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Earth Resistivity Measurement for Ground Water Distribution in Patani Area of Delta State, Nigeria

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Abstract

The execution of water borehole project is expensive; there is therefore the need for surface resistivity measurements before drilling. Vertical Electrical Sounding (VES) using Schlumberger configuration is one of the most reliable geophysical techniques and was carried out in Patani area of Delta state to obtain and document not only the layer/s of the near surface aquifer but to determine the thickness and depth to the aquifer and hence recommend the area/s boreholes could be drilled for potable and sustainable water supply. A total of 7vertical electrical soundings data were obtained from 7 locations evenly spread and spaced using the Schlumberger array method. The apparent resistivity values obtained in the field were plotted against half current electrode spacing in a log-log graph. The resulting curves were interpreted both qualitatively by inspection and quantitatively by matching small segments of the field curves using two-layer model and their corresponding auxiliary curves. The resistivity and thickness obtained from the partial curve matching were improved upon by employing an iterative computer program to obtain the layer parameters. The type of curves, the resistivity of the sediments and the knowledge of the local geology of Patani were used as guides in the analysis and interpretation of the layer parameter in terms of probable and sustainable water supply.

The Geoelectric section of Patani revealed one aquifer within the third and the fourth geoelectric layers of the earth. This layer consists of the medium to coarse sand formations of resistivity values ranging from 109.0 Ωm ***to 200*** Ωm ***with an average thickness of 20m.***

Generally, boreholes could be drilled to a maximum depth of 32.0 m to the fourth layer within the medium to coarse sand except in Ekise and Farkas where it has to be drilled to a depth of 20.0m for an appreciable and sustainable quantity of water.

It could therefore be concluded that boreholes for potable, appreciable and sustainable water supply should be located at Ekise area in Patani main town to a depth of 20.0 m, since the area has the highest thickness of aquifer of about 22.2 m and is confined.

Keywords: Patani, potable water, contamination, Oginware, Taware, Ekise, Farkas, Secretariat, Osuware, boy's model, geoelectric section and resistivity

1.0 Introduction

Water is not only essential to man but a basic necessity in life; it is foremost needed by man to quench his thirst and used domestically in our homes for washing, bathing and cooking. Water is also used for agricultural activities like irrigation, animal husbandry and serves as recreation spots such as swimming pools. Due to these and many more important uses of water man tends to migrate from places of inadequate water supply to places where water can easily be obtained such as streams, rivers and lakes. These sources of water are classified as surface water. Water can also be obtained from other sources other than the surface; it could be obtained under the earth crust and this is called groundwater.

Groundwater is described as water which exists below the earth surface within saturated layers of sand, gravel and pore spaces in sedimentary as well as crystalline rocks [1]. It is therefore defined as water found underground in the cracks and spaces in the soil, sand and rock and originates from rain, melted snow, sleet and hail that soak into the ground. The water moves down into the ground due to the effect of gravity passing between particles of soil, sand and gravel or rock until it reaches a depth where the ground is filled or saturated with water. The top of this saturation zone is called the water table. Below this water table is an underground layer of water-bearing permeable rock or unconsolidated materials such as gravel, sand or silt from which groundwater can be usefully extracted and is called an aquifer. Aquifer therefore is a geological formation, group of formations or part of a formation that contains sufficient saturated permeable materials capable of yielding significant quantities of water to springs and wells [2].

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Schlumberger arrangement of the Vertical Electrical Sounding is preferable [3, 4] because of its cheapness, spread of accuracy, depth determination, suitability in differentiating between the over burden and the fresh bedrock as well as acceptability. Some of the investigations carried out using the Schlumberger configuration of the vertical electrical soundings include:

A Geoelectric investigation of groundwater resources and aquifer characteristics in Utagba-Ogbe kingdom Ndokwa land area of Delta State, Nigeria was carried out [5] where the study revealed Utagba-Ogbe Kingdom as an extensive sandy unit. The best layer of the aquifer in Utagba-Ogbe kingdom for groundwater development is at a depth between 35.00 - 45.00m within the second layer. This layer consist medium-grained sand to coarse grained sand formations, which is the best formation to obtain an appreciable quantity of water for sustainable groundwater development since it has high porosity. Also, Hydro geophysical investigation of groundwater resources in Amai Kingdom Ndokwa land area of Delta State was carried out [6].

Oyedele [7] Used VES to determine depth to the freshwater/saltwater interface, thickness of each aquifer unit and the prevailing hydro geophysical and hydro geochemical parameters concerning aquifer salinization. The depths to freshwater bearing layer ranges between 3.6m to over 29.6m while the depth to interface ranges from 5m to more than 155m.

Atakpo [8] adopted resistivity survey in accessing the contamination of groundwater by hydrocarbons in Uvwiamuge locality, Delta State, Nigeria. He concluded that the resistivity survey revealed pollution of groundwater as a result of exploration and exploitation for petroleum in the area. The result shows that the total hydrocarbon content (3.96 mg/l - 8.10mg/l) is above the maximum allowable value specified by World Health Organization (WHO).

Ayolabi [9] used VES to determine the units and groundwater quality in Irawo area of Ikorodu Lagos. The study reveals three aquifer units with varying groundwater quality.

Anomohenran [10] determined groundwater potential in Asaba, using surface geoelectric sounding method. His results indicate that there are four to five distinct formations in the study area. Analyses of the data suggest that water bearing formation exist in the third formation having resistivity range of 318 Ωm to 567 Ωm. The thickness of the aquifer ranges from 20.4 m to 33.9 m, while the depth range is from 43.5 m to 52.8 m. He therefore recommended that boreholes for good drinking water and water scheme be drilled to the third layer of the various locations investigated.

Since improper sub-surface investigation result to unsuccessful borehole sinking or extraction of groundwater, there is a need for geophysical application in sub-surface water determination. This project is limited to field acquisition of geophysical data using the Schlumberger arrangement of the vertical electrical sounding to assess the groundwater potential, determine near surface geologic formation, locate the aquiferous region and the thickness of the aquifer within Patani town in Delta State and hence determine the depth boreholes could be drilled for significant and appreciable quantity of water.

2.0 Description and Location of Study Area

Patani is a small town located in the southern part of Delta state known as the Niger-Delta region and lies within latitude **005° 13.177’** and longitude **006° 11.122’.** It is situated thirty meters away from River Niger with a linear settlement along the River Niger while twenty meters off road is a scattered settlement as shown in fig. 1 below.

Patani has two major roads which are tarred, these are; the new market road and the back road with some network of roads that are semi-tarred. It has man- made vegetation and the River Niger area is thickly populated as a result of their major occupation which is farming and fishing. The area receives rainfall of about seven months per year. The top most layer of the soil is more of humus content sticky clayish water content.

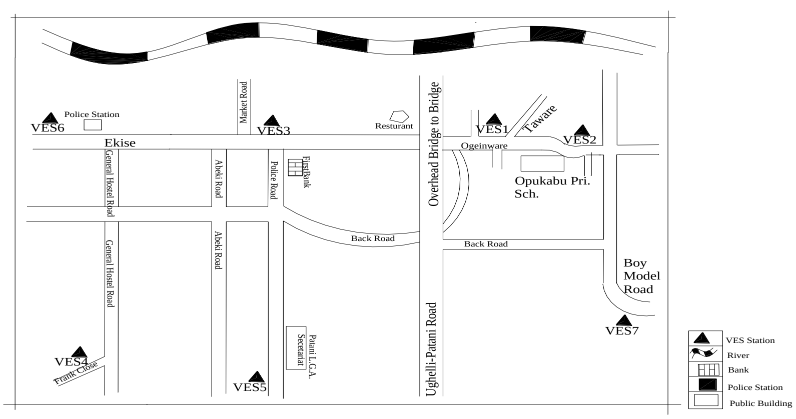

Fig 1: Base Map of Patani

3.0 Field Procedure

The schlumberger configuration was adopted with a maximum current electrode separation (AB/2) of 150m, which was deemed sufficient in allowing a depth penetration of 112m. Potential electrode separation was increase several times during the sounding at MN/2 equals 1.0m and up to 20m

The procedure involves the introduction of current into the earth measuring potential difference between two electrodes resulting from an applied current through two other electrode outsides but in line with the potential electrodes. The distance of the fixed electrode from the two current electrodes were equal and was connected to the Terrameter via point AB on the Terrameter. Similarly, two potential electrodes of equal spacing and on opposite side of the fixed electrode to the point MN on the Terrameter were established with the current electrodes, potential electrodes and the fixed electrode in a straight line. After proper connections had been made, the Terrameter was switched on, thus the current and the voltage readings on the Terrameter were noted. After readings had been taken, the current electrodes were moved systematically to a new point along the line that is equidistant from the fixed electrode, and then the readings of the current and voltage were noted. When the ratio of the distance between the current and the potential electrodes become too large, the readings becomes insignificant and fluctuates, hence to minimize field error the potential electrodes are then increased outwards. This procedure continues until considerable numbers of readings were taken.

4.0 Interpretation of Field Result

The Vertical Electrical Sounding field data were plotted on a log-log graph using a transparent sheet with the same modulus as that of the 2-layer master curves. The apparent resistivity (en) values were plotted along the ordinate (y-axis) and the electrode separations = AB/2 was plotted along the abscissa (x-axis).

The field curve was super imposed on the master curve with the axes parallel and then moved around the master between the curves until one of the model curves matched it.

The field curves were matched segment by segment with the 2-layer master curve and the corresponding auxiliary curve. The interpretation of field curves starts from left portion to the right portion and the choice of the master curve and auxiliary curve depends on the shape of the field curve. A mark is introduced at the origin of the master curve on the field curve as a cross (+) which serves as the origin of the coordinate. The procedures are:

- Choose an appropriate master curve either ascending or descending depending on the orientation and shape of the field curve.
- The apparent resistivity (ℓa) plotted against AB/2 on the transparent paper as obtained in the field is superimposed on the master curve to ascertain the curve of best fit.
- The axis of the master and field curve are kept parallel, while the transparent paper with the field curve on it is slide on the various master curves until a satisfactory curve of the best fit is obtained.
- The line where the field curve fits is traced out and the point where it starts to deviate is marked with a cross (+) sign and the figure assigned to that line is marked as K_1.
- The marked field curve is placed on an appropriate auxiliary curve and the cross (+) point is traced vertically to derive the depth index (D_1).
- After getting the K_1 and D_1 values, the transparent paper with the field curve are then placed on the bi-logarithm paper and the point marked K_1 is traced both vertically and horizontally to obtain its apparent resistivity (ℓa) and thickness (h) respectively.
- The real resistivity and thickness of each layer are calculated using the parameters in table 1 below.

Table 1: Parameters for calculating theapparent resistivity and thickness of various layers

Layers	Resistivity	Thickness
1	ℓ	h1
2	$\ell 1 \times K_1$	$h1r \times DI_1$
3	$\ell 2r \times K_2$	$h2r \times DI_2$
4	$\ell 3r \times K_3$	$h3r \times DI_3$

Table 2: Qualitative analysis of curve types (ρ represent the resistivity of the layers).

VES	Curve Characteristics	Curve Type	No of Layers
VES1	$\rho_1>\rho_2<\rho_3<\rho_4$	HA	4
VES2	$\rho_1>\rho_2<\rho_3<\rho_4$	HA	4
VES3	$\rho_1>\rho_2<\rho_3>\rho_4<\rho_5$	KHK	5
VES4	$\rho_1>\rho_2<\rho_3<\rho_4$	HA	4
VES5	$\rho_1>\rho_2<\rho_3<\rho_4$	HA	4
VES6	$\rho_1>\rho_2<\rho_3<\rho_4$	HA	4
VES7	$\rho_1>\rho_2<\rho_3<\rho_4$	HA	4

This gives an insight into the type of curve as shown in table 2 below.

The raw field data obtainedwas imputed into the resistivity software program (Win Resist) in a computer which in turn displays an automatically plotted graph. The thickness and resistivity values obtained from the partial curve matching were then imputed into the program as model parameters. The process is now run by the program as a routine. Hence, the layer parameters are automatically adjusted by the program if no match is obtained,then iteration was done or achieved until the error tolerance limit set for the program is minimum, the model match becomes the interpreted layer parameters. The results obtained from computer iteration of the study area are shown in Figures 2 to 8.

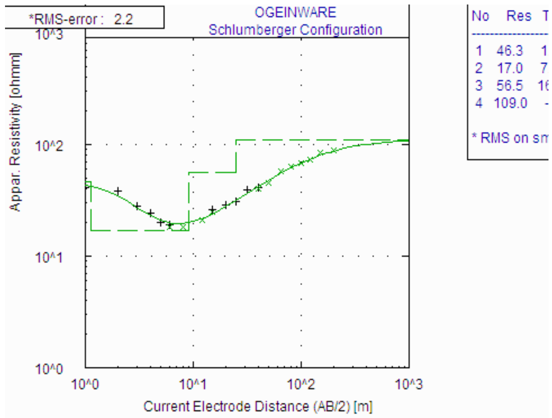

Fig 2: Resistivity Plots of VES1 in Patani

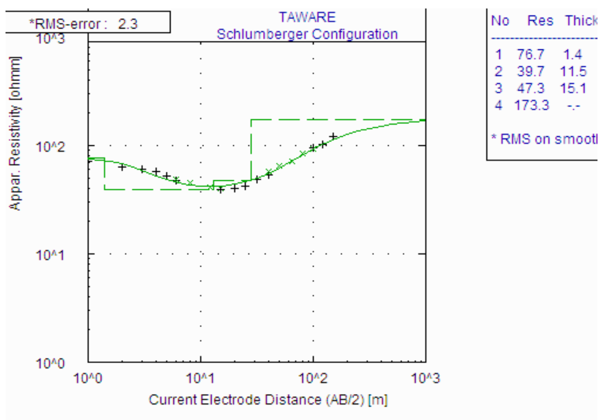

Fig 3: Resistivity Plots of VES2 in Patani

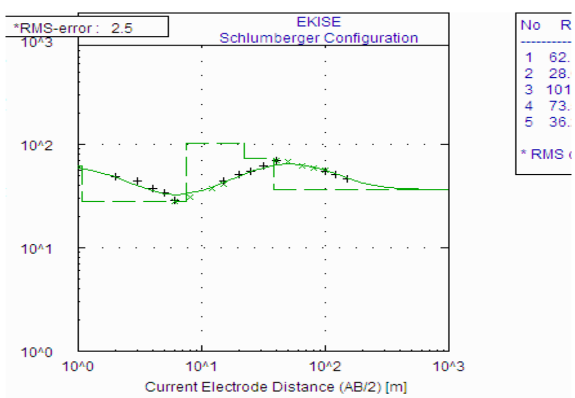

Fig 4: Resistivity Plots of VES3 in Patani

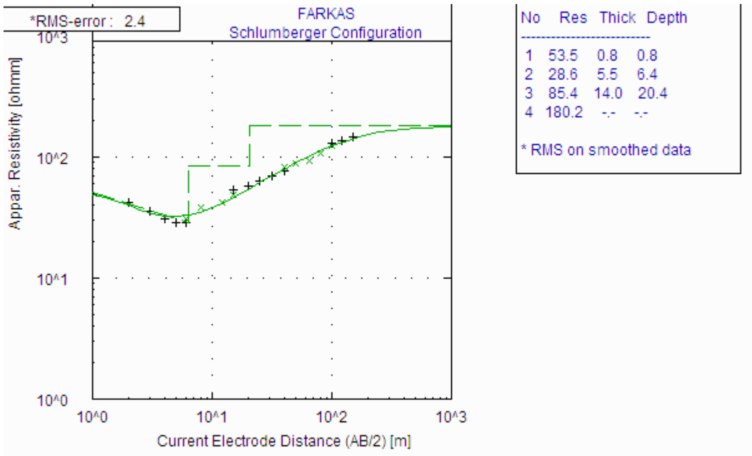

Fig 5: Resistivity Plots of VES4 in Patani

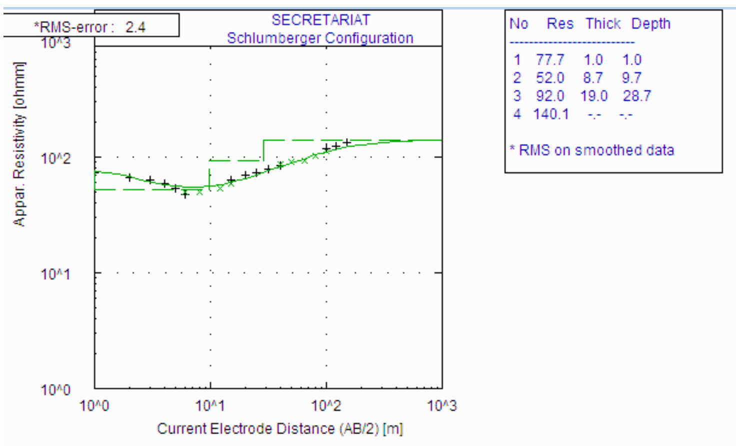

Fig 6: Resistivity Plots of VES5 in Patani

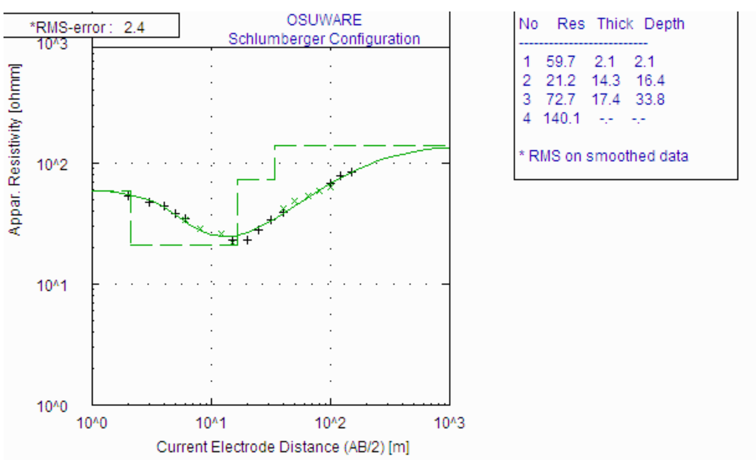

Fig 7: Resistivity Plots of VES6 in Patani

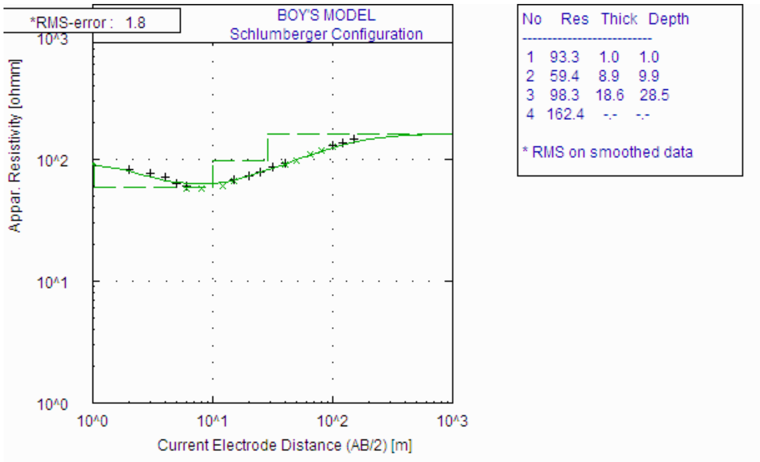

Fig 8: Resistivity Plots of VES7 in Patani

5.0 Discussion of Results

The results of the investigations revealed that:VES 1 is an HA- type curve with four layers. The first layer is the top soil, with resistivity value of 46.3 Ωm, thickness of 1.1m and a depth of 1.1m. The second layer have resistivity value of 17.0 Ωm, a thickness of 7.9m and a depth of 9.0m which infers clay, the third layer have resistivity value 56.5 Ωm, a thickness 16.1m and a depth of 25.1m which infers fine sand, the fourth layer have resistivity value of 109.0 Ωm and this infers medium to coarse, that is at an infinite depth, this layer is the aquifer.

VES 2 is an HA- type curve with four layers. The first layer is the top soil, with resistivity value of 76.7 Ωm, thickness of 1.4m and a depth of 1.4m the second layer have resistivity value of 39.7 Ωm, a thickness of 11.5m and a depth of 12.9m which infers clay, the third layer have resistivity value 47.3 Ωm, a thickness 15.1m and a depth of 28.0m which infers fine sand, the fourth layer have resistivity value of 173.3 Ωm, and this infers medium to coarse, that is at an infinite depth this layer is the aquifer.

VES 3 is a KHK- type curve with five layers. The first layer is the top soil, with resistivity value of 62.1 Ωm, thickness of 1.1m and a depth of 1.1m the second layer have resistivity value of 28.0 Ωm, a thickness of 6.4m and a depth of 7.5m which infers clay, the third layer have resistivity value 101.9 Ωm, a thickness 14.8m and a depth of 22.2m which infers medium to coarse and this layer is the aquifer, the fourth layer have resistivity value of 73.5 Ωm, with thickness 16.5m and at a depth of 38.7m, the fifth layer has resistivity value of 36.2 which infers clay and this layer is at an infinite depth. Hence the aquifer in this area is confined.

VES 4 is an HA- type curve with four layers. The first layer is the top soil, with resistivity value of 53.5 Ωm, thickness of 0.8m and a depth of 0.8m the second layer have resistivity value of 28.6 Ωm, a thickness of 5.5m and a depth of 6.4m which infers clay, the third layer have resistivity value 85.4 Ωm, a thickness 14.0m and a depth of 20.4m which infers fine sand, the fourth layer have resistivity value of 180.2 Ωm, and this infers medium to coarse,that is at an infinite depth and this layer is the aquifer.

VES 5 is an HA- type curve with four layers. The first layer is the top soil, with resistivity value of 77.7 Ωm, thickness of 1.0m and a depth of 1.0m the second layer have resistivity value of 52.0 Ωm , a thickness of 8.7m and a depth of 9.7m which infers sandyclay, the third layer has resistivity value 92.0 Ωm, a thickness 19.0m and a depth of 28.7m which infers fine to medium sand, the fourth layer have resistivity value of 140.1 Ωm which infers medium to coarse, that is an at infinite depth this layer . This also is the aquifer.

VES 6 is an HA- type curve with four layers. The first layer is the top soil, with resistivity value of 59.7 Ωm, thickness of 2.1m and a depth of 2.1m the second layer have resistivity value of 21.2 Ωm, a thickness of 14.3m and a depth of 16.4m which infers clay, the third layer has a resistivity value of 72.7 Ωm, a thickness 17.4m and a depth of 33.8m which infers fine sand, the fourth layer have resistivity value of 140.1 Ωm, and this infers medium to coarse that is at an infinite depth, this layer is the aquifer.

VES 7 is an HA- type curve with four layers. The first layer is the top soil, with resistivity value of 93.3 Ωm, thickness of 8.9m and a depth of 9.9m the second layer have resistivity value of 59.4 Ωm, a thickness of 8.9m and a depth of 9.9m which infers sandclay, the third layer have resistivity value 98.3 Ωm, a thickness 18.6m and a depth of 28.5m which infers fine to medium sand, the fourth layer have resistivity value of 162.4 Ωm, and this infers medium to coarse, that is at an infinite depth, this layer is the aquifer.The Geoelectric section of Patani shown in figure 9 revealed one aquifer within the third and the fourth geoelectric layers of the earth. This layer consists of the medium to coarse sand formations of resistivity values ranging from 109.0 Ωm to 200 Ωm with an average thickness of 20m.

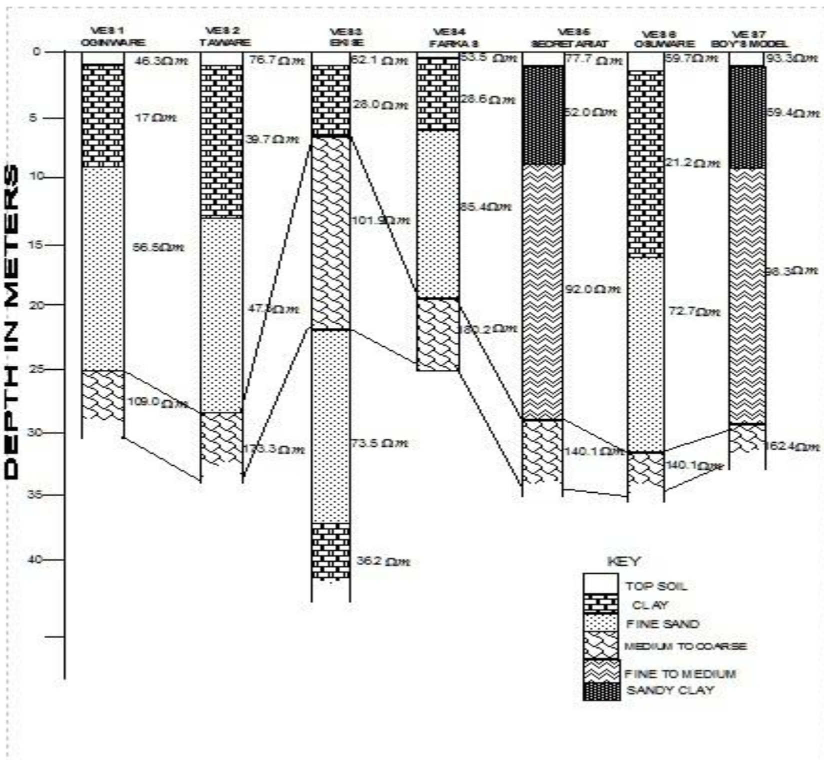

Fig 9: Geoelectric section of Patani

6.0 Summary and Conclusion

From the aforementioned analysis, the resistivity values recorded are generally low due to the geology of the area, the first layer is sandy clay while apart from VES 5 along the secretariat road and VES 7 toward the boy's model school that has sandy clay in the second layer, the second layers are generally clay formation with a thickness of between 5.0 m – 10.0 m. Furthermore, the geoelectric section revealed that the aquifer generally in Patani is in the fourth layer at an average depth of 32.0 m except VES 3 taken along Ekise road and VES 4 in Farkas area that has the aquifers in the third layers at an average depth of 20.0 m.

Also, it was revealed that apart from the areas within Ekise road that has a confined aquifer due to the fact that the aquifer is bounded by a clay formation in the second and the fifth layers respectively, the rest aquifers are not confined. In the event of pollution, every other area in Patani apart from the Ekise region is likely to be contaminated.

However, in VES 4 along Farkas road, borehole could be drilled to depth 20.0 m while in areas within VES 1 (Ogeinware), VES 2 (Taware), VES (Secretariat) 5, VES 6 (Osuware) and VES (Boy's model) 7, boreholes could be drilled to an average depth of 32.0 m but the thickness of the aquifer in these areas are not encouraging for appreciable, sustainable and potable water supply.
It could therefore be concluded that boreholes for appreciable and sustainable water supply should be drilled to a maximum depth of 32.0 m to the fourth layer within the medium to coarse sand in Patani main town except in Ekise and Farkas areas where it has to be drilled to a depth of 20.0m for an appreciable and sustainable quantity of water since the area has the highest thickness of aquifer of about 22.2 m and is confined.

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