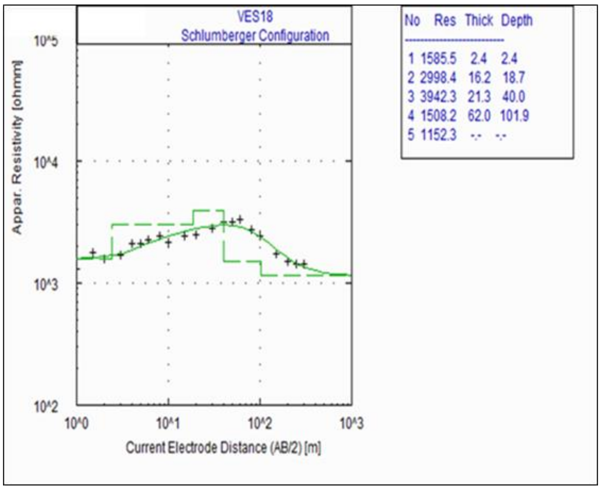


**Figure 3** Modeled curve for VES 18

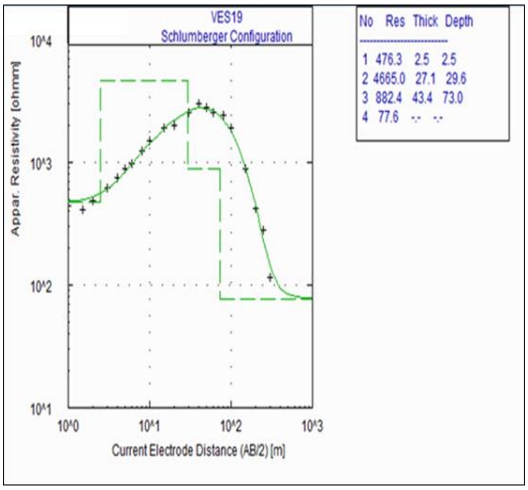


**Figure 4** Modeled curve for VES 19

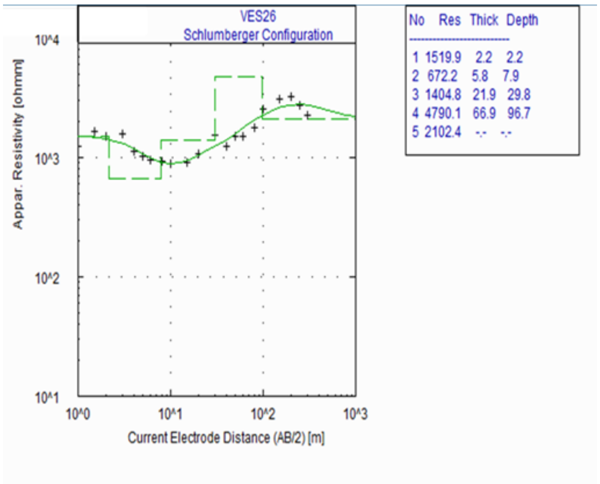


**Figure 5** Modeled curve for VES 26

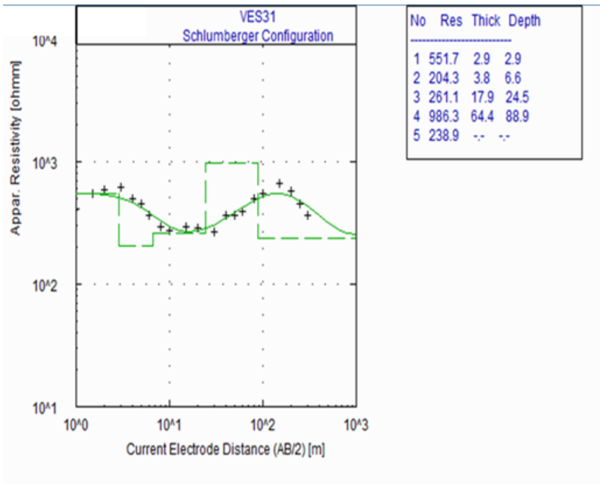


**Figure 6** Modeled curve for VES 31

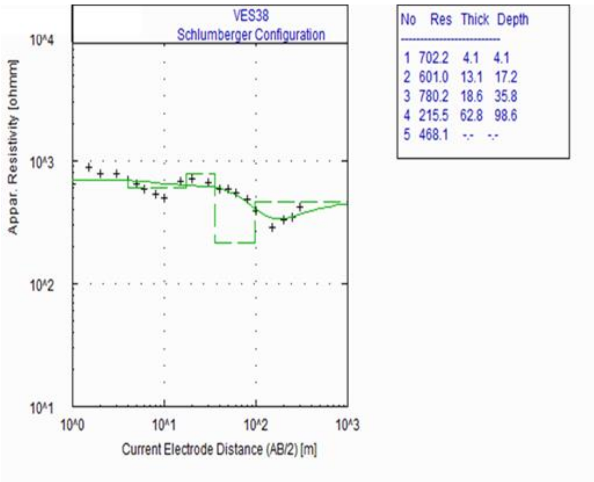


**Figure 7** Modeled curve for VES 38

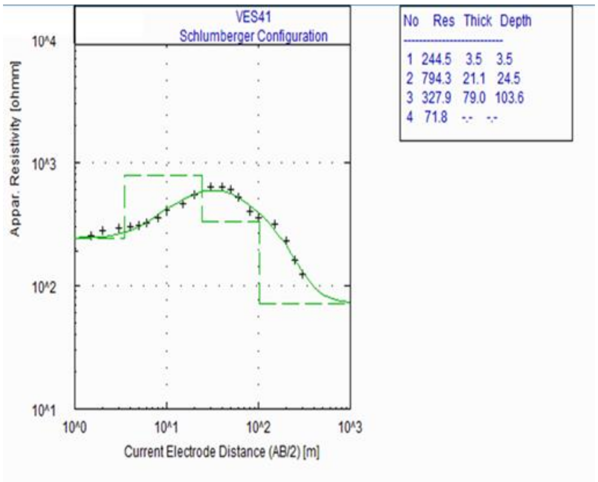


**Figure 8** Modeled curve for VES 41

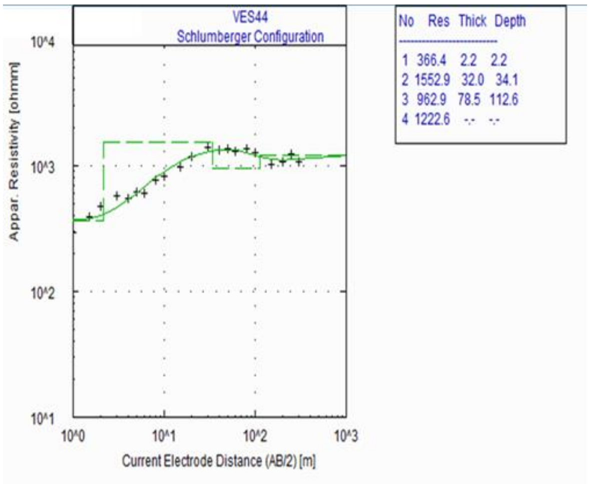


**Figure 9** Modeled curve for VES 44

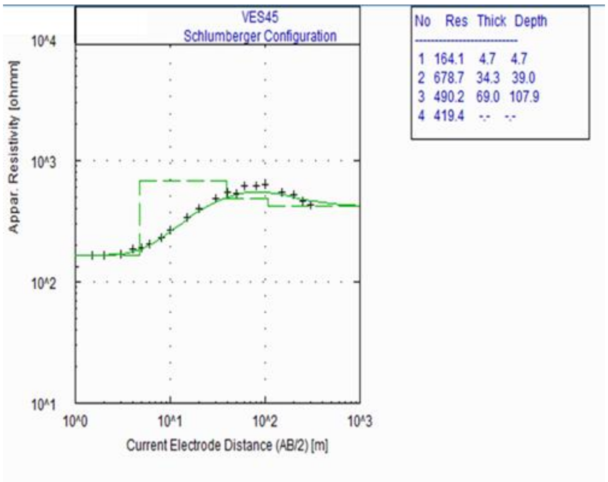


**Figure 10** Modeled curve for VES 45

Various curve types were obtained from the modeling of the VES data. The predominant curve types were KQ (8 VES points), AK (6 VES points), KH (6 VES points), HK (3 VES points), HAK (3 VES points), AKQ (3 VES points), HA (2 VES points) and HKQ (2 VES points). Other curve types such as H, K, Q, AA, QH, HAA, KQH, HKH, HKA, KHH, KHK and AKH were also obtained within the study area. The variability of the curve types was basically due to the inhomogeneity of the explored subsurface indicating the area of study as a transition zone between the Pliocene-Pleistocene Benin formation/Coastal plain sand and the Middle Eocene Bende-Ameke Group

## 4 Conclusion

The study has presented a complete overview of the variation of considered geo-electric parameters across the study area. Aquifer lithologic composition, depth to aquifer and aquifer resistivity values were seen to vary considerably across the various VES locations. Advancing from south to the northern extreme of the study area, aquifer lithologic composition changed from coarse grained sand to fine/coarse grained sand and to clayey sand. Deep seated/confined aquifers reaching an interpreted drill depth of about 110 m were also found northwards compared to an interpreted drill depth of about 22.7 m inland. Most of the aquifers encountered were prolific with some reaching a thickness of over 60 m. Aquifer resistivity values were also found to vary markedly across the area.

## Compliance with ethical standards

### *Disclosure of conflict of interest*

No conflict of interest.

## References


[1] Edet A. Hydrogeology and groundwater evaluation of a shallow coastal aquifer, southern Akwa Ibom State (Nigeria). Appl Water Sci. 2017; 7: 2397–2412.

[2] Bear J. Hydraulic of groundwater. McGraw-Hill International Book, New York. 1979.

[3] Udo AA, Ijeh IB, Eyenaka FD, Agabi DA. Geoelectric Investigation of Groundwater Potentials in Ini Local Government Area of Akwa Ibom State, Nigeria. Journal of Research and Innovations in Engineering. 2019; 4(1) 59-70.

[4] Zaporezec A. Groundwater contamination inventory: A methodological guide. IHP-VI series on Groundwater No. 2, UNESCO. 2012.

[5] World Water Assessment Programme (WWAP). Water: A shared responsibility. The United Nations World Water Development Report. UNESCO, Paris, France. 2016.

[6] International Association of Hydrogeologists. Groundwater— more about the hidden resource. 2020.

[7] Ibuot JC, Akpabio GT, George NJ. A survey of the repository of groundwater potential and distribution using geoelectrical resistivity method in Itu Local Government Area (L.G.A), Akwa Ibom State, southern Nigeria. Cent. Eur. J. Geosci. 2013; 5(4): 538-547

[8] George N, Obianwu V, Udofia K. Estimation of Aquifer Hydraulic Parameters via Complementing Surfacial Geophysical Measurement by Laboratory Measurements on the Aquifer Core Samples. International Review of Physics. 2011; 5(2).

[9] Ijeh IB. Investigation of Variation in Resistivity with depth in Parts of Imo River Basin, South-eastern Nigeria. IOSR Journal of Applied Physics. 2014; 6(1): 47-54.

[10] Evans UF, Abdulsalam NN, Mallam A. Natural vulnerability estimate of groundwater resources in the coastal area of Ibaka community, using Dar Zarrouk geoelectrical parameters. Journal of Geology & Geophysics. 2017; 6(4): 1000295.

[11] Reyment RA. Aspects of the Geology of Nigeria. University of Ibadan Press, Ibadan. 1965.

[12] Kogbe CA. Geology of Nigeria. Rock View (Nigeria) Limited, Jos. 1989; 325-334.

[13] Wright JB. Review of the Origin and Evolution of the Benue Trough in Nigeria. In: Kogbe, C.A., Eds., Geology of Nigeria, Rock View (Nigeria) Limited, Jos. 1989; 359-376.

[14] Edet A, Ramadan A, Broder M, Okereke C. Numerical Groundwater Flow Modeling of the Coastal Plain Sand Aquifer, Akwa Ibom State, SE Nigeria. *Journal of Water Resource and Protection*. 2014; 6: 193-201.

[15] Okwueze EE, Selemo A, Ezeanyim VI. Preliminary lithologic deductions from a regional electrical resistivity survey of Ogoja, Nigeria. *Nigerian Journal of Physics*. 1995; 7: 15-17.

[16] Udo AA, Igboekwe MU, Chukwu GU, Dedan NK, Odeleye IS, Dick MD, Rabiu JA. An Assessment of Nitrate Groundwater Pollution in an Agricultural Area in Akwa Ibom State, Nigeria. International Journal of Scientific & Engineering Research. 2000; 11(2): 89-99.

[17] Akamkpo AO. Use of Vertical Electrical Sounding (VES) and Geographic Information System (GIS) in mapping of groundwater parameters in Umudike, Southeastern Nigeria. Unpublished Ph.D Thesis, Department of Physics, Michael Okpara University of Agriculture, Umudike, Nigeria. 2013.

[18] Bhattacharya PK, Patra HP. Direct Current Geoelectric Sounding: Principles and Interpretation. Elsevier Science Publishing Co., Inc. 1968.

[19] Chakravarthi V, Shankar GBK, Muralidharan D, Harinarayana T, Sundararajan N. An integrated geophysical approach for imaging subbasalt sedimentary basins: case study of Jam River Basin, India. Geophysics. 2007; 72(6): B141–B147.