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Geoelectrical Sounding Survey For Aquifer Determination In Some Northern Parts of Edo State - Nigeria

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Abstract

31 Geoelectrical soundings investigation comprising 17 soundings in Auchi VES 2 and 14 soundings in Igarra VES 3 all in the northern part of Edo State has been carried out. The aim of the survey was to explore the ground water potential of the areas and ascertain the structures that are needed for the occurrence of ground water. Schlumberger electrode configurations were used for data acquisition which was thereafter reduced to apparent resistivity values. The true depths and resistivity values were determined by curve matching and iterative processing techniques. From the interpretation of results, it was found that ten geoelectrical layers characterized Auchi VES 2 while seven geoelectric layers characterized the Igarra VES 3. For the Auchi sounding, the thicknesses of wet top soil to dry sand vary from 0.71 – 176m with resistivity values of 145 – 8122 ohm-m while for Igarra sounding, the thicknesses of lithology (top soil to fresh basement) ranges from 0.45 – to 16.63m with corresponding resistivity values of 293.00 – 1187.92 ohm-m. A borehole is thus recommended at 25.37m depth for Auchi VES 2 while at Igarra VES 3 a borehole at 8.10m depth is recommended.

1.0 Introduction

Northern parts of Edo State especially Auchi and Igarra have in recent times experienced acute water shortage. This is because the surface source of water are seasonal and are not available on a permanent basis or one often contaminated with water borne pathogens, [5]. Consequently, there is high rate of shallow hand-dug wells; drilling of boreholes and in some cases construction of dams.

This paper therefore describes the geo-electric investigation undertaken in Auchi and Igarra both in the northern part of Edo State with the aim of exploring ground water potential of the areas. Underground water especially in basement areas occurs in the deeply weathered and fractured areas [7]. The greater the intensity of fracturing and sandy weathering, the higher the yield from wells and boreholes located in the areas. There is therefore urgent need to have a reliable water supply to the growing towns of Auchi and Igarra due to the erratic nature of the public water supplies in the country.

2.0 Background Geology

Auchi and Igarra generally are characterized by medium to coarse-grained biotite granite. Some wells exist in both towns but there are no borehole logs except some private wells outside which was said to have encountered fresh basement at about 47 meters in Auchi and 12 meters in Igarra.

3.0 Theory And Methods Of Study

When electrical current is passed into the ground by pair of electrodes called the current electrodes, their potential drop is measured through another pair of electrodes called the potential electrodes. The electrodes have practically zero resistance because it is a metallic body. The principle of operation depends on the fact that any subsurface variation in conductivity utters the form of current flow within the earth and thus in turn affect the distribution of electric potential. Thus it is possible to have information about the subsurface formations from the potential measurement made at the surface

Measurements were taken whenever the outer current electrodes are moved further apart so that current penetrates deeper into the ground while the inner electrodes are fixed unless the signals become too small to be readable. Apparent resistivities are then calculated at each spacing and thereafter plotted on biloga scales as a function of Pd/L.

The interpretation of the Schlumberger soundings assumes that the array measures to electrified strength, [10]. Let the current passing into the earth through one of the current electrodes be +1. We also assume that the earth is homogenuous, extends to infinity in the downward direction and has a resistivity P. if we describe a hemispherical shell of radius S and thickness dr1 around the electrode, the potential difference across the shell will be

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$$dV = \frac{IPdr_1}{2\pi r^2{}_1} \tag{3.1}$$

$$\therefore \int dV = \frac{-\int IPdr_1}{2\pi r^2{}_1} \tag{3.2}$$

The potential at point C is given by:

$$V_c = \frac{IP}{2\pi}\left(\frac{1}{r_1} - \frac{1}{r_2}\right) \tag{3.3}$$

$$\mathrm{V_d} = \frac{\mathrm{IP}}{2\pi}\left(\frac{1}{\mathrm{R}_1} - \frac{1}{\mathrm{R}_2}\right) \tag{3.4}$$

The potential difference between C&D is:

$$\Delta V = \frac{IP}{2\pi}\left(\frac{1}{r_1} - \frac{1}{r_2} - \frac{1}{\mathrm{R}_1} + \frac{1}{\mathrm{R}_2}\right) \tag{3.5}$$

Cross multiplying the L.H.S

$$2\pi\Delta V = IP\left(\frac{1}{r_1} - \frac{1}{r_2} - \frac{1}{\mathrm{R}_1} + \frac{1}{\mathrm{R}_2}\right)$$

$$P = \frac{2\pi\Delta v}{I}\left(\frac{1}{\frac{1}{r_1} - \frac{1}{r_2} - \frac{1}{\mathrm{R}_1} + \frac{1}{\mathrm{R}_2}}\right) \tag{3.6}$$

Let K, the geometric factor be:

$$\mathrm{K} = 2\pi\left(\frac{1}{\frac{1}{r_1} - \frac{1}{r_2} - \frac{1}{\mathrm{R}_1} + \frac{1}{\mathrm{R}_2}}\right) \tag{3.7}$$

Assumptions:

Let $r_1 = \frac{AB}{2} - \frac{CD}{2}$, $r_2 = \frac{AB}{2} + \frac{CD}{2}$, $\mathrm{R}_1 = r_2$, $\mathrm{R}_2 = r_1$

Then k becomes

$$\mathrm{K} = 2\boldsymbol{\pi}\left(\frac{\mathbf{1}}{\frac{\mathbf{1}}{\frac{\mathbf{AB}}{\mathbf{2}} - \frac{\mathbf{CD}}{\mathbf{2}}} - \frac{\mathbf{1}}{\frac{\mathbf{AB}}{\mathbf{2}} + \frac{\mathbf{CD}}{\mathbf{2}}} - \frac{\mathbf{1}}{\frac{\mathbf{AB}}{\mathbf{2}} + \frac{\mathbf{CD}}{\mathbf{2}}} + \frac{\mathbf{1}}{\frac{\mathbf{AB}}{\mathbf{2}} - \frac{\mathbf{CD}}{\mathbf{2}}}}\right) \tag{3.8}$$

Adding like terms, we have;

$$\mathrm{K} = 2\boldsymbol{\pi}\left(\frac{\mathbf{1}}{\frac{\mathbf{2}}{\frac{\mathbf{AB}}{\mathbf{2}} - \frac{\mathbf{CD}}{\mathbf{2}}} - \frac{\mathbf{2}}{\frac{\mathbf{AB}}{\mathbf{2}} + \frac{\mathbf{CD}}{\mathbf{2}}}}\right) \tag{3.9}$$

Taking the LCM, we get

$$K = 2\pi\left(\frac{1}{\frac{2\left(\frac{AB}{2} + \frac{CD}{2}\right) - 2\left(\frac{AB}{2} - \frac{CD}{2}\right)}{\left(\frac{AB}{2} - \frac{CD}{2}\right)\left(\frac{AB}{2} + \frac{CD}{2}\right)}}\right) \tag{3.10}$$

Let AB/2 = J so that equation (3.10) becomes

$$K = 2\boldsymbol{\pi} \left(\frac{1}{\frac{2J+CD-2J+CD}{\left(J-\frac{CD}{2}\right)(J+\frac{CD}{2})}} \right) \tag{3.11}$$

$$K = 2\boldsymbol{\pi} \left(\frac{1}{\frac{2CD}{\left(J-\frac{CD}{2}\right)(J+\frac{CD}{2})}} \right) \tag{3.12}$$

Considering the lower part and taking the LCM we have

$$\left(\frac{2J-CD}{2}\right) \left(\frac{2J+CD}{2}\right) = \frac{4J^2-(CD)^2}{4}$$

$$\text{K=2 } \pi \left(\frac{1}{\frac{2CD}{\frac{4J^{2-}(CD)^2}{4}}} \right) \tag{3.13}$$

$$K = 2\boldsymbol{\pi} \left(\frac{1}{2\text{CD}} * \frac{4\text{J}^2 - (\text{CD})^2}{4}\right) \tag{3.14}$$

After some algebra, we get

$$\text{K} = \pi \text{ CD} \left(\left(\frac{J}{CD}\right)^2 - \frac{1}{4} \right) \tag{3.15}$$

But apparent resistivity is given by

$$\rho_a = \frac{KV}{1} \quad \text{and} \quad k = \pi CD \left(\left(\frac{J}{CD}\right)^2 - \frac{1}{4} \right)$$

$$\boldsymbol{\rho_a} = \frac{\pi CDV}{1} \left(\left(\frac{J}{CD}\right)^2 - \frac{1}{4} \right)$$

For schumbeger electrode array, where apparent resistivity is the resistivity of the homogenous layer, it is a weighted average of the true resistivities of the various homogenous layers. Interpolation was done in terms of variation of apparent resistivity with depth for the various layer encountered. The potential for a two layer earth was given by [3] as

$$V(r) = I\rho(1 + 2r) \int_0^\infty k(\lambda, k, h) I_0 \, (\lambda_r) d\lambda$$

Where

$$k = (\rho_2 - \rho_1)/(\rho_2 + \rho_1)$$

$$k(\lambda) = \frac{ke^{-2\lambda h}}{1-ke^{1-2\lambda h}} \equiv kernel\ function$$

I_0 = Bassel function of zero order
r = Distance between current and potential electrodes
h = thickness
ρ = resistivity
λ = function of anisotropy

Subscript 1 and 2 indicate the first and second layers respectively

This is the basic equation employed in all resistivity work for one current (I) source in a homogenous half earth [4].

In areas of known geology like the Auchi and Igarra towns, the symmetrical array is best suited to get the vertical variation in resistivity with depth. Of the two popular methods (Wenner and Schlumberger), the Schlumberger array was used in this survey because of the fact that for a given electrode separation current penetrates deeper so that it is more economical, in terms of manpower, one person can operate the potential electrode, the records thus making it also economical. Schlumberger array is less sensitive to lateral in homogeneities as well as stray current and finally the field curves are generally smoother and free steep gradients.

Accordingly, two (2) Schlumberger vertical electrical soundings (VES) were made in the study areas with a maximum current electrode spacing (AB/2) of 147m. The axes of the soundings were aligned parallel to the geologic strike in order to reduce the effects of lateral variations. Various measurements were taken conveniently at two different stations –one at Auchi VES 2 whiles the other in Igarra VES 3. The Schlumberger electrode configuration was used to determine the static water levels and the effect of weathering bedrock topography. On the whole, thirty one (31) vertical soundings were carried out in both locations (Auchi 17, Igarra 14) while the ABEM Terrameter SAS 300 was utilized in data gathering. The maximum current electrodes distance was 1000m for the 2 locations while resistivity meter reading in the form of resistance values were reduced to apparent resistivity values.

Interpretation of data results was done by curve matching which involves the comparison of curve obtained from the field data with the standard characteristic curve called **MASTER CURVE.** Theoretically, calculated types of curve have been prepared by various workers showing apparent resistivity against half the current electrode spacing for a variety of 2,3 or 4 layered models with different resistivity value for each layer. To match a field curve obtained from the field, it is only necessary to slide the field curve around on the master curve until the field curve coincides more or less with one of the master curves. This gives information about the thickness and apparent resistivity of the various layers.

4.0 RESULTS

The apparent resistivity values were plotted against AB/2. Curve matching and computer iterative processing techniques were used to determine both true resistivity and depth values. All the VES curves were characterized by a rising terminal branch which indicates a semi-finite basal unit of high resistivity.

Table 1: Soundings data for Auchi VES 2

S/N	AB/2 (m)	Observed Resistivty (ohm-m)	Computed Resistivity (ohm-m)	Log difference
1	1.0	200.00	210.59	-0.02
2	1.47	255.00	287.64	-0.04
3	2.15	420.00	384.79	0.04
4	3.16	560.00	538.93	0.02
5	4.64	850.00	747.30	0.06
6	6.81	1045.00	1017.28	0.01
7	10.0	1371.00	1356.62	0.00
8	14.7	1714.00	1770.51	-0.01
9	21.5	2164.00	2245.45	-0.02
10	31.6	3101.00	2788.56	0.05
11	46.4	3792.00	3412.47	0.05

12	68.4	4887.00	4108.69	0.08
13	100	5066.00	4713.84	0.03
14	147	5276.00	4903.89	0.03
15	213	4376.00	4487.06	-0.01
16	316	3093.00	3713.42	-0.08
17	464	3341.00	3115.70	0.03

Table 2: Soundings data for Igarra VES 3

S/N	AB/2 (m)	Observed Resistivty (ohm-m)	Computed Resistivity (ohm-m)	Log difference
1	1.0	226.00	213.66	0.02
2	1.47	170.00	185.46	-0.04
3	2.15	176.00	175.98	0.00
4	3.16	185.00	181.19	0.01
5	4.64	190.00	190.35	-0.00
6	6.81	200.00	199.14	0.00
7	10.0	210.00	213-55	-0.01
8	14.7	230.00	244.19	-0.03
9	21.5	290.00	297.40	-0.02
10	31.6	370.00	376.00	-0.01
11	46.4	540.00	476.10	0.05
12	68.4	670.00	591.73	0.08
13	100	750.00	715.30	0.02
14	147	770.00	837.54	-0.04

Table 3: Various layers in Auchi VES 2

Layers	**Resistivity. (m)**	**Thickness (m)**	**Cum. Thickness (m)**	**Lithology**
1	145	0.71	0.71	Wet top soil
2	1606.50	1.09	1.80	Lateritic layer

3	5060.00	5.09	6.89	Lateritic layer
4	3456.00	18.48	25.37	Aquifer
5	2640.09	8.32	33.69	Aquifer
6	7767.56	32.73	66.42	Sandstone
7	2571.43	39.79	106.21	Fresh water
8	1532	70.28	176.49	Fresh water
9	8122	Infinity	Infinity	Dry sand
10	8122	Infinity	Infinity	Dry sand

Table 4: Various Layers of Igarra VES 3

Layers	Resistivity. (m)	Thickness (m)	Cum. Thickness (m)	Lithology
1	293.00	0.45	0.45	Top soil
2	126.03	0.64	1.09	Dry clay zone
3	207.00	2.60	3.69	Dry sand zone
4	172.57	4.41	8.10	Aquifer bearing
5	412.00	8.53	16.63	Fresh basement
6	1044.09	38.17	54.80	Fresh basement
7	1187.92	Infinity	Infinity	Fresh basement

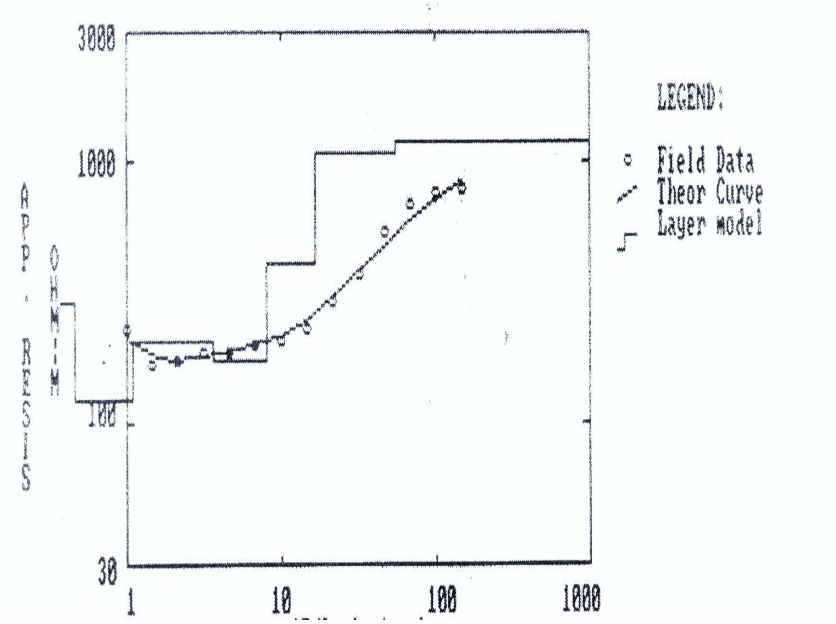

Figure 1: Field and theoretical curves for VES 3

location: Igarra

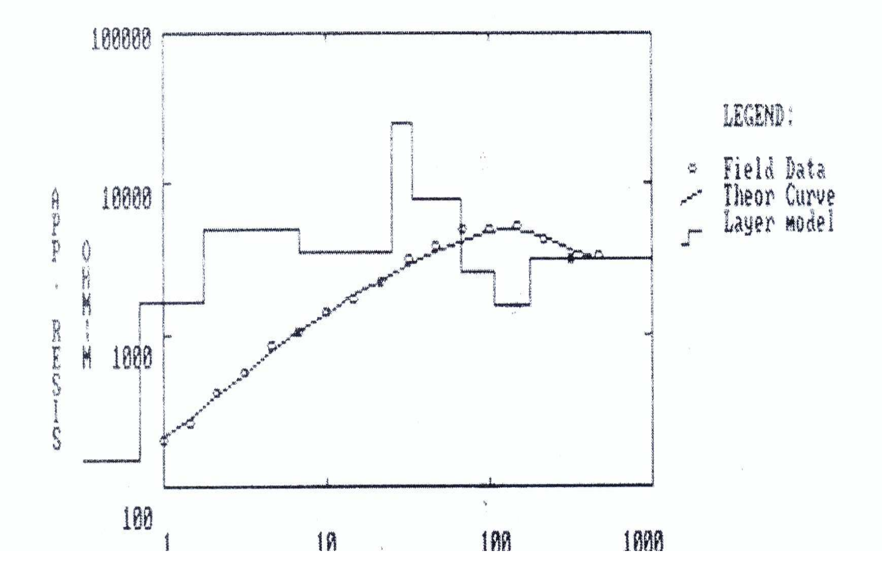

Figure 2: Field and theoretical curves for Auchi VES 2

Location: Auchi

5.0 Discussion

In this paper, we have outlined the various results from a geoelectric survey for the groundwater in the crystalline basement areas around Igarra and Auchi towns both Edo State. For the Auchi (VES 2) layer one is considered to be wet top soil because of its low resistivity value; two and three is well compacted lateritic layers which is attributable to its higher resistivity values. Layers four and five has a considerable abrupt decreases in resistivity value and it correspond to an aquifer, layer six experiences anomalous increase and it correspond to sandstone or hard rock; layers seven and eight correspond to fresh basement zone while the last two layers are considered to be of dry sand. For Igarra (VES 3), layer one is observed to be top soil; layer two is a dry zone; layer three was observed to be a dry sand zone; layer four is an aquifer zone (water is located) while layers five to seven correspond to fresh basement zones.

6.0 Conclusion

Vertical electrical sounding with schlumberger electrode configuration was used to investigate some northern sections of Auchi VES 2 and Igarra VES 3. The results obtained shows that geological and geoelectrical sections correlate well and that at a depth of 25.37m probed in Auchi VES 2 and 8.10m probed in Igarra VES 3, rich aquifer can be found. It is also recommended that further investigation be carry out in other areas of Auchi and Igarra in order to ascertain the availability of rich aquifer in within those areas.

Finally, this study has not only provided information on the depth of the ground water, thickness of the aquiferious unit in Auchi and Igarra towns but also becomes relevant to the development of an effective water scheme for the areas.

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