Journal of Physical Sciences and Environmental Safety
Volume 2, Number 1, 2012

ELECTRICAL RESISTIVITY SURVEY FOR GROUND WATER POTENTIALS, AN OVERVIEW

[1]Opeh, R; [2]Molua, O.C; and [3]Okoh. H
[1]Department of Physics and Energy Studies, Western Delta University Oghara, Delta State
[2]Physics department, College of Education, Agbor. Delta State
[3]Physics department, College of Education, Mosogar. Delta State
E-mail:opehraymond@yahoo.co.uk
Corresponding author: Opeh. R.

ABSTRACT
A geophysical survey for ground water resources was carried out. This was successfully done by employing the electrical resistivity method to investigate the water table variations within the areas covered, with the application of Schlumberger arrangement. Electrical resistivity technique has its base on inserting four electrodes in the ground in which two of the electrodes are current electrodes and the other two are potential electrodes. ABEM TERRAMETER SAS 300B was the principal instrument used in this survey. This instrument measures the ground resistance and the apparent resistivity of the subsurface was calculated the data obtained was analyzed by the computation of the apparent resistivity and plotting the graph of the half electrodes spacing and the apparent resistivity. Interpretation was done by computer assisted evaluation procedure in which depths of the water table was estimated for the three VES. For VES 1, the water table was found at about 47.5m, VES 2 is about 47.0m, and VES 3 is from 61.5m.

KEY WORDS: *Electrical resistivity, Schlumberger arrangement, apparent resistivity, VES.*

INTRODUCTION
The rapid growth of the population in most part of the globe has in no small measure ushered in depletion of natural resources. Against this backdrop, man has continued to strive hard to develop methods of replenishing these bounties of nature. Underground water is a ground source of water to man apart from the surface water from rainfall and streams.

Groundwater occurs in the zone of saturation below the earth surface. This water when tapped is large enough for man to sustain life and in many areas it can be used in agricultural activities like irrigation and industrial activities. The application of geophysical principles was used to investigate the ground water of the study area. The method centers on the use of electrical resistivity for ground water exploration. They are several forms electrode arrangement that can be used in carrying out resistivity measurements. In most arrangements; both sets of electrodes are laid out along a line. The current electrodes are generally placed outside of the potential electrodes. For a better result of this project, the Schlumberger method was used in tacking the problems encountered during ground water investigation. The resistivity survey techniques involve the introduction of an artificial source of current into the ground through point electrodes. ABEM TERRAMETER SAS 300 was used by employing the Schlumberger electrode arrangement to determine resistivity.

Brief Geology of the Study Area

The study was carried out in Idemli local Government Area of Anambra State, Nigeria. Covering Umunachi and Eziowelle towns. The general geology of Idemili and its environs is mainly the Nanka sand. The geologic unit that is predominant is the Nanka sand of the lower Ecocene called the Persian. The formation that is underlying the Nanka sand is the Imo-shale and the formation overlying it is the Ogwashi-Asaba formation. The thickness of Nanka sand is about 350 metres. The Imo-shale, which is directly under the Nanka sand, has a thickness of about 1000 metres.Ogwashi-Asaba formation, which is above the Nanka sand, has a thickness of about 1163 metres. Erosive forces can expose this sand in places open to erosion due to non-availability of cementing material in the area. The Nanka sand of the Anambra sedimentary basin consist of four lithologic units of crossed stratified medium to coarse, often pebbly loose sand beds with intercalating of thin gypsiferous shale by Nkisi river in the North and Ndemili river in the West. The rivers are fed by many streamlets. The survey area is located between latitude $6^{o}8'$N and $6^{o}11.5'$N,and longitudes $6^{o}52.6'$E and $6^{o}58'$E covering Umunachi and Eziowelle towns.

Basic Theory of Electrical Resistivity

Consider a completely homogeneous isotropic earth layer of a uniform resistivity. From the aspect of quantitative treatment, let us consider a homogenous layer of length, L and a resistance, R through which a current I, is flowing. The potential difference across the ends of the resistance will be given by Ohm's law and;

$$\Delta V = IR \quad \text{------------------------------- (1)}$$

The area of cross-section A, resistivity ℓ, resistance R and the layer is specified by its length L from the equation below;

$$\ell = \frac{RA}{L} \quad \text{--------------- (2)}$$

The SI unit of resistivity is Ohm-metre (Ωm). While the conductivity is $\sigma = \left[\frac{1}{\ell}\right]$ of a material can be defined as the reciprocal of resistivity and is measured in Ohm per metre (Ωm^{-1}) the word "mho" being carried by spelling "Ohm" backward ($Sharma, P.V. 1976$)

Therefore, it follows that R = ℓL/A and equation 1 can be rewritten as

$$\frac{\Delta V}{I} = \frac{\ell L}{A} \quad \text{---3}$$

Or $$gradV = \ell j \quad \text{-------------------------------4}$$

where j is the current density per unit of cross-sectional area and grad V is the potential gradient. Consider a semi-infinite conducting layer of uniform resistivity bounded by the ground surface and assume a current of strength + 1 entering at point C_1 on the ground surface as shown below

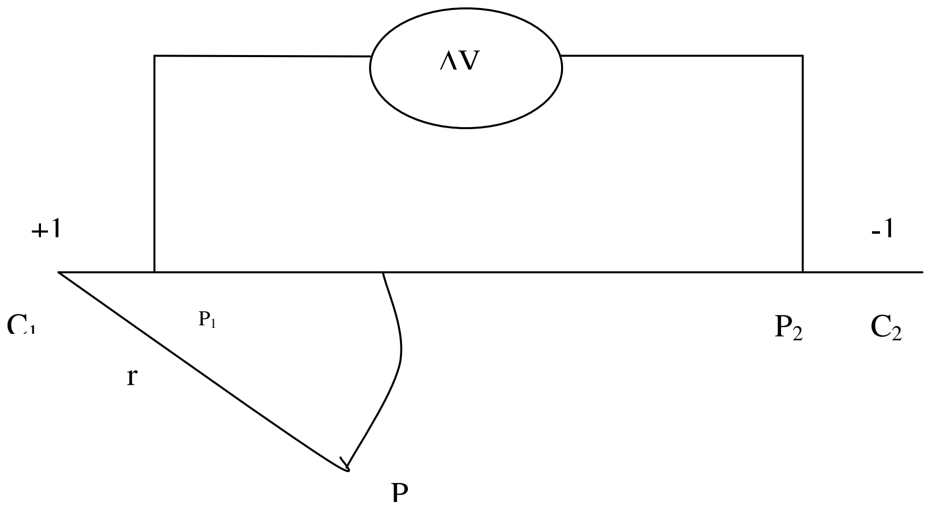


Fig.1: Shows a method of calculating potential distribution due to a current source in a homogeneous medium The current density j, at a distance r, away from the current source, would be:

$$j = \frac{I}{2\pi r^2} ------a$$

$$-\frac{dv}{dr} = \ell j -----b \qquad ----------------------5$$

The potential gradient associated with the Current is given in equation (1.3). Now lets substitute j in equation 1.4a. Into equation 1.4b. We then have that

$$\frac{-dv}{dr} = \frac{\ell I}{2\pi r^2} ------------------------6$$

The potential at distance r in fig. 1 can be obtained by integrating equation (6)

$$-\int dv = \frac{\ell I}{2\pi}\int r^{-2} dr$$

$$-v = -\frac{\ell I}{2\pi} r^{-1}$$

$$\therefore v = \frac{\ell I}{2\pi r} ------------7$$

The above equation 7 can be said to be the basic equation, which enables the calculation of the potential distribution in a homogeneous conducting semi-infinite medium. It is also easy to see from equation (7) that the potential difference between points P_1 and P_2 (fig 1 caused by current + 1 at the "source" entry point C_1) is given as:

$$v = \frac{I\ell}{2\pi}\left[\frac{1}{C_1P_1}\right] - \frac{I\ell}{2\pi}\left[\frac{1}{C_1P_2}\right]$$

$$v = \frac{I\ell}{2\pi}\left[\frac{1}{C_1P_1} - \frac{1}{C_1P_2}\right] ------8$$

In the same manner, the potential difference between P_1 and P_2 is

$$v = \frac{I\ell}{2\pi}\left[\frac{1}{C_2P_1} - \frac{1}{C_2P_2}\right] -------9$$

The total potential difference between P_1 and P_2 is therefore, given by the sum of the right hand sides of equation (1.7) and (1.8) which is:

$$v = \frac{I\ell}{2\pi}\left[\frac{1}{C_1P_1} - \frac{1}{C_1P_2}\right] - \frac{I\ell}{2\pi}\left[\frac{1}{C_2P_1} - \frac{1}{C_2P_2}\right]$$

$$v = \frac{I\ell}{2\pi C_1P_1} - \frac{I\ell}{2\pi C_1P_2} - \frac{I\ell}{2\pi C_2P_1} + \frac{I\ell}{2\pi C_2P_2}$$

Collecting like terms

$$v = \frac{I\ell}{2\pi}\left[\frac{1}{C_1P_1} - \frac{1}{C1P_2} - \frac{1}{C_2P_1} + \frac{1}{C_2P_2}\right] -------10$$

or

$$\ell = 2\pi G\frac{\Delta v}{I}(Sharma, P.V.1976) ----------11$$

Where:

$$G = \left[\frac{1}{C_1P_1} - \frac{1}{C_1P_2} - \frac{1}{C_2P_1} + \frac{1}{C_2P_2}\right]^{-1}$$

G denotes the geometric factor of an electrode configuration.

Here, the value of ℓ for a homogeneous conducting medium is independent of the positions of electrodes and is not affected when the positions of the current and potential electrodes are interchanged.

METHODOLOGY

The method applied for this research work is the vertical electrical sounding (VES) method, which is also known as electrical drilling or expanding probe. For this work three sounding points were occupied using the Schlumberger array method with the electrode spacing varying from 1.5m to about 370m and it helps in showing the multi-layered sub-surface.

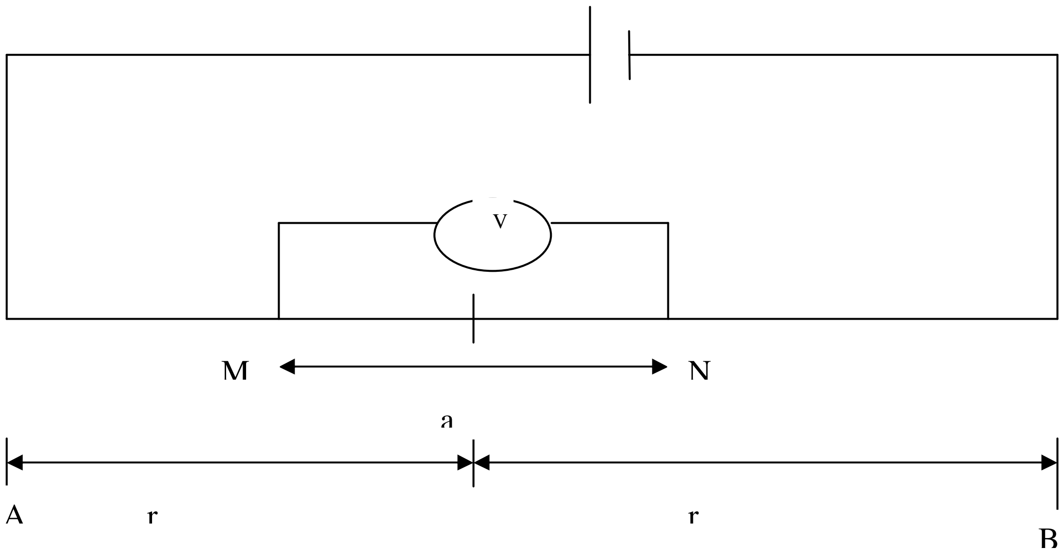


Fig 2: The current was fed into the ground using two current electrodes A & B spaced at a distance AB apart as shown in fig 2 above. At the centre of these two electrodes the voltage, was measured between the potential electrodes M & N placed at a distance of MN apart. The ABEM TERRAMETER has a high resolution and gives a direct readout of the resistance of the ground in Ohms. A maximum current electrode separation (AB) of 370m was used on both sides and the corresponding potential electrodes (MN) was occasionally expanded from 0.5m to 14.0m for VES 1 & VES 3for greater depth penetration. The readings of the resistance were converted to apparent resistivity by using the expression below:

$$\ell_a = \frac{\pi\left[\left(\frac{AB}{2}\right)^2 - \left(\frac{MN}{2}\right)^2\right]R}{MN}$$

Where
ℓ_a = apparent resistivity
R = ground resistivity
AB = separation between current electrodes
MN = separation between potential electrodes.
Therefore, we can define the VES method as the use of electrical methods with depth control in which electrode spacing is increased to obtain information from greater depths at a given surface location. It is used for detecting changes in the resistivity of the earth with depth beneath the given location. The principles of VES are based on the fact that the wider the current electrode separation, the deeper the current penetration. As the current reaches greater depths subsequent readings are progressively taken

RESULTS & DISCUSSIONS
A field survey was conducted through the vertical electrical sounding (VES). The data obtained from the measurement are represented in table a, b and c for VES 1, 2 and 3 respectively.

AB/2 (m)	MN/2 (m)	R (Ω)	ℓ_a (Ωm)
1.5	0.5	88.20	554
2.0	-	57.10	673
2.5	-	44.80	844
3.5	-	30.40	1145
4.5	-	22.90	1438
6.0	-	14.51	1629
8.0	-	10.21	2042
10.0	-	7.90	2474
15.0	-	3.93	2773
10.0	3.5	57.90	2279
15.0	-	27.60	2634
20.0	--	16.16	2813
30.0	-	8.36	3331
40.0	-	5.22	3720
50.0	-	3.57	3986
60.0	14.0	2.66	4283
50.0	-	15.53	3963
60.0	-	11.33	4327
80.0	-	6.40	4664
100.0	-	3.64	4015
130.0	-	1.78	3338
170.0	-	0.73	2351
220.0	-	0.34	1855
280.0	-	0.15	1316
370.0	-	0.09	1427

TABLE A FOR VES 1

AB/2 (m)	MN/2 (m)	R (Ω)	ℓ_a (Ωm)
1.5	0.5	38.7	243
2.0	-	23.4	276
2.5	-	17.78	335
3.5	-	13.03	491
4.5	-	9.63	606
6.0	-	6.52	732
8.0	-	4.20	840
10.0	-	3.16	990
15.0	-	1.693	1195
10.0	3.5	18.35	722
15.0	-	10.01	955
20.0	--	6.81	1185
30.0	-	4.10	1634
40.0	-	2.60	1853
50.0	-	1.78	1988
60.0	14.0	1.275	2053
50.0	-	7.89	2040
60.0	-	5.01	1913
80.0	-	2.96	2060
100.0	-	2.03	2233

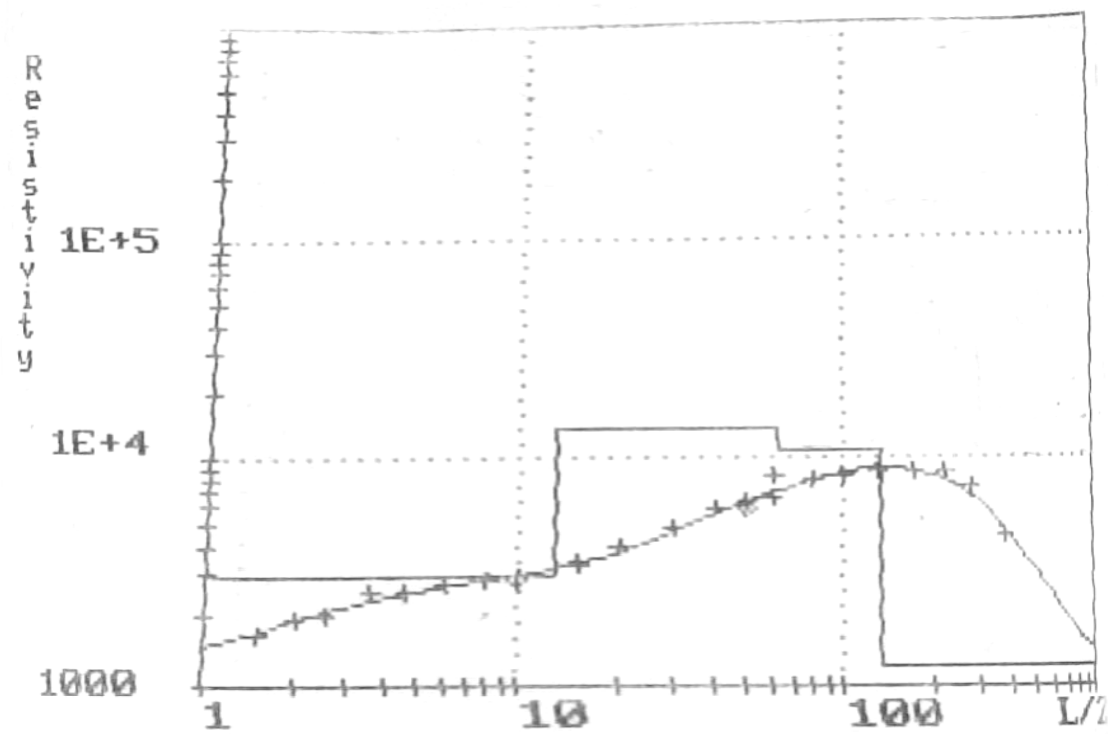
130.0	-	1.218	2283
170.0	-	0.668	2151
220.0	-	0.325	1758
280.0	-	0.193	1694
370.0	-	0.081	1242

TABLE B FOR VES 2

AB/2 (m)	**MN/2 (m)**	**R (Ω)**	ℓ_a **(Ωm)**
1.5	0.5	262.0	1645
2.0	-	162.0	1908
2.5	-	106.0	2008
3.5	-	65.0	2464
4.5	-	39.0	2492
6.0	-	24.30	2724
8.0	-	14.11	2822
10.0	-	9.11	2853
15.0	-	4.75	3352
10.0	3.5	69.70	2743
15.0	-	34.60	3302
20.0	--	23.10	4019
30.0	-	11.90	4741
40.0	-	8.08	5758
50.0	-	5.63	6286
60.0	14.0	5.16	8244
50.0	-	22.50	5816
60.0	-	17.23	6581
80.0	-	11.10	7727
100.0	-	7.52	8272
130.0	-	4.56	8546
170.0	-	2.58	8346
220.0	-	1.337	8366
280.0	-	0.625	7231
370.0	-	0.293	4494

TABLE C FOR VES 3

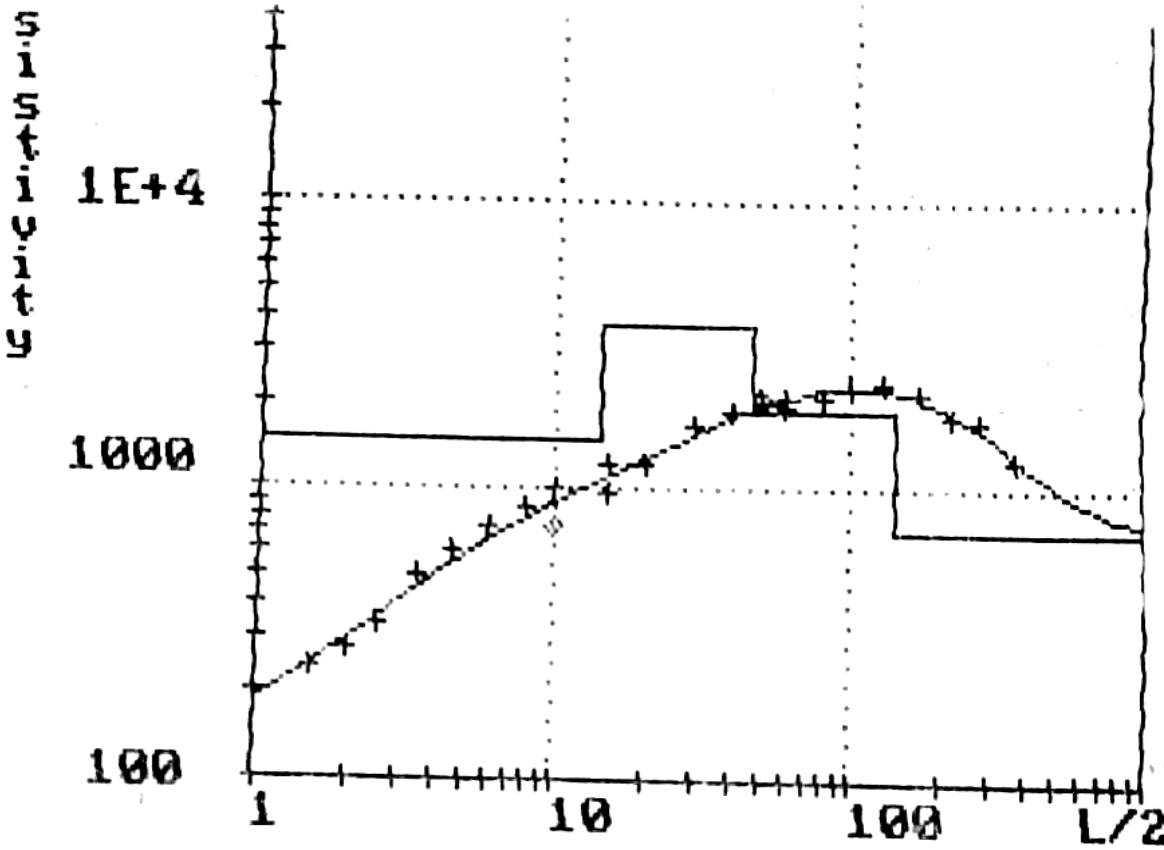
The graphs below represent VES 3, VES 2, and VES 1 in that order. (OB 3, OB 2, OB 1 respectively)



ata (File) name OB 3 Date
roject name PROJECT Direction lay out E-W
ode name Remarks
oordinates UMUNACHI/EZOWELE Schlumberger O'Neill

/2 (m)	Rho (Ohm.m)	L/2 (m)	Rho (Ohm.m)	L/2 (m)	Rho (Ohm.m)
1.5	1645.0	10.0	2743.0	80.0	7727.0
2.0	1908.0	15.0	3302.0	100.0	8272.0
2.5	2008.0	20.0	4019.0	130.0	8546.0
3.5	2464.0	30.0	4741.0	170.0	8346.0
4.5	2492.0	40.0	5758.0	220.0	8366.0
6.0	2724.0	50.0	6286.0	280.0	7231.0
8.0	2822.0	60.0	8244.0	370.0	4494.0
10.0	2853.0	50.0	5816.0		
5.0	3352.0	60.0	6581.0		

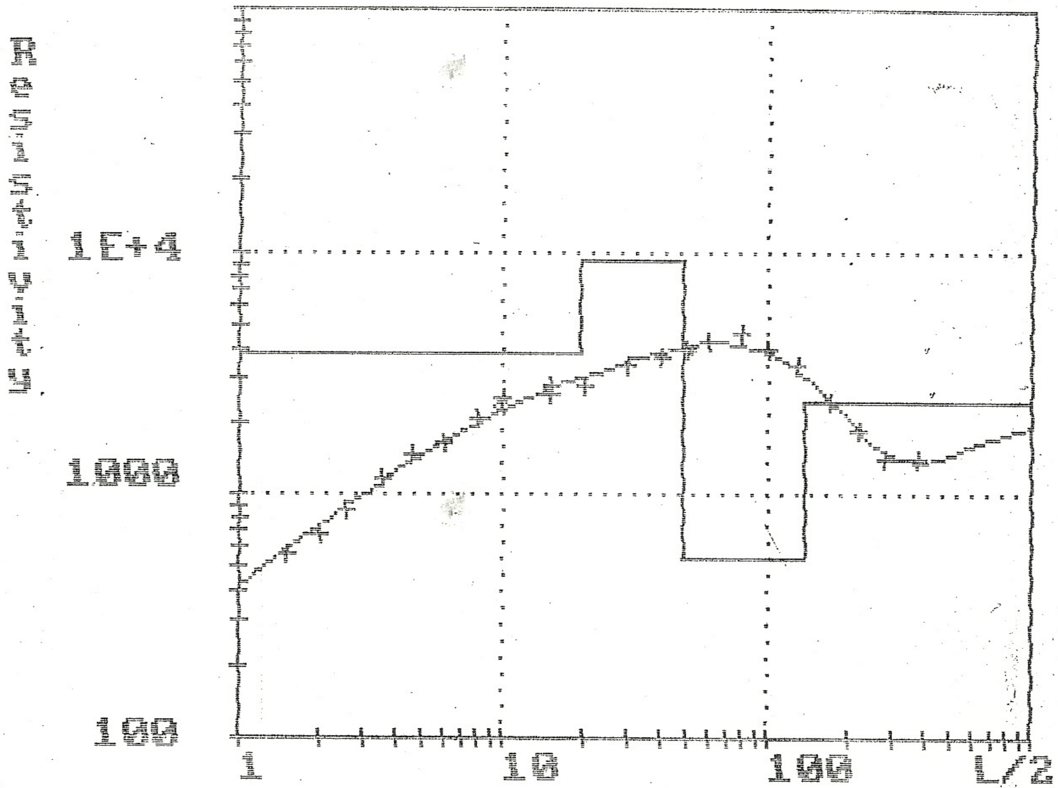
istivity (Ohm.m)	Depth (m)
1210.0	0.7
2940.0	13.0
13600.0	61.5
10800.0	134.0
1230.0	



Data (File) name	OB 2	Date	
Project name	PROJECT	Direction lay out	E-W
Code name	814	Remarks	
Coordinates	UMUNACHI/EZOWELE	Schlumberger	O Neill

L/2 (m)	Rho (Ohm.m)	L/2 (m)	Rho (Ohm.m)	L/2 (m)	Rho (Ohm.m)
1.5	243.0	10.0	722.0	80.0	2060.0
2.0	276.0	15.0	955.0	100.0	2233.0
2.5	335.0	20.0	1185.0	130.0	2283.0
3.5	491.0	30.0	1634.0	170.0	2151.0
4.5	606.0	40.0	1853.0	220.0	1758.0
6.0	732.0	50.0	1988.0	280.0	1694.0
8.0	840.0	60.0	2053.0	370.0	1242.0
10.0	990.0	50.0	2040.0		
15.0	1195.0	60.0	1913.0		

Resistivity (Ohm.m)	Depth (m)
146.0	0.8
1450.0	14.2
3660.0	47.0
1880.0	141.0
715.0	

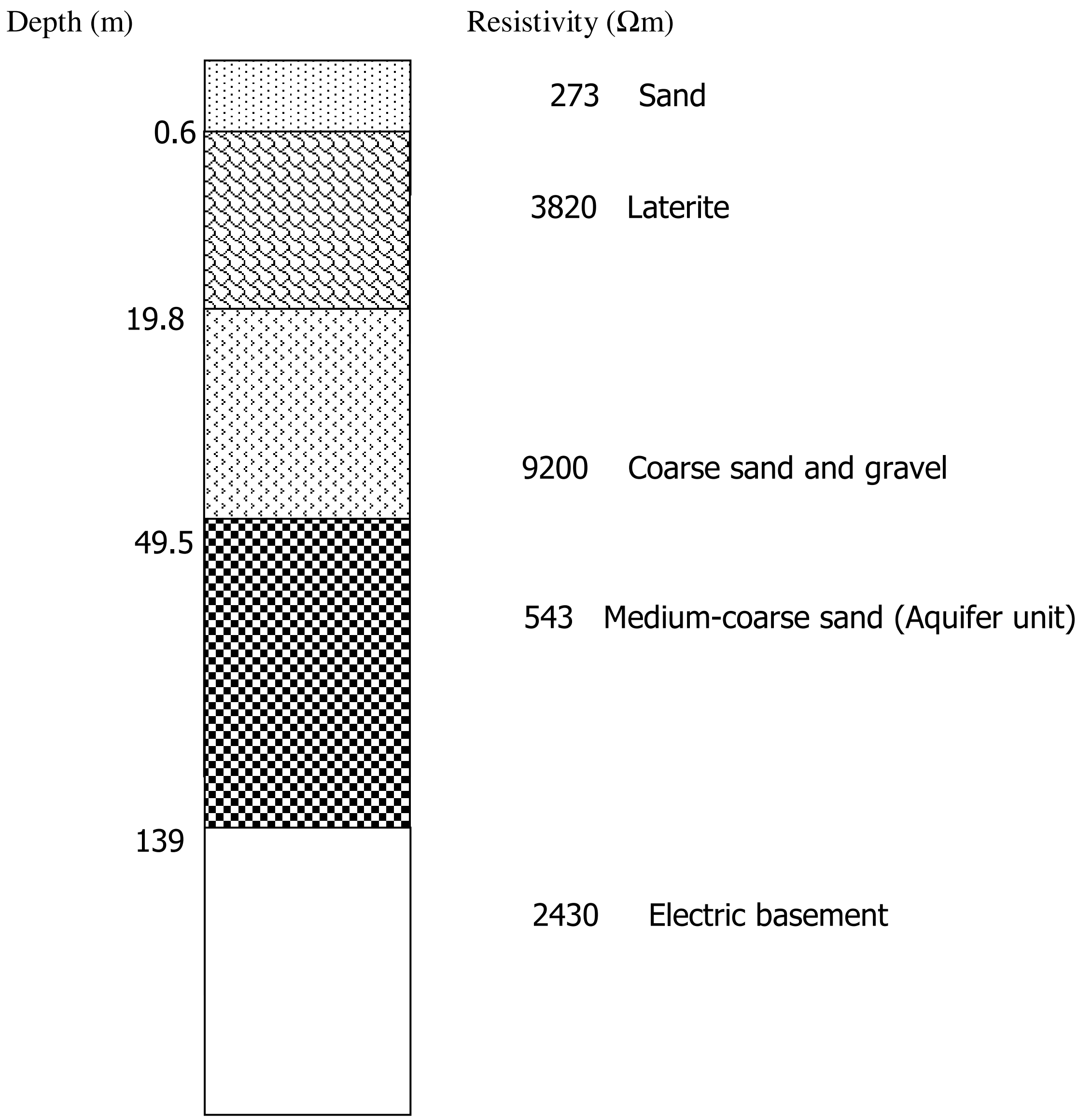


Data (File) name QB 1
Project name PROJECT
Code name
Coordinates UMUNACHI/EZIOWELE Schlumberger / O'Neill

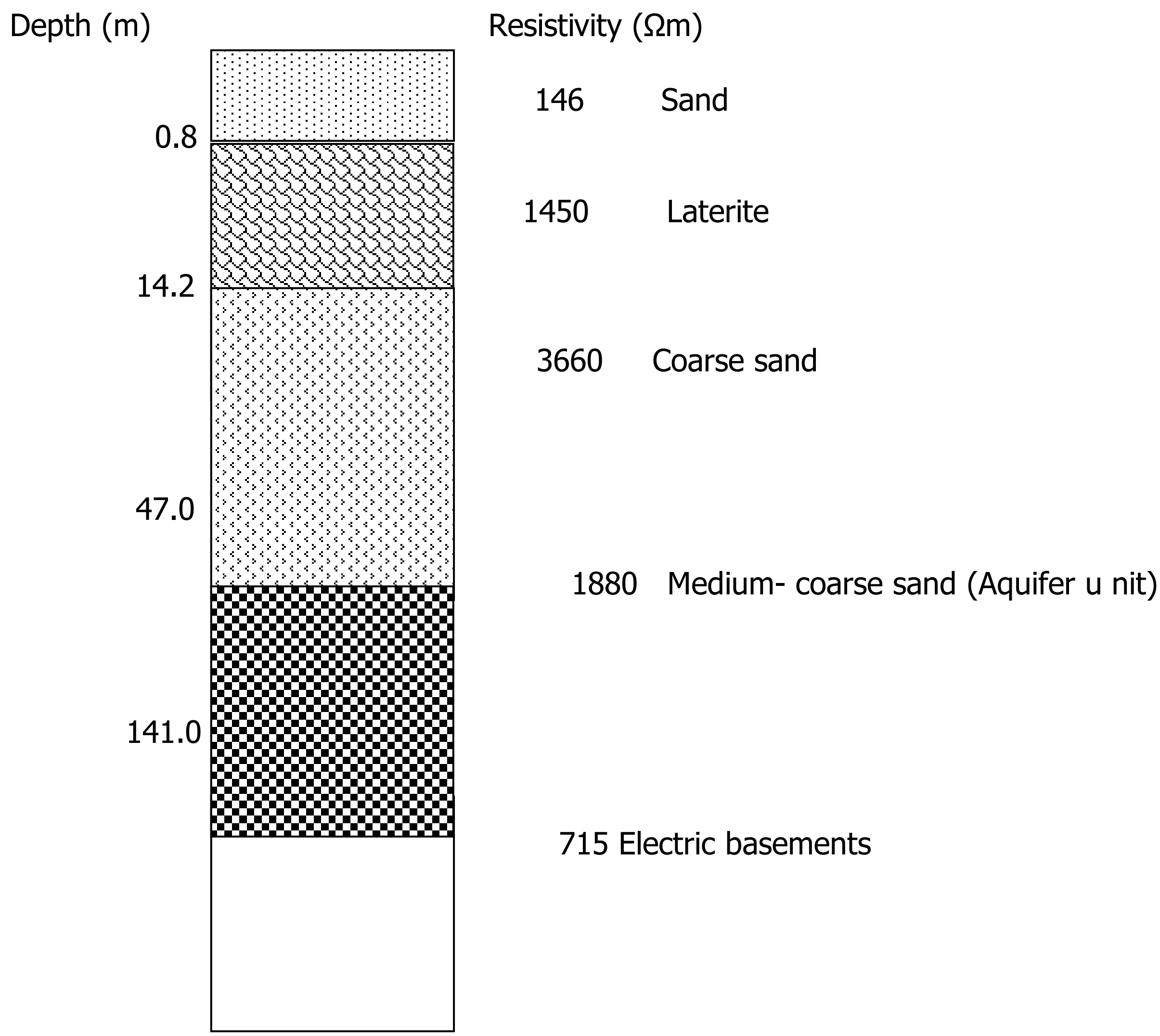
Date
Direction lay out E-W
Remarks

L/2 (m)	Rho (Ohm.m)	L/2 (m)	Rho (Ohm.m)	L/2 (m)	Rho (Ohm.m)
1.5	554.0	10.0	2279.0	80.0	4664.0
2.0	673.0	15.0	2634.0	100.0	4015.0
2.5	844.0	20.0	2813.0	130.0	3338.0
3.5	1145.0	30.0	3331.0	170.0	2351.0
4.5	1438.0	40.0	3720.0	220.0	1855.0
6.0	1629.0	50.0	3986.0	280.0	1416.0
8.0	2042.0	60.0	4283.0	370.0	1426.0
10.0	2474.0	50.0	3963.0		
15.0	2773.0	60.0	4327.0		

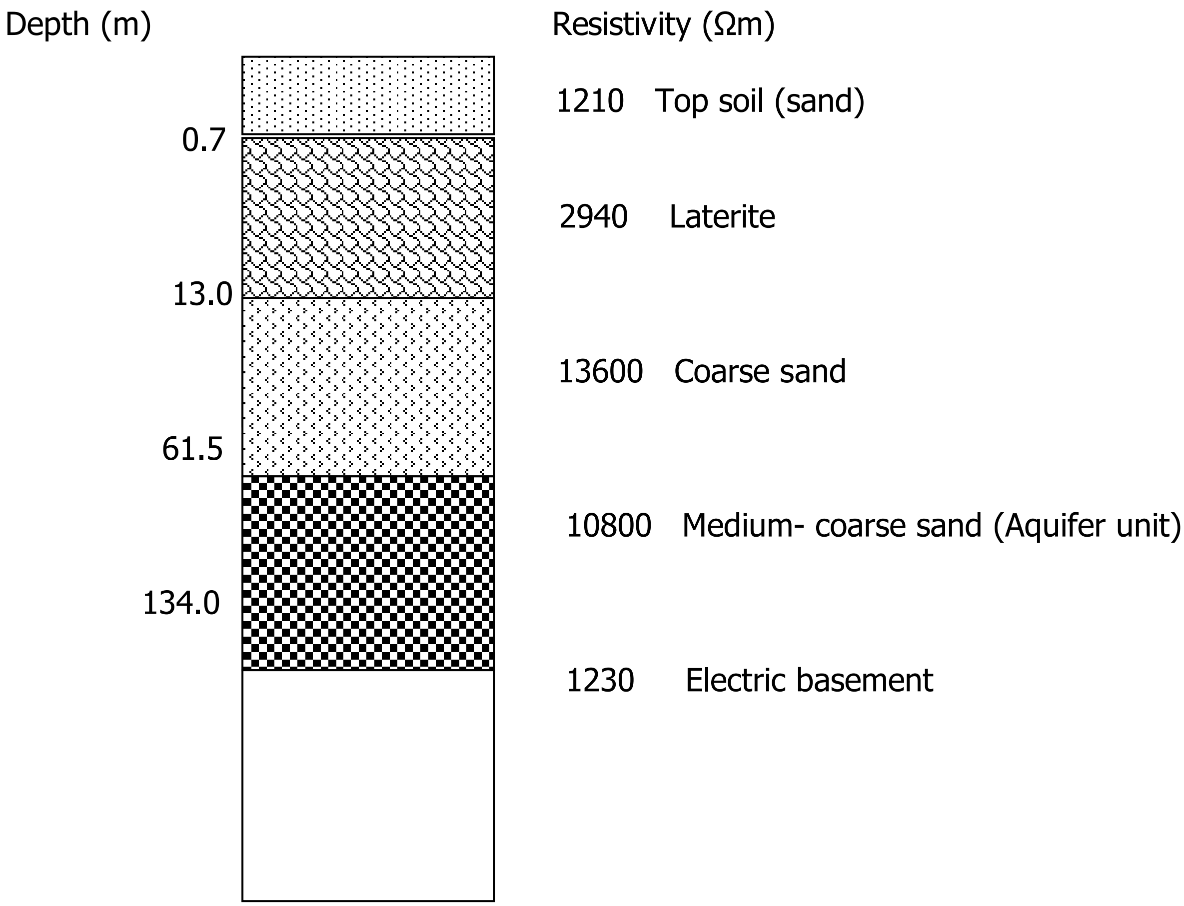
Resistivity (Ohm.m)	Depth (m)
273.0	0.6
3840.0.	19.8
9200.0	47.5
543.0	139.0
2430.0	



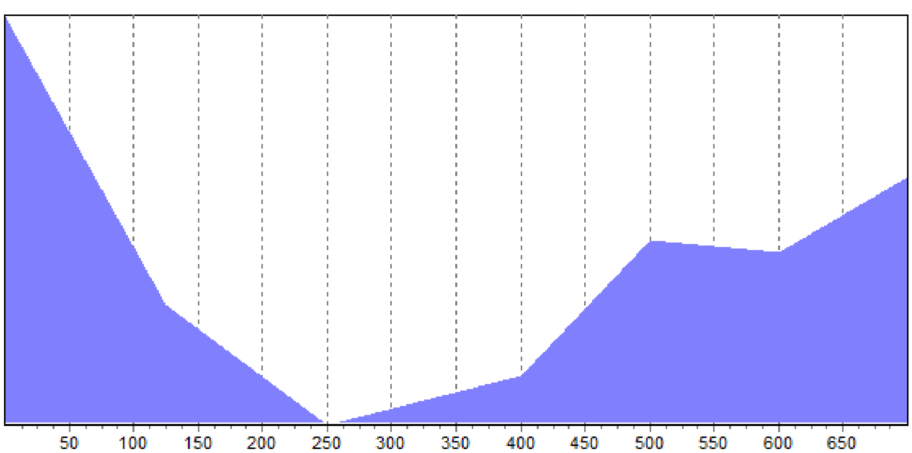
Geo-electric section of VES 1 (Not to scale)

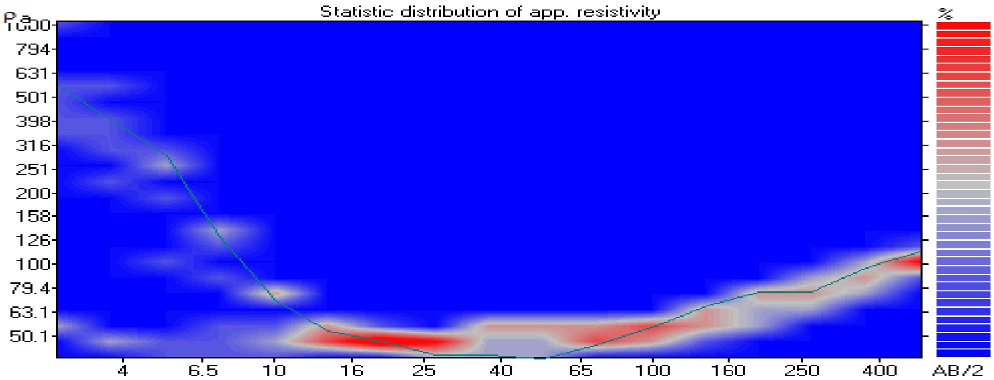


Geo-electric section of VES 2 (not to scale)



Geo-electric section of VES 3 (not to scale)





COMPUTER PROGRAM ANALYSIS

The qualitative interpretation of geo-electrical sounding data for the purpose of this work involves mainly direct computer interpretation. This is very useful in the determining the thickness and corresponding resistivity of various layers. The data from these sounding stations were sent to the computer for analysis and interpretation. From the information gotten, the stratigraphic properties of the various layers were deduced.

GEOELECTRIC SECTION ANALYSIS

From VES 1, the first layer is about 0.6m thick and it represents the top soil. The second layer is about 27.7m thick and it consists of laterite with a resistivity of about 384Ωm. The last layer Has a resistivity of about 2430 Ωm and it is the electric basement zone. From VES 2, the first layer is about 0.8m thick and it represents the top soil and its resistivity is about 146 Ωm. The thickness of the second layer is about 32.8m and it consists of laterite. The third layer is made up of coarse sand and has a high resistivity of about 3660 Ωm. the fourth layer is made up of medium coarse sand. This layer is a potential aquifer layer with respect to available lithological logs of boreholes already drilled in the area And from VES 3, the first layer represents the top soil and is about 0.7m thick and its resistivity is about 1210Ωm. The thickness of the second layer is about 12.3m and it is made up of laterite soil. The third layer is made up of coarse sand and is about 48.5m thick. And the fourth layer contains medium coarse sand has a high resistivity of about 10800Ωm. This is the aquifer unit.

The results are summarized in the table below:

VES	**RESISTIVITY(Ωm)**	**DEPTH (m)**
VES 1	543	47.5
VES 2	1880	47.0
VES 3	10800	61.5

TABLE D: Showing the Resistivity and Depths of the Various Depths of Interest

Given the table above, VES 1 has the lowest resistivity of 543Ωm with the depth of water table at about 47.5m.This VES has a higher potential for water. Water bearing zones always have a low resistivity. So it is advisable to sink boreholes in the areas such as VES 1. VES 1& 2 have a lower quantity of water as can be seen from their very high resistivities. So, for the purpose of sinking boreholes, the drilling should be done up to 57m in areas such as VES 1.

CONCLUSION

Three vertical electrical sounding was conducted to acquire information on the hydro geological potentiality of the areas. Computer program was employed for the interpretation of the results from the field. The results of aquiferous zones and depth of each sounding stations can really help in borehole sitting in the study area. Ability to select priority areas for ground water development by the use of resistivity sounding measurements bring about a substantial reduction in exploration costs by the number of drill holes made to obtain groundwater information. The good correlation with available borehole data justified the usefulness of the method as a first approach in solving groundwater problems or for planning groundwater development programmes. The depth of water tables in the area surveyed varies from 47.5m to 61.5m.

REFERENCES

Beck, A.E. (1981): Principles of Exploration Methods, Macmillian, London.

Burke, K.E. (1972): Longshore Drift Submarine Canyons and Submarine Fans In the Development of the Niger-Delta: Am. Assoc. Petroleum Geologist. Bull. Vol. 56, pp. 1975 – 1983.

Dobrin, M.B. (1976): Introduction to Geophysical Prospecting. McGraw-Hill, New York.

Kamerlin G, P. (1978): Hydrocarbon Habit of Tertiary Niger-Delta, AAPG. BULL. Vol. 62, pp. 1-39.

Merki, P.J. (1970): Structural Geology of the Cenozoic Niger-Delta, African Geology. Univ. of Ibadan Press, pp. 251 – 268.

Murat, R.C. (1970): Stratigraphy and Paleogeography of the Cretaneous and Lower Tertiary in Southern Nigeria. African Geology, Univ. of Ibadan Press, pp. 635 – 648.

Osemeikhian, J.E.A. & Asokhia, M.B. (1994): Applied Geophysics Samtos Services L.T.D. Lagos, Nigeria.

Rayment, R.A. (1965): Aspects of the Geology of Nigeria. Univ. Of Ibadan Press (1969): Ammonite Biostratigraphy, Continental Drift and Oscillatory Transgression; Nature Vol. 224, pp. 137 – 140.

Sabet, A Mohamed (1975): Vertical Electrical Resistivity Soundings to Locate Groundwater Resources: A feasibility Study, Bull. 73, pp. 4 – 5.

Sharma, P. V. (1976) Methods in Geochemistry and Geophysics, (11) Geophysical Methods in Geology. Elsevier Scientific Publishing Company Amsterdam/Oxford/New York.

Shelton, J. W. (1968): Role of Contemporaneous Faulting