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Full Length Research Paper

Determination of aquifer characteristics in Eket, Akwa Ibom State, Nigeria, using the vertical electrical sounding method

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This work is about geoelectric investigation involving eight vertical electrical soundings carried out in Okon, Ofriyo, Idua, Ikot Udoma, Atabong, Mkpok, Afaha Eket and Ikot Eket in Eket local government area of Akwa Ibom State, southern Nigeria. The total current electrode spread varied from 300 m to 400 m and this depended on access roads, topography, human settlements and general infrastructure. The survey was aimed at investigating the resistivity of consolidated and unconsolidated formations of the study area and the depth of the Aquifer. The ABEM Terrameter, signal averaging system (SAS) 1000 was used in carrying out the soundings. Data obtained were interpreted using Hemkler computer program. This helped to produce various lithologic deductions for the sites surveyed. In general, there exists a common feature in the resistivity variation pattern of low-high-low in the area. The result shows a wide range of resistivity variation ranging from 0.70 to 27,885.60 Ωm. Four out of the eight sounding curves reflected the presence of four geoelectric layers, while the remaining four sounding curves reflected the presence of three geoelectric layers. The curve types reflected in this study are the K-type curve and the KH-type curve. Locations 4, 5 and 6 were productive (that is, water producing) with shallow aquifer depths of between 16.00 m and 30.40 m from the earth surface. Efforts should be made to check the quality of water in such a region, since aquifer in the region is located at shallow depths from the surface of the earth.

Key words: Vertical electrical sounding (VES), aquifer, resistivity, lithology, terrameter.

INTRODUCTION

Of all the natural resources, water is the most commonly used in all aspects of life. Water is no doubt one of the most essential needs of human beings, for drinking and other domestic purposes. Its presence or lack of it determines to a great extent the nature of the natural environment in which our life and majority of our economic activities depend on (Igboekwe and Akankpo, 2011). Groundwater is a natural resource that is of immense importance to life. Its characteristics are greatly determined by the properties of the immediate geologic formations (Atakpo, 2009; Akankpo and Igboekwe, 2011). Groundwater constitutes over 90% of the world's readily available freshwater resources with the remaining 10% in lakes, reservoirs, rivers and wetlands (Baswinkel, 2000; Asonye et al., 2000).

Groundwater is often contained in aquifers. An aquifer is an underground water saturated stratum of formation that can yield usable amount of water to a well. There are two different types of aquifers based on physical characteristics. If the saturated zone is sandwiched between layers of impermeable materials, it is called a confined aquifer; if there is no impermeable layer immediately above the saturated zone, it is called an unconfined aquifer. Usually, an aquifer can produce an economically feasible quantity of water to a well or spring (Humblin, 1989; Okwueze, 1996). Aquifer characteristics are greatly influenced by formation strata and terrain type (Akpokodje and Etu-Efeotor, 1987). Hence, the acquisition of viable deep water wells is mainly dependent on adequate and reliable empirical knowledge

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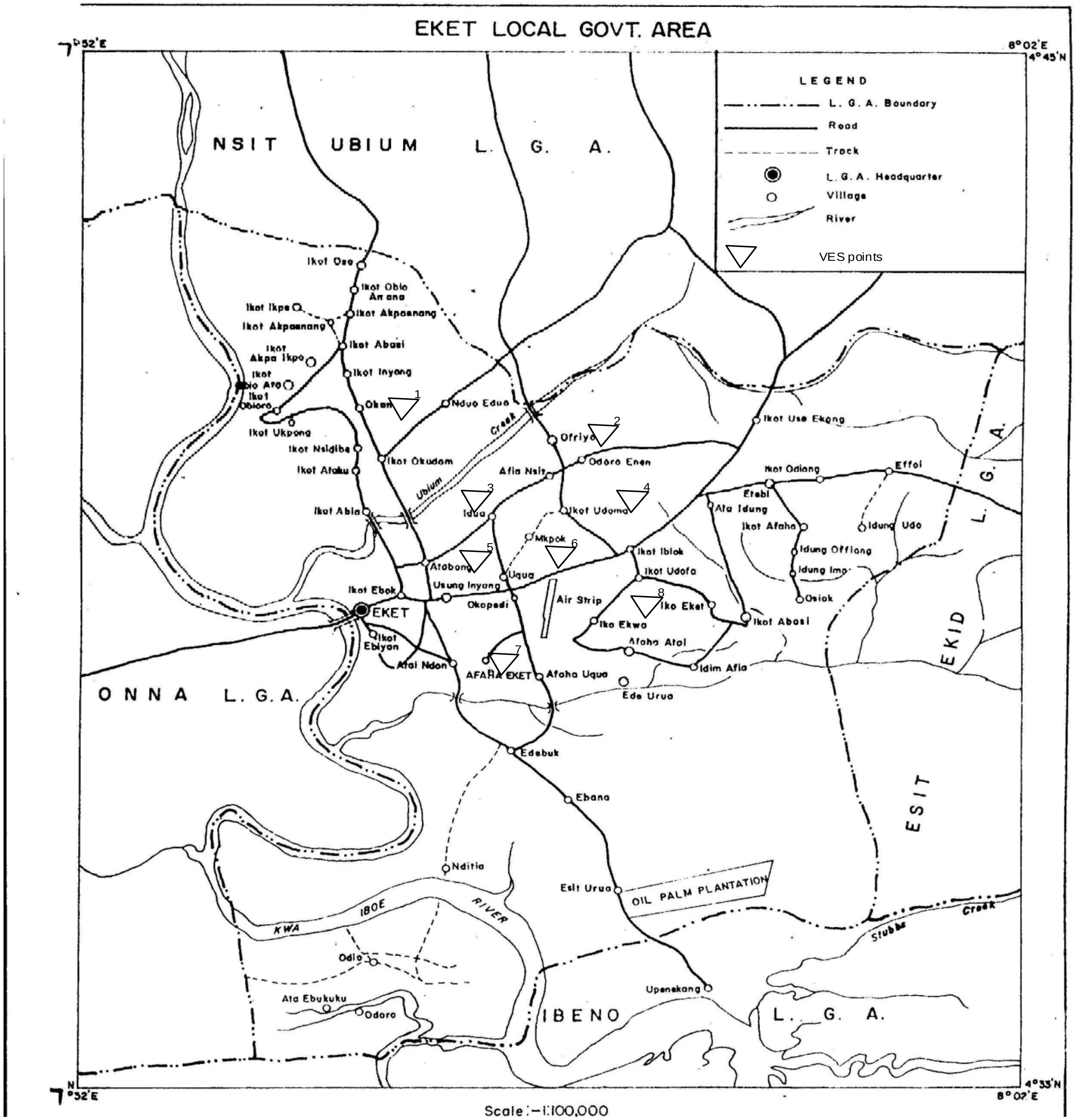

Figure 1. Base map of the study area showing vertical electrical sounding points.

of the geology of the area and the depth of aquifer (Okolie et al., 2005; Okolie, 2011). This study was therefore carried out to ascertain the formation strata and aquifer characteristics in Eket area of Akwa Ibom state of Nigeria.

In Eket, Akwa Ibom State (Figure 1), bore holes are drilled by mini companies whose personnel do not keep careful records of the depths at which water (aquifer) was obtained over time. In this study, eight electrical resistivity soundings using ABEM Terrameter SAS 1000 were carried out. Schlumberger electrode spread ranging from 300 to 400 m was maintained. The aim was to provide careful records of depths at which water could be obtained in Eket local government while drilling. Further

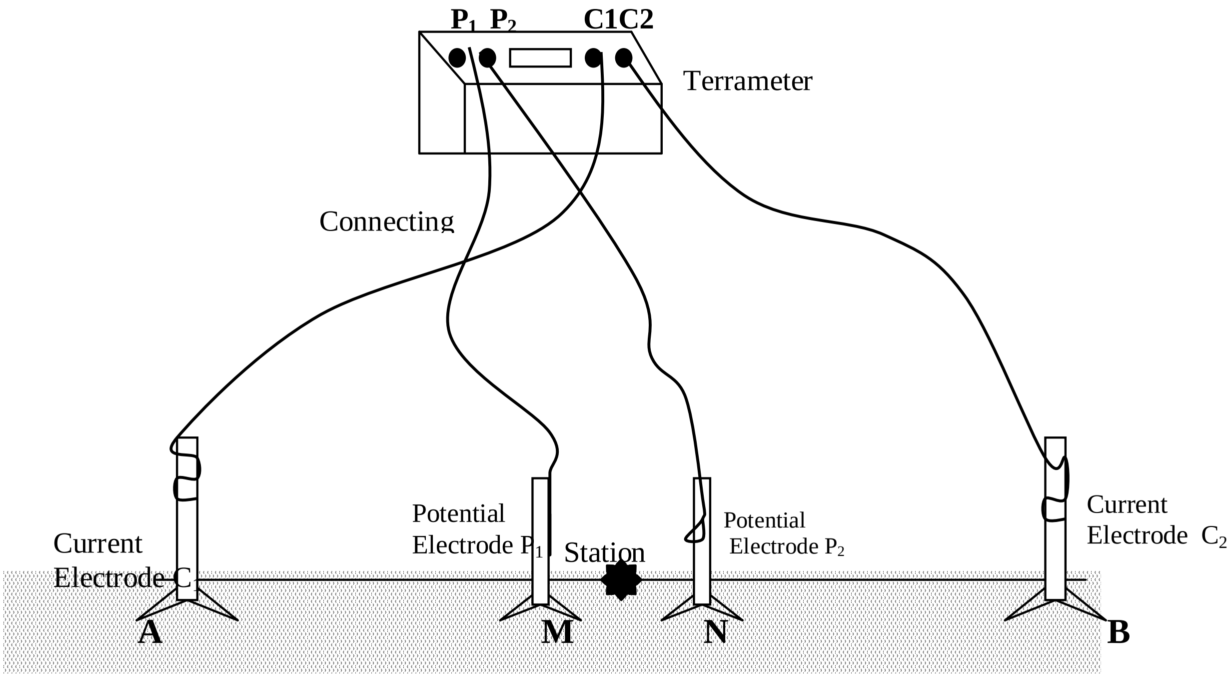

Figure 2(a). Vertical electrical sounding field layout for Schlumberger array.

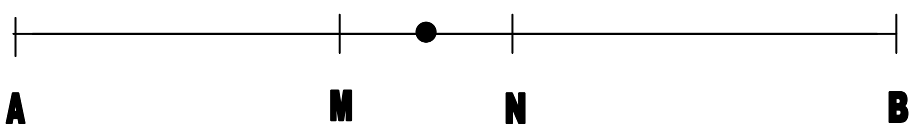

Figure 2(b). Schlumberger array.

analysis of the aquifer, using the data obtained was made thereafter.

Eket is located between latitude 4°33[1] and 4°45[1] and between longitude 7°52[1] and 8°02[1] (Figure 1). The area is underlain by sedimentary formation of Late Tertiary and Holocene ages. Deposits of recent alluvium and beach ridge sands occur along the coast and the estuaries of the Imo and Qua Iboe Rivers, and also along flood plains of creeks. The area consists mainly of coastal plain sands. The sands are mature, coarse and moderately sorted. The coastal plain sands otherwise known as the Benin Formation overlies the Bende-Ameki Formation and dips southwestward (Mbonu and Ebeniro, 1991). The landscape of Eket comprises of a generally low-lying plain and riverine areas with no portion exceeding 175 m above mean sea level. The physiography of Eket is that of a beach ridge complex characterized by a succession of sub parallel sand ridges.

MATERIALS AND METHOD

Variation of electrical conductivity is investigated here with the help of electrical resistivity sounding. Eight Schlumberger vertical electrical soundings (VES) were collected using a maximum current electrode separation of AB/2 of 400 m. Digital averaging equipment, the ABEM SAS 1000 Terrameter, was used for direct current (DC) resistivity work. The instrument displays directly the apparent resistivity of the subsurface under probe. It has an in-built dc power source. Four stainless metal stakes were used as electrodes (Igboekwe et al., 2006; Okwueze, 1996).

The Schlumberger electrode configuration was used in all the soundings. In the Schlumberger configuration, all the four electrodes are arranged collinearly and symmetrically placed with respect to the centre. In this array the potential electrode separation is very small compared to the current electrode separation (Figure 2a and b).

The distance between the potential electrodes is increased only when the signal is too small to measure. Apparent resistivity ρ_a is given by

$$\rho_a = \pi \left\{ \frac{\left[\frac{AB}{2}\right]^2 + \left[\frac{MN}{2}\right]^2}{MN} \right\} \frac{V}{I} \qquad (1)$$

where $AB/2$ is half the current electrode separation and $MN/2$ is half the potential electrode separation (Dobrin, 1983). The apparent resistivity is plotted against half the current electrode spacing on a double logarithmic graph. To get the layer parameters (resistivity and thickness) of the subsurface, these sounding curves

Table 1. General VES results from computer modeling.

VES No	Location	ρ_1 (Ωm) h_1 (m)	ρ_2 (Ωm) h_2 (m)	ρ_3 (Ωm) h_3 (m)	ρ_4 (Ωm) h_4 (m)	Total thickness	No of layers	Curve type
1	Okon	333.00 0.90	1375.30 14.00	344.00 45.00	451.20 -	59.90	4	KH
2	Ofriyo	801.30 5.60	5184.70 26.30	149.90 -	- -	31.90	3	K
3	Idua	963.40 6.80	27,885.60 37.70	585.20 -	- -	44.40	3	K
4	Ikot Udoma	622.30 2.70	949.60 16.00	166.80 26.90	438.20 -	48.60	4	KH
5	Atabong	705.10 0.90	1392.20 18.00	518.30 47.50	732.40	66.50	4	KH
6	Mkpok	245.00 3.10	8749.20 30.40	631.10 -	- -	33.50	3	K
7	Afaha Eket	1150.10 0.70	1250.20 12.30	980.20 67.30	1800.40 -	80.30	4	KH
8	Iko Eket	1436.00 2.10	711.90 7.40	2013.30 -	- -	9.50	3	H

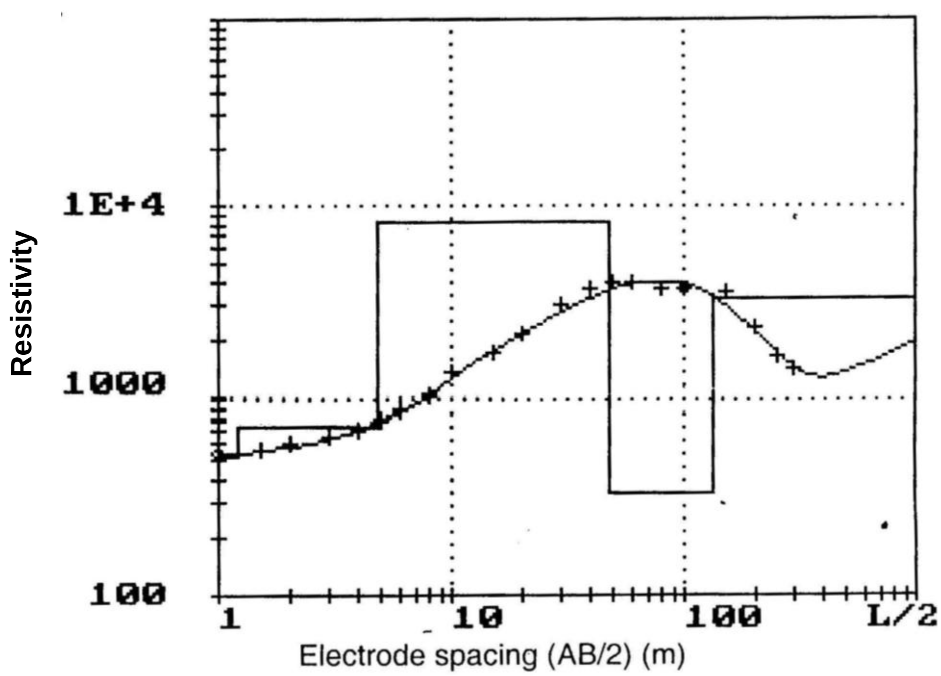

Figure 3. A computer modeled curve of VES 3 at Idua.

are first interpreted with the help of theoretically computed master curves by partial curve matching and drawing auxiliary point diagrams (Igboekwe et al., 2006; Griffiths and King, 1981; Zohdy and Bisdorf, 1989). Based on this preliminary interpretation, initial estimation of the resistivities and thicknesses of the various geoelectric layers were obtained. These were later used as starting point models for a fast computer assisted interpretation. The VES computer modeling programme, Schlumberger automatic analysis, version 0.92 (S.A.A. V.0.92) developed by Hemkler in 1985 was employed in the modeling of the VES data. The results of this computer modeled data and curves are shown in Table 1 and in Figures 3, 4 and 5.

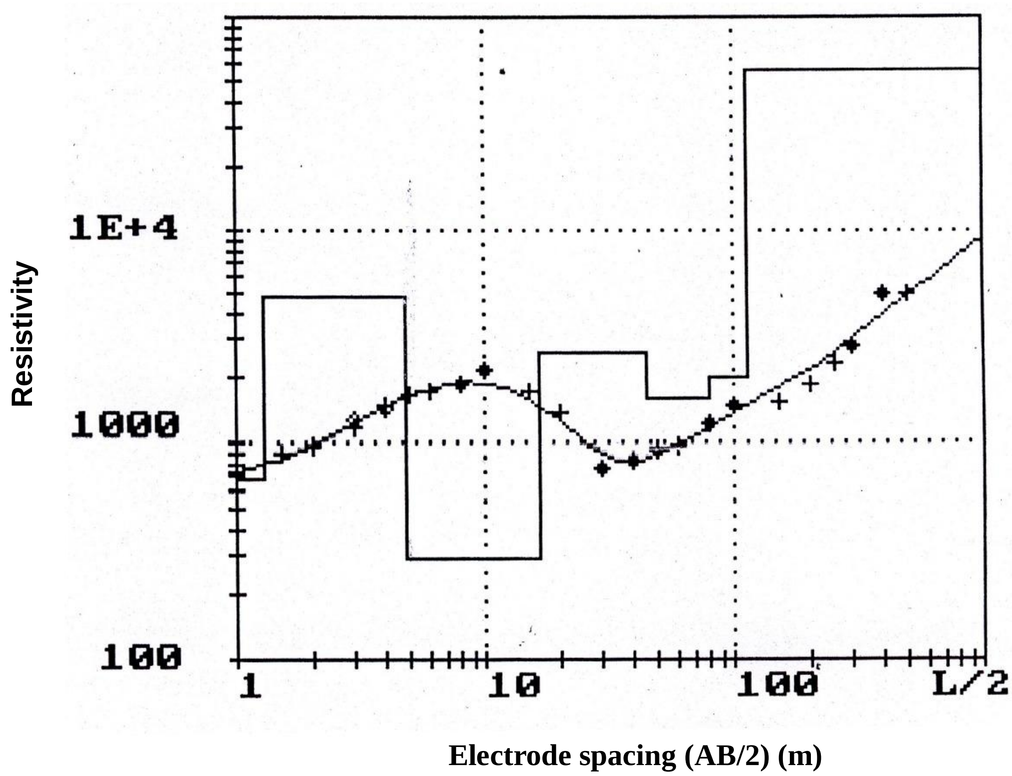

Figure 4. A computer modeled curve of VES 5 at Atabong.

RESULTS AND DISCUSSION

Table 1 shows the result of the computation of resistivity and depth at each measurement point done with the Hemkler computer program (Hemkler, 1985). The software performs inversion of resistivity sounding data collected using Schlumberger array. The computer modeling results for all the sounding locations in the area show that three or four layers could be distinctly defined (see Table 1). For VES 1, a four layered lithologic deduction was obtained. The first layer has a resistivity value of 333.0 Ωm and thickness of 0.90 m. The second layer has a resistivity value of 1375.3 Ωm and a thickness of 14.0 m. The third layer has a resistivity value of 344.0 Ωm and a thickness of 45.0 m while the fourth layer has a resistivity value of 451.2 Ωm and an indefinable thickness. The lithologic deduction showed that the first layer with resistivity 333.0 Ωm is medium sand. The second layer is coarse sand. The third layer is medium sand and the fourth layer is coarse sand.

The Lithologic deduction for VES 2 showed the presence of three layers: the first layer being medium sand, the second layer being coarse sand and the third layer being fine sand. The first layer has a resistivity value of 801.3 Ωm, a thickness of 5.6 m. The second layer has a resistivity value of 5184.7 Ωm and a thickness of 26.3 m while the third layer has a resistivity value of 149.90 Ωm.

VES 3 presents a three layered lithologic unit. The first layer has a resistivity value of 963.4 Ωm and a thickness of 6.8 m. The second layer has a resistivity value of 27885.6 Ωm and a thickness of 37.7 m, while the third layer has a resistivity value of 585.2 Ωm. The first layer is medium sand; the second layer is gravel, while the third layer is medium sand.

VES 4 presents a four layered lithologic units. The first layer is medium sand with a resistivity value of 622.3 Ωm and a thickness of 2.7 m; the second layer is medium-coarse sand with a resistivity value of 949.6 Ωm and a thickness of 16.0 m. The third layer is fine sand with a resistivity value of 166.8 Ωm and a thickness of 26.9 m, while the fourth layer is medium sand with a resistivity value of 438.2 Ωm.

VES 5 represents another four layered lithologic units. The first layer is medium sand with a resistivity value of 705.1 Ωm and a thickness of 0.9 m; the second layer is medium-coarse sand with a resistivity value of 1392.2 Ωm and a thickness of 18.0 m. The third layer is fine sand with a resistivity value of 518.3 Ωm and a thickness of 47.50 m, while the fourth layer is medium sand with a resistivity value of 732.4 Ωm.

VES 6 presents another three layered lithologic unit. The first layer has a resistivity value of 245.0 Ωm and a thickness of 3.1 m. The second layer has a resistivity value of 8749.2 Ωm and a thickness of 30.4 m, while the third layer has a resistivity value of 631.1 Ωm. The first

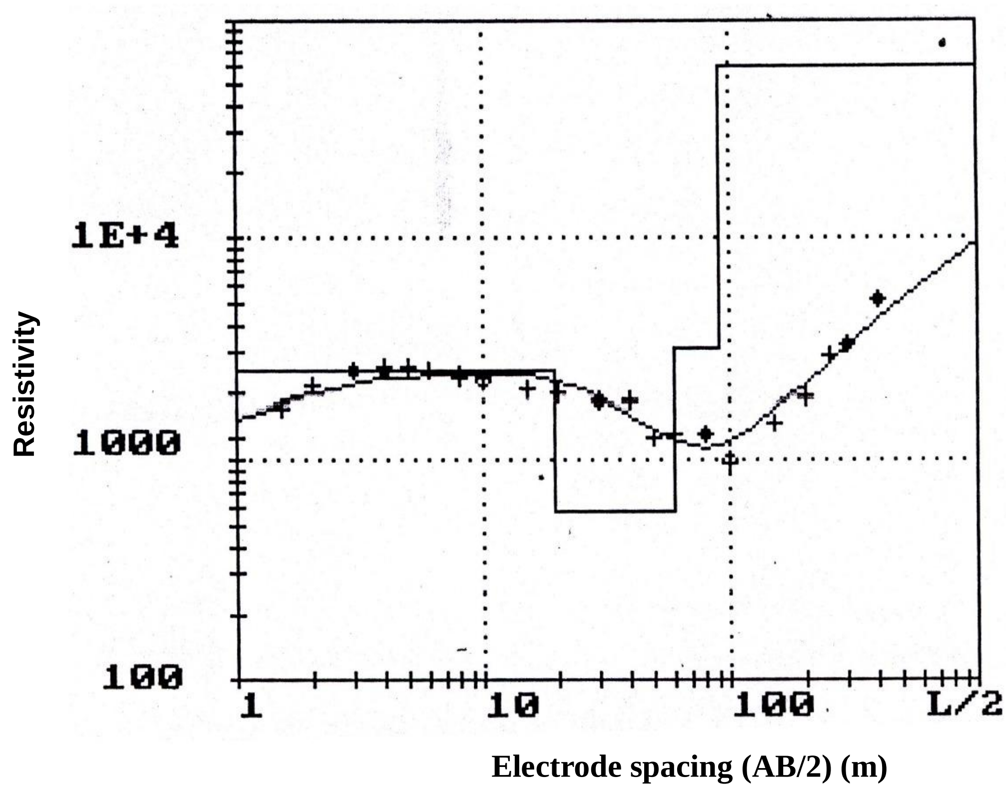

Figure 5. A computer modeled curve of VES 7 at Afaha Eket.

layer is fine sand; the second layer is coarse sand, while the third layer is medium sand.

VES 7 represents another four layered lithologic units. The first layer is coarse sand with a resistivity value of 1150.1 Ωm and a thickness of 0.7 m; the second layer is medium-coarse sand with a resistivity value of 1250.2 Ωm and a thickness of 2.1 m. The third layer is medium sand with a resistivity value of 980.2 Ωm and a thickness of 12.3 m, while the fourth layer is medium sand with a resistivity value of 1800.4 Ωm.

VES 8 has three lithologic units. The first layer has a resistivity value of 1436.0 Ωm and a thickness of 2.1 m. The second layer has a resistivity value of 711.9 Ωm and a thickness of 7.4 m, while the third layer has a resistivity value of 2013.3 Ωm. The first layer is coarse sand; the second layer is medium sand, while the third layer is coarse sand.

In general, there exists a common feature in the resistivity variation pattern of low-high-low in the area. The result shows a wide range of resistivity variation ranging from 0.7 to 27885.6 Ωm. Four of the eight sounding curves reflected the presence of four geoelectric layers, while the remaining four reflected the presence of three geoelectric layers. The curve types presented in this study are the K-type and the KH-type curves (Figures 3, 4 and 5). Locations 4, 5 and 6 were water producing with shallow aquifer depths of between 16.0 and 30.4 m from the earth's surface. These locations showed the presence of fine, medium and coarse grained sands.

Conclusion

In Eket area of, Akwa Ibom State, aquifers are located at very shallow depths. The depth ranges from 16.0 to 30.0 m from the earth's surface. This means that it is more economical to sink boreholes in such a region than in other regions with deeply buried aquifers. Since good aquifer is not found at every site investigated, it becomes necessary to carry out preliminary geophysical surveys before sinking boreholes in such a region. This is to avoid economic wastes. It is further recommended that efforts should be made to examine the quality of water in such a region because of the shallowness of aquifers in the region.

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