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Underground Water Exploration Using Electrical Resistivity Method in Edo State, Nigeria*

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Abstract: A Geophysical exploration involving the use of vertical electrical sounding was carried out in a sedimentary environment to determine the suitability of the method for underground water studies. The Vertical Electrical Sounding (VES) was done using the schlumberger electrode array configuration and the schlumberger automatic analysis method of interpretation was adopted. The VES data were obtained from two sites in Edo state, Nigeria. The interpretation of the data showed that the total depth to the aquifer layer is 241.48 m (796.90 ft) and 229.13 m (756.13 ft), respectively. These values correlated with the value 206.1 m (680.00 ft) obtained from the geologic section of a nearby borehole. The high correlation between the VES results and the borehole values showed that the method is suitable for underground water exploration.

Key words: Underground water, exploration, resistivity, sounding, Edo

INTRODUCTION

The advent of technology has made the quest for water for all purpose in life to drift from ordinary search for water to prospecting for steady and reliable subsurface or ground water from boreholes. In Nigeria, presently, borehole has rescued the citizenry from acute shortage of water. The geoelectric method has been found to be very reliable for ground water studies over the years. Asokhia *et al*. (2000), proposed a simple computer iteration technique for the interpretation of vertical Electrical Sounding. Pulawski and Kurht (1997), Zohdy *et al*. (1974) and Ujuanbi (2000) used this method to map clay deposit in a dual geological environment. This method was also used in the assessment of the ground water resources potentials within the Obudu basement, Okwueze (1996). Etu-Efeotor *et al*. (1998) carried out an assessment of the near surface underground water resources potential within the eastern Niger Delta. Olorunfemi *et al*. (1995) carried out a pre-drilling geophysical investigation for ground water development in the proterozoic basement of the northern rural part of Kaduna State. The total well depth of borehole installed at the Jehovah Witness Watchtower, Igieduma, is 680 ft (206.1 m).

This research therefore is centered on the used of vertical electrical sounding for underground water studies in a sedimentary environment.

THEORY

Ohms law provides the relationship between electric field and current density and it states that

$$\overline{J} = \sigma\overline{E} \qquad (1)$$

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Where:
σ = Conductivity (a constant)

For an isotropic medium, the conductivity will be a scalar quantity so that J and E will be in the same direction. For anisotropic medium, the conductivity is a tensor of second rank σ_{ij} so that

$$\overline{J} = \sigma_{ij}\,\overline{E} \tag{2}$$

The subscript i and j maybe any of the X, Y, or Z spatial directions. The basis of all resistivity prospecting with direct current is given by:

$$\nabla\sigma_{ij}\nabla V = 0 \tag{3}$$

In the isotropic case Eq. 3 reduces to laplaces equation

$$\nabla^2 V = 0 \tag{4}$$

For a horizontal earth model the solution to Eq. 4 according to Stefanesco *et al*. (1930) becomes

$$V(r)=\frac{I\rho_1}{2\pi}\left[\frac{1}{r}+2\int_0^\infty \theta_n(\lambda)J_0(\lambda r)dr\right] \tag{5}$$

Where, $J_0 = \overline{E}$ is the zero order Bessel function of the first kind and θ_n, is called the kernel function which is a function of the thickness and reflection coefficient for an assumed earth model.

By differentiating Eq. 5, the Schlumbeger apparent resistivity over an n- layered earth becomes

$$\rho_a(r) = \rho_1\left[1+2r^2\int_0^\infty \lambda\theta_n(\lambda)J_1(\lambda r)d\lambda\right] \tag{6}$$

Where, J_1 is the first order Bessel function of the first kind.

The evaluation of this integral of Eq. 6 has been done in a number of ways. In this study we have adopted, Ghosh (1971) in which it is possible to determine a linear digital filter, which converts resistivity transform samples into apparent resistivity values for theoretical models.

MATERIALS AND METHODS

Vertical electrical sounding was carried out using schlumberger electrode configuration. The ABEM SAS 300B Tetrameter was used for the investigation in the two locations. The maximum current electrode spacing (AB/2) was 400 and 500 m for VES 1 and VES 2, respectively. The resulting sounding curves was interpreted using partial curve matching as well as computer iteration techniques (Res1-Dinverse or Schlumberger automatic analysis). This study was carried out in Edo state (Igieduma and Ehor) towards the end of June, 2006.

RESULTS AND DISCUSSION

The acquired data were processed and interpreted qualitatively and quantitatively by using curve matching techniques to generate the initial model for the computer interactive method of interpretation (Res1-Dinverse).

From the results as shown in the Fig. 1 and 2 with respect to Table 1a, b and 2a, b, seven geoelectric layers were encountered with resistivities as shown in the model parameters 1 and 2.The VES 1 curve is KH curve type with $\rho_1<\rho_2>\rho_3<\rho_4$ Asokhia (1995).

The VES 2 curve is also a KH curve type with $\rho_1<\rho_2>\rho_3<\rho_4$. The sixth layer for both model 1 and 2 with thickness 66.6 and 105 m, resistivities 8200 and 7350.00 Ωm, corresponds to a total depth of 241.48 m (796.90 ft) and 229.13 m (756.13 ft), respectively. In correlation with the lithologic log of an existing borehole data from a nearby borehole, total depth value of 206.1 m (680 ft). The VES results of both locations presents a high correlation of the presented values with an existing functional borehole. This study showed a clear support or confirmatory proof of the depth to aquifer in a sedimentary environment, in Edo state.

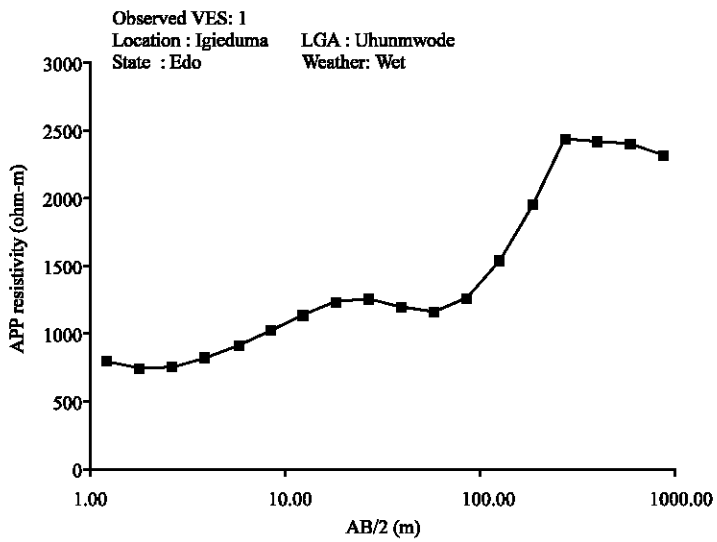

Fig. 1: Resistivity curve of VES 1

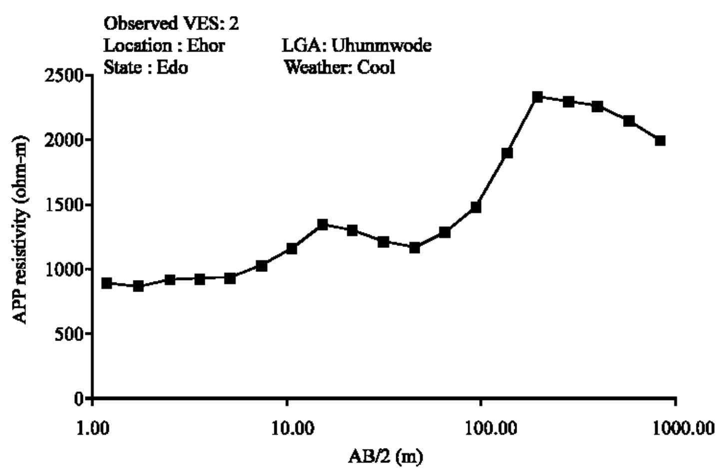

Fig. 2: Resistivity curve for VES 2

Table 1a: Model parameter 1with RMS Error (%): 2.43

Geoelectric layer	Resistivity (ohm-m)	Thickness (m)	Cumulative thickness (m)
1	910.00	0.38	0.38
2	690.00	2.40	2.78
3	1560.00	12.50	15.28
4	830.00	46.60	61.88
5	6500.00	66.60	128.48
6	8200.00	113.00	241.48
7	7380.00	Infinity	Infinity

Table 1b: Observed (field) and computed (theoretical) data

$\frac{AB}{2}$(m)	ρ_a(ohm-m) observed value	ρ_a(ohm-m) computed value
1.00	820.22	797.05
1.47	732.15	745.61
2.15	729.78	750.29
3.16	845.02	815.16
4.64	961.69	910.17
6.81	902.79	1018.20
10.00	1062.32	1137.66
14.70	1288.35	1236.56
21.50	1349.32	1254.65
31.60	1210.00	1193.85
46.40	1106.00	1159.58
68.10	1380.00	1264.93
100.00	1545.00	1538.48
147.00	2061.00	1945.59
215.00	2522.00	2431.32
250.00	2489.78	2417.12
300.00	2467.56	2400.45
400.00	2389.96	2312.56

Table 2a: Model parameter 2 with RMS Error (%): 2.47

Geoelectric layer	Resistivity (ohm-m)	Thickness (m)	Cumulative thickness (m)
1	890.00	0.43	0.43
2	880.00	4.10	4.53
3	1910.00	12.70	17.23
4	740.00	43.80	61.03
5	6290.00	63.10	124.13
6	7350.00	105.00	229.13
7	7040.00	124.00	353.13
8	820.00	Infinity	Infinity

Table 2b: Observed (field) and computed (theoretical) data

$\frac{AB}{2}$(m)	ρ_a(ohm-m) observed value	ρ_a(ohm-m) computed value
1.00	950.32	895.01
1.47	823.87	864.72
2.15	804.45	921.02
3.16	954.00	930.61
4.64	973.56	940.20
6.81	914.34	1029.33
10.00	1100.04	1157.76
14.70	1290.00	1345.14
21.50	1365.00	1300.00
31.60	1220.00	1210.11
46.40	1112.00	1168.12
68.10	1298.00	1289.44
100.00	1496.67	1480.62
147.00	1984.56	1898.72
215.00	2460.34	2342.84
250.00	2350.89	2300.12
300.00	2279.00	2268.23
400.00	2156.23	2148.96
500.00	2100.00	2000.00

CONCLUSION

This research has shown that in a sedimentary environment, Vertical Electrical Sounding (VES) have proved to be very reliable for underground water studies and therefore the method can excellently be used for shallow and deep underground water geophysical investigations.

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