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Determination of Ground Water Potential Using Electrical Resistivity Method

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Abstract: ***A resistivity survey was carried out to study groundwater potential in Ignatius Ajuru University of Education in Rumuolumini Town, Rivers State of Nigeria with the aim of determining the depth, thickness, resistivity and lithology at which potable water can be obtained. Two Vertical Electrical Soundings were conducted using the Schlumberger configuration. The VES data were subjected to an iteration software (IPI2WIN) which showed that the area is composed of top soil, clay, mud and sand. Based on the interpretation, interested layer under the geoelectric section is sand (made up of fine – coarse sand) in VES1-2 which signifies two aquiferous zones. The first aquifer where good quality groundwater can be gotten is due to its depth and thickness of the sand body. The second aquifer is shallow, due its depth and thin thickness, the filling of the pore spaces with overlying mud formations must have reduced the efficiency of this aquifer and it suspected to be contaminated due to the dump site. It is therefore recommended that boreholes for sustainable water supply must not exceed a depth of between 40.00m – 55.00m because of the confining bed in the fifth geoelectric layer. Further research should be carried out in this area in other to verify the contaminant nature of the aquifer by using lateral mapping method (wenner array).***

Keywords: Aquifer, Depth of Aquifer (Water Table), Resistivity, Conductivity, Thickness, Vertical Electrical Sounding (VES)

1. General Introduction

The electrical techniques have been used in a wide range of geophysical investigation such as mineral exploration, engineering studies, geothermal exploration, archaeological investigation, permafrost mapping and geological mapping. Resistivity is the resistance in ohm meter of a unit cube material. According to ohm's law. Resistance $R=\frac{V}{I}$, where V – is the potential difference in volts and I – is the current in amperes. Resistivity measures apparent resistance of ground to direct current flow. Resistance is also the inverse of conductance. The importance of groundwater as a water supply source to the socioeconomic development of any nation is tremendous. However, the difficulties in exploration and exploitation usually encountered in the basement areas where aquifers are both inaccessible and compartmentalized, requires the use of multi-disciplinary approach involving geological, hydro-geological mapping and geophysical investigation to ensure success. The use of geophysics for ground water exploration and water quality evaluation has increased over the last few years due to the rapid advances in computer software and associated numerical modelling solutions. The vertical electrical sounding (VES) has proved very popular with groundwater prospecting due to straightforwardness of the techniques (Adepelumi et al. 2001; Akaolisa, 2006; Ozebo et al. 2008; Rao et al., 2008 and Adiat et al., 2009).

The data obtained from this work will be used in inferring subsurface features (aquifers) that are capable of holding groundwater so as to locate possible and suitable sites for productive borehole in the study area. It is also to provide background information for the future ground water development in the study area as a means of reducing incidences of borehole failures.

The aim of this study is to determine the depth to bedrock, aquifer thickness, and to delineate the various lithology. It can also be used to determine the ideal depth at which we can get aquifer for potable drinking water in the locations and possibly prevent any water borne diseases resulting from such challenges.

2. Location of Study

This study was carried out at Ignatius Ajuru University of Education in Rumuolumini Town, Port Harcourt in Rivers State of Nigeria with longitude $6^0$56'22.4" and latitude $4^0$48'23.8N" and is accessible through networks of linked roads and covers an area of about 2,720 m^2.The area is located within the Niger Delta Basin and is characterized by alternate wet and dry seasons, with a total annual rainfall of about 240cm; relative humidity of over 90% and mean annual temperature of 27^{0}C (Udom and Esu, 2002). The areas are dominated by moderate vegetation cover and slightly flat topography (figure 1).

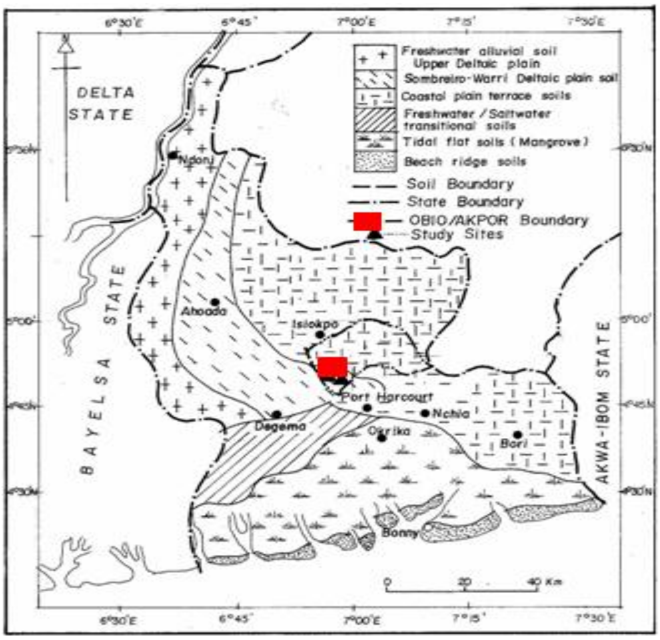

Figure 1: Geologic Map of the Study Area (Adapted from Ehirim et al., 2009)

3. Methodology

Instrumentation

The equipment used for measuring the resistivity is the ABEM Terrameter SAS (Signal Averaging System) model 300B or 1000 and other accessories such as: cables, electrodes, hammer, pegging sticks and measuring tapes. The Terrameter comprises of a 12 Volts D.C. battery powered deep penetration resistivity meter, with an output of current electrode separation of up to 2000meters. It uses a power oscillator at very low frequency of 4Hz to drive current into the ground which produces a current deflection in the galvanometer. The same current that goes into the ground passes through a potentiometer, which is now adjusted to produce the same deflection in the galvanometer; the ratio $(\frac{V}{I})$ is now directly given by the resistance of the potentiometer which is read off in the display. The potential and current terminals of the Terrameter were connected to the electrodes, and the instrument is designed in such a way that it can be easily carried from one point to another; it is also versatile and very sensitive.

Field procedure

The survey includes a total of two vertical electrical sounding (VES). Field work started by marking out sounding stations for vertical electrical sounding. The coordinate point where the VES was carried out are longitude $6^0$54'22.4" E and latitude $4^0$48'23.8"N. A series of resistivity measurement were taken with a Schlumberger electrode configuration. As usual, the midpoint of the potential electrode configurations remained fixed at the observation stations while the length of the configuration generally increased. The VES was taken with a maximum current electrode spread AB/2 of 150 meters and MN/2 of 15meters. A well defined electrical signal current was injected into the ground through the current electrodes. The resulting voltage was measured between the potential electrodes. The Terrameter then calculated and displayed the quotients ($\frac{\Delta V}{I}$), which is the resistance 'R' of the earth path through which the current passed. The geometrical factor for Schlumberger arrangement is $K = \pi\left[\frac{\left(\frac{AB}{2}\right)^2 - \left(\frac{MN}{2}\right)^2}{MN}\right]$.

By multiplying the displayed resistance R with K that depends on the electrode separation, the apparent resistivity (ρ_a) was obtained (table 1).

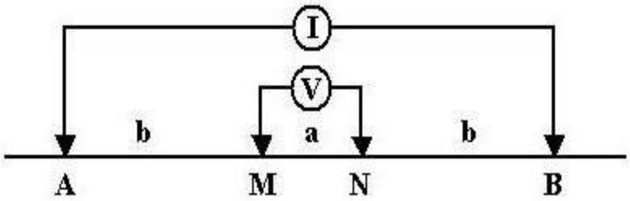

Figure 2: Diagram of a Schlumberger Configuration

Table 1: Calculated K and ρ_a values

AB/2 (m)	MN/2 (m)	Geometric Factor K	Resistance (Ω)	Apparent Resistivity (Ωm)
1.0	0.3	4.7667	1.121	5.3437
1.5	0.3	11.3143	0.373	4.2204
2.0	0.3	20.4810	0.1482	3.0354
2.5	0.3	32.2667	0.0858	2.7686
4.0	0.5	49.5000	0.0342	1.6930
5.0	0.5	77.7857	0.0316	2.4581
7.0	0.5	153.2143	0.00072	0.1103
8.0	1.0	99.0000	0.033	3.2671
10.0	1.0	155.5714	0.0226	3.5161
12.0	1.0	224.7143	0.018	4.0450
15.0	1.5	233.3571	0.0161	3.7572
20.0	1.5	416.6905	0.0104	4.3338
25.0	2.5	388.9286	0.009	3.5005
30.0	2.5	561.7857	0.0021	1.1798
40.0	5.0	495.0000	0.0027	1.3366
50.0	5.0	777.8571	0.0022	1.7114
70.0	10.0	754.2857	0.0077	5.8083
80.0	10.0	990.0000	0.007	6.9303
100.0	10.0	1555.7143	0.0133	20.6919
120.0	15.0	1485.0000	0.0026	3.8612
150.0	15.0	2333.5714	0.0004	0.9335

Field data processing

The VES field data was processed using the IPI2WIN resistivity sounding interpretation software version 3.0 (2003), to determine the true resistivity and depths of subsurface formations. This computer program automatically generated model curves using initial layer parameters (resistivities and thickness) derived from partial curve matching of the field curves with standard curves, and calculates the true layer parameters of the geo-electric section. The results are presented in terms of the resistivities and depths of the geo-electric for the position.

4. Presentation and Interpretation of Results

The resulting model curves have RMS errors of <5% curves with 5 interpretable geoelectric layers for VES 1 which exhibit KK type curve and three interpretable geoelectric layers for VES 2 which exhibit H type curve. The results are of the form of figures and tables.

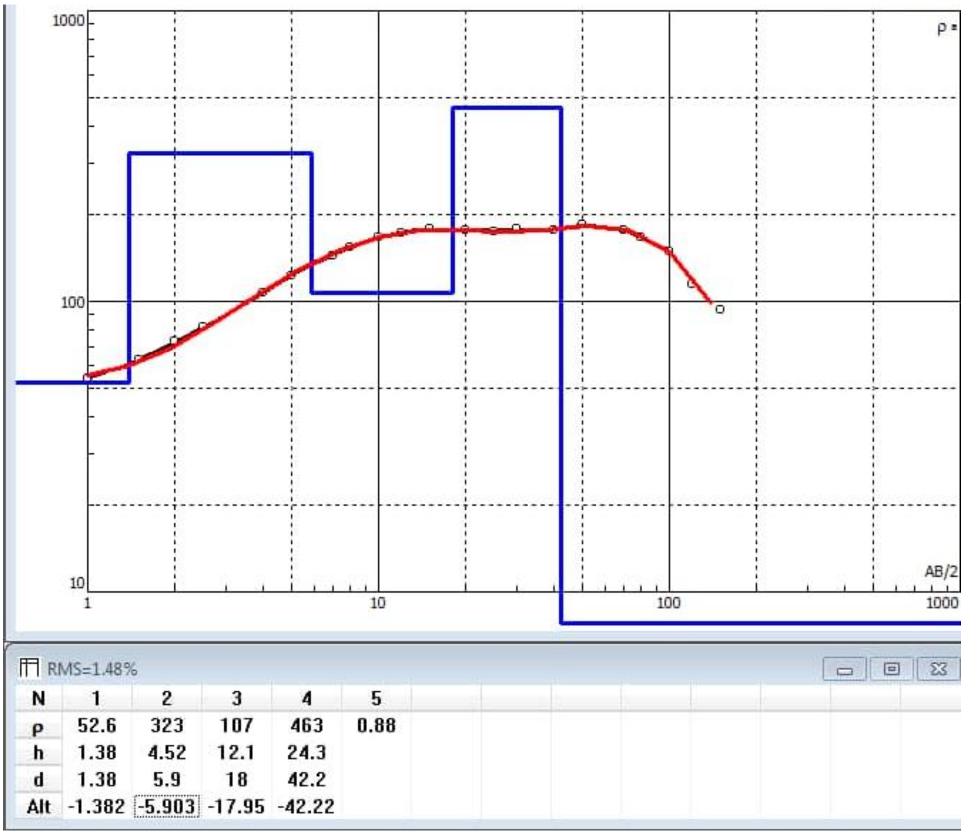

Figure 3: VES 1

Table 2: Resistivities and Depth of VES 1

Layers	RHO (Ωm)	Depth (m)	Thickness (m)	Lithology
1	52.60	1.38	1.38	Shale
2	323.00	5.90	4.52	Clay
3	107.00	18.00	12.10	Mud
4	463.00	42.2	24.20	Sand
5	0.88			

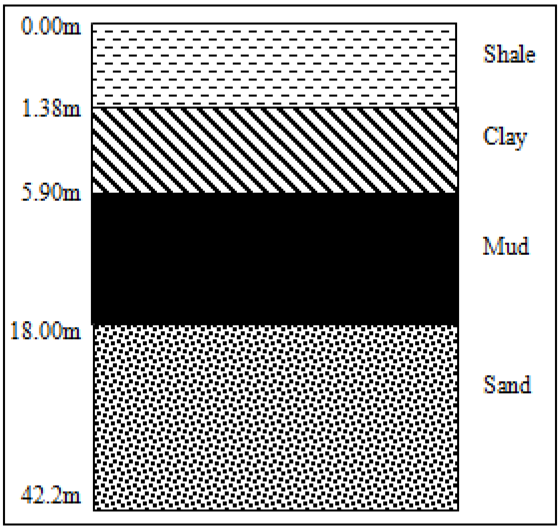

Figure 4: Lithologic Log and Interpreted Geoelectric sections with depth.

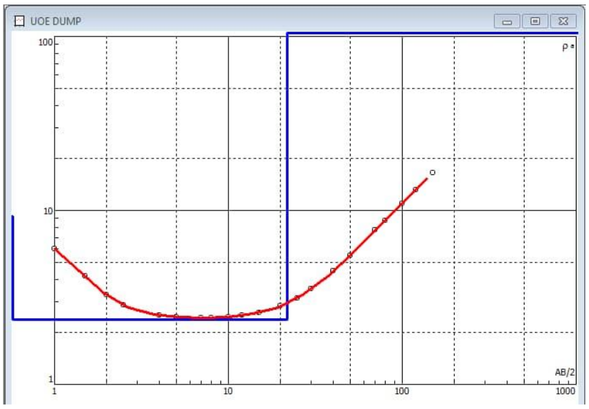

Figure 5: VES 2

Table 3: Resistivities and Depth of VES 2

Layers	RHO (Ωm)	Depth (m)	Thickness (m)	Lithology
1	9.26	0.516	0.516	Shale
2	2.36	21.8	21.28	Clay
3	2368.00			Sand

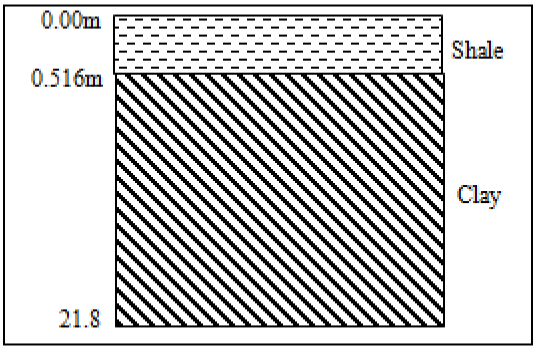

Figure 6: Lithologic Log and Interpreted Geoelectric sections with depth

5. Interpretation of Results

The geologic map of the Niger Delta places the study area in Benin formation such that the lithologic units that are expected in this are mainly between fine to medium and coarse sands with clay intercalations. A resistivity range proposed by Keller and Frischknecht (1966) for some selected sedimentary rocks and soil materials is adopted in the interpretation of VES results.

Table 4: Resistivity range of lithologic units (Keller et al., 1966)

Lithologic Unit	*Resistivity Range*
Top soil	70 – 300
Clay	1 – 100
Sand	60 – 1000
Sandstone	8 – 4000

Qualitatively speaking the first curve type is KK type with five layers, the second curve type is H type with three layers as shown in figures (3 and 5), shows the resistivity and depth of these layers. The first geoelectric layer corresponds to the topsoil with resistivity values of 27.7Ωm. This reflects shale formations. The thickness of this layer varies from 0.00m -1.96 m. Though the sand in this layer contains water, it is not a good aquifer. The second geoelectric layer has a resistivity value of 71.60Ωm at the depth of 4.92m with thickness of 2.96m, which corresponds to clay lithology. The third geoelectric layer has a resistivity value of 192.00Ωm at the depth of 12.80m with thickness of 7.88m, which corresponds to mud lithology. This is the first aquifer and it is shallow because of its depth and thin thickness. The fourth geoelectric layer has a resistivity value of 430.00Ωm at the depth of 41.20m with thickness of 28.4m which corresponds to sand lithology. It serves as the second aquifer where good quality groundwater can be gotten, due to its depth and thickness of the sand body. The fifth geoelectric layer has a resistivity value of 172.00Ωm at unknown depth.

6. Discussion of Results

Results shows that the first has KK type curve with five geoelectric layers ($\rho_1<\rho_2>\rho_3<\rho_4>\rho_5$), the second has H type curve with three geoelectric layers ($\rho_1>\rho_2<\rho_3$) of vertical electrical sounding curve. The layers are interbeded with shale, clay, mud and sand since the area of study is located in the Benin formation.

In VES 1 (table 1) its resistivity values ranges from 29.20Ωm to 401.00Ωm at an average depth of 15.22m, of which good water can be located the depth of 15.22m to 40.8m. In VES 2 (table 2) its resistivity values ranges from 14.20Ωm to 249.00Ωm at an average depth of 15.30m, of which good water can be located the depth of 15.30m to 41.50m. In VES 3(table 3) its resistivity values ranges from 29.20Ωm to 401.00Ωm at an average depth of 15.18m, of which good water can be located the depth of 15.18m to 40.80m. So basically, good potable water can be gotten from a depth of 15m to 43m at Ignatius Ajuru University of Education in Rumuolumini Town and its environs.

7. Conclusion

From the above analysis, two near subsurface aquifers have been identified along Ignatius Ajuru University of Education in Rumuolumini town. The first aquifer where good quality groundwater can be gotten is due to its depth and thickness of the sand body. The second aquifer is shallow, due its depth and thin thickness, the filling of the pore spaces with overlying mud formations must have reduced the efficiency of this aquifer and it suspected to be contaminated due to the dump site. It is therefore recommended that boreholes for sustainable water supply should be drilled to a depth of 15.00m – 55.00m based on average analysis within this environs.

8. Recommendation

It should be noted that boreholes for sustainable water supply must not exceed a depth of between 40.00 m – 55.00 m at Ignatius Ajuru University of Education in Rumuolumini town because of the confining bed in the fifth geoelectric layer. Further research should be carried out in this study in other to verify the contaminant nature of the aquifer by using lateral mapping method (wenner array).

References

[1] Adepelumi, A.A., Ako, B.D., Ajayi, T.R. (2001). Groundwater contamination in the basementcomplex area of Ile-Ife, southwestern Nigeria: A case study using the electricalresistivity geophysical method. Hydrogeology Journal, 9, 611–622.

[2] Adiat, K. A. N, Olayanju, G. M, Omosuyi G. O. and Ako B. D., 2009. Electromagnetic profiling and electrical resistivity soundings in groundwater investigation of a typical basement complex – a case study of Oda town Southwestern Nigeria. Ozean Journal of Social Sciences 2(4), 333-359.

[3] Akaolisa, C. (2006). Aquifer Transmissivity and Basement Structure Determination Using Resistivity Sounding at Jos Plateau State Nigeria. Environ Monit Assess 114, 27–34 (2006). https://doi.org/10.1007/s10661-006-1075-8

[4] Ehirim, C.N., Ebeniro, J.O. and Olanigan, O.P. (2009). A Geophysical Investigation of Solid Waste Landfill Using 2-D Resistivity Imaging and Vertical Electrical Sounding Methods in Port Harcourt Municipality, Rivers State, Nigeria. Pacific Journal of Science and Technology. 10(2): 604-613.

[5] IPI2WIN software Moscow State University **2003**, Version 3.0.

[6] Keller, G. V. and Frischknecht, F. C. (1966). Electrical methods in geophysics Prospecting, Pergamon London.

[7] Ozebo, V. C., Odunaike, R. K., Balogun, A. A., 2008. Identification of depth to top limestone body within concession at Ibse, southwestern Nigeria, Using vertical electrical sounding. Journal of Earth Sciences, 2(3), 99-107.

[8] Rao, K. N., Rao, C. U. B., Rao, T. V., 2008. Estimation of sediment volume through geophysics and GIS analysis. A case study of the red sand deposit along

Visakhpatnam coast. Journal of Indian Geophysical Union, 12(1), 23- 30.

[9] Udom, G.J., Ushie, F.A. and Esu, E.O. (2002). A geochemical survey of groundwater in Khana and Gokana Local Government Areas of Rivers State. *Journal of Applied Science and Environmental Management.* 6(1):53 – 59.

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