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Geophysical investigation of effects of topographic complexities on groundwater potential in Ibusa, Delta State Nigeria

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ABSTRACT

Ibusa is situated a few kilometres from the River Niger near Delta State capital, Asaba. .Despite its nearness to the course of River Niger, it is positioned on a cliff which makes the acquisition of groundwater a serious problem for the inhabitants. It marks a transition point from the river bank to the hinterland and between geological formations. It is therefore, necessary to carry out geophysical survey within and around Ogboli, Ezukwu and Achala in Ibusa to determine the topographic complexities and their effects. Thus, ten VES soundings were made using Schlumberger array with a sensitive SAS 1000 terrameter. The results show that virtually all sites in the study area exhibit A – type curve. They also indicate that while Ogboli and Ezukwu villages have typically deep aquifers enclaved by deep rooted rocks, neighbouring Achala village is a low land zone with shallow aquifer. In addition Ogboli and Ezuikwu villages consist of thick lateritic top soil to about 10 m, remarkable weathered rocks of high iron content at shallow depths of 15 – 18 m and a thick formation of hard granite at far depth. False aquifers exist at shallow depths of 30 – 40 m while viable aquifer is at 80 – 110 m. On the other hand, Achala possess loose top soil to considerable depth followed by a thin layer of lateritic soil, a layer of medium to gravely sand and viable aquifer at about 30 – 40 m

Key words: Topographic complexities, Schlumberger, formations, aquifers, Ibusa Nigeria.

INTRODUCTION

The problem of potable water for domestic and industrial utilities has generally been an age long issue in Ibusa despite its nearness to Asaba, the bank of river Niger where groundwater is easily obtained. A number of boreholes have been dug in Ibusa without success. In some cases many trial wells are drilled before seeming success is achieved in Ogboli and Eziukwu villages for example. However, this problem does not exist in Achala which is about 2 km away. This work suggests that these variations could be due to topographic changes. Hence, a geophysical study was initiated to ascertain the effects of topographic complexities and determine the depths of viable aquifers in these villages in Ibusa. The study was made in Ibusa, Nigeria using a sensitive

Self Averaging System (SAS) 1000 terrameter and the field data were analysed qualitative and quantitative methods from which the geoelectric sections of the area were obtained

1.1 LOCATION OF STUDY AREA

Asaba is the capital of Delta state. It is situated on the western bank of the River Niger while Onitsha is on the eastern bank. A few kilometres still on the west of Asaba is Ibusa. Precisely, Ibusa is located about eight kilometres west of Asaba. It is within Latitude 6^{o}32'W and 6^{o}28'W and Longitude 6^{o}32'E and 6^{o}34'E (Fig 1). It is bounded by a number of small streams from heterogynous sources which indicate that Ibusa is on a cliff. Its nearest neighbours are Ogwashi-Uku to the west and Okpanam to the north.

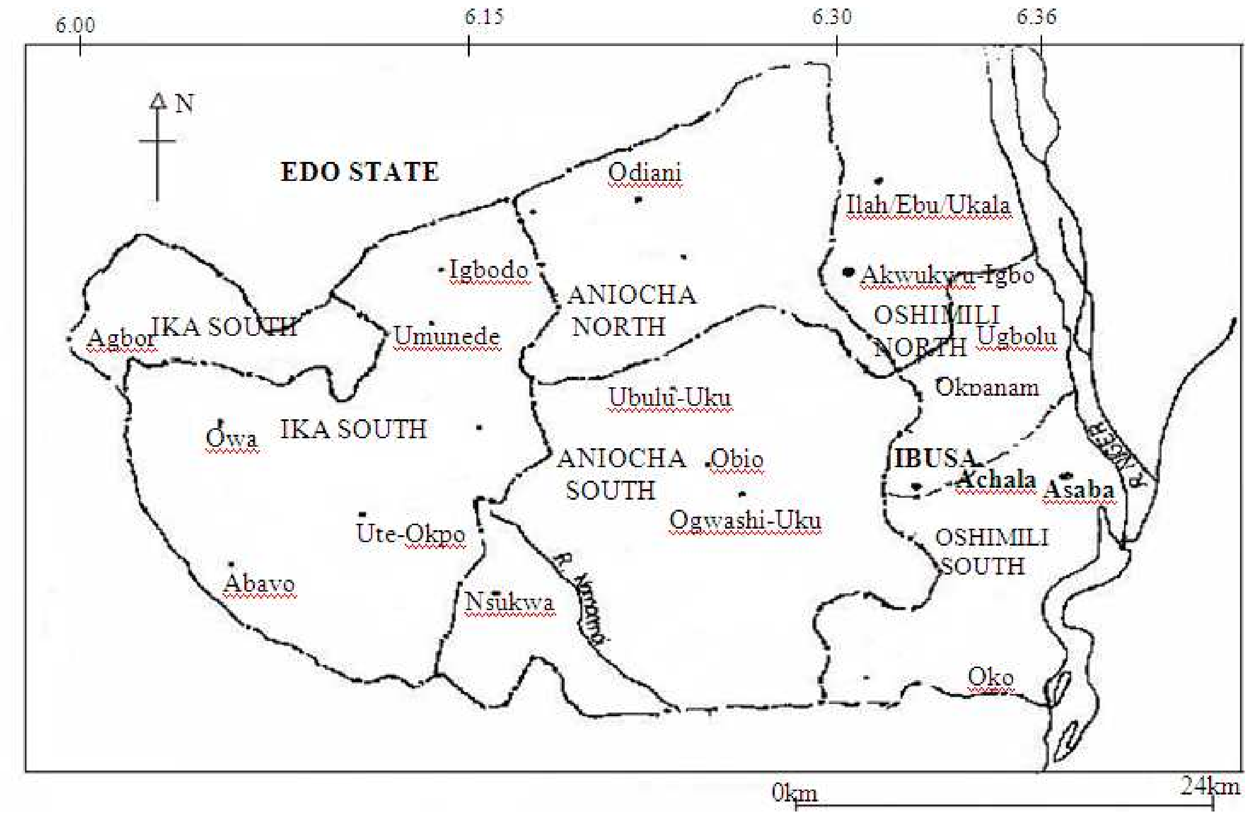

Fig. 1

MATERIALS AND METHODS

The vertical electrical sounding (VES) was used to determine the electrical resistivities and depths of the subsurface layers with a sensitive ABEM SAS 1000 terrameter. On the whole, ten VES stations were established and surveyed in three neighbouring villages at Ibusa, Delta State, Nigeria using the Schlumberger array. The Schlumberger array of electrical resistivity method was applied due to its relatively low cost of field operation, logistics of reduced man power and reliability on application to formation and groundwater investigations (1).

On taking a sounding, the terrameter sends current into the earth through a pair of conducting electrodes, automatically computes and displays the apparent resistivity of the subsurface structure under investigation (2).

Generally, the arrangement consists of a pair of current electrodes and a pair of potential electrodes which are driven into the subsurface to make a good contact with the earth in a particular site of interest (Fig 2).

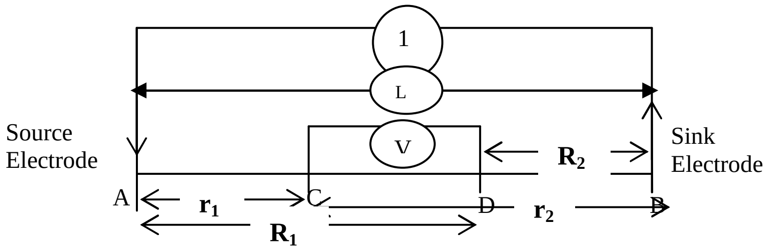

Fig 2: General four-electrode configuration for resisitivity survey

Thus, the potential difference (V_c – V_D) between the two inner electrodes measured by the voltmeter connected between C and D (3) is

$$\nabla V = (V_c - V_D) = \frac{I}{2\pi}\left\{\left(\frac{1}{r_1}-\frac{1}{r_2}\right)-\{\frac{1}{R_1}-\frac{1}{R_2}\}\right\}\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

Hence, the subsurface resistivity by (4) is

$$\rho = 2\pi\frac{\Delta V}{I}\left\{\frac{1}{\left(\frac{1}{r_1}-\frac{1}{r_2}\right)-\left(\frac{1}{R_1}-\frac{1}{R_2}\right)}\right\}\ldots\ldots\ldots\ldots\ldots\ldots 2$$

$$\Rightarrow \rho = 2\pi r\left\{\frac{1}{\left(\frac{1}{r_1}-\frac{1}{r_2}\right)-\left(\frac{1}{R_1}-\frac{1}{R_2}\right)}\right\}\ldots\ldots\ldots\ldots\ldots\ldots 3$$

.

The apparent resistivity is obtained since formation measurements are not made directly (5). Moreover the wider the electrode spacing, the deeper is the current penetration. Current penetration to a depth say Z achieved with a current electrode spread L, (Fig 2) (6) is given by

$$3L = Z$$

$$\Rightarrow \quad L = Z/3\ldots\ldots\ldots\ldots\ldots\ldots 4$$

In this work, the Schlumberger array was used to ensure deep penetration and for logistics of limited man power in the field. The Schlumberger array required that the current electrode spacings are increased on a logarithmic scale while the potential electrodes are kept at small separations relative to the current electrodes separations (Fig 3) ensuring that AB ≥ 5CD (7). Thus, only current electrodes need to be shifted to new position for most readings while potentials electrodes are kept undisturbed for up to three or four readings. The current and potential pairs of electrodes therefore have a common midpoint O, but the distance between adjacent electrodes differs (8).

Hence, the potential at electrode P_1 from C_1 (Fig 3) (9).will be

$$V_{P1} = \frac{\rho I}{2\pi}\left\{\frac{1}{a-b/2}-\frac{1}{a+b/2}\right\}\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 5$$

And the potential at P_2 from C_1 is

$$V_{P_2} = \frac{\rho I}{2\pi}\left\{\frac{1}{a+b/2} - \frac{1}{a-b/2}\right\} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 6$$

where a>>b as in Schlumberger array.

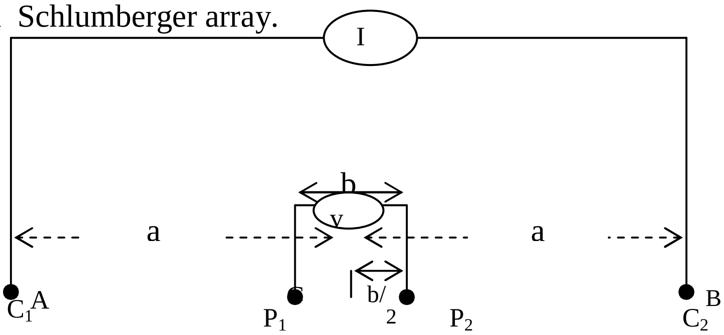

Fig 3: Schlumberger field electrode arrangement

Where "a" is the distance between the current electrode and station midpoint, "b" is the distance between potential electrodes and "2a" is the current electrode separation

The potential difference "dV" between the two potential electrodes is therefore,

$$dV = \frac{\rho I}{2\pi}\left(\frac{8b}{4a^2 - b^2}\right) \quad becomes$$

$$= \frac{\rho I b}{\pi a^2}$$

$$and \quad \rho_{as} = \frac{\pi a^2}{b}\frac{dV}{I} = \frac{\pi a^2}{b}R \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 7$$

where ρ_s is apparent resisitivity for Schlumberger array and Geometric factor for Schlumberger array is $K_s = \frac{2\pi}{8b}\left(4a^2 - b^2\right)$ (10).

Hence, for $a >> b,\ K_S = \frac{\pi a^2}{b}$ ……………………………………………..8

Table1: Sample Field Data (Apparent Resistivities in Study Area, Ibusa)

MN/2 (m)	AB/2 (m)	Eziukwu VES 1 (Ωm)	Ogboli VES 1 (Ωm)	Ogboli VES 2 (Ωm)	Achala VES 1 (Ωm)	Achala VES 2 (Ωm)
0.2	1.00	78	118	150	75	62
	1.47	85	127	162	81	84
	2.15	97	178	130	76	108
	3.16	132	240	148	95	124
2/1.0	4.64	216	148	218	115	147
	6.81	105	128	242	128	110
1.0/3.0	10.00	168	172	294	189	128
	14.70	207	235	321	203	157
	21.50	239	398	426	130	132
	31.60	344	710	585	296	146
3.0/8.0	46.40	324	761	843	368	215
	68.10	327	1356	895	347	235
8/16	100.00	398	2563	1256	296	255
	147.00	538	1987	2272	521	219
16/30	215.00	853	1845	3532	772	405
30/50	316.00	715	3431	2188	943	278
	464.00	947	5613	1095	650	195

The apparent resistivity values (Table 1) recorded by the field tarrameter were plotted against half current electrode spacing on a 3- decade bi-log graph from which the qualitative and quantitative analyses were made using partial curve matching technique to obtain the apparent resistivity replacement and depth Index of each formation in the sites. These were matched with corresponding master and auxiliary curves and the results were used to perform and obtain Resist software computer iteration for effective analysis and formation stratification and interpretation (Fig 5 – 9) (11).

RESULTS AND DISCUSSION

The results show that virtually all sites in the study area exhibit A – type curve (Fig 5 – 9). However, while Ogboli and Eziukwu consist of nine distinct formation strata, Achala has seven layers. Also, Ogboli and Eziukwu possess loose top soil, thick lateritic top soil to about 10 m, shale, remarkable weathered rock of high iron content at shallow depths of 15 – 18 m, a thick formation of hard granite or rock shielded at far depth of about 70 - 80m. False aquifers with high iron content exist at shallow depths of 30 – 40 m in Ogboli and Eziukwu, while viable aquifer is within 80 – 110 m and typically enclaved by deep rooted rock shield. In contrast, neighbouring Achala is a low land zone has fine top soil, a thin layer of lateritic soil clayey sand, silt and perched aquifer at shallow depths of about 10 metres, a layer of medium to gravely sand and shallow aquifer at about 30 – 40 m. Its main aquifer is at about 30 metres (Figs10&11) (12). This is in consonance with monitored direct log data. These remarkable contrasts are greatly attributed to topographic complexities.

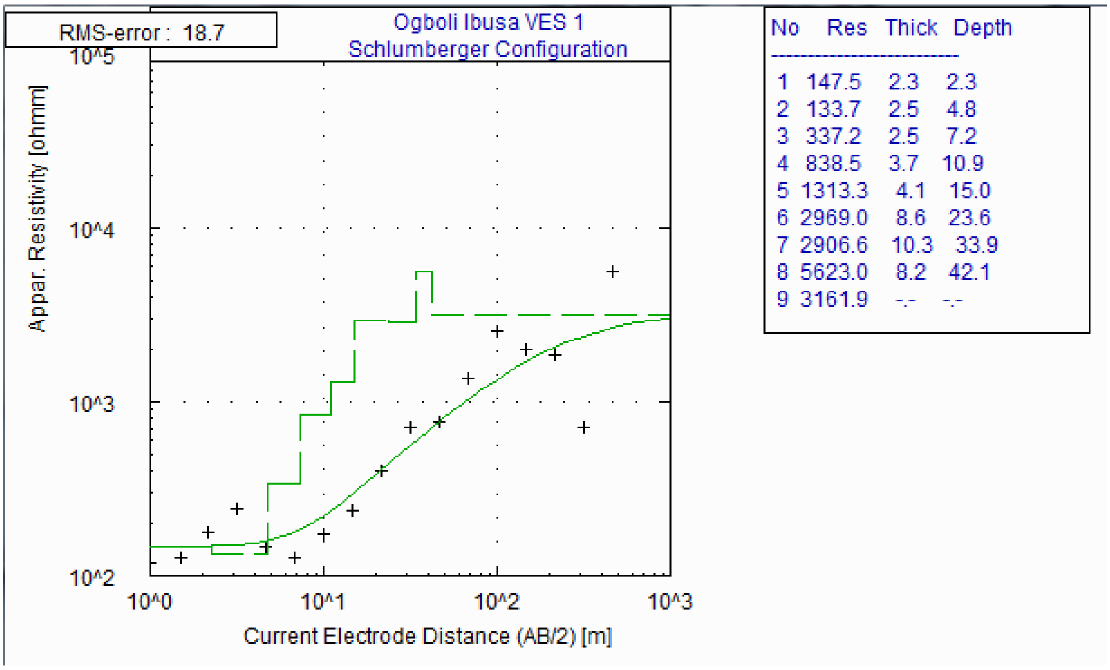

FIG 5: Sample Plot for Site 1 in Ogboli, Ibusa

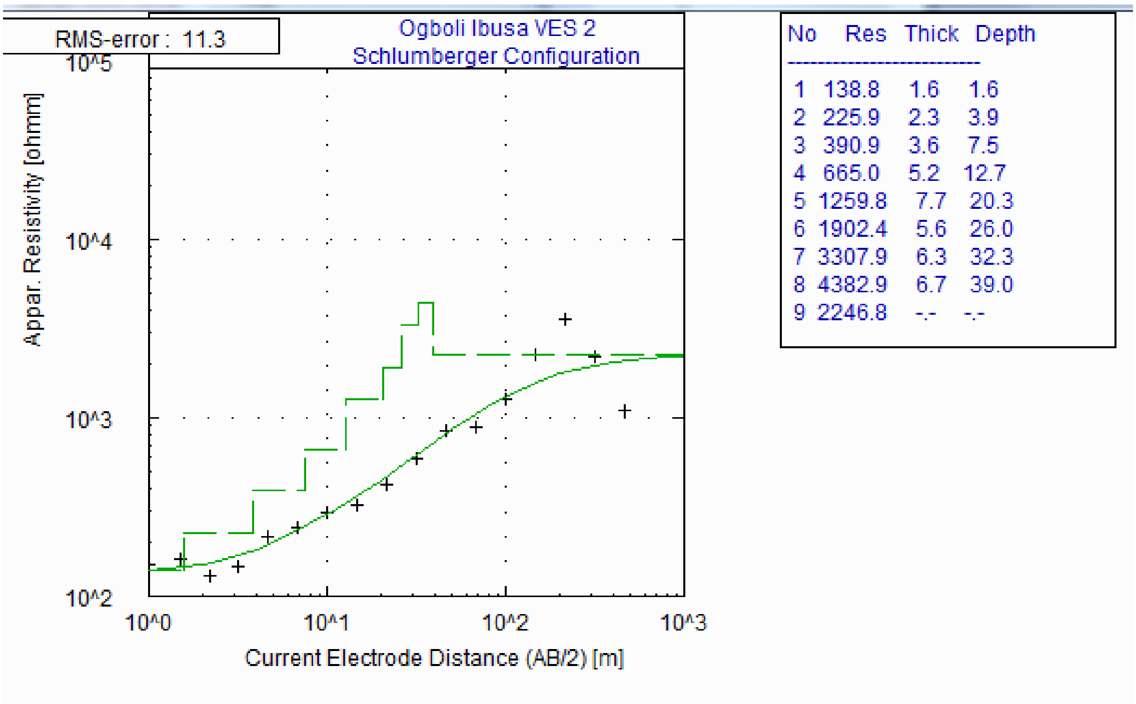

FIG 6: Sample Plot for Site 2 in Ogboli, Ibusa

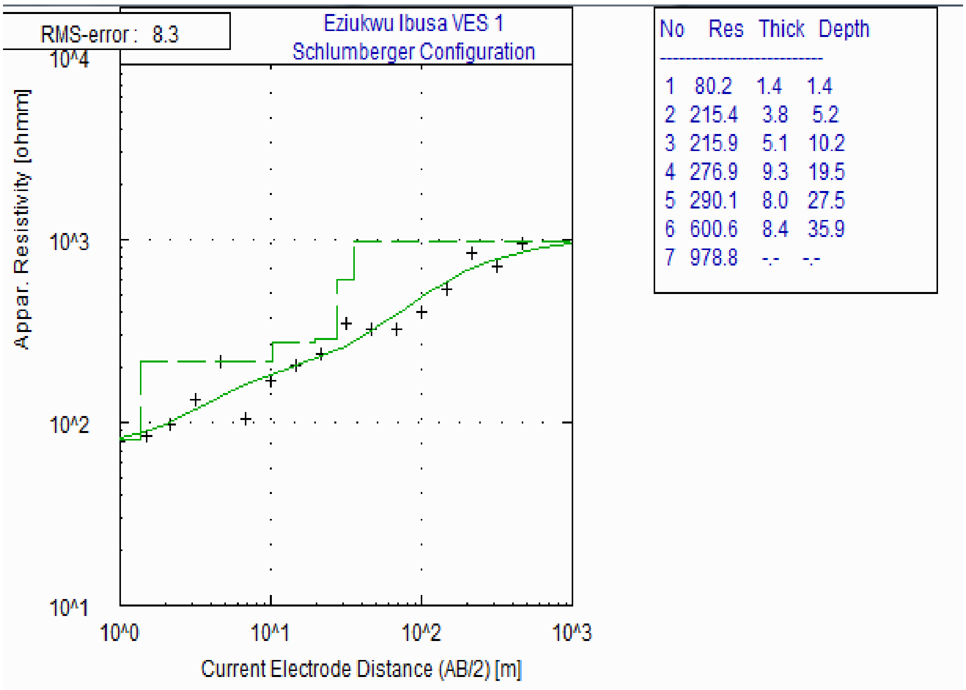

FIG 7: Sample Plot for Site 1 in Eziukwu, Ibusa

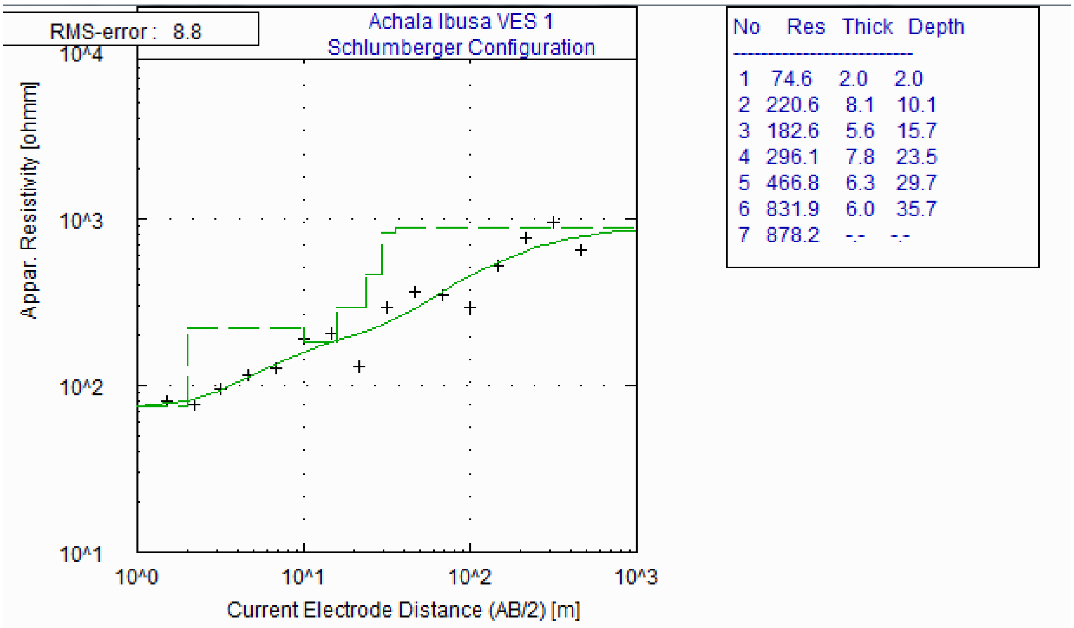

FIG 8: Sample Plot for Site 1 in Achala, Ibusa

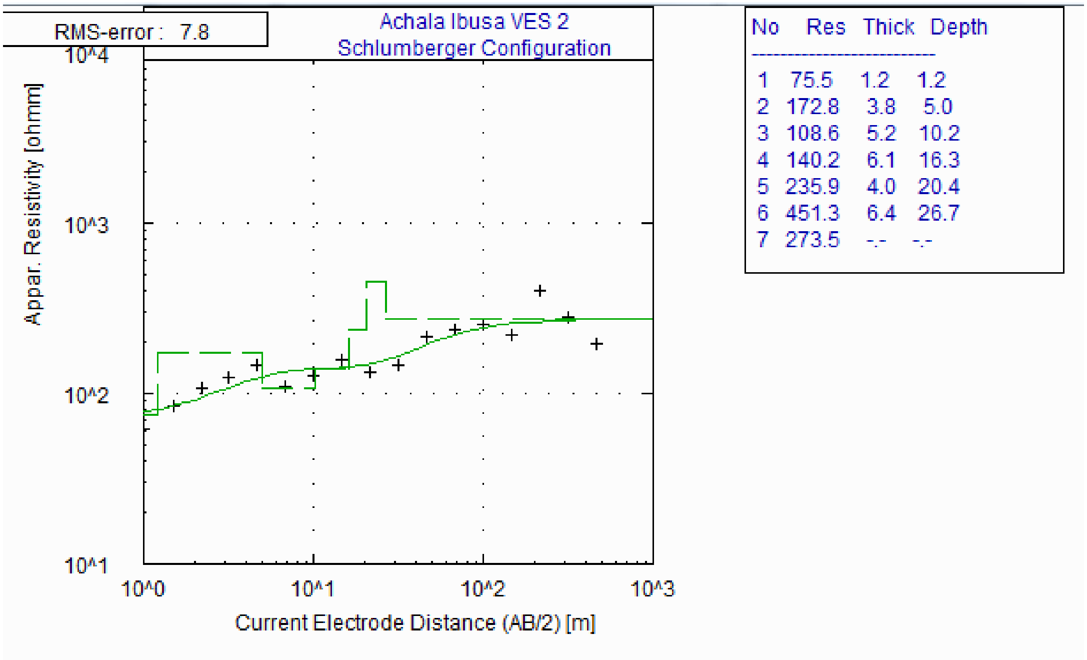

FIG 9: Sample Plot for Site 2 in Achala, Ibusa

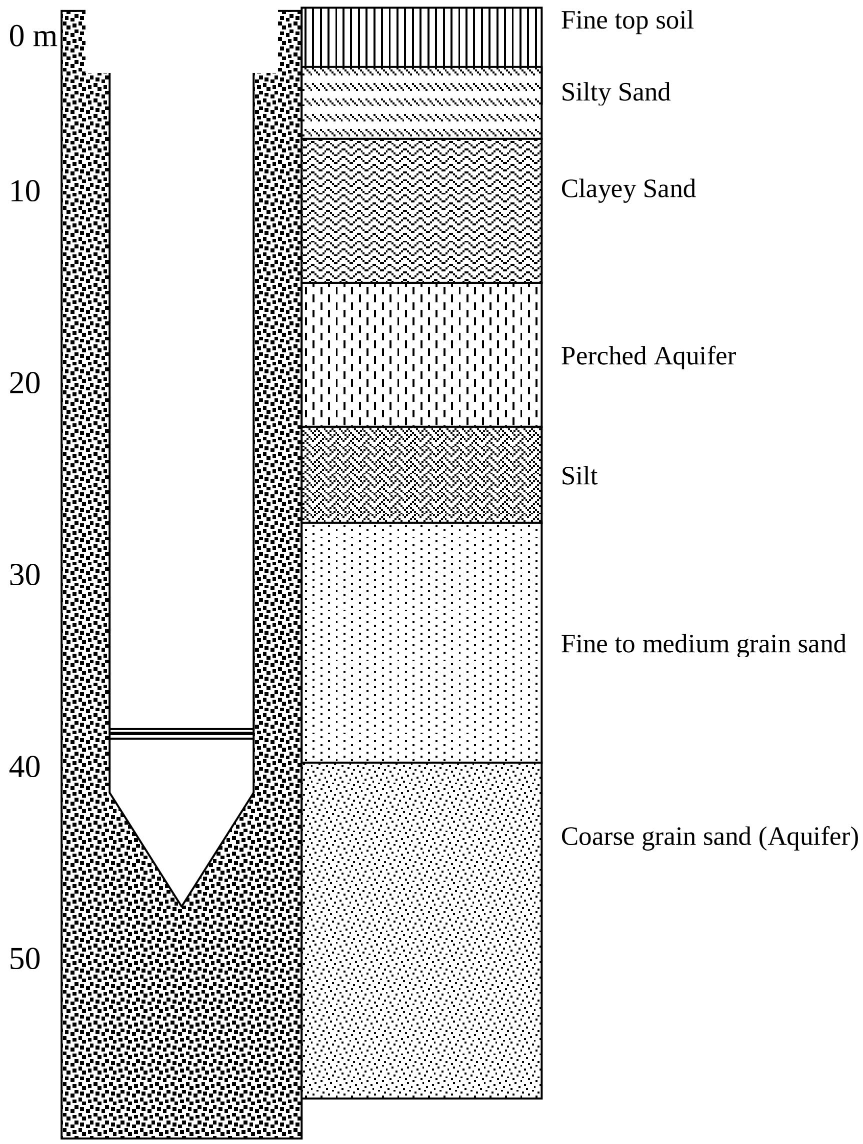

Fig 10: Geoelectric section of Achala in Ibusa

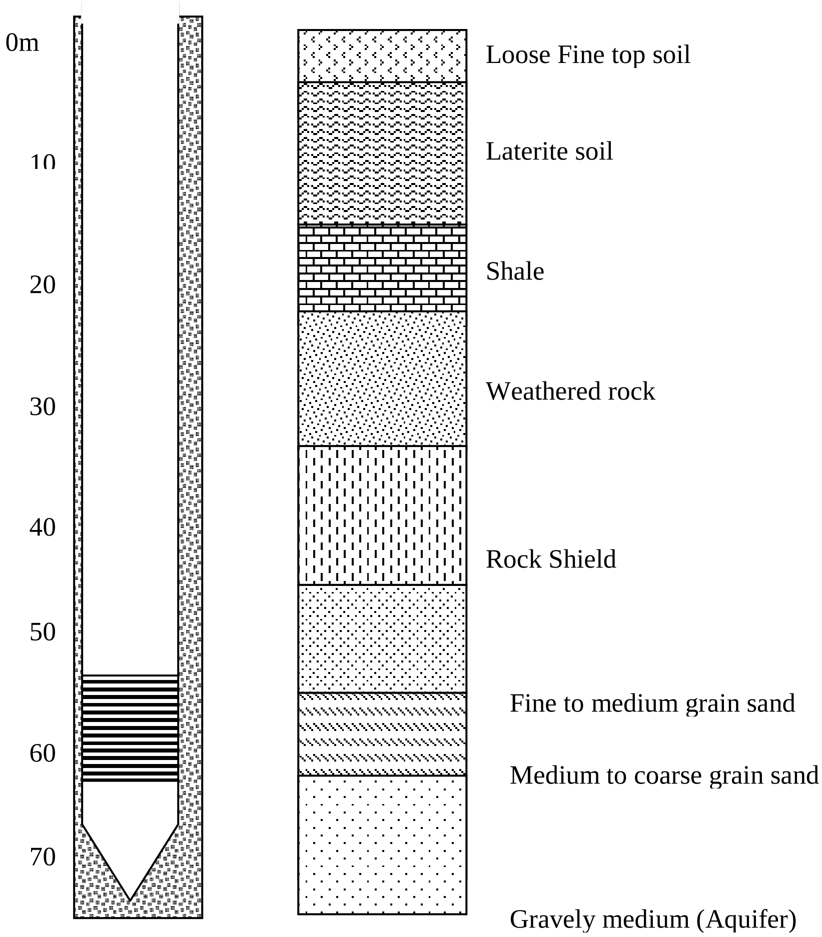

Fig 11: Geoelectric Section of Ogboli & Eziukwu, Ibusa

CONCLUSION AND RECOMMENDATION

Subsurface formation at Ibusa is a blend of basement complex and sedimentary terrain. Virtually, all sites in Ogboli, Eziukwu and Achala exhibit A-curve which indicates that the curve type here is invariant with respect to topography. However, there are marked variations in subsurface strata and groundwater distributions

The geoelectric section (Fig 10) shows promising aquifers are readily available in Achala where low resistivity subsurface strata due to the presence of clayey sand and its relative closeness to River Niger. These sites at Achala are indicative of high water bearing medium (aquifer) with medium to coarse grain sand at 25 – 30 m depth. Perch aquifers also exit at shallow points of about 12 m. Sites around Ogboli and Eziukwu consist of high resistive formations to far depth with no distinct aquifer. These sites also possess rock shield formation at far depth which may be associated to the sudden change in topography as one drifts away from the bank of river Niger (Fig 11). It is therefore recommended that for effective bore hole siting in the study area sites on the East end of Ogboli and Eziukwu as well as those in Achala should be the target. This will ensure long term continuous supply for both domestic and industrial utilities for many a people living in Ibusa and within and around Asaba metropolis.

REFERENCES

[1] B.D. Ako and V.C. Osundo *Journal of African Earth Science,* (**1986**), 5, 527 – 534
[2] M.B. Dobrin, *Introduction to Geophysical Prospecting* McGraw-Hill Publishers, New York, (**1976**), 10-15.
[3] P. Keary, and M Brooks, *An Introduction to Geophysical Exploration. 2nd edition* Blackwell Scientific London Edinburgh, (**1991**), 172-180
[4] D.H. Griffith and R.F. King *Applied Geophysics for engineers and geologists* Pergamon press NY, (**1976**), 11 - 34
[5[E. C. Okolie, F. C. Ugbe, J.E.A. Osemekhian, *Journal of Nigerian Association of Mathematical Physics,* (**2006**), 10, 83 – 90
[6] W. Lowrie, *Fundamentals of Geophysics,* Cambridge University Press (**1997**), 212 -216
[7] E. E. Okwueze and V.I. Ezeanyim, *Journal of Mining and Geology* (**1985**), 22, (1&2), 193-198
[8] J.O. Oseji, E.C. Okolie, E.A Atakpo,. *Journal of Applied Sciences and Environmental Management* (**2005**), 9, (1) 157-160
[9] Zohdy A.A.R *USGS open file* Rep, (**1988**), 66, 188 – 291
[10] E. C. Okolie, J. C. Egbai J. O Oseji, *Journal of Science and environment*, (**2008**), 7, 91 – 98
[11] E. E Okwueze, M. N Umego, A. A Baimba, F. A Ntaji, D. E Ajakaiye, *Stygologia,* (**1988**), 4 (2), 103 – 115
[12] E.C Okolie, J.E.A. Osemeikhian, Ujambi, O *Journal of Applied Science and Environmental Management*, (**2007**) 11 (2) 181-186