IOSR Journal of Applied Geology and Geophysics (IOSR-JAGG)
e-ISSN: 2321–0990, p-ISSN: 2321–0982.Volume 3, Issue 6 Ver. III (Nov. - Dec. 2015), PP 14-20
www.iosrjournals.org

Geoelectric Investigation of Groundwater Potential of Ihiala and Its Environ, Anambra State, Nigeria

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Abstract: *The electrical resistivity method was employed to determine the groundwater potential of Ihiala and its environ. The lithostratigraphic units within the study area include: Benin Formation and OgwashiAsaba Formation. Twelve vertical electrical soundings (VES) were carried out with the Abem Tetrameter (SAS 1000) using the Schlumberger electrode configuration, with a maximum current electrode spacing (AB) of 1000 meters. The interpretation of the VES data was carried out by computer iteration using winResist software. The result obtained from the study area within the geological terrain often referred to as sedimentary environment revealed four to seven geo-electric layers at the various locations. Results also indicate that depths to aquifer varied between 26.0m and 98.68m, thickness of aquifer between 11.41m and 38.50m and resistivity of aquifer between 153Ωm and 24691Ωm respectively at the various sounding locations. Finally, VES stations along BB^1 profile drawn through North-South direction which comprise of VES 4,10,9 and 7 have been chosen as the areas that hold the best prospect for sustainable groundwater development.*
Key words: *Schlumberger Configuration, Aquifer Resistivity and Abem Terrameter*

I. Introduction

Water is vital to life; it has no substitute. Over fifty percent (50%) of Nigerians live in arid or semi-arid areas where water is scarce. Only about 3% of earth water is fresh with about twenty-five percent (30%) of that amount as groundwater (Awake, 2001). This groundwater is generally free from bacteriological pollution and has an almost constant quality and temperature. If withdrawals from the ground were moderate, groundwater supplies would remain constant but the natural water cycle is not being fully replaced, therefore the level of groundwater gets farther from the surface and it becomes difficult to dig deep enough to reach it. From an earlier study on Ihiala, a fast growing town in Anambra State, with a population of about 400,000; there is need for scientific data for the provision of social infrastructures and water cannot be neglected(Okwuchukwu, 2006).

Presently, there is no municipal water supply in Ihiala and some of the supply is from rivers and streams. However, the groundwater conditions of this area when properly understood could be used as an effective tool in the planning of a reliable groundwater scheme for people in the area.

The seismic, magnetic, gravity and electrical resistivity methods have been useful in groundwater investigations. However, because of some factors such as cost effectiveness, availability of equipment and its simplicity, the DC resistivity method was used in the study. When carrying out the method, artificial generated current is introduced into the ground, the potential difference induced by the current is measured at the surface.Deviations from the normally expected potential difference give information on the form and electrical properties of the subsurface geology. (Keary and Brooks, 1988).

1.1 Description of the study Area

The study area, Ihiala, and its evirons is located in Ihiala local Government Area of Anambra State, South East Nigeria. The area lies approximately between latitudes 5° 47’ 60”N and 5°55’ 12”N and between longitudes 6° 47’ 60” E and 6° 52’ 80” E and covers an area of 8.6square kilometer. The area is made up of plain lands and hills. To the West lies the alluvial plains and the East lies the Awka-Orlu uplands with elevation ranging from 30 to 80m. The climate of the area is tropical with an average yearly rainfall of 1500mm while average daily temperature ranges from 22°C to 32°C (Egboka and Okpoko, 1999; NIMET, 2012).

Two climatic seasons exist: the wet season which is experienced from the month of April to October and the dry season which is felt from November to March. During the dry season, the influence of the Sahara air mass affects 95% of the country (Iwena, 2010). The air is dry and dusty. The rainy season is characterized by heavy flooding, groundwater infiltration and percolation. Figure 1 shows the map of the study area with sounding points.

1.2 Geology of the Area

The geology of the study area consists of two easily distinguishable geologic Formations: the Ogwashi-Asaba Formation (Oligocene–Miocene) and the Benin Formation (Miocene– Pleiostocene). Table 1 shows the summary of geology of the area.

Table 1 Table showing the summary of geology of the study area

Age	Formation	Maximum approximate thickness(M)	Lithology
Ogwashi-Asaba	Oligocene-Miocene	244m	Alternation of Lignite, with clays and shales
Benin	Miocene-Pleistocene	200m	Alternation of coarse sands with clays and shales

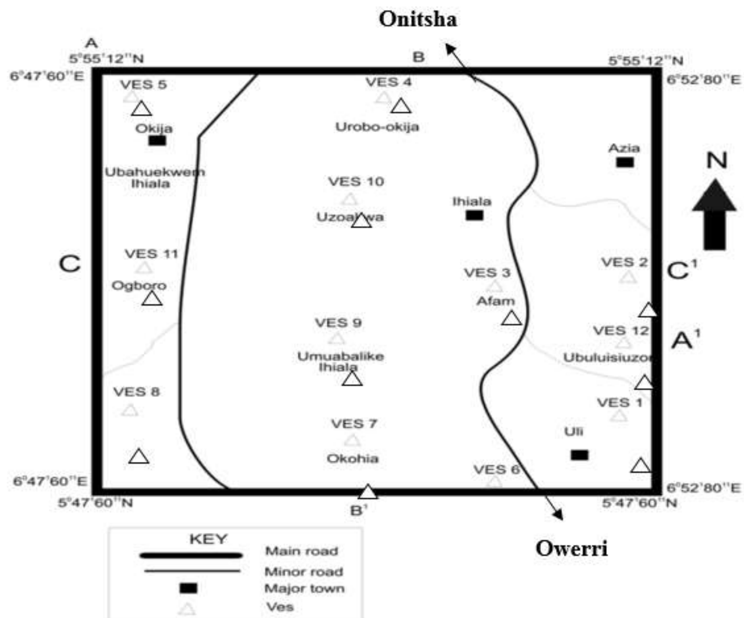

Figure 1 Location and accessibility map showing the sounding point

1.3 Hydrogeology of the Study Area

The study area is drained by Orashi River and its tributaries, the Awgbu River and Omai River all in the Northern part (Okija), and Akazi River and Abanze River in the central part (Ihiala), there is also Atamili River in the Southern part (Uli). The Orashi and Akazi Rivers are the major rivers in this area.

During the rainy season, the waters of the rivers in the area are muddy, have fast flow rates and tend to overflow their banks. The muddy nature of the waters is as a result of sediments that are eroded into the rivers from the surrounding hillslopes. In the dry season, due to decrease in precipitation, the level of the rivers falls and there is a marked decrease in flow rates. The surface of the waters appear less muddy as the erosive processes occurring during this period are not as intense as in the rainy season. Although, streams are lacking in some part of the area, perhaps due to the geology and elevation of the area, streams do sparsely exist in major parts of the area hence give great hopes to groundwater availability and productivity.

II. Materials And Methods

2.1 Theory of the Resistivity Method

In the electrical resistivity method of geophysical survey, an artificial source of direct current (DC) or a low frequency alternating current (AC) is used to inject current into the ground through two current electrodes and then the resulting potential difference developed in the subsurface is measured by means of two potential electrodes. Any subsurface variation in conductivity alters the form of current flow into the earth and this affects the distribution of electrical potential at the surface to a degree depending on the size, shape, location and electrical resistivity of the subsurface masses (Obichukwu, 2014).

2.2. Vertical Electrical Sounding (VES)

The technique used for the survey is the vertical electrical sounding. The technique (VES) gives detailed information on the vertical succession of different conducting zones or formations and their individual thickness and true resistivity below a given point on the earth surface (Telford et al., 1976).

The technique is particularly useful if the sub-surface layers to be studied are horizontally or nearly horizontally stratified. The sounding point, which is the midpoint of the electrode array, is fixed while the length of the whole array is gradually increased. As a result, the current penetrates deeper and deeper, the apparent resistivity being measured each time the current electrodes are moved outwards (Ekwe et al., 2006).

2.3 Methodology

In this research work, the Schlumberger array of electrical resistivity survey was adopted. The basic field equipment for this study is the ABEM Terrameter (SAS 1000) which displays apparent resistivity ρ_a. It is powered by a 12V DC power source. Other accessories to the terrameter include the booster, four metal electrodes, cables for current and potential electrodes, three (3) hammers, measuring tapes and cell phone for long distance measurements.

In the Schlumberger configuration, the four electrodes are positioned symmetrically along a straight line, the current electrodes on the outside and the potential electrodes on the inside. To change the depth range of the measurement, the current electrodes are displaced outwards while the potential electrodes in general are left at the same position. When the ratio of the distance between the current electrodes to that between the potential electrodes become too large, the potential electrodes will be displaced outwards otherwise the potential difference becomes too small to be measured with sufficient accuracy (Koefed, 1979). During the field work, when a sounding is taken, the Abem terrameter performs automatic recording of apparent resistivityρ_a and digitally displays it.

For Schlumberger array, apparent resistivity is given by

$$\rho = \pi R(\frac{a^2}{b} - \frac{b}{4}) \qquad \text{(Adamu, 2001)}$$

Wherea = half current electrode separation; b = half potential electrode separation

III. Results and Discussion

The interpretation was done by computer iteration using Win Resist software and partial curve matching. Figure 2 and Table 1 shows the interpreted curves and results obtained from VES 1 data while Table 2 is the summary of the result obtained from the interpreted data.

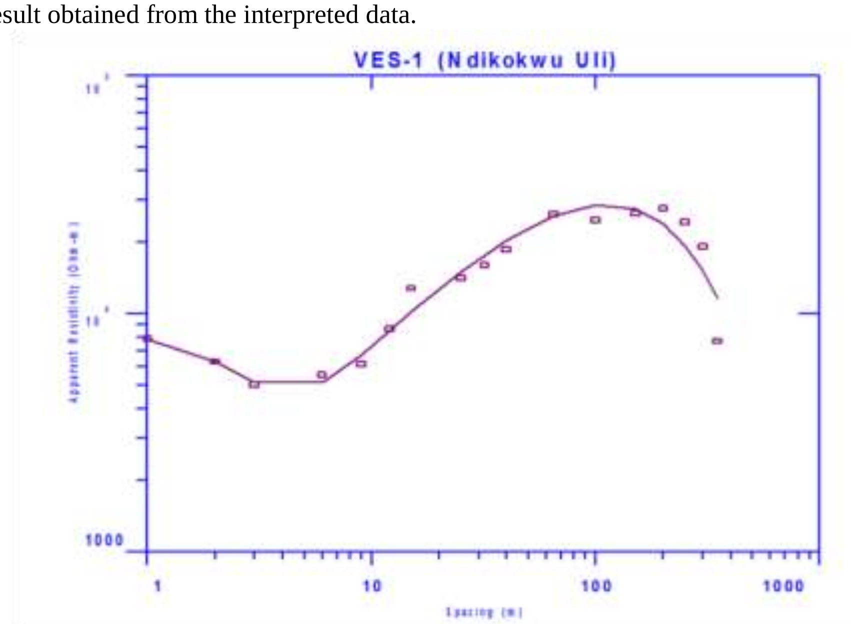

Figure 2 Sounding curve for VES 1

Table 2Result from interpretation of the VES 1

Layer	Resistivity (Ωm)	Thickness (m)	Depth (m)
1	8298	1.07	0.00
2	3208	3.39	1.07
3	45519	60.13	4.46
4	24691	34.09	64.59
5	2242		98.68

The first step in the interpretation of VES data is to group the curve into types. This is done by visual inspection. There are four types of curves, HA, HK, KH and AK respectively. VES 1 and 2 are of HA type, VES 3, 11 and 12 are of KH type, VES 4, 6, 7 and 9 are of AK type while VES 5, 8 and 10 are of HK type. Table 3 shows the analysis of curve types.

Table 3Analysis of Curve Types

VES	Curve type	Curve characteristics	Number of Geoelectric layers
1	HA	$\rho_1 > \rho_2 > \rho_3 < \rho_4$	5
2	HA	$\rho_1 > \rho_2 > \rho_3 < \rho_4$	5
3	KH	$\rho_1 < \rho_2 < \rho_3 > \rho_4$	4
4	AK	$\rho_1 < \rho_2 < \rho_3 > \rho_4$	5
5	HK	$\rho_1 > \rho_2 < \rho_3 > \rho_4$	5
6	AK	$\rho_1 < \rho_2 > \rho_3 > \rho_4$	4
7	AK	$\rho_1 < \rho_2 > \rho_3 > \rho_4$	4
8	HK	$\rho_1 > \rho_2 < \rho_3 > \rho_4$	6
9	AK	$\rho_1 < \rho_2 > \rho_3 > \rho_4$	4
10	HK	$\rho_1 > \rho_2 < \rho_3 > \rho_4$	7
11	KH	$\rho_1 < \rho_2 < \rho_3 > \rho_4$	5
12	KH	$\rho_1 < \rho_2 < \rho_3 > \rho_4$	5

3.1Correlation along different profiles

3.1.1 VES points along AA' Profile

AA´ is a cross section drawn in the northwest – southeast direction of the study area as shown in Figure1, the VES along this direction is VES 5, 3 and 12 as shown in Figure 3 VES 5 is a HK type curve and has five layers, VES 3 and 12 are KH type of curve. The first geoelectric layers correspond to laterite with an average resistivity value of 1659.7Ωm and average thickness of 0.81m. VES 5 has the fourth layers as aquifer bearing layer with a thickness of 22.09m and a depth of 57.81m with a resistivity value of 984.3Ωm. Aquifer is found at the third layer in VES 3 with a thickness and depth of 17.60m and 5.21m respectively and because it is not deeply seated, it is likely to be susceptible to pollution while VES 12 has aquifer at the fourth layer with a resistivity of 743.4Ωm, depth of 39.43m and thickness of 24.58m respectively.

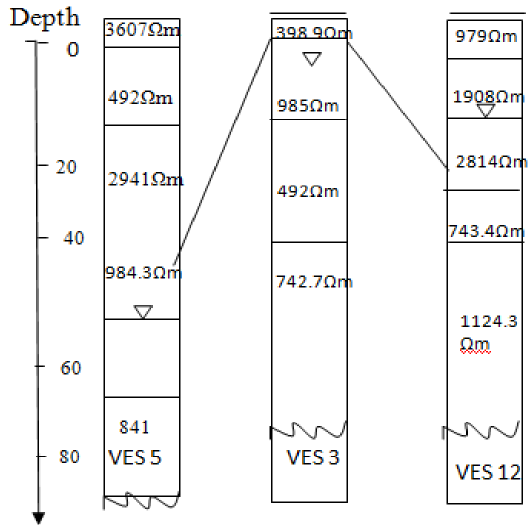

Figure 3 Geoelectric Cross section along AA[I]

3.1.2 VES Points along BB[I] Profile

BB[I] is a cross section drawn through North-South direction as indicated in Figure 1. The VES along this section are VES 4, 10, 9 and 7 as shown in Figure 4. VES 7 and 9 are AK type and contains four layers each, VES 4 is a five layer AK type while VES 10 is a seven layer with HK type. The first layers is interpreted as the laterite with a resistivity values ranging between 200.3Ωm in VES 4 and 2865Ωm in VES10.VES4 has aquifer seated at the third layer with a thickness of 26.25m and a depth of 43.03 m and resistivity of 983 Ωm. VES 10 has a multiple aquifer seated at the third and sixth layer respectively. A sandstone aquitard of depth 59.60m and thickness of 31.41m and resistivity of 511.0 Ωm occupying the third layer is in VES 9 while VES 7 has its aquifer at the third layer with a thickness of 38.50m and a low resistivity of 153.3Ωm.

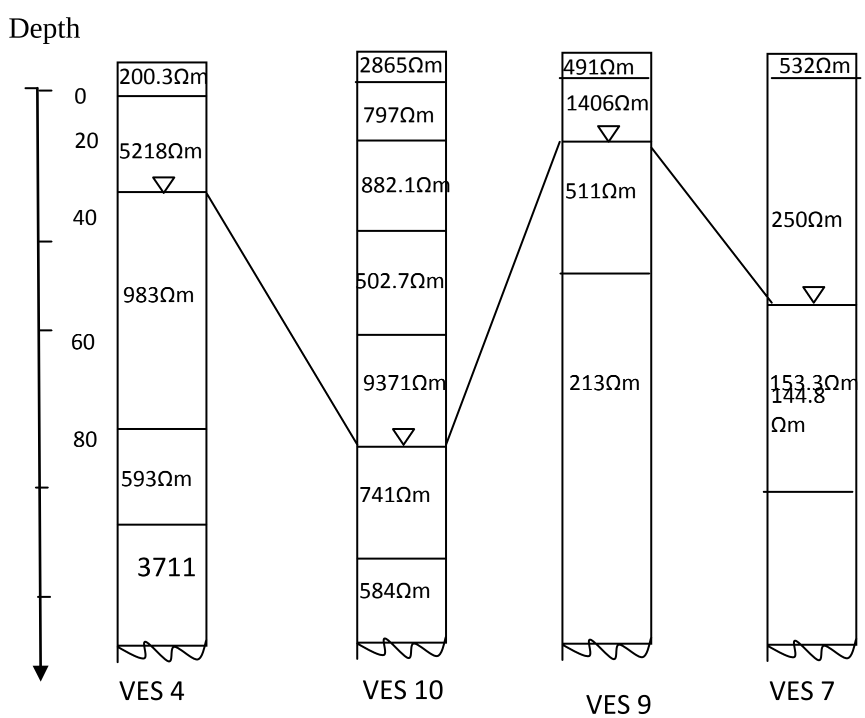

Figure 4 Geoelectric Cross section along BB[I]

3.1.3 VES Points along CC^{l} Profile

CC^{l} is another cross section drawn through East-West direction and covers a distance of about 19 km as indicated in Figure 1. The VES along this direction are VES 11, 3 and 2. VES 11 has a low resistivity value of 164.6Ωm as shown in Figure 5. The VES along this profile has aquifer deeply seated at the second to the last layer and is interpreted as saturated sandstone. The resistivity value of this layer ranges from 492.1Ωm to 90.5Ωm and has an average thickness and average depth values of 15.9m and 56.43 m respectively as indicated in Figure 5.

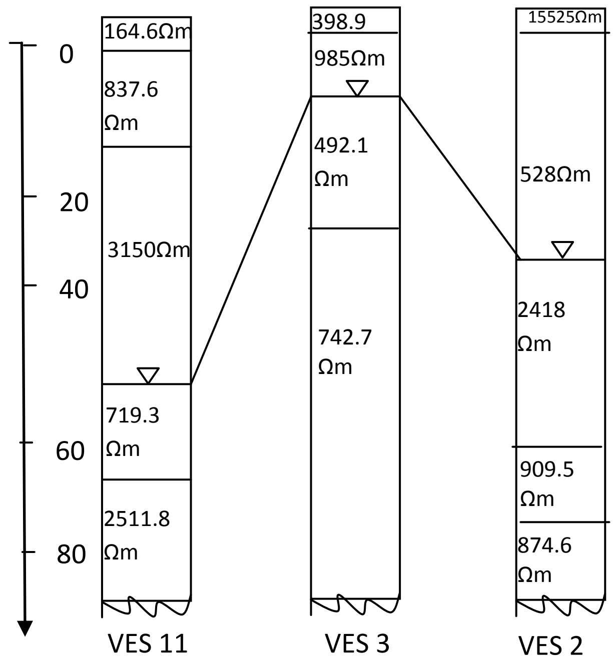

Figure5 Geoelectric Cross section along CC^{I}

VES Number	Location	Aquifer thickness h (m)	Aquifer resistivity (m)	Depth to Water(m)	Curve Type	Number of layers
1	Ndikokwa	34.09	2469	64.59	HA	5
2	Ansu Rd Uli	19.40	1309	62.50	HA	5
3	Okohia Ihiala	38.50	153	75.80	KH	4
4	Umuabalike Ihiala	11.41	511	39.60	AK	5
5	Afam	17.60	492	32.81	HK	5
6	Mbosi	13.87	909	63.08	AK	4
7	Ogboro Ihiala	16.28	719	73.40	AK	4
8	UbuluIsiuzor	24.58	7343	64.01	HK	6
9	Uruobo Okija	15.91	983	43.03	HA	4
10	Okija	22.09	984	57.81	AK	7
11	Ihiala	14.86	843	26.00	HK	5
12	Uzoakwa Ihiala	18.41	441	81.43	HK	5

Table 4 Summary of the results obtained from interpreted VES data

IV. Conclusion

The outcome of the research will serve as a veritable tool to both government and individuals especially those involved in groundwater development as to the depth to aquifer, the composition and thickness of aquifers present within the study area.

Based on our findings, the VES along BB^{l} drawn along North-South direction which comprises VES 4, 10, 9 and 7 that are located at UruoboOkija, Uzoakwa Ihiala,Umuabalike Ihiala and Okohia Ihiala respectively have been chosen as the areas that hold the best prospect for sustainable groundwater development. The thickness of the aquifers at these areas indicate a very good potential for groundwater occurrence. It is hoped that the results from the present study if properly utilized, would go a long way in reducing the cases of borehole failures within the study area.

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