# Geoelectric Investigation for Groundwater Development of Southern Part of Nigeria.



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## ABSTRACT

A resistivity survey was carried out in order to study groundwater potentials in the southern part of Nigeria; Obio Etoi, Obio Offot, the University of Uyo, all of the Uyo Local Government Area, and Akwa Ibom State. Twelve vertical electrical soundings using the Schlumberger array were conducted.

The soundings were carried out with current electrode spacing (AB/2) ranging from 1m to 400m using Terrameter model 300 and its accessories. The field data acquisition was carried out by moving two to four of the electrodes used between each measurement. All of the data was first calculated in the field to check its quality. The apparent resistivity obtained from the field was plotted against half the current electrode separation (AB/2) on the bilogarithmic graph paper to obtain the initial parameters, which were used in a computer program to obtain final parameters.

From the interpreted results, six subsurface layers were distinguished in each of the regions, the resistivity ranging from 307 to 16100Ωm (thickness 0.6 – 26.7m) in Obio Offot, 1260 to 16300Ωm (thickness 0.79 – 110.9m) in Obio Etoi and 526 to 17000Ωm (thickness 0.23 and above) in the University of Uyo. The formation boundaries were thus delineated using the resistivity values obtained from the interpretation of field data. The top fine sandy layers (27, 39 and 20m could be a major source of shallow well water, but the aquifers may be susceptible to contamination. Deep boreholes can be reached at less than 75.69, 75.2 and 60m without contamination.

(Keywords: vertical electrical sounding, groundwater, aquifers, subsurface, Schlumberger array, VES)

## INTRODUCTION

The importance of natural resources to man has led to the development of many remote sensing techniques most of which involves physical measurements at the earth surface that would give information on the structure or composition of concealed rocks and mineral deposits. In some parts of the world, governments are unable to provide enough portable water for their people and as such, water needed for daily activities is obtained from ground water sources (Clark, 1996).

A number of geophysical exploration techniques are available for geological studies, these include: seismic, gravity, magnetic, electrical, radiometric, electromagnetic, heat flux, and well logging methods. The choice of a particular method depends on the objective of survey and then by other factors such as cost considerations, the nature of the terrain, availability of analytical tools, operational convenience, and the kind of subsurface information needed. Of all the geophysical methods, those that are very good in providing information about variation data with depth are the vertical electrical sounding (VES) and the reflection and refraction seismic (Dobrin, 1976). This study used the electrical resistivity method.

Geo-electric measurements enable the electrical resistivity of the subsurface to be determined. Through this type of measurements, one can produce a resistivity picture of a subsurface, which could also be converted into a geological picture showing layering structures with thickness of each horizon.

The theory and fields methods used for resistivity surveys are based on the use of direct current which requires that an electric current be injected into the ground by pair of surface electrodes which are connected above the ground by adequate wire which leads to a source of current supply and below ground by earth itself, thus completing the circuit (Frederic 1961). The resultant potential field (voltage) is measured at the surface by a voltmeter between second pair of electrodes because it allows greater depth of investigation than alternating current and because it avoids the complexities caused by effects of ground inductance and capacitance and resulting frequency dependence of resistivity (Telford et al. 1990). Also it makes the resistivity to be limited to region with conducting surfaces. The subsurface earth resistivity can be calculated by knowing the electrode spacing, geometry of electrode position (K), applied current (I), and measured voltages (V).

This paper describes a geoelectric investigation undertaken in Uyo in southern Nigeria, for groundwater development.

## LOCATION AND GEOLOGY OF AREA

The study area lies within Uyo. Uyo is located in the southern part of Nigeria between latitude $5^0$ $05'$ North to $4^0$ $55'$ N and longitude $8^0$ $00'$ East to $7^0$ $50'$ East. The city has a hilly or undulating nature and semi equatorial type of climate. The major vegetation belt within the area is fresh water swamp forest and rain forest (Ekwere et al. 1994). The map of the study area is shown in Figure 1.

## VERTICAL ELECTRICAL SOUNDING (VES) INVESTIGATION

The Vertical Electrical Sounding, (VES) is a field technique used to observe the variations of resistivity with depth. For homogenous and horizontally stratified earth, VES results represent only resistivity variation across the layers up to the maximum depth of probe. Practically, as the spacing between the current electrodes is increased about a center, the total volume of earth included in the measurement also increases both vertically and horizontally (Telford, et al 1990 and Okweze et al 1995).

The field procedure involves measuring the apparent resistivity as the mid point of the array is kept fixed while the distance between the current is progressively increased. The Schlumberger configuration was used in this study. After data acquisition, the apparent resistivity values are plotted against half the current electrode spacing on bilogarithmic graph paper.

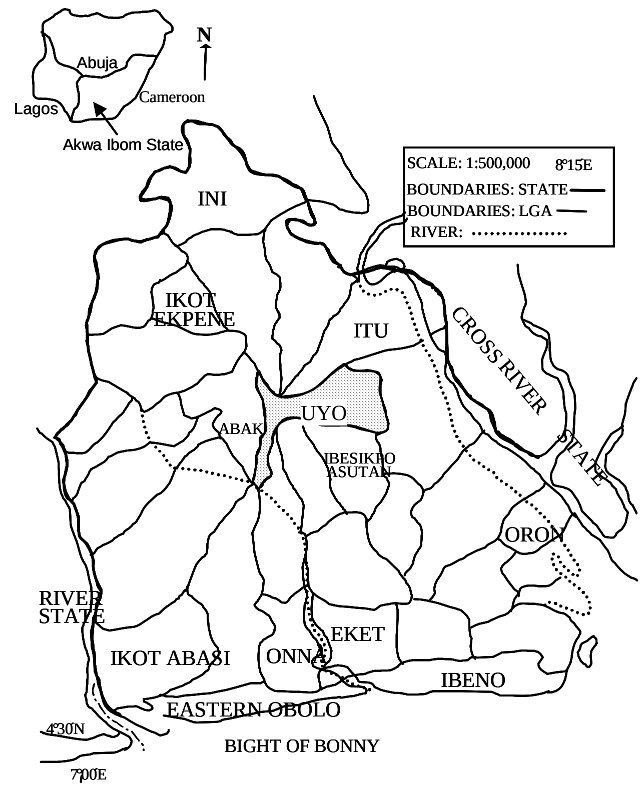


**Figure 1:** Map of Uyo, Akwa Ibom State, Southern Nigeria.

## DATA ACQUISITION

The Terrameter SAS 300 was used in the study; it transmits a well- defined and regulated square wave, which minimizes induction effects and attenuation. The current was introduced into the ground by a pair of steel stakes driven into the ground. The electrode separation allows for the calculation of apparent resistivity of the earth apparent resistivity for each current electrode separation AB. Measurements were taken manually using the Terrameter that will normally provide a direct readout of resistance. In order to convert the resistance reading to an apparent ground resistivity, a geometric factor was applied to the data, based on the Schlumberger configuration used in this study.

In this configuration, the two potential electrodes were located at the center of the spread and closely spaced compared to the two current electrodes that were also located symmetrically about the center point. In order to increase the depth of investigation, the current electrode separation was increased while the potential separation remained constant. In this way, only two electrodes required moving.

Four soundings at each of the locations were carried out, thus having a total of twelve. A representative data obtained for each of the locations are presented (Tables 1, 2 and 3).

## DATA ANALYSIS AND INTERPRETATION

The apparent resistivity data were plotted against electrode separation and interpreted quantitatively through visual inspection. Secondly, the linear filter theory (computer modeling and inversion process) approach was used in data analysis and interpretation (Keller, 1966). This method provided an automatic means of analyzing how a model is determined. Interpretation made from the raw unprocessed resistivity field data can be difficult. A representative analysis from each of the locations are presented.

### Computer Modeling (Obio Etoi)

The topmost layer is resistive with resistivity of 1260Ωm and the thickness is 0.79m. The resistivity of the topmost layer signifies the topsoil. The second layer is about 1.21m thick with a resistivity of 2490Ωm and it consists mainly of clayey sand. The third layer is of resistivity value of 1140Ωm with thickness of 3.5m and it signifies the presence of fine sand. The fourth layer is about 13.8m thick with resistivity of 4410Ωm. The layer can be associated with medium-coarse sand. The fifth layer has a lower resistivity than the fourth and the sixth layer. The layer has resistivity of 2360Ωm and is about 28.8m thick. It is probably made up of fine sand. The sixth layer has a resistivity of 30600Ωm with thickness of 110.9m. The layer is associated with coarse sand. The seventh layer has the highest resistivity of 16300Ωm with undetermined thickness. This layer may consist of sandstone (Table 4 and Figure 2).

**Table 1**: Data from Obio Etoi. Variation of Apparent Resistivity with Varying Electrode Separation.

| $^{AB}/_2$ = a (m) | MN = b (m) | K | Resistance R (Ω) | Apparent resistivity ρa (Ωm) |
|---|---|---|---|---|
| 1.0 | 0.5 | 5.89 | 229.5 | 1351.76 |
| 1.5 | 0.5 | 13.75 | 108.25 | 1488.44 |
| 2 | 0.5 | 24.75 | 65.30 | 1616.18 |
| 3 | 0.5 | 56.16 | 31.40 | 1763.42 |
| 3 | 1 | 27.49 | 54.70 | 1503.70 |
| 4 | 1 | 49.48 | 33.3 | 1647.68 |
| 4 | 0.5 | 100.14 | 22.3 | 2233.12 |
| 5 | 1 | 77.75 | 21.2 | 1648.30 |
| 7 | 1 | 153.15 | 11.35 | 1738.25 |
| 7 | 2 | 75.40 | 17.67 | 1332.32 |
| 10 | 2 | 155.51 | 8.66 | 1346.72 |
| 10 | 1 | 313.37 | 5.29 | 1657.72 |
| 15 | 2 | 351.86 | 5.29 | 1861.34 |
| 20 | 2 | 626.75 | 4.245 | 2660.60 |
| 30 | 2 | 1412.15 | 2.288 | 3233.82 |
| 30 | 5 | 561.56 | 5.06 | 2841.49 |
| 40 | 2 | 2511.70 | 1.38 | 3466.15 |
| 50 | 5 | 1566.87 | 1.89 | 2961.38 |
| 70 | 5 | 3074.83 | 1.235 | 3797.42 |
| 70 | 20 | 753.98 | 4.00 | 3015.92 |
| 100 | 20 | 1555.09 | 2.19 | 3405.65 |
| 100 | 5 | 6279.26 | 0.825 | 5180.39 |
| 150 | 20 | 3518.58 | 1.173 | 4127.29 |
| 200 | 20 | 6267.48 | 1.289 | 8078.78 |
| 300 | 40 | 7037.18 | 0.536 | 3771.93 |
| 400 | 20 | 25117.03 | 1.919 | 48199.58 |

**Table 2:** Data from Obio Offot. Variation of Apparent Resistivity with Varying Electrode Separation.

| $^{AB}/_2$ = a (m) | MN = b (m) | K | Resistance R (Ω) | Apparent resistivity ρa (Ωm) |
|---|---|---|---|---|
| 1.0 | 0.5 | 5.89 | 86.1 | 507.13 |
| 1.5 | 0.5 | 13.75 | 52.0 | 715.0 |
| 2 | 0.5 | 24.75 | 35.6 | 881.1 |
| 3 | 0.5 | 56.16 | 22.3 | 1252.37 |
| 3 | 1 | 27.49 | 45.0 | 1237.05 |
| 4 | 1 | 49.48 | 30.7 | 1519.04 |
| 4 | 0.5 | 100.14 | 16.49 | 1651.31 |
| 5 | 1 | 77.75 | 24.55 | 1908.76 |
| 7 | 1 | 153.15 | 15.12 | 2315.6 |
| 7 | 2 | 75.40 | 28.65 | 2160.21 |
| 10 | 2 | 155.51 | 15.80 | 2457.06 |
| 10 | 1 | 313.37 | 8.20 | 2569.63 |
| 15 | 2 | 351.86 | 7.6 | 2674.14 |
| 20 | 2 | 626.75 | 3.67 | 2300.17 |
| 30 | 2 | 1412.15 | 1.598 | 2256.62 |
| 30 | 5 | 561.56 | 3.66 | 2055.31 |
| 40 | 5 | 1001.38 | 1.578 | 1580.18 |
| 40 | 2 | 2511.70 | 0.715 | 1795.87 |
| 50 | 5 | 1566.87 | 1.032 | 1617.00 |
| 70 | 5 | 3074.83 | 0.465 | 1429.80 |
| 70 | 20 | 753.98 | 1.262 | 951.52 |
| 100 | 20 | 1555.09 | 1.235 | 1920.54 |
| 100 | 5 | 6279.26 | 0.37 | 2323.32 |
| 150 | 20 | 3518.58 | 0.635 | 2234.30 |
| 200 | 20 | 6267.48 | 0.840 | 5264.68 |
| 300 | 40 | 7037.18 | 2.30 | 16607.74 |

**Table 3:** Data from University of Uyo Site. Variation of Apparent Resistivity with Varying Electrode Separation.

| $^{AB}/_2$ = a (m) | MN = b (m) | K | Resistance R (Ω) | Apparent resistivity ρa (Ωm) |
|---|---|---|---|---|
| 1 | 0.25 | 5.89 | 524.5 | 3089.31 |
| 1.5 | 0.25 | 13.75 | 243 | 3338.82 |
| 2 | 0.25 | 24.74 | 141 | 3488.34 |
| 3 | 0.25 | 56.16 | 47.6 | 2656.4 |
| 3 | 0.50 | 27.49 | 103.7 | 2842.5 |
| 4 | 0.50 | 49.48 | 51.1 | 2528.4 |
| 4 | 0.25 | 100.11 | 20.7 | 2072.9 |
| 5 | 0.50 | 77.75 | 34.1 | 2651.3 |
| 6 | 0.50 | 112.31 | 14.16 | 1589.2 |
| 8 | 0.50 | 200.28 | 2.17 | 435 |
| 8 | 1.00 | 88.98 | 10.19 | 995.5 |
| 10 | 1.00 | 155.51 | 0.708 | 110.101 |
| 10 | 0.50 | 313.37 | 2.07 | 649 |
| 15 | 1.00 | 351.86 | 1.827 | 642.848 |
| 20 | 1.00 | 626.75 | 6.12 | 3835.71 |
| 30 | 1.00 | 1412.15 | 6.2 | 8755.33 |
| 30 | 2.50 | 561.56 | 6.74 | 3783 |
| 40 | 2.50 | 1001.38 | 6.65 | 6661.68 |
| 40 | 1.00 | 2511.70 | 5.96 | 14968.73 |
| 50 | 2.50 | 1566.87 | 1.60 | 2512.2 |
| 60 | 2.50 | 2258.02 | 1.06 | 2393.5 |
| 80 | 2.50 | 4017.31 | 18.36 | 73744.4 |
| 100 | 5 | 6729.26 | 0.925 | 5180.39 |
| 150 | 20 | 3818.58 | 1.213 | 4217.29 |
| 200 | 20 | 6267.48 | 1.289 | 8178.78 |
| 300 | 20 | 14121.15 | 0.330 | 4569.98 |

**Interpreted Results for Obio Etoi**

RE = resistivity (ohm.m). DB = Depth to Bottom (m).

1. $RE_1$ = 1260 - $DB_1$ = 0.79 - Top soil
2. $RE_2$ = 2490 - $DB_2$ = 0.20 - Clayey soil
3. $RE_3$ = 1140 - $DB_3$ = 5.5 - Fine sand
4. $RE_4$ = 4410 - $DB_4$ = 19.3 - Medium coarse sand
5. $RE_5$ = 2360 - $DB_5$ = 48.1 - Fine sand
6. $RE_6$ = 30600- $DB_6$ = 159 - Coarse sand
7. $RE_7$ = 16300- Undefined

**Table 4:** Resistivities of the Geoelectric Layer at Obio Etoi (Computer Modeling).

| Geoelectric layer | Resistivity (Ωm) | Thickness (m) |
|---|---|---|
| **First layer** | 1260 | .79 |
| Second layer | 2490 | 1.21 |
| Third layer | 1140 | 3.5 |
| Fourth layer | 4410 | 13.8 |
| Fifth layer | 2360 | 28.8 |
| Sixth layer | 30600 | 110.9 |
| Seventh layer | 163000 | - |

**Computer Modeling (Obio Offot)**

The topmost layer has resistivity of 303Ωm and thickness of .6m. This is associated with topsoil. The second layer is of resistivity value 6310Ωm with thickness of 4.8m and this signifies the presence of coarse sand.

The third layer is about 4.5m thick with resistivity of 1370Ωm and it consists mainly of fine sand. The fourth layer has a resistivity lower than the third layer.

**Interpreted results for Obio Offot**

RE = Resisitivity DB = Depth to Bottom (m).

1. $RE_1$ = 307 - $DB_1$ = 0.6 - Top soil
2. $RE_2$ = 6310 - $DB_2$ = 5.4 - Coarse sand
3. $RE_3$ = 1370 - $DB_3$ = 9.9 - Fine sand
4. $RE_4$ = 493 - $DB_4$ = 23.4 - Clay
5. $RE_5$ = 3180 - $DB_5$ = 35.9 - Fine sand
6. $RE_6$ = 1650 - $DB_6$ = 62.6 - Coarse sand
7. RE7 = 16100 - Undefined

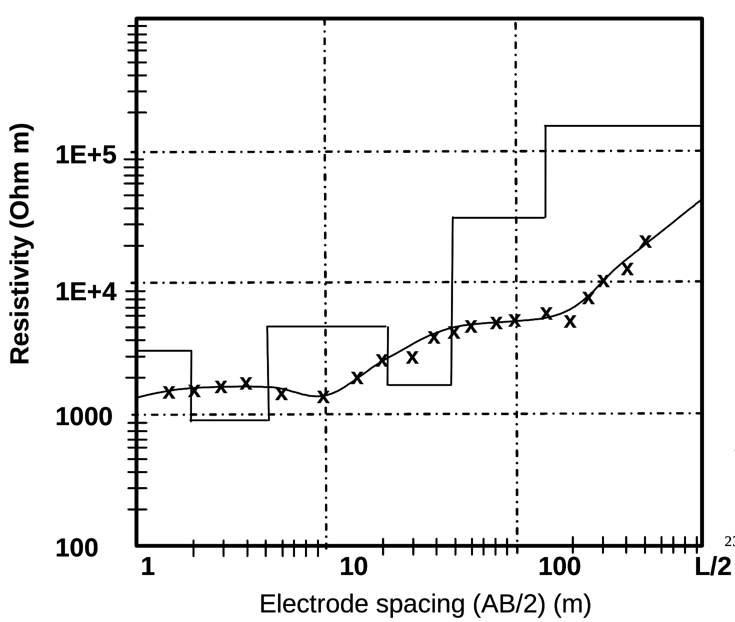


**Figure 2a:** Computer Inverse Modeling for Data Obtained at Obio Etoi.

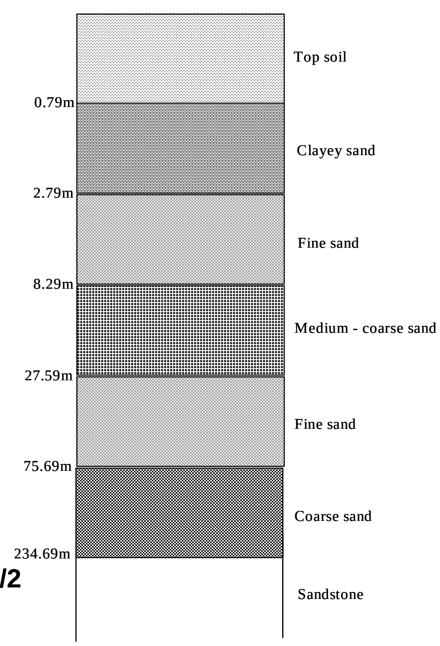


**Figure 2b:** Lithology at Obio Etoi, Deduced from Computer Modeling.

The thickness of the fourth layer is 13.5m. It is most likely clay. The fifth layer is about 12.5m thick with resistivity of 3180Ωm. It consists mainly of clay. The sixth layer has resistivity of 16500Ωm with thickness of 26.7m. It is associated with coarse sand. The lithology and thickness of the seventh layer is undetermined but its resistivity value is 161000Ωm (Table 5 and Figure 3).

**Table 5:** Resistivities of the Geoelectric Layer at Obio Offot (Computer Modeling).

| Geoelectric layer | Resistivity (Ωm) | Thickness (m) |
|---|---|---|
| First layer | 307 | .6 |
| Second layer | 6310 | 4.8 |
| Third layer | 1370 | 4.5 |
| Fourth layer | 493 | 13.5 |
| Fifth layer | 3180 | 12.5 |
| Sixth layer | 16500 | 26.7 |
| Seventh layer | 161000 | |

**Interpreted Results for Uniuyo**

RE = Resisitivity DB = Depth to Bottom (m).

1. $RE_1$ = 307 - $DB_1$ = 0.8 - Top soil
2. $RE_2$ = 6310 - $DB_2$ = 8.2 - Coarse sand
3. $RE_3$ = 1370 - $DB_3$ = 10.9 - Fine sand
4. $RE_4$ = 493 - $DB_4$ = 23.4 - Clay
5. $RE_5$ = 3180 - $DB_5$ = 35.9 - Fine sand
6. $RE_6$ = 1650 - $DB_6$ = 63.6 - Coarse sand
7. $RE_7$ = 16100 - Undefined

**Computer Modeling (Uniuyo)**

The topmost layer has resistivity of 310Ωm and thickness of 0.8m. This is associated with topsoil. The second layer is of resistivity value 6320Ωm with thickness of 7.4m and this signifies the presence of coarse sand. The third layer is about 2.7m thick with resistivity of 1390Ωm and it consists mainly of fine sand. The fourth layer has a resistivity lower than the third layer.

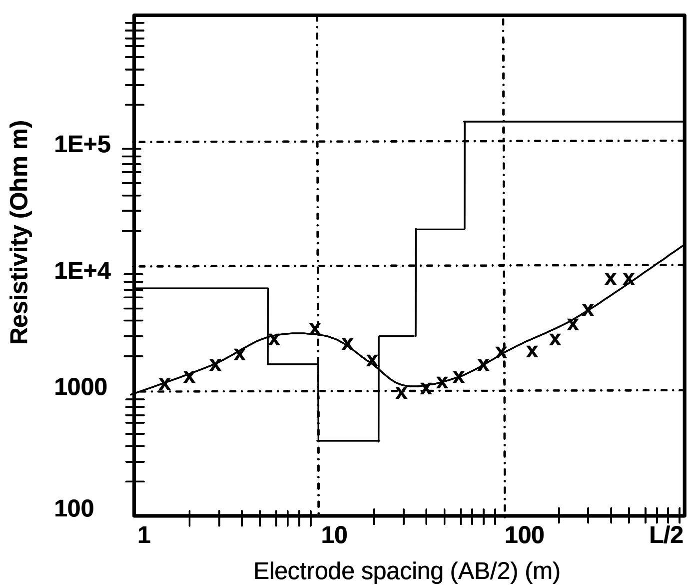


**Figure 3a:** Computer Inverse Modeling for Obtained at Obio Offot.

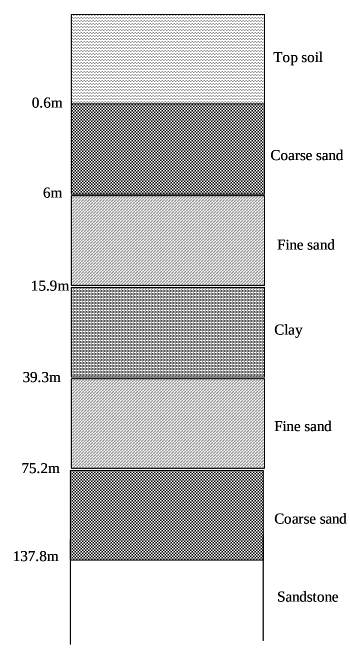


**Figure 3b:** Lithology at Obio Offot, Data Deduced from Computer Modeling.

The thickness of the fourth layer is 12.5m. It is most likely clay. The fifth layer is about 12.5m thick with resistivity of 3190Ωm. It consists mainly of clay. The sixth layer has resistivity of 16600Ωm with thickness of 27.7m. It is associated with coarse sand. The lithology and thickness of the seventh layer is undetermined but its resistivity value is 162410Ωm (Table 6 and Figure 4).

**Table 6:** Resistivities of the Geoelectric Layer at Uniuyo (Computer Modeling).

| Geoelectric layer | Resistivity (Ωm) | Thickness (m) |
|---|---|---|
| **First layer** | 310 | 0.8 |
| Second layer | 6320 | 7.4 |
| Third layer | 1390 | 2.7 |
| Fourth layer | 503 | 12.5 |
| Fifth layer | 3190 | 12.5 |
| Sixth layer | 1660 | 27.7 |
| Seventh layer | 162410 | |

## CONCLUSION

The interpretation of the resistivity data indicates the presence of an aquifer between fine sand and medium coarse sand with thicknesses of 3.5m and 13.8m. Another aquifer is found between fine sand and coarse sand with thickness of 28.8m and 110.9m all at Obio Etoi. The subsurface geoelectric layers in this region are: top soil, clay soil, fine sand, medium coarse sand, fine sand, and coarse sand.

At Obio Offot and Uniuyo, the interpretation of the data reveals two major producing aquifers. The first one is between coarse sand and fine sand with thicknesses of 13.5 and 12.5m each. The delineated layers are: topsoil, coarse sand, fine sand, clay, fines sand, and coarse sand. The results have shown a well-defined geoelectrical structure, which has been differentiated into layers.

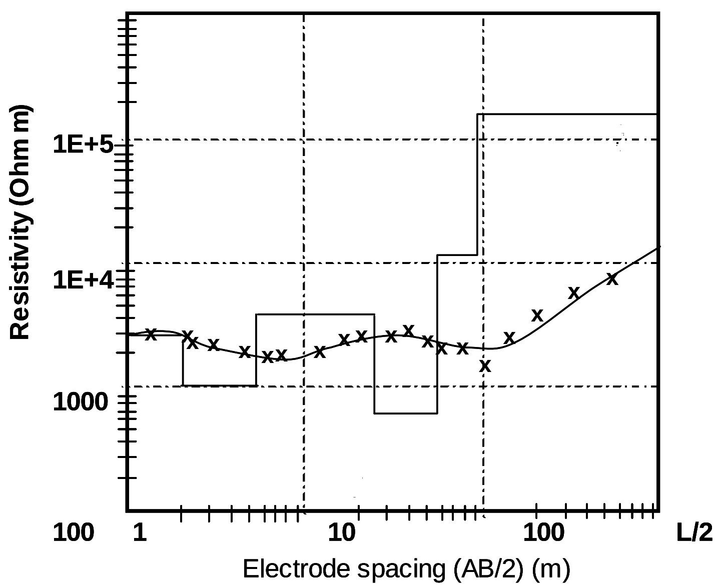


**Figure 4a:** Computer Inverse Modeling for Data Obtained at Uniuyo.

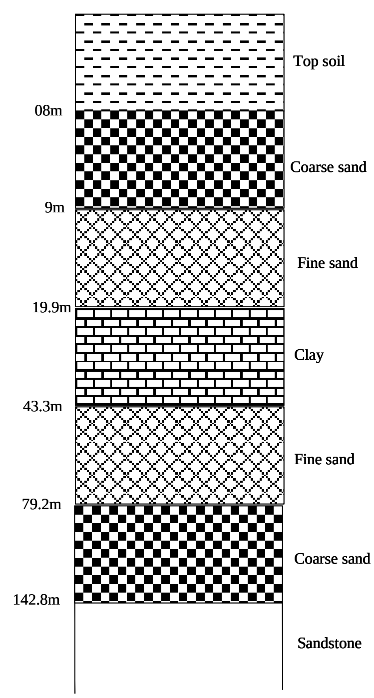


**Figure 4b:** Lithology at Uniuyo, Deduced from Computer Modeling.

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## SUGGESTED CITATION


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