APPLICATION OF PHYSICS IN UNDERGROUND WATER EXPLORATION
(A CASE STUDY OF THE ACQUIFER LEVEL OF OWAN L.G.A

BY

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ABSTRACT

Ground water is playing an increasing significant role in solving man's water needs for home and industries. The resistivity method can be used to establish ground water level and to determine the soil lithology with some degree of accuracy. In this work the schlumberger array method of resistivity survey was used to establish the ground water level of Owan L.G.A of Edo state. The results obtained are in agreement with available borehole log.

INTRODUCTION

In Nigeria, like most developing countries of the world, clean water is not continuously available or may not be available at all (Oyegun, 1988).

A significant feature in ground water study is the aquifer. This is a geological material, which yields significant amount of water to a well (Waltz, 1969). It indicates a water bearing formation in which the rocks have large pores, which are connected so that water can flow freely. The knowledge of its level can be useful in planning to sink a borehole as a source of fresh water. Establishing the level of aquifer requires appropriate geological exploration tool and technique. Many methods are bound among them are: Spontaneous potential, Induced Polarization, and apparent resistivity methods. In this work the apparent resistivity method is employed. This is because more electrical resistivity surveys are usually very useful and convenient techniques when searching for groundwater and in the exploration of minerals (Hackett, 1956).

THEORY

The electrical resistivity method as a tool for geophysical exploration is based on the fact that the underlying rock materials have resistance to current, and as such Ohm's law could be applied to them.

If the earth is homogeneous, the resistivity measure is true resistivity; otherwise it is called apparent resistivity, which is a weighted average of the resistivities of the various formations.

The usual practice is to introduce current into the ground by means of two current electrodes and measure the potential drop through a second pair of potential electrodes

Adopting Ohm's law, the voltage

$V = IR$ Or $R = v/I$ ----------------(1)

R, the resistance of the body is

$R = pl/A$ And $p = RA/L$ ----------------(2)

Where is the resistivity of the material of length L and area, A

Single Current Electrode / potential Equation

Using the equation (2), and considering a point source in a plane, which is bounded between a perfect insulator and a semi-infinite isotropic homogenous conductor of resistivity, , (fig 1.)

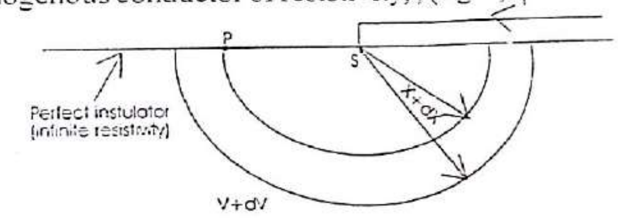


Fig 1

Response of the hemispherical shell of radius x is from equation (2) --------------

(3) $R = pdx/2\pi^2 x$

By applying Ampere's rule and Ohm's law, the current flowing across th shell is

$$I = \frac{v-(v+dv)}{pdx} = \frac{2\pi x^2\ dv}{p\ \ dx}$$

Or $dv = -\frac{pIdx}{2\pi x^2}$ ------------------(4)

The potential at the a point is the work done against the electric field in bringing a unit positive charge from infinity to that point.
Therefore by integrating from infinity to x we have:

$$V_p = \int_{\infty}^{x} dv = \frac{-\rho I}{2\pi}\int_{\infty}^{x}\frac{x}{x^2} = \frac{\rho I}{2\pi}\left(\frac{1}{x}\right)_{\infty}^{x} \qquad V_p = \frac{\rho I}{2\pi x}$$

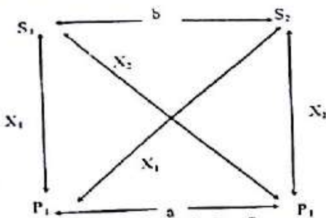
This gives the potential due to a point current source as S.

Double current electrode potential equation

If now a second source S_2 is added as in fig.2 below, the potential of each source will affect the other when the distance between the sources is finite.

Let the current S_1, be I and from s_2, be I_2, the potential at P_1 due to S_1 is rI/px and that due to S_2 rI/px

Fig.2 Plan View of Generalised Four electrode Array



In the many array systems S_1 and S_2 form a dipole system since S_1 and S_2 are usually connected to the two terminals of a battery. Thus we can assume that the current entering the ground via S_1, eventually leaves via S_2 and $I_1 = I_2 = I$ (say), so that

$$V = \rho I \frac{1}{2}\left(\frac{1}{x_1} - \frac{1}{x_2} - \frac{1}{x_3} + \frac{1}{x_4}\right) \text{-----------(6)}$$

(Physical principles of exploration methods. Beck, 1981)

METHODOLOGY

Apparent Resistivity Concept

In equation (6). the term in square bracket can be regarded as the contribution from the electrode system to the observed voltage and the inverse can be put as K, so that from equation (6)

$$\rho l = 2\pi \frac{v.k}{I} \text{ ———————(7)}$$

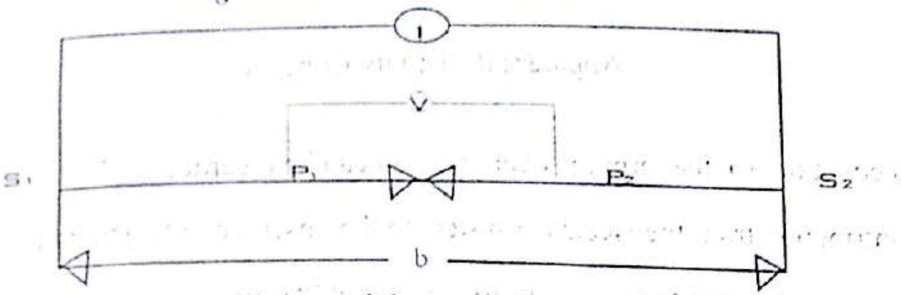
By measuring Äv and I, and with the knowledge of the electrode configuration, can be obtained. Over homogeneous isotropic ground. this resistivity will be constant for any current and electrode array. That is. if the current is maintained constant and the electrode moved around as is done in practice; the potential will adjust at each configuration to keep the ratio Äv/I constant. In a homogeneous earth is called the true resistivity.

In an inhomogeneous earth, however. moving the whole array while varying the electrode spacing, the ratio will generate change; thus different values of will be obtained for each measurement. In such a case is known as the apparent resistivity . The apparent resistivity has no physical other than its complex dependence on the resistivity distribution within the subsurface and on the particular electrode array used in the measurement. Variations in indicate change in subsurface conditions. (Black,1981).

Schlumberger Array Systems

This system uses the four-electrode array system in which. most often. S_1 and S_2 are kept fixed while P_1 And P_2 are moved along the line keeping a, constant.

Fig 3: Schlumberger Array System



The electrodes are collinear and the current electrodes are relatively widely spaced apart while potential electrodes, which are in between (fig 3) current electrodes are closely spaced and fixed in position. By applying equation (6) to the parameters of fig 3. it gives

$$P = \frac{\pi}{2} \frac{V}{1} a \quad \frac{1}{a(b-x)^2} + \frac{1}{(4x2-a)^2} \text{ ....(8)}$$

Often the values of 'a' is small compared with 'b' and the increments in b are integral multiple of 2a. if this is the case and $b = (2n+1)a$, where n is an integer, then equation (8) becomes

$P = \pi an(n+1) v/1$

Here $K = \pi a(n+1)n$...... ....(9)

Usually the current input is kept constant. but if b reaches such a large value that the voltage between the potential probes is too small for accurate reading, the current may be increased or the value of 'a' increased.

FIELDWORK/STUDY AREA

This study was carried out in Owan Local Government Area of Edo state, Nigeria. Three locations were chosen for this study. These are Ozalla 6.01' 6.47N; Uhonmora 5.57'E; 6;,52'N and Sabo 50,56'E;60,54'N. (Oredo L.G.C, 1992).

These formed a "block of study" to show how the lithology and aquifer level could change with a block of 50m which this study covered in a linear pattern.

Instrumentation/Array system: The schlumberger array (fig 3) system was chosen for this study because, in addition to its being widely used, it is less sensitive to the influence of near-surface lateral heterogeneities. The Equipment include:

(i) Cables

(ii) Electrodes

(iii) ABEM TERRAMETER

PROCEDURE AND MEASUREMENTS

At the site, the cables were connected to the terrameter, which has four terminals (two potential P_1 and P_2; S_1 and S_2 current terminals). These cables were connected to four electrodes. Those connected were P_1 and P_2, which are fixed, while the distances of S_1 and S_2 from the fixed ones were varied. Each electrode was driven into the ground and the equipment switched on. Readings were then and the equipment switched off to allow for the movement of the current electrodes (S_1 and S_2). This yielded a rapidly decreasing potential difference across the potential electrodes. This potential difference ultimately exceeded the measuring capacity of the instrument, thus necessitating the introduction of a new value four times larger than the preceding value, and the survey continued. A total of 42 vertical soundings were taken, 14 in each location.

DATA ANALYSIS

Tables 1-3 show the current electrode separation AB/2 during the measured; observed values of resistivities at each sounding, and the corresponding computed values, layer and layer thickness. Computer iterative analysis employing digital linear filters was employed in the analysis of data, using the programme in Ambrose Alli University, Ekpoma. Computer centre. Several computer programmes have been written for (similar) resistivity interpretations (Osemeikhian and Asokhia, 1994). Like other programmes, it gave a set of layer parameter employing a 9 point and 20 point digital filter (Koefoed, 1979). With a set of layer model, and by trial and error, an appropriate model is obtained with the least possible error. The computer, on a logarithmic scale graph, automatically plotted the graphs.

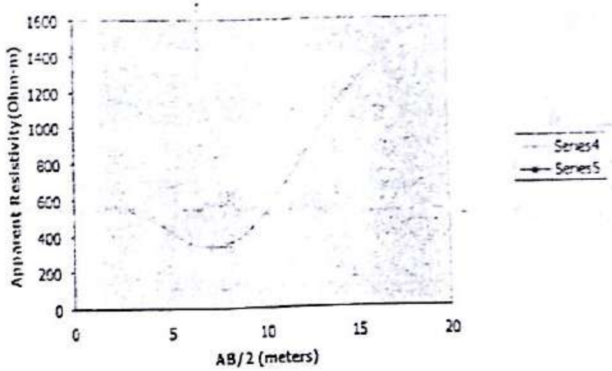
Table 1: Vertical Electric sounding (VES) for Ozalla

Layer	Resistivity (Wm)	Thickness (m)
1	507	1
2	272	5
3	1466	

AB/2 (m)	Observed values (W-m)	Computed Values
1.00	561	535.48
1.47	428	492.76
2.15	348	428.70
3.16	272	366.96
4.64	302	335.92
6.81	384	351.18
10.00	481	417.50
14.70	615	529.83
21.70	703	672.25
31.60	867	832.80
46.40	1000	993.89
68.10	1210	1140.75
100.00	1466	1259.44
147.00	1522	1245.59

RMS Error: 10.42%

Fig 4. Res versus Electrode spacing for Ozalla



Discussion of result and conclusion

Table 4. Below shows the summary of the result of the computer iterative analysis and approximate aquifer of each location.

Table 4: Layer Parameters of Locations

Location	Layer Model depth	Layer Depth	Apparent resistivity m	Approximate Aquifer depth
1. Ozalla	1st	1m	567	6
	2nd	5m	272	
	3rd	∞	1466	
2. Sabo	1st	1m	221	13
	2nd	12m	50	
	3rd	∞	82	
3. Uhonmora	1st	1m	311	9
	2nd	8m	160	
	3rd	∞	10	

B. Soil Llithology

Ozala: sand, Wet sand, Clayey sand

Sabo: sand, clayey sand: Wet sand

Uhornmora: sand, wet sand, sandy clay.

In Ozalla three layers are identified, a first layer of sand, with resistivity of 597 Wm followed by a less resistive layer of sand and corresponding to the first aquifer at a dept of 6m. the third layer resistivity is 1466Wm.

In Sabo, there are three layers with resistivities 311,160,and 10Wm respectively for the first, second and third layers. The first layer is sand, followed by a less resistive layer of clay sand and a third layer of wet sand. There is evidence of an aquifer at this layer due to the low resistivity.

Uhonmora showed a three layer classification of sand, a less resistive layer of wet sand, followed by sandy clay. The low resistivity of the second layer suggests existence of an aquifer.

RECOMMENDATIONS

The existing borehole lithology shows that Ozalla has the first aquifer ot approximately 6m. However, there was no borehole log to compare with Sabo and Uhonmora locations. It is recommended that there is need to compare the results with borehole log to confirm the lithology.

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