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Determination of water table using electrical sounding technique: A case study of Afuze Edo State, Nigeria

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Abstract

This work investigated water-bearing formation and determined the water table in Afuze, a major town in Edo state, Nigeria, using electrical sounding techniques with the schlumberger electrode configuration The ABEM SAS 300B Terrameters was used in this work to carry out Resistivity soundings from several locations which were evenly distributed within the study area. The value of the apparent resistivities got, were computed manually and with computer and plotted on log-log graph, all of which are shown in this work. The interpretation was done qualitatively and quantitatively by comparison of resistivity curve type and curved matching techniques respectively. Models were generated for computer iterative technique and Borehole data were also collected using spontaneous potential logging method as well as driller's log in some selected sites within the study area so as to correlate surface measurement with borehole records. Analysis based on three depth related resistivity contour VES, as well as selected cross sectional profiles confirm the existing dual regional geological environment of the area. Finally, it was established, from The result obtained that the water bearing formation at Afuze was mainly sand and was found at depth between 32.6m-50m.

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1.0 Introduction

There is no doubt that water is among the commonest but most precious substances on earth, vital for any form of life. In Africa, Afuze is a major town in Edo State Nigeria, where there is problem of acute water shortage due to the fact that there is hardly any natural surface water such as streams, lakes, springs, rivers and so on, and where available they may too far from the communities or hilly to fetch water for domestic use. Consequently the importance of underground water investigation cannot be over looked The geophysical techniques most widely employed for exploration work are seismic, gravity, magnetic, electromagnetic, radioactive, and electrical logging methods. For the purpose of this work, the electrical method was used. Electrical resitivity is commonly used for ground water investigation. It involves the measurement of apparent resistively of soils and rocks as a function of depth or position. (Osemeikhian and Asokhia, 1994) [6].

Vertical Electrical Sounding [VES] is the most widely used electrical technique because it enables quantitative interpretation of measured apparent resistivity data to be made. In practice the basic principle underlying this method is to pass current into the ground by means of two electrodes called current electrodes and to measure potential differences by means of two other electrodes called potential electrodes. The principle of operation depends on the fact that any sub-surface variation in conductivity alters the form of current flow within the earth and this in turn affects the distribution of electric potential. Thus, it possible to have information about the sub-surface formations from potential measurements made at the surface. (Okwueze, 1996) [5].

2.0 Theory

It has been shown (Zohdy, 1973) [7] that the electric potential V due to a single point source in a homogeneous and isotropic medium is giving by

$$V = \frac{I\rho}{2\pi R} \tag{2.1}$$

where I = Current magnitude Passed [A]

ρ = Apparent resistivity [Ωm]

R = Distance [m]

The case of a single current source connected to the ground is shown in Figure 1

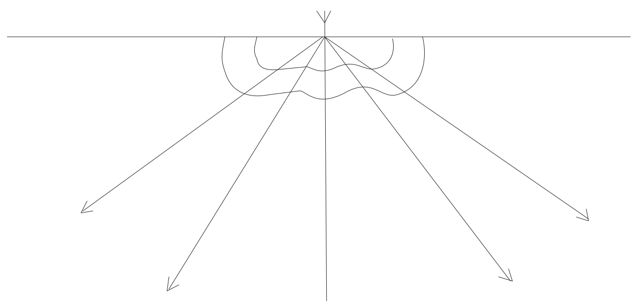


Figure 1: Single current source

However in prospecting, two current electrodes are normally used. This case is shown in Figure 2.

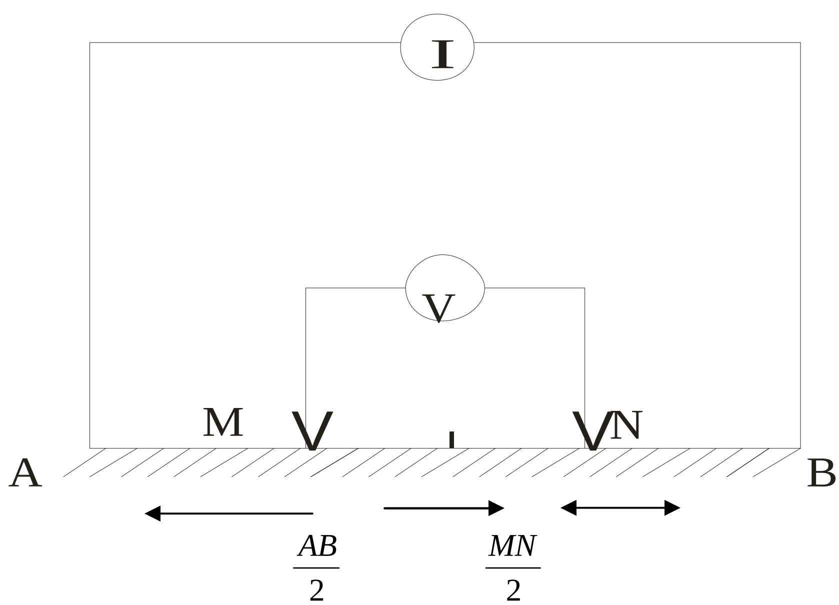


Figure 2: Two current sources

In Figure 2, (Dobrin, 1988 [3]), A and B are current electrodes, while M and N are potential electrodes. The potential due to *A* at *M* is given by.

$$V_M^A = \frac{I\rho}{2\pi(AM)} \tag{2.2}$$

while the potential due to *A* at *N* is given by

$$V_N^A = \frac{I\rho}{2\pi(AN)} \tag{2.3}$$

Similarly

$$V_M^B = \frac{I\rho}{2\pi(BM)} \tag{2.4}$$

$$V_N^B = \frac{I\rho}{2\pi(BN)} \tag{2.5}$$

The potential at *M* due to *A* and *B* is given by

$$V_M^{A,B} = V_M^A - V_M^B \tag{2.6}$$

Therefore

$$V_M^{A,B} = \frac{I\rho}{2\pi(AM)} - \frac{I\rho}{2\pi(AM)} \tag{2.7}$$

$$= \frac{I\rho}{2\pi}\{\frac{1}{AM} - \frac{1}{BM}\} \tag{2.8}$$

Similarly

$$V_N^{A,B} = \frac{I\rho}{2\pi(AN)} - \frac{I\rho}{2\pi(BN)} \tag{2.9}$$

$$= \frac{I\rho}{2\pi}\left\{\frac{1}{AN} - \frac{1}{BN}\right\} \tag{2.10}$$

Difference in potential at *M* and *N* is thus given by

$$\Delta V = V_M^{A,B} - V_M^{A,B} \tag{2.11}$$

That is.

$$\Delta V = \frac{I\rho}{2\pi}\left\{\frac{1}{AM} - \frac{1}{BM}\right\} - \frac{I\rho}{2\pi}\left\{\frac{1}{AM} - \frac{1}{BM}\right\} \tag{2.12}$$

$$= \frac{I\rho}{2\pi}\left\{\frac{1}{AM} - \frac{1}{BM} - \frac{1}{AN} + \frac{1}{BN}\right\} \tag{2.13}$$

Therefore, the ground resistivity is given by

$$\rho = \frac{\Delta V}{1}\frac{2\pi}{\left\{\frac{1}{AM} - \frac{1}{BM} - \frac{1}{AN} + \frac{1}{BN}\right\}} \tag{2.14}$$

Equation (2.14) can be written as

$$\rho = K\frac{\Delta V}{1} \tag{2.15}$$

Thus

$$K = \frac{2\pi}{\left\{\frac{1}{AM} - \frac{1}{BM} - \frac{1}{AN} + \frac{1}{BN}\right\}} \tag{2.16}$$

And K is defined as the geometric factors of the electrode array system. When the ground is uniform, the resistivity calculated from equation 15 above should be constant and independent of both electrode spacing and surface location. For an inhomogeneous Earth, however the resistivity will vary with the relative position of the electrode. Any computer value is therefore referred to as 'apparent resistivity' Pa and will be a function of the ininhomoegeneity (Beck, 1981 [2]).

3.0 Data acquisition and interpretation of sounding curves.

The ABEM SAS 300B was utilized in data gathering. A total of three vertical electrical soundings [VES] were undertaken in Afuze town, each sounding point being approximately 1000m from each other. The schlumberger electrode arrangement was used for measurements. The maximum current electrodes spacing was 147*m* for all sounding points (Asokhia, 1995 [1]).

The apparent resistivity values obtained from the measurements were plotted against half the current electrode spacing. The sounding curves [VES 1-3] are shown in Appendices I, II, and III. The result displayed shows the geoelectric layer thickness and the cumulative thickness in metres of the studied area.

Location VES (1) has seven layers with resistivities ranging from 65.07.00 Ω*m* at the top layer to 349.00 Ωm at the 7^{th} layer. With thickness from 1.63m to a very large value respectively.

Location VES (2) has five layers with resistivities ranging from 12.39 Ω*m* at the top layer to 21.70 Ω*m* at the 5^{th} layer with thickness from 0.60*m* to a very large value respectively.

Location VES (3) also has five layers with resistivities ranging from 57.40 Ω*m* at the top layer to 835.00 Ω*m* at the 5^{th} layer with thickness from 1.00*m* to a very large value respectively.

4.0 Result and discussion

The results obtained from the computer interactive analysis in all the sounding and the results of the curve matching at Afuze VES 2 was interpreted.

4.1 Results of the Matching Afuze VES 2

$P_1 = 19\Omega\text{m}$

$P_2 = P_1 k_1 = 19 \times 7 = 133\Omega\text{m}$

$P_3 = P_{12} k_2 = 55 \times 2/3 = 36.67\Omega\text{m}$

$P_4 = P_{r3} k_3 = 36 \times 3/7 = 15.43\Omega\text{m}$

$P_5 = P_{r4} k_4 = 15.5 \times 11/9 = 18.94\Omega\text{m}$

$h_1 = 1M$

$h_2 = d_1 h_1 = 4 \times 1 = 4m$

$h_3 = d_2 h_2 = 1.8 \times 4.2 = 7.56m$

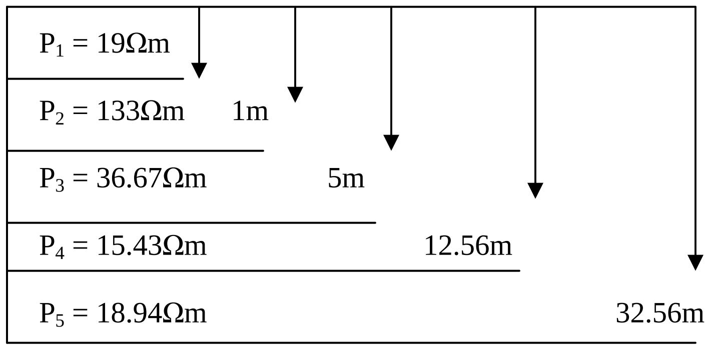
$h_4 = d_3 h_3 = 2 \times 10 = 20m$

$h_5 = \alpha$

Table 1

Layer	Resitivities (*nm*)	Thickness *H*(*m*)	Cumulative Thickness (*m*)
1	19	1	1
2	133	4	5
3	36.67	7.56	1..56
4	15.45	20	32.56
5	18.94	α	α

A geoelectric section along survey traverse would thus show



The thickness of the fifth layer is very large. The field curve has actually shows five geoelectric layers of the form $p_1 \prec p_2 \prec p_3 \prec p_4 \prec p_5$. This agrees with the geoelectric session presented above. This is an alteration of KQ curve. (Emenike, 2001 [4]).

5.0 Conclusion

The Afuze area of Edo state has been found to be a basement environment. From the observations, the water table at Afuze can be found between 32.6m-50.00m. This has been verified by the calculations shown from the curve matching and from the computer interpretation. Based on the interpretation of the VES curves, it was found out that the water formation [aquifiers] at Afuze is mainly sand.

Appendix I

Figure 1: Afuze site - VES Number 1

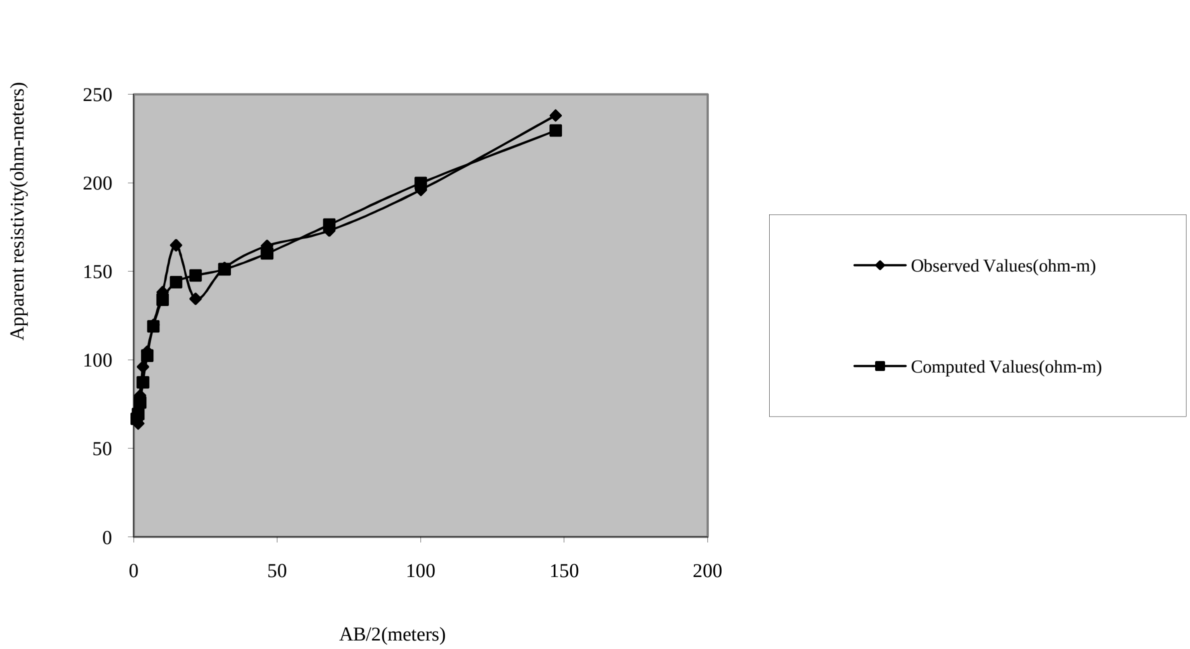


Table 1: Observed (Field) and computed (Theoretical) Data

AB/2 Values(m)	Observed Values(ohm-m)	Computed Values(ohm-m)
1.00	67.46	66.78
1.47	64.10	69.52
2.15	79.84	75.95
3.16	96.11	87.36
4.64	104.73	102.45
6.81	119.9	118.97
10.00	138.2	134.07
14.70	164.77	143.89
21.50	134.51	147.76
31.60	152.00	151.23
46.40	164.41	160.15
68.10	173.00	176.36
100.00	196.00	199.87
147.00	238.00	229.58

Model Parameters

Geoelectric Layer	Resistivity (ohm-meter	Thickness (m)	Cumulative Thickness(m)
1	65.07	1.63	1.63
2	187.15	1.28	2.89
3	87.66	0.83	3.72
4	226.35	5.08	8.8
5	64.71	3.79	12.59
6	183.35	43.87	56.46
7	349	infinity	infinity

RMS Error (%) 2.59

Appendix II

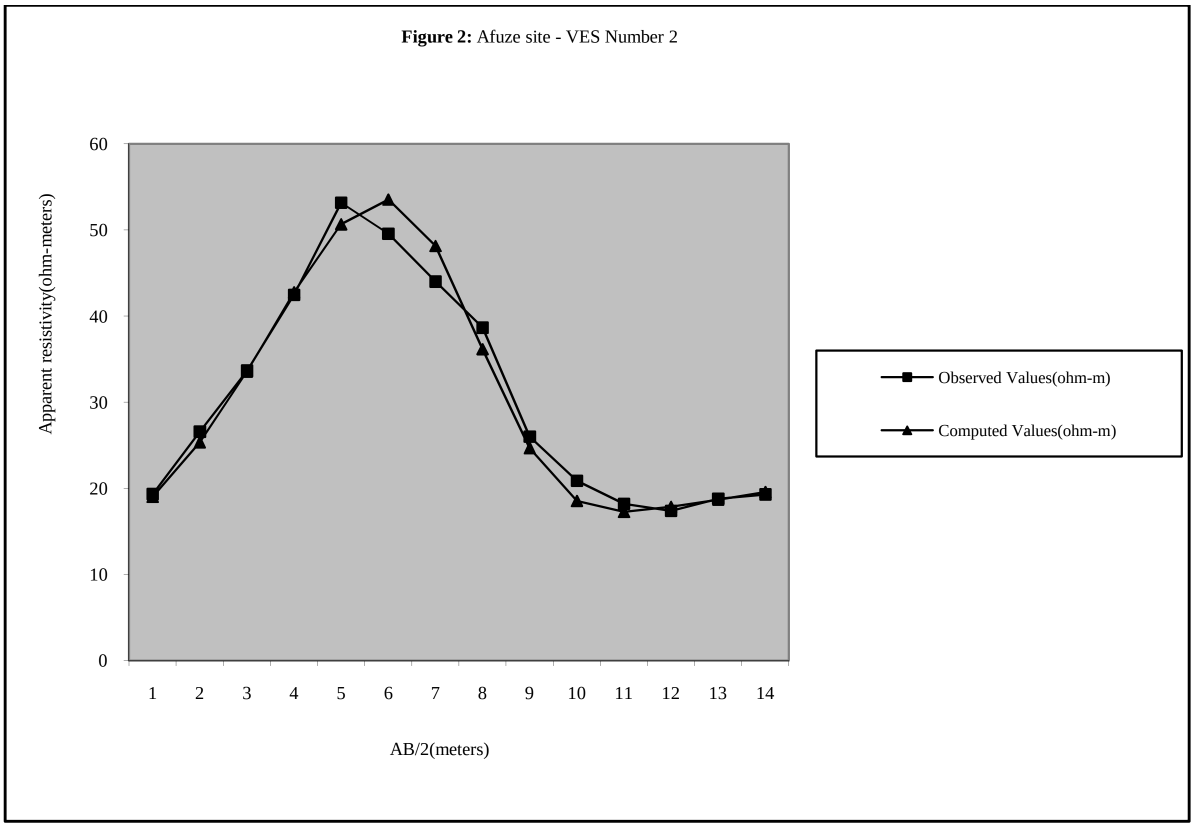


Table 2: Observed (Field) and computed (Theoretical) data

AB/2 Values(m)	Observed Values(ohm-m)	Computed Values(ohm-m)
1	19.33	19
1.47	26.58	25.34
2.15	33.67	33.57
3.16	42.46	42.77
4.64	53.15	50.66
6.81	49.56	53.54
10	44	48.15
14.7	38.65	36.16
21.5	26	24.67
31.6	20.87	18.53
46.4	18.2	17.27
68.1	17.39	17.85
100	18.8	18.7
147	19.3	19.57

Model Parameters			
Geoelectric Layer	Resistivity (ohm-meter	Thickness (m)	Cumulative Thickness(m)
1	12.39	0.6	0.6
2	137.18	2.42	3.02
3	13.83	13.61	16.63
4	18.14	36.35	52.98
5	21.7	infinity	infinity

RMS Error (%) 2.43

Appendix III

Figure 3: Afuze site - VES Number 3

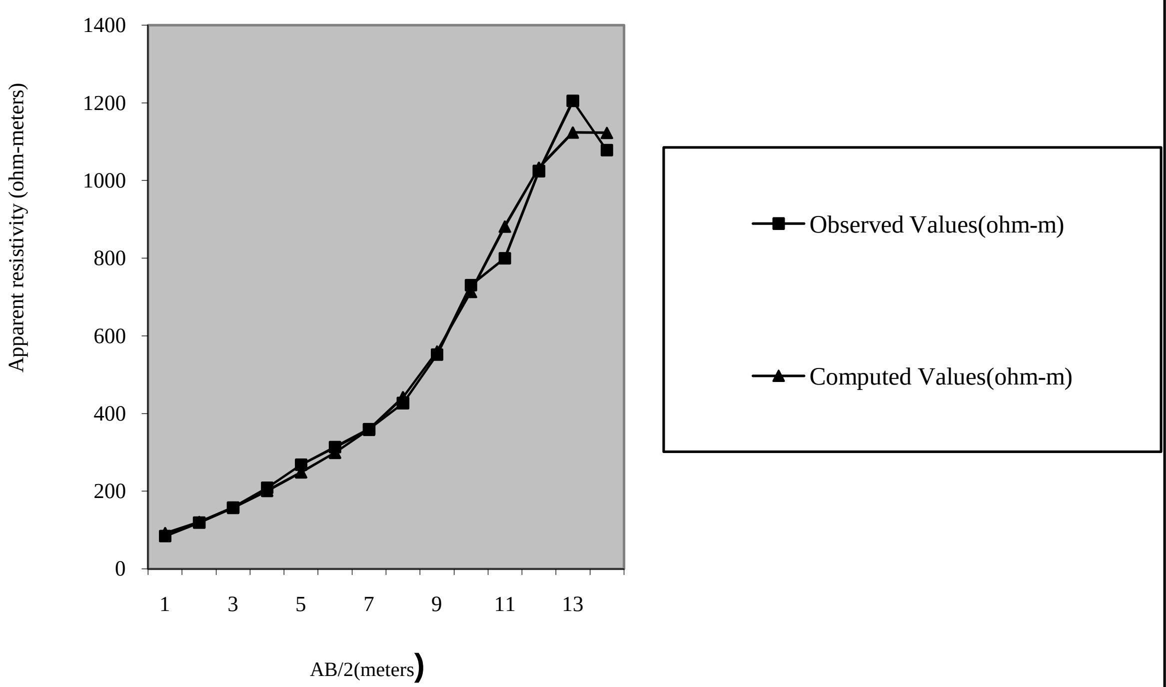


Table 3: Observed (Field) and computed (Theoretical) data

AB/2 Values(m)	Observed Values(ohm-m)	Computed Values(ohm-m)
1	84.04	91.27
1.47	118.46	119.96
2.15	157.52	156.84
3.16	208.25	200.54
4.64	267.52	248.12
6.81	313.09	298.63
10	359.44	357.99
14.7	426.51	441.29
21.5	551.54	559.4
31.6	730.42	712.9
46.4	799.54	881.55
68.1	1024.22	1033.01
100	1205	1123.77
147	1078.15	1123.05

Model Parameters

Geoelectric Layer	Resistivity (ohm-meter	Thickness (m)	Cumulative Thickness(m)
1	57.4	0.56	0.56
2	428.32	2.04	2.6
3	370.93	5.62	8.22
4	1781	43.06	51.28
5	835	infinity	infinity

RMS Error (%) 2.15

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