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Resistivity Survey For Aquifer Delineattion Using Vertical Electrical Sounding (VES) A Case Study Of Ogbogoro Local Government Area, Port Harcourt, Rivers State, Nigeria.

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ABSTRACT

This study was carried out within Obio-Akpor Local govt. area of Rivers state to determine groundwater potential and aquifer properties, to meet rising demand of potable water, arising from steep population growth as well as enhance supply. The Electrical Resistivity method (VES) technique, Schlumberger configuration and ABEM SAS 300 Terameter was employed to investigate and determine overburden thickness and layer resistivity. The resistivity data retrieved from the terameter is processed, analyzed and interpreted to determine needed information such as geology, layer thickness and potential of groundwater in the area. The results were presented in terms of resistivity, depth and thickness which revealed that the area of study has five geo-electric sections and an AK- type sounding curve. The geo-electric layers also range from 1.98m-62.27m, while the water table is at a depth of 40m from the surface. From the interpretation, the area is composed of topsoil and sand.

INTRODUCTION

1.1 Background to study

"Groundwater is defined as water in the zone of saturation and from which wells, springs and underground runoff are supplied." This is usually stored in geological formations (Palacky et al, 1981). The increased interest in recent years ground water has led to a need for more intensive studies of the geometry and properties of aquifers. This is because over half of the world population depends on ground water for domestic, industrial, as well as agricultural purposes.

Geophysics has played a useful part in ground water explorations for many years and improvements in instruments and the development of better methods is resulting in a widening of its applications. A geophysical model created can be used to support other studies which involve primarily one, two, and three-dimensional modelling. Resistivity imaging is one of the geophysical surveys which have been used to map groundwater and is widely used for environmental surveys. This technique has been used to determine subsurface resistivity anomalies and recently it has become popular for the investigation of water movement in vadose zones. The growing population in Obio/Akpor has been projected to be about 2million by 2018. As a result, the water supply must be efficient to meet the water demand of inhabitants in the area. An electrical resistivity survey has been adopted in groundwater exploration and has helped in revealing the geology of the subsurface layer. The objective of vertical electric sounding is to deduce the variation of resistivities with depth below a given point and correlate it with available geological information to infer groundwater depth while determining layer of promising well or yield. The electrical resistivity of the surface is a function of the pore spaces between the particles which allow electric current to flow through it. Therefore, layers with large pore spaces such as sand and sand stones will have a high resistivity value compared to a clay layer with higher pore spaces between its particles. The nature of the sub surface resistivity when the electric current is injected into it is processed and analyzed to give the different lithology and thickness of the layers present and Information about the components of the different layers can infer presence of groundwater in the area.

Banjo (2008) carried out vertical electrical soundings in Hara, Remo in Nigeria within a sedimentary basin, using the Schlumberger configuration. A total of ten VES stations revealed 3-5 layers which include top soil, clayey/sand clay, clayey sand, conglomerate sandstones and wet sands, with resistivity values ranging from133.3Ωm- 8095. 6Ωm.They concluded that the probable stations more suitable for making boreholes were station VES 1,2,3.The results obtained showed that the study area has good land for boreholes and other engineering and agricultural activities that enhance groundwater and storage. Opara et al. (2012) using vertical electrical sounding technique, carried out geophysical evaluation of Ngor-Okpala area and its environs in Southe a s t e r n Nigeria. They evaluated the frequency, nature, and hydraulic parameters of the aquifers of the area with a total of twenty-eight (28) VES stations with maximum electrode spacing AB/2=500m using the ABEM terameter. The interpretation of data obtained from combined matching of VES curves and geophysical software revealed an average of six (6) geo electric sections and determined the water table depth of between 18m-62m as well as aquifer thickness ranging from 24m-84m.The hydraulic conductivity ranged from 9.21m/day to 10.27m/day. The study area was eventually recommended as a homogenous geological environment with excellent aquifer potential, as well as characteristics such as high yielding capacity and transmissivity. Okolie, et al. (2010) carried out a geophysical survey in Ogume, delta state. The survey showed existing ground water distribution using SAS 300 terameter in the Schlumberger array. The results revealed resistivity curve types, A, H, and Q. Some of the sites, having high resistivity values, contained medium to coarse grain gravelly sand which are indicative of high bearing aquifers. The need for adequate water supply has always been the primary concern of our societies, especially in semi-arid and arid regions, and even the areas with abundant rainfall such as tropical regions. The problem of gaining an adequate supply of quality water is generally becoming more severe due to ever increasing population, irrigation, and industrialization. Geophysical methods are known to be the most accurate means delineating aquifers for proper groundwater development. If aquifers are not properly delineated, there are bound to be failed borehole projects, this study will be useful in delineating aquifers in Ogogoro so that productive boreholes can be drilled in the area.

Therefore, the aim of this study was to delineate aquifers in the area for ground water abstraction. To achieve this aim, the following objectives must be considered. (i)Delineation of aquifers in the area using vertical electrical sounding. (ii)Determination of the thickness of the delineated aquifers. (iii)Recommending appropriate drill depths in the area, for successful drilling of boreholes. (iv) Determine the depth to water bearing formations in the area. (v)accurate drill depths of boreholes in the area.

2.0 MATERIALS AND METHODS

2.1. Study area

Ogbogoro community is found in Obio-Akpor L.G.A. of Rivers State, Nigeria. Obio- Akpor is bounded by Port Harcourt (L.G. A) to the south, Oyigbo to the east, Ikwerre to the north, and Emuoha to the west. It is located between latitudes 4° 45' N and 4° 60'N and longitudes6° 50'E and 8° 00' E. The study area is accessible through the Ozuoba-Ogbogoro Road; as well as other roads leading to the are

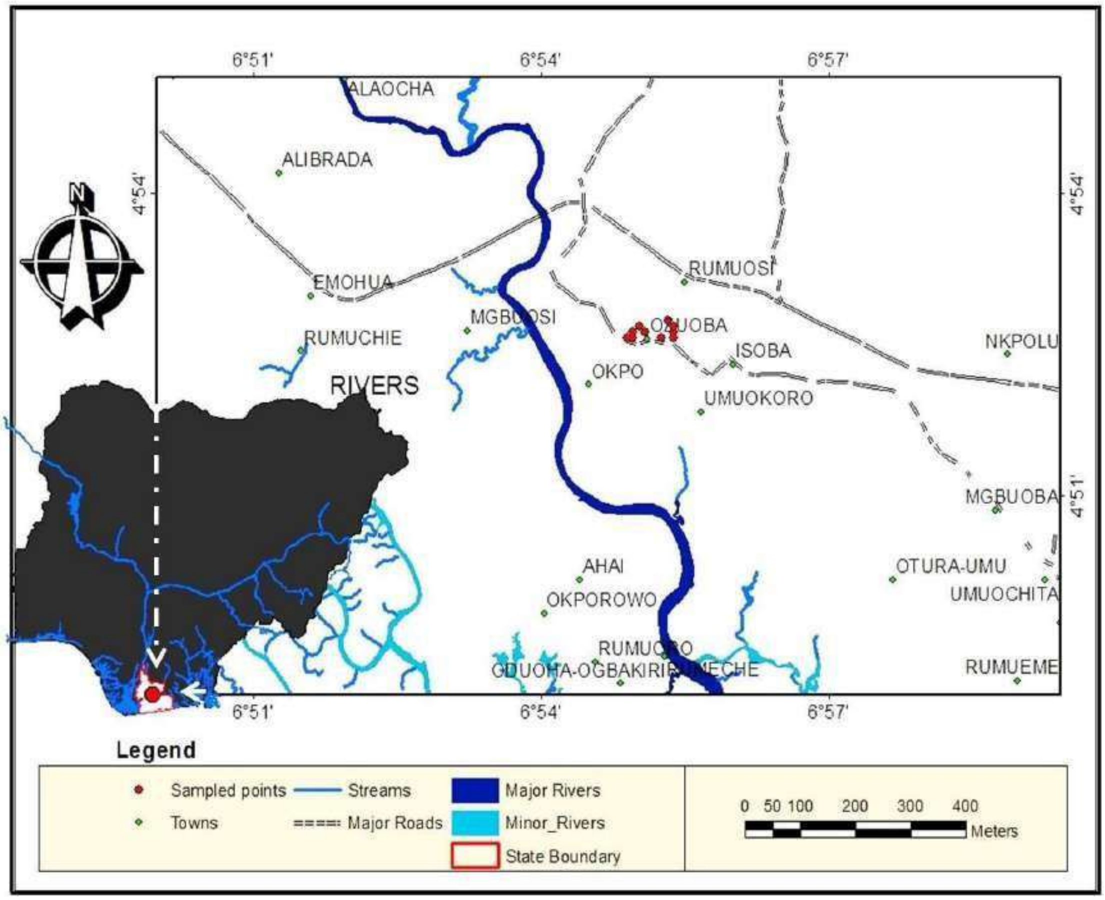

Fig 1: Map of the study area

2.1.1. Climate and Vegetation

Generally, Nigeria has a tropical climate that is dominated by two seasons, namely dry and rainy seasons. Annual rainfall in the Niger Delta is high and varies from500mm per annum at the coasts, to about 300mm at the northeastern parts of the delta and peaks during the months of June, July and December. During the rainy seasons, torrential rainfall occurs after the monsoon season, which occurs between April and October and may be experienced between April and November, while dry conditions prevail between the months of November and March (Etu-Efeotor and Odigi,1983).

2.1.2. Temperature:

High temperature recorded in the region is occasioned by its proximity to the equator. A mean temperature of 27°C is obtained, while temperatures in the coastal areas are highest in February, March, and April. At an average temperature of 27.6 Annual temperatures are typically between 25°C to 28°C.

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Drainage: Drainage in the study area is poor, being relatively low lying, with much surface water and high rainfall. Some parts of the area tidally flooded while other parts may be flooded seasonally. The area is drained by mainly freshwater systems and tidal systems. Riverbank levees are prominent and valley side slopes are very gentle and experience a great deal of erosion and accretion. Due to high rainfall, the soil in the area is usually sandy or sandy loam. It is usually leached underlain by an impervious pan.

2.1.3. Geology and hydrogeology of the area.

The Niger Delta is geologically known to have three main stratigraphic units namely Benin, Agbada, and Akata formation. The area is geologically composed of various quaternary deposits that override the three main stratigraphic units of Benin, Agbada, and Akata Formations. This includes the upper delta lithofacies, the Benin formation; the delta-front lithofacies, the Agbada Formation and the pro-delta marine shale. The modern Niger Delta comprises of three basic units, which include: The Akata Formation, the Agbada Formation and the Benin Formation. The Akata Formation ranges from Paleocene to Holocene. It is the lowest and oldest litho- stratigraphic unit in the Niger Delta complex. It is a mobile formation and can be squeezed into shale diapirs in the basin that are formed from being over pressured and not being dehydrated properly. This Formation is estimated to be up to 7000m thick, containing planktonic foraminifera which indicates a shallow marine shelf depositional environment (Etu-Efeotor, 1997). The Agbada formation: The Agbada Formation dates to the Eocene in age. The formation overlies the Akata Formation in a sequence of sandstone and shale. It is a marine facies defined by both fresh water and deep-sea characteristics comprising of minor shale interactions in an upper dominant sandy unit and a lower shale unit thicker than the overlying upper sandy unit. This Formation is estimated to be 3700metres thick and is rich in micro fauna at the base. Benin formation: The Benin Formation is Oligocene and younger in age. It is the topmost unit of the Niger Delta complex. It overlies the Agbada Formation. It is composed of upper deltaic plain deposits, continental flood plain sands and alluvial deposits, consisting mainly of fine to coarse sands and gravel which may be consolidated or unconsolidated. It is estimated to be up to 2000m thick and is the most prolific aquifer in the Niger Delta.

Table 1: Geologic units of the Niger Delta (After Short and Stauble, 1967)

Geologic Unit	Lithology	Age
Alluvium(general)	Gravel, sand, clay and silt	Quaternary
Freshwater back swamp membe belt	Sand, clay, some silt gravel	Quaternary
Mangrove and salt water, back swamps	Medium-fine sands, clay and some silts	Quaternary
Active/abandoned beach, ridge	Sand, clay and some silt	Quaternary

Sombrero-Warri deltaic plain	Sand, clay and some silt	Quaternary
Benin Formation (Coasta plain sand)	Coarse to medium sands with subordinate sil and clay lenses	Miocene
Afam clay member		Oligocene
Agbada Formation	Mixture of sand, clay, and silt	Eocene

2.2. Materials

The instrumentation used in carrying out the resistivity survey includes: the ABEM SAS 300 terameter and its accessories like the connecting cables, four electrodes, measuring tapes, geologic hammers and the Global Positioning System (GPS).

Terrameter: The terameter is a compact, digital resistivity meter which is composed of transmitter and receiver functions in one unit, designed to measure extremely weak electrical signal. The instrument can transmit up to 2900mA, which is sufficient for ordinary resistivity surveying. It is highly sophisticated and has an inbuilt battery which was charged before commencement of the survey. Resistivity displayed ranged from 0.1Ω-63.7Ω. **Electrodes**: The four electrodes used (current and potential) were made of steel with a rounded top and a sharp end base for ease of penetration into the ground. They were driven through the surface of the earth, into the subsurface with the aid of a hammer. The electrodes were as well connected to connecting cables. **Cables:** Four Conducting cables were used on the field. Two 250-400mm electrodes were used in connecting the current electrodes (C1 and C2) while the other two were used in connecting the potential electrodes (P1 and P2). **Measuring tape**: The measuring tapes had lengths ranging from 0m-50m and were used to measure the distances between the electrodes (electrode spacing). **Hammer**: The hammer was used to drive the electrodes into the ground for proper electrical contact. **Global positioning system**: The GPS is a very compulsory geological instrument in any geophysical survey. It can be used to note one's location on the globe as regards to longitude, latitude and elevation. The GPS used was a handheld receiver (Garmin nuvi 265W/265WT 4.3-inch-wide screen, portable GPS navigator).

2.2.1. Data acquisition

In this study, a levelled terrain, preferably an open field in the study area, was selected and the Schlumberger array was used in conducting 10 vertical electric soundings. The Schlumberger array consists of four electrodes (current and potential) which were positioned on a straight line, adjacent from each other with the current electrodes C1 and C2 on the outside and the potential electrodes P1 and P2 on the inside. The maximum current electrode spacing AB/2 was 150m. The current electrodes were moved at intervals, while the potential electrodes remained stationery until the observed voltage was too small to be measured. A total of 10 VES soundings were carried out in the study area. The instrument used for this survey, the ABEM SAS 300 terameter, automatically displayed resistance readings for each of the VES points on the read-out screen. The displayed resistance values were jotted down on the VES sheet during the survey. The G.P.S was used in locating and obtaining the coordinates of each VES station.

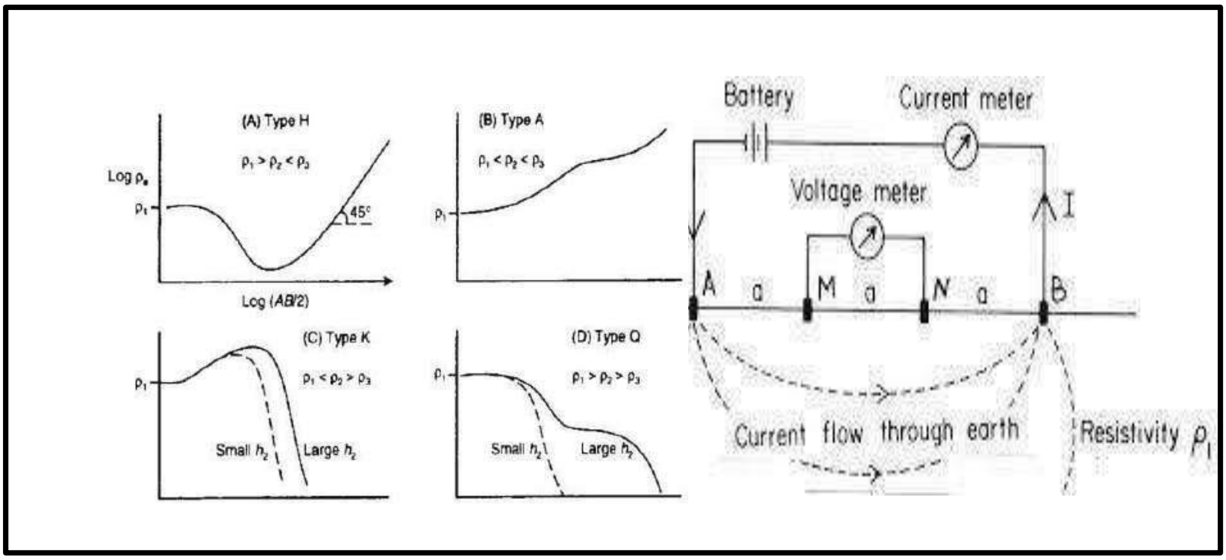

Fig 3.1. Resistivity curve types and Schlumberger array used in the study (Garofalo et al.,2014).

The Schlumberger method involves the supply of direct current or low frequency alternating current into the ground through a pair of current electrodes and the measurement of the resulting potential difference, through another pair of electrodes called potential electrodes.

2.2.1. Data processing

Resistivity data obtained from the vertical electric sounding technique were converted to apparent resistivity values, by multiplication with the geometric factor (K). The calculated apparent resistivity values for each corresponding electrode spacing were used for interpretation. The values were plotted on a graph, against AB/2 (Current electrode spacing) using the log-log sheet, with AB/2 on the abscissa and apparent resistivity on the ordinate axis, respectively. Field resistivity data were processed using computer software IPI2WIN and OFFIX Schlumberger analysis software. This computer program automatically generated model curves, using initial layer parameters (resistivity, thickness, depth and conductance) derived from partial curve matching, with already known standard curves.

2.3. Field operational problem

The electrical resistivity method has some inherent limitations that affect the resolution and accuracy that may be expected from it.

2.3.1. Like all methods using measurements of a potential field, the value of a measurement obtained from a given location represents a weighted average of the effects produced over a large volume of material, with the nearby portions contributing primarily. This tends to produce smooth curves, which are not susceptible to high resolution for interpretation.

2.3.2. Lateral inhomogeneity: this usually degrades the equity of the resistivity data. The problem could be solved by the application of a special configuration, called tri- potential system

2.3.3. Poor electrodes contact brings about data errors, especially if the poor contact is at current electrodes position.

It may occur due to the very dry ground surface and can be remediated by creating saltwater medium around the electrodes.

2.3.4. Dip effect: this occurs in situations where the horizontal interface is dipping. The quality of data is seriously affected, likewise the interpretation. The dip effect may be negligible, if the angle of inclination is below 45º.

2.3.5. Instrument malfunctions

2.3.6. Cable leakages

2.4. Minimization of field operational problems

The layout of electrodes was done with non-conducting measuring tapes, since tapes of conducting materials, if left on the ground during measurement, can influence apparent resistivity values. Resistivity measurements could be affected by metallic fence, rails, pipes and other conducting materials. If left on the ground during measurement, these conductors can influence apparent resistivity values. The effects of such linear conductors may be minimized, but not eliminated, by laying out the electrode array on a line perpendicular to the conductor. Electrical noise and other disturbing factors at site may affect the resistivity survey. The terameter battery was fully charged and overhead tension cables were avoided

3. RESULTS AND DISCUSSION

3.1.1. Results

The Schlumberger array VES was used for the study, specifically the Abem SAS 300 terrameter. Current electrode spacing ranged from 1-150m.The apparent resistivity values pa was plotted against electrode spacing AB/2. The VES results show curve types A, K, KH and AK with varying resistivity trends. The field curves were interpreted by the well-known method of matching using geophysical software IPI2WIN. The results are presented in terms of the resistivity, thickness, depths and the geo- electric sections reveal stratigraphic layers (model) of topsoil, underlying sands of varying sizes in the subsurface.

The lithological interpretations and geology of the resistivity samplings are summarized below:

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VES	Curve type	No. of layers	Resistivity (Ωm)	Thickness (m)	Depth (m)	Lithology	Remarks
1.	AQ	1 2 3 4 5	247 418 4,607 7,696 375	1.29 1.13 9.25 8.2	1.29 2.42 11.7 20	Topsoil Sand Sand Sand	Vadose zone Vadose zone Aquifer Aquifer
2.	A	1 2 3 4 5	211 875 163 7,881 2,079	1.42 1.86 4.47 17.2	1.42 3.28 7.75 24.9	Topsoil Sand Clayey Sand Sand	Vadose zone Vadose zone Aquifer Aquifer
3.	K	1 2 3 4 5	467 628 866 7,528 1.421	1.43 1.95 4.38 20.1	1.43 3.39 7.77 27.9	Topsoil Sand Sand Sand	Vadose zone Vadose zone Aquifer Aquifer
4.	KA	1 2 3 4	373 169 2,382 345	1.4 1.02 16.7	1.4 2.41 19.2	Topsoil Sand Sand	Vadose zone Aquifer Aquifer
5.	KA	1 2 3 4	150 355 973 190	2.51 3.6 16.8	2.51 6.1 22.9	Topsoil Clayey Sand Clayey sand	Vadose zone Vadose zone Vadose zone
6.	KA	1 2 3 4 5	107 1,397 32.1 7,211 1,315	1.01 6.3 2.36 19.6	1.01 7.31 9.68 29.3	Topsoil Sand Clayey sand Sand	Vadose zone Vadose zone Vadose zone Aquifer

7.	KH	1 2 3 4 5	430 1,210 124 5,733 1,517	1.1 6.19 4.41 19.7	1.1 7.29 11.7 31.4	Topsoil Sand Clayey sand Sand	Vadose zone Vadose zone Aquifer Aquifer
8.	H	1 2 3 4	260 574 157 1,631	1.16 0.839 18.4	1.16 2 20.4	Topsoil Sand Sand	Vadose zone Vadose zone Vadose zone Aquifer
9.	KH	1 2 3 4	150 556 160 1,407	1.18 1.71 18.1	1.18 2.89 21	Topsoil Sand Clayey sand	Vadose zone Vadose zone Vadose zone Aquifer
10.	AK	1 2 3 4	149 437 135 1,682	1.63 4.72 17	1.63 6.35 23.4	Topsoil Sand Sand	Vadose zone Vadose zone Vadose zone Aquifer

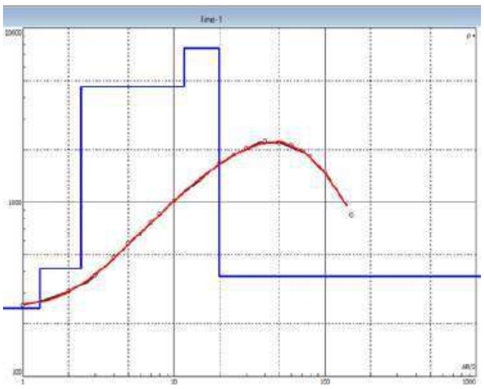


Fig 3.1: Resistivity curve type KA for VES 1

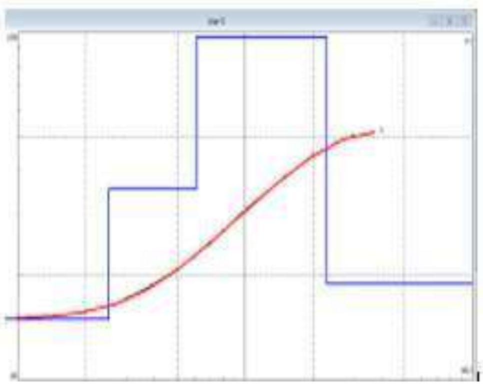
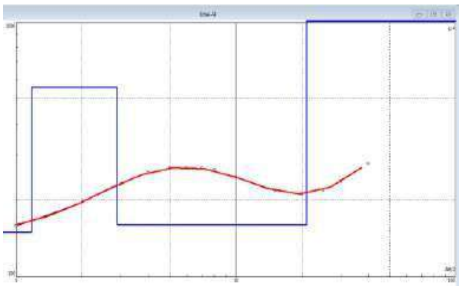


Fig 3.2: Resistivity KA curve-type for VES 2



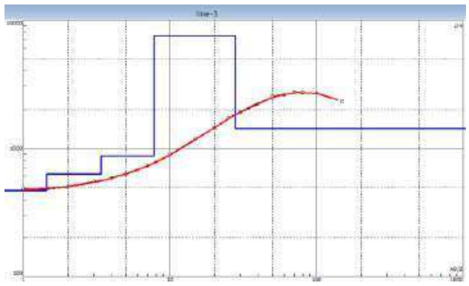
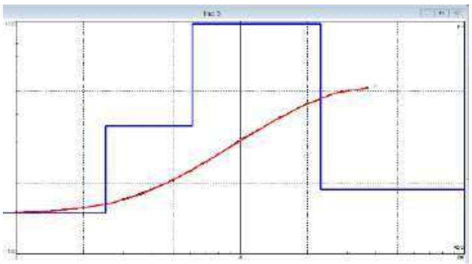


Fig 3.3: Resistivity curve type K for VES 3

Fig 3.4: Resistivity curve type KA for VES 4



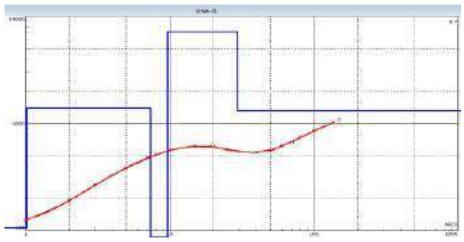
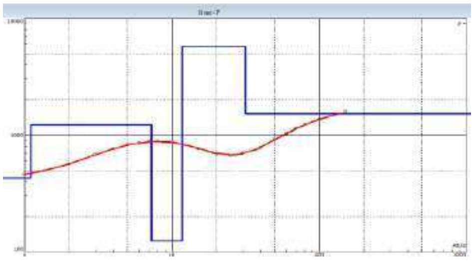
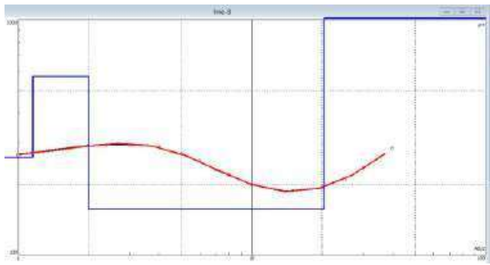
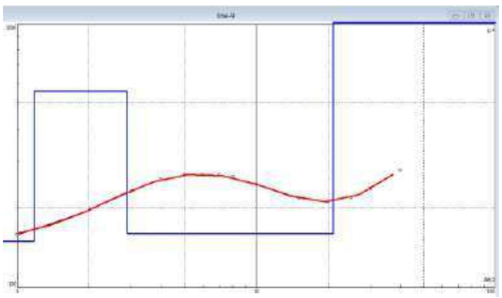


Fig 3.5: Resistivity curve type KA for VES 5

Fig 3.6: Resistivity curve type KA for VES 6







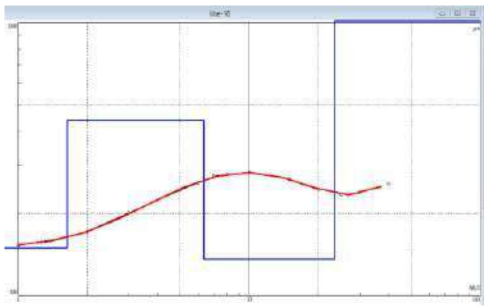


Fig 3.7: Resistivity curve type KH for VES 7

Fig 3.8: Resistivity curve type H for VES 8

Fig 3.9: Resistivity curve type KH for VES 9

Fig 3.10: Resistivity curve type AK for VES 10

3.1.2. Discussion

VES 1: The resistivity trend for VES Curve shows P1<P2<P3<P4>P5, having VES Curve type AQ. The geo-electric section reveals five layers with resistivity values 247,418,4,607,7696 and 375Ωm respectively and sand-clay lithologies. The increasing resistivity values with depth indicate the presence of fresh water in the subsurface. (Muhammad. A., *et al* 2007) The maximum depth probe of this sounding was 20m, and the static water level was delineated to be at a depth of 11.7m. This sounding consists of two probable aquifers having a high resistivity value of 4,607Ωm and 7,696Ωm in the 3rd and 4th layers respectively.

VES 2: The composition of the geo-electric layers includes lateritic topsoil, clay and sand. The geo-electric section also reveals five subsurface layers with minimum resistivity value 211Ωm and maximum of 2,089Ωm. The resistivity trend P1<P2>P3<P4<P5.The decreasing resistivity values from P3 to P5 may indicate the presence of heavy metals which accounts for increasing conductance. The topsoil at a depth of 1.42m has the lowest resistivity value of 211Ωm, thus having the highest moisture content and the fifth layer, at a depth of 24.9m has a resistivity value of 2,079Ωm. There exists two aquiferous layers in the 4th and 5th layers at depths of 24.9m and below having apparent resistivity values 7,881Ωm and 2,079Ωm respectively. The thickness of the aquifer in the 4th layer is 17.2m.

VES 3. The results of resistivity sounding 3 show K-type curve which is indicative of a high resistivity layer sandwiched between two low resistivity values. The resistivity trend for this sound isP1<P2<P3, P4>P5, with maximum resistivity value of 7,528Ωm in the 4th layer as revealed in the geo-electric section in Fig 4.6. The increasing resistivity with depth occurs as electrode spacing increases. This region consists of two aquifers; the first aquifer has apparent resistivity value of 7,528Ωm at a depth of 27.9m and overburden thickness of 20.1m. The 2nd,3rd,4th, and 5th layers are majorly composed of sand. Underlying the topsoil, is a relatively thin layer of sand (3.39m) beneath which the static water level exists at a depth of 23. 37ft.There exists one aquiferous layer, which is the first layer having good quality fresh water in the sub surface.

VES 4: Resistivity sounding curve type 4 shows increasing resistivity values from P1- P3 and a reduction from P3 to P4 between the 3rd and 4th layers. P1>P2<P3>P4.The geo- the highest resistivity value is that of the 3rd geo-electric layer (2,079), at a depth of 19.2m from the surface as well as over burden thickness of 16.7m. This layer is aquiferous and has good potential for fresh ground water. It is composed of loose sands with relatively high. moisture content.

VES 5. The resistivity trend for VES 5 shows P1<P2<P3>P4 with maximum apparent resistivity in the third layer (973Ωm) which is composed of loose coarse sands at a depth of 68.7ft and thickness of 16.8m. The reason for the sudden decrease in apparent resistivity could be attributed to grain size variation as depth increases. The topsoil is at a depth of 2.51m from the surface, while the 4th and last layer is found at a depth below 22.9m. As indicated from resistivity values, the probable aquiferous layer in this region, being the 3rd layer has no fresh water in the subsurface. This region has poor aquifer conditions and arguably no prospect zone.

VES 6: The resulting curve type (KA) is indicative of a high resistivity layer sandwiched between two low resistivity layers and decreasing depth. The resistivity trend here; P1<P2>P3<P4>P5 indicates a random increase and decrease in apparent resistivity values which may be because of mixed lithologies in the first three layers. The geo-electric section reveals twoaquiferous layers as the 3rd and 4th layers with apparent resistivity values 7,211Ωm and 1,315Ωm respectively, both existing at depths below 29.3m. The third layer is a more prolific aquifer than the fourth as revealed by its high apparent resistivity value. The topsoil, at a depth of 1.01m from the surface comprises basically of a mixture of laterite and clays. This heterogeneity in the top layer accounts for the large difference in apparent resistivity values of the topsoil and the underlying second layer. (Alaminiokumah G.I., *et al* 2017).

VES 7: The apparent resistivity trend shows P1<P2>P3<P4>P5, with maximum apparent resistivity value 5,733Ωm in the fourth layer. The geo-electric layers reveal only one aquiferous layer, being the 4^{th} layer at a depth of 31.4m, having an overburden thickness of 19.7m. The maximum apparent resistivity value is seen in the 4^{th} layer and the minimum in the third layer (124Ωm). The final and 5^{th} layer have a resistivity value of 1,517Ωm and this layer is interpreted as sand.

VES 8: The apparent resistivity curves indicate that there were four sub surface layers. These layers consist of topsoil and sand, of identifiable thickness and depth. The resistivity trend; P1<P2>P3<P4 reveals high resistivity at the 2^{nd} and 4^{th} layers. The apparent resistivity is highest in the 4^{th} layer (1,631Ωm) which is composed of compacted sand at a depth of 20.4m. This places the SWL between 2-18m. The topsoil is at a depth of 1.16m from the surface and is interpreted to be sand as well.

VES 9: Apparent resistivity trend shows P1<P2>P3<P4, with maximum resistivity (1,407) in the 4^{th} and last geo-electric layer. The resulting curve type indicates a high resistivity value, sandwiched between two low resistivity values.

The KH curve type may also indicate a low resistivity layer sandwiched between a high resistivity layer. This result indicates that fresh water might exist to a depth up to a depth of 21m, placing SWL somewhere between 12m- 20m.

VES 10. The resulting curve type is indicative of decreasing resistivity with depth. It also indicates a low resistivity layer, sandwiched between two high resistivity layers. Apparent resistivity trend shown by the curve type reveals that P1<P2>P3<P4, with maximum resistivity value in the 4^{th} layer, as revealed by the geo-electric sections. The 4^{th} layer is aquiferous, at a depth of 23.4m with an overburden thickness of 17m.

4. CONCLUSION

Ten vertical electric sounds were used to evaluate subsurface hydrogeological conditions of the area to a depth of about 29m. The results reveal that groundwater abstraction in the area is possible. Based on interpretation of the VES results, five subsurface geoelectric layers exist consisting primarily of sand and clays. The increasing resistivity values, ranging from 107m-7696Ωm, indicate the presence of fresh water. Other parameters such as depth and thickness of the aquifers were also determined. The results reveal that groundwater abstraction in the Ogbogoro area of Obio-Akpor LGA is possible. The use of geoelectrical sounding provides an inexpensive method for characterizing ground water conditions of the area. This study has been able to clearly delineate four to five unconfined aquifers of meaningful hydro geologic significance in the study area, ranging from depths of 3.39m-22m. Resultant curve types show significant trend from A-type-type, KH-type and AK-type. Information obtained from this study could be relevant for the development of an effective water scheme for the area and for borehole drilling to obtain sustainable amounts of ground water. We recommend that drilling and citing boreholes in the area should be done by certified hydrogeologists with the required expertise. Additionally, intensive geochemical investigation should be carried out in the study area, to determine if the water is potable. Boreholes can be drilled at depths of 19m-20m to obtain water that is free of sand. It is not advisable to drill above this depth as the aquifer is too shallow and can be easily conducted and deeper boreholes should be dug for ease of ground water recharge.

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