ELECTRICAL RESISTIVITY SURVEY FOR GROUNDWATER EXPLORATION IN PARTS OF AGBOR, DELTA STATE, NIGERIA.

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ABSTRACT

Vertical Electrical Sounding (VES) is the most widely used geophysical techniques for groundwater prospecting. However the interpretation of VES has been subjected to several indistinctness and efforts are on to tackle them. Electrical soundings using the Schlumberger configuration were carried out in Agbor, Ika South Government Area of Delta State to determine the hydrogeological settings in terms of depth of aquifer and effect of topography of the town. These were carried out in ten different locations with maximum current electrode separation of 800m which expectantly represent the whole area of research. The resistivity data is then interpreted by curve matching and computer iteration where the geological model parameters and curves were obtained. Three to six geological layers were observed within the whole locations. These ranges from topsoil, laterite, coarse grained sand, clay, clayey sand, and fine sand. The resistivities for the whole locations ranges from54.0Ωm to 7526Ωm and thickness from 0.4m to 193.6m. Some boreholes drilled and logged within the area of the research correlated very well with the interpreted geoelectric data.

Key words: resisitivity, VES, aquifer,geological section, groundwater potential.

INTRODUCTION

Electrical prospecting method makes use of a variety of techniques, each based on some specific electrical property of characteristic of material in the earth. The resistivity method is designed to yield information on formations or bodies having anomalous electrical conductivity. It is employed in geophysics to map bedrock and in ground water studies.

This study is aimed at knowing the hydrogeological problems in terms of the static water levels and aquifers in the exploration of water for domestic and industrial purposes at Agbor in Delta State of Nigeria.

The need for ground water supply increases continually according to the development of an area. This is highly applicable to Agbor the area of research. However, the availability of groundwater resources frequently insufficient to supply the water need when an area experiences high growth of water requirement for commercial and industrial purposes.

The town Agbor, the Headquarter of Ika South Local Government Area is fast increasing in population for the last ten years. This could be attributed to the presence of two higher institutions and companies springing up. This has resulted in continuous influx of people thereby increasing the population leading to high demand for portable water. Hence, there arise the need to carry out geophysical and hydrogeological surveys of Agbor to provide information on the possible sites for sitting boreholes for portable and sustainable water supply to take care of the teaming population.

The applications of electrical resistivity methods are based on the wide range of variations of specific resistivities. In most cases near the surface, electric conductivity is controlled by porosity, granularity, water content and water quality (Egbai and Asokhia, 1998).

The resistivity of reservoir rock is determined by the way in such an electric current can flow through it. As the formation water is the only conductive material present in the rock, it depends on:

The resistivity of the formation water: depends on temperature, and the concentration of salts dissolved in the water, that is its salinity.

The amount of formation water: depends on the amount of pore space, and the extent to which this pore space is filled with formation water, that is water saturation.

The geometry of the formation water: the more tortuous the path followed by the current, the higher will be the resistivity.

Resistivity measurements are associated with varying depths depending on the separation of the current and potential electrodes in the survey, and can be interpreted in terms of a lithologic and/or geohydrologic model of the subsurface. Resistivity values collected are called apparent because the resistivity values measured are actually averages over the total current path length but are plotted at one depth point for each potential electrode pair.

Recently, other electrical geophysical methods such as electromagnetic induction (EM) and ground penetrating radar (GPR) become increasily popular. The methods are still applied preferentially on saline irrigated areas. Some successful applications of the methods were reported on accessing quality of forest soils (McBride *et al.,* 1997a), finding perched water locations (Freeland *et al.,* 1997b) and outlining permafrost layers (Arcone *et al.,* 1998).

Vertical electrical sounding (VES) is very popular in geophysical surveys, such as gas, oil, and coal exploration (Verma and Bandyopadnyay, 1983), it is rarely used in shallow subsurface studies. The method was applied to estimate hydraulic conductivity (Mazac *et al.,* 1990) and texture (Banton *et al.,* 1997) of the stratified soils and sediments. Barker (1990) applied VES to a landfill outlining at a 40m depth.

The Schlumberger array was used in this work because it is sensitive to the influence of near surface lateral heterogeneities and its interpretation techniques are more developed than other arrays.

Well logging involves probing the earth with instruments which gives continuous readings recorded at the surface as they are lowered into boreholes. The result of resistivity, survey carried out is confirmed by drilling, borehole logging and borehole measurement (for already existing borehole) to determine the static water level.

Further references in this area could be seen from the work of the following eminent geophysicists: Israil *et al*. (2006), Egwebe *et al.* (2006), Clipton and Foster (1995) and Alile *et al*, (2008).

Resistivity of water varies from 0.20Ωm to about 100.00Ωm depending on ionic concentration and dissolved solids contained in it (Ali *et al.,* 1999). Resistivity of natural water varies from 1.00Ωm to 1000.00Ωm while clay varies from 1.00Ωm to 120.00Ω (Zohdy and Martin, 1993).

THEORY

The electrode configuration for the Schlumberger resistivity survey is as shown in Figure 1 below

Further work on resistivity sounding…

THEORY

The electrode configuration for the Schlumberger resistively survey is as shown in figure 1 below:

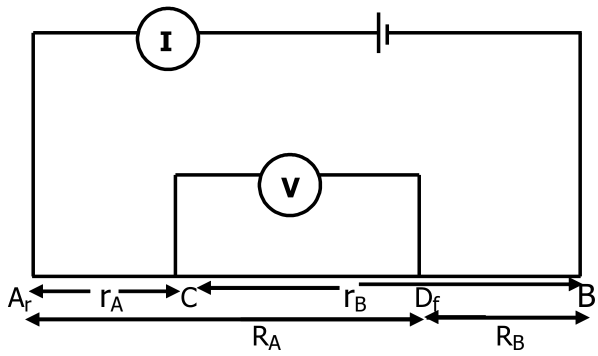

***Fig 1 :** Schlumberger Electrode Configuration*

The potential between the two electrodes C and D could be calculated as shown

$$V_C = \frac{\rho I}{2\pi}\left\{\frac{1}{r_A} - \frac{1}{r_B}\right\} \quad \text{and } V_D = \frac{\rho I}{2\pi}\left\{\frac{1}{R_A} - \frac{1}{R_B}\right\}$$

Potential difference is given as $\Delta V = V_C - V_D$

$$\Delta V = \frac{\rho I}{2\pi}\left\{\frac{1}{r_A} - \frac{1}{r_B}\right\} - \left\{\frac{1}{R_A} - \frac{1}{R_B}\right\}$$

$$\rho = \frac{2\pi\Delta V}{I} \cdot \frac{1}{\left\{\left\{\frac{1}{r_A} - \frac{1}{r_B}\right\} - \left\{\frac{1}{R_A} - \frac{1}{R_B}\right\}\right\}}$$

Thus $\rho = K \times R$

where $R = \frac{\Delta V}{I}$

$$K = \frac{2\pi}{\left\{\frac{1}{r_A} - \frac{1}{r_B}\right\} - \left\{\frac{1}{R_A} - \frac{1}{R_B}\right\}}$$

If b =the distance CD and
a = the distance between AB,
then for the Schlumberger's configuration, a $\geq$ 5b
where

$$K = \frac{\pi a^2}{b} \left\{ 1 = \frac{b^2}{4a^2} \right\} \text{ and}$$

$$\rho_a = \frac{\pi a^2}{b} \left\{ 1 - \frac{b^2}{4a^2} \right\}$$

K = geometric factor and ρ_a =apparent resistivity obtained from the field resistivity data.

Fig. 1: Schlumberger Electrode Configuration

C_1C_2 are the current electrodes

P_1P_2 are the potential electrodes

STUDY AREA

Agbor, a town in Delta State of Nigeria lies within latitude 6°10'N and 6°20'N, and longitude 6°10'E and 6°15'E. The drainage of the town is highly affected by the presence of the river causes extremely high erosion during the rainy season resulting in the undulating nature of the town with a valley between two hills. The major vegetation of the area in the rain forest. Agbor is situated within the humid south climatic zone of Nigeria with a high, long rainy season from March to October followed by a short dry season that lasts from November to February.

DATA ACQUISITION AND ANALYSIS

A total of seven Vertical electrical soundings (VES) were carried out at various locations in the study area with a maximum current electrode separation of 800m.

The field in the Schlumberger electrode array system is to expand the current electrodes successively while the potential difference across the potential electrodes which ultimately exceeds the measuring capabilities of the instrument. At this point, a new value for potential electrode separation is selected, typically 2 to 4 times larger than the preceding value and survey is continued. The distance between the potential electrodes must never exceed 2/5 of AB/2 where AB is the current electrodes (fig.1), that is CD$\leq$ AB/2 where CD is the potential electrodes (Egbai and Asokhia,1998).

The geophysical instrument used was the Abem Terrameter SAS (signal averaging system) 1000B with inbuilt booster which helps in injecting more current for greater depth of penetration. The locations surveyed are as follows:

Charles Street	location 1
Okoh Street	location 2
College of Education, Agbor	location 3
Imudia Street	location 4
Melekwe Street	location 5
Ajuebor Street	location 6
Ugbaja Street	location 7
Mariere Street	location 8
Okobi Street	location 9
Baleke Street	location 10

Qualitative interpretation was done first by curve fitting. Curves of the logarithms of apparent resistivities are plotted on the y-axis against the logarithms of AB/2 on the x-axis. The results of curve fitting show a rough estimate of later resistivities, thickmesses and aquifer depths (Table 1). The results of the curve matching were used to obtain the thickness and resistivity value used for a quantitative computer iteration using the Resist Software (Vander Velpen, 1988). The results obtained from the computer iteration modeling are as presented in Table 2.
Some of the curves are presented in Figure 2 while the geoelectric section is presented in Table 2.

Table1. Qualitative analysis of curve types (ℓ shows resistivity of the layer)

VES	Curve Type	Curve Characteristics	No. of Geoelectric layers	% error
1	K	$\ell_1 < \ell_2 > \ell_3$	3	8.96
2	K	$\ell_1 < \ell_2 > \ell_3$	3	7.87
3	KHK	$\ell_1 < \ell_2 > \ell_3 < \ell_4 > \ell_5$	5	8.81
4	K	$\ell_1 < \ell_2 > \ell_3$	3	7.8
5	KQH	$\ell_1 < \ell_2 > \ell_3 > \ell_4 > \ell_5 < \ell_6$	6	1.61
6	KQH	$\ell_1 < \ell_2 > \ell_3 > \ell_4 > \ell_5 < \ell_6$	6	1.81
7	AKH	$\ell_1 < \ell_2 < \ell_3 < \ell_4 > \ell_5 < \ell_6$	6	0.9
8	HKA	$\ell_1 > \ell_2 < \ell_3 < \ell_4 < \ell_5$	5	3.8
9	KA	$\ell_1 < \ell_2 > \ell_3 < \ell_4$	4	3.5
10	K	$\ell_1 < \ell_2 > \ell_3$	3	3

Table 2. Ves Results and Geoelectric section

VES	Resistivity(Sum)	Thickness(m)	Lithology	Curve types
1	54/7526/806	1.8/23.6	Topsoil/clayey/fine white sand	K
2	50/575/154	1.3/17.5	Topsoil/white gravel/white sand	K
3	582/1057/806/11131/5327	1.3/9.0/12.7/22.4	Top soil/laterite/clayey sand/fine sand/coarse grained sand	KHK
4	155/2767/858	0.5/30.7	Topsoil/clayey sand/fine sand	K
5	158/894/548/191/184/1664	0.4/3.6/6.4/50.6/82.6	Topsoil/laterite/white gravel/clayey sand/fine sand	KQH
6	131/6651/1149/242/116/3193	1.0/0.6/40.7/121.1/193.6	Laterite/white sand/clayey sand/fine sand/clay	KQH
7	205/309/1427/3481/287/445	0.6/2.7/1.8/2.40/144.0	Topsoil/laterite/clayey sand/fine sand/clay	AKH
8	135/128.5/233.7/276.0/3079.9	1.0/4.3/3.8/18.2	Topsoil/laterite/clayey sand/coarse grain sand	HKA
9	172.8/707.0/424.3/733.3	0.8/3.0/35.7	Topsoil/laterite sand/clay	KA
10	917.8/1697.8/714.4	1.0/4.0	Top soil/clayey sand/fine white sand	K

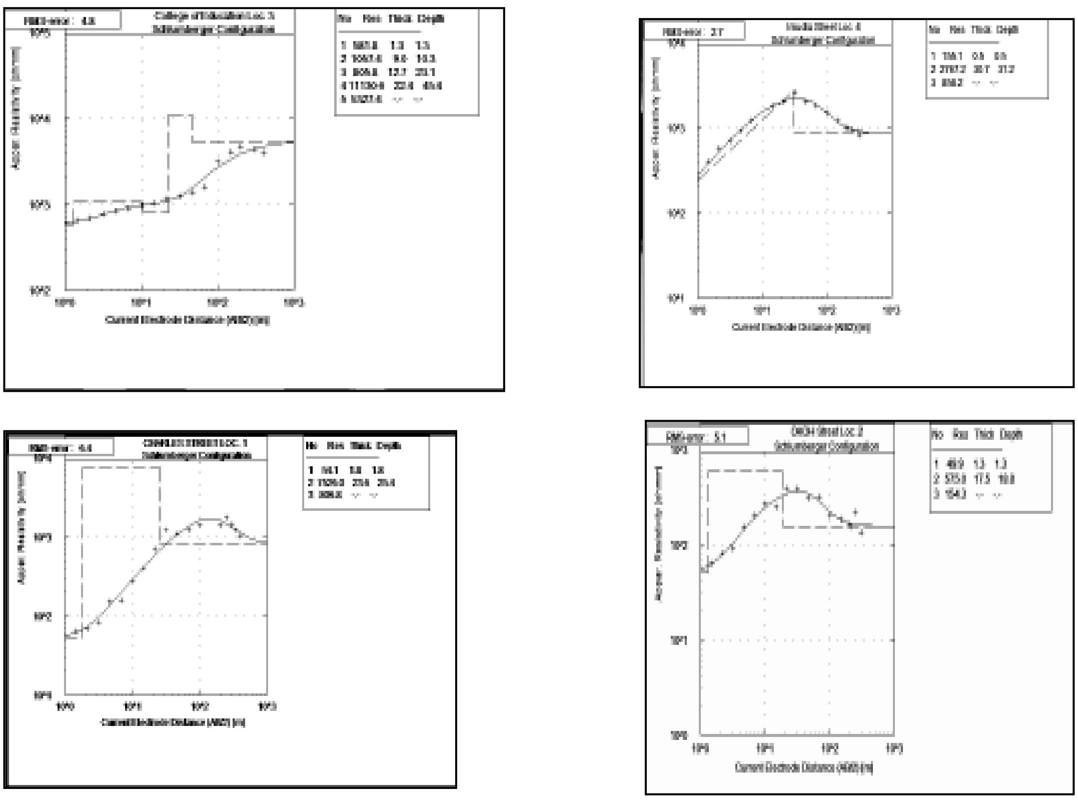

Fig. 2: *VES for some locations*

RESULTS AND DISCUSSION

The interpretation of the vertical electrical sounding curves show the following curves types; K, KHK, KQH, AKH, HKA, and KA. This is as shown in Fig 1 and Table 1. The analysis of the ten VES curves show that the layers vary generally from 3 to 6.

Location 1, 2, 4 and 10 are Charles Street, Okoh Street, Imudia Street and Baleke Street respectively. There are three layered "K" type curves. The aquifer in these locations varies from 10m to 28.0m and within the third layer. These locations have good groundwater potential since they are close to the river. The lithology is made mostly of fine white sand. The thickness of the first layer for these locations varies from 1.0m to 1.8m while the second layer varies from 4.0m to 23.6m. The resistivity for the first layer ranges from 50.0Ωm to 917.8Ωm, while the second layer ranges from 575.0Ωm to 7526.0Ωm and the third layer from 154.0Ωm to 858.0Ωm. The aquifer is heavily prone to pollution because of dumps due to gulley erosion. These locations are very close to the river and refuse brought from the top of the town due to erosion are deposited here. Sinking of boreholes within these locations is therefore not recommended.

Locations 3 and 8 (College of Education, Agbor and Mariere Street) are of "KHK" curve type and "HKA" respectively. The resistivity of the College of Education location is 582.0Ωm for the first layer, followed by 1057.0Ωm for the second layer, 806.0Ωm for the third, 1113.0Ωm for the fourth layer and 5327.0Ωm for the fifth layer with 1.3m,9.0m,12.7m and 22.4m thickness for the first four layers respectively. The lithology is made of top soil, laterite, clayey sand, fine sand and coarse grained sand. Mariere Street has resistivity for the first layer 135.0Ωm, followed by 128.5Ωm for the second layer, 233.7Ωm for the third layer, 276.0Ωm for the fourth and finally 3079.9Ωm for the fifth layer. The thickness varies from 1.0m to 18.2m. The geoelectric section is of topsoil, laterite, clayey sand, fine sand and coarse grained sand. The aquifer for these two locations are located within the fourth layer. These locations are good for borehole construction and are recommended because of high aquifer.

Location 5, 6, 7 (Melekwe Street, Ajuebor Street and Ugbaja Street) are of 6 layers of KQH, KQH and AKH respectively. Location 5 has 158.0Ωm, 894.0Ωm, 548.0Ωm, 191.0Ωm, 184.0Ωm and 1664.0Ωm for layers one to five respectively with thickness ranges from 0.4m to 82.6m. Location 6 has resistivities ranging from 116.0Ωm to 3193.0Ωm with thickness varying from 1.0 to 193.6m. The resistivity of location 7 varies from 205.0Ωm to 3481.0Ωm while the thickness ranges from 0.6 to 144.0m. The aquifer for these locations is located within the fifth layers. These locations are good for borehole construction but will be expensive as a result of the depth of the acquifer.

Location 9 (Okobi Street) is made of 4 layers having resistivities ranging from 172.8Ωm to 733.3Ωm with thickness varying from 0.8m to 35.7m. The layers are made of topsoil, laterite, sand and clay with aquifer located in the third layer. This area is very good for borehole construction because of high aquifer.

The results of the various locations show that as one goes further from the river (River Orogodo) the aquifers become lower thereby becoming more difficult in drilling boreholes. The areas within valley have higher aquifer compared to the areas on top of the hill.

CONCLUSION

Geophysical investigation was conducted at Agbor with the aim of providing useful information on the hydrogeogical nature of the aquifer potential of the town. It is very proper to determine the suitability or otherwise of drilling boreholes in any given location once the surface geophysical survey results have been properly interpreted. The resistivity and thickness values for the various locations were fully established using the VES interpreted results. The geoelectric section and the borehole logs for the various locations were equally established. The aquifers are within the depth which varies from 10m to about 80m. The locations very close to the river having very high aquifer are vulnerable to contamination as a result of refuse dump caused by erosion and the thin overlying geoelectric layer. The area is generally made of unconfined aquifers and the interpretation shows that the water bearing formation is within the sandy layers. This survey has provided an insight into the subsurface condition of Agbor which will help in groundwater exploration for the teaming population.

ACKNOWLEDGEMENT

I wish to express my sincere thanks and appreciation to my MSc physics students, University of Benin, Benin City where the data were obtained during their field work. Professor Idiodi is equally acknowledged for assisting me in doing my Sabbatical Leave in University of Benin, my wife and Sister Lady Egbai, F.O is acknowledged for her moral and financial support during the period.

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