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Full Length Research Paper

Evaluation of soil profile on aquifer layer of three locations in Edo state

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This investigation was carried out in three locations (Ekpoma, Irrua, and Uromi) all in Esan central and North-East region respectively of Edo state, Nigeria. The aim was to find out how soil profile depth is related to aquifer layer. Verifying how relief and (physical properties) such as heat, temperature, and resistivity affects the aquifer layer. Result of the study proved that location, relief, and the factors, such as radiation, heat, temperature, resistivity and moisture contributed to either a low or high aquifer layer. Increased radiation resulted to increment in temperature, heat, resistivity, and less moisture content in the soil profile horizon. Whereas relief was an over riding factor that influence the aquifer depth. With maximum soil profile depth of 528.90, 476.67, and 495.96 m, the aquifer layers for Ekpoma, Irrua, and Uromi respectively indicated that relief played a prominent role as observed in their topography. Therefore in hydrological investigation the contribution of this study would give a guide on effective aquifer layer position in the studied location in Edo State Nigeria.

Key words: Evaluation, soil profile, aquifer layer.

INTRODUCTION

Edo state is geologically characterized by deposits, laid during the tertiary and cretaceous periods (Reyment, 1965). The various formations in the geology of Edo State are the Benin, Bende Ameki, Ogwashi-Asaba, Imo and Nsukka formations. In this study the entire investigated area is underlain by sedimentary rocks with about 90% of sandstone and shale intercalation. It has coarse grained locally fine grained in some area, poorly sorted, sub-angular to well rounded which bears lignite streaks and 1000d fragment (Kogbe, 1976). Sedimentary rock of the study areas consistute the Benin formation which has high potential for ground water reservoir. In Benin City water is easily obtained. In Ekpoma, Irrua and Uromi, where the aquifer layer is deep, and found within the range of 405 to 500 m shown by the hydrogeology of the Ishan plateau, experiences water scarcity.

Relief and geology have a compelling influence on vertical electrical sounding (VES). The relief position determines the depth to the upper surface (water table) of the ground water aquifer. The higher the relief, the deeper the vertical electrical sounding is expected to probe into the subsurface. In the case of a confined aquifer the type or nature of the overlying rock is of greater importance. Obviously the more impervious the overlying rock is the better confined of the aquifer will be. This study was therefore aimed at evaluating the soil profile on aquifer layers of three locations (Ekpoma, Irrua and Uromi) in Edo State, Nigeria. To investigate how depth of the aquifer layer was related to soil profile depth. In view of suggesting the need to move very deep in the profile horizons when there are impervious materials within the soil profile.

Flow principles indicate that water is seldom at rest in soil. The direction and the role of its movements is of fundamental importance to many processes like places in the biosphere. Flow in soil is a special case of a larger problem of fluid flow in porous media (Kirkham and Power, 1972).

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METHODOLOGY

In the research work, the schlumberger array in electrical resistivity survey was adopted. The basic field equipment for this study is the

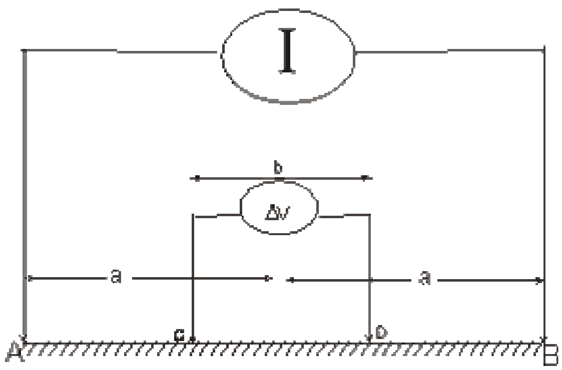

Figure 1. Schlumberger array

ABEM Terrameter SAS 300B (Figure 1) which displays apparent resistivity values digitally as computed from ohm's law. It is powered by a 12.5V DC power source. Other accessories to the terrameter includes the booster, four metal electrodes, cables for current and potential electrodes, harmers (3), measuring tapes, walking talking or phones for very long spread (Asokhia, 1995). In this configu-ration, the four electrodes are positioned symmetrically along a straight line, the current electrodes on the outside and the potential electrodes on the inside. To change the depth range of the mea-surements, the current electrodes are displaced outwards while the potential electrodes in general, are left at the same position.

When the ratio of the distance between the current electrodes to that between the potential electrodes becomes too large, the poten-tial electrodes must also be displaced outwards otherwise the pot-ential difference becomes too small to be measured with sufficient accuracy (Koefoed, 1979).

Measurements of current and potential electrode positions are marked such that AB/2 ≥ MN/2.

Where AB/2 = Current electrode spacing and
MN/2 = Potential electrode spacing

Generally, the arrangement consists of a pair of current electrodes and a pair of potential electrodes. These are driven into the earth in a straight line to make a good contact with the earth. The current electrode spacing is expanded over a range of values for measurements in the field. The values of AB/2 increases as the measurements progresses while the potential electrodes separa-tions are guided accordingly. The potential electrodes are kept at small separations relative to the current electrodes separations (Milson, 1939). One of the major advantages this method has over other methods is that only the current electrodes need to be shifted to new position for most readings while potential electrodes are kept constant for up to three or four readings (Reinhard and Fro-hlich, 1974). During the exploration work (field work) taking a soun-ding, the ABEM Terrameter SAS 300B (Self Averaging System) performs automatic recording of both voltage and current, stacks the results, computes the resistance in real time and digitally dis-plays it (Dobrin and King, 1976).

From the theory we have that the potential at C due to A is

$$V_c = \frac{\rho I}{2\pi}\left\{\frac{1}{a-b/2} - \frac{1}{a+b/2}\right\} \quad (1)$$

Where

$a \Rightarrow$ midpoint $\Rightarrow$ distance between the current electrodes and station.

b $\Rightarrow$ distance between potential electrodes

$\rho \Rightarrow$ layer resistivity

The potential at D due to A becomes

$$V_D = \frac{\rho I}{2\pi}\left\{\frac{1}{a+b/2} - \frac{1}{a-b/2}\right\} \quad (2)$$

The potential difference dV between the two potentials is therefore given by

$$dV = V_C - V_D \quad (3)$$

$$\therefore dV = \frac{\rho I}{2\pi}\left\{\frac{1}{a-b/2} - \frac{1}{a+b/2}\right\} - \frac{\rho I}{2\pi}\left\{\frac{1}{a+b/2} - \frac{1}{a-b/2}\right\} \quad (4)$$

$$dV = \frac{\rho I}{2\pi}\left\{\frac{2}{a-b/2} - \frac{2}{a+b/2}\right\} \quad (5)$$

$$dV = \frac{\rho I}{2\pi}\left(\frac{8b}{4a^2-b^2}\right) \quad (6)$$

The apparent resistivity value is the product of the geometric factor and the resistance recorded in the resistivity meter. In each station, several soundings and apparent resistivity values will be obtained by expanding the current electrode spacing after each reading as required by Schlumberger array for deeper penetration into the earth and structural responses. The geometric factor, K, for Schlumberger configuration will be used. That is

$$\therefore \begin{aligned} K &= \frac{\pi}{2}\left\{\frac{(AB/2)^2 - (MN/2)^2}{MN/2}\right\} \\ K &= \pi CD\left\{\left(\frac{L}{CD}\right)^2 - 0.25\right\} \\ L &= 2(AB/2) \end{aligned} \quad (7)$$

RESULTS AND DISCUSSION

PLATE I: Verification in resistivity across the soil profile for Ekpoma, Edo State Nigeria. (Table 1a, 1b and Figure 2).
Observed Ves: 1.
L.G.A.: Esan West.
Location: Ekpoma.
Weather: Hot.
State: Edo.

PLATE II: Variation in resistivity within the soil profile for Irrua Edo State Nigeria. (Table 2a, 2b and Figure 3).
Observed Ves: 2.
L.G.A.: Esan Central.
Location: Irrua.
Weather: Hot.
State: Edo.

PLATE III: Variation in resistivity within the soil profile in Uromi, Edo state Nigeria. (Table 3a, 3b and Figure 4).
Observed Ves: 3
L.G.A. : Esan North-East.
Location: Uromi.

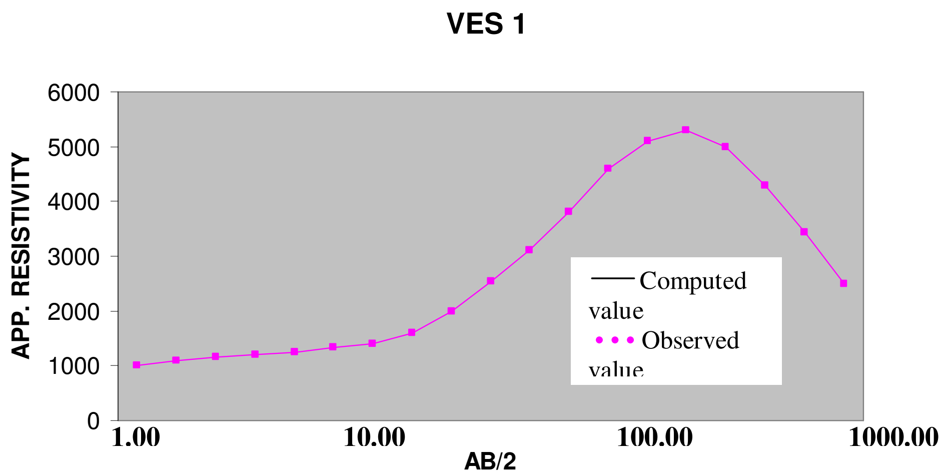

Figure 2. Plate I.

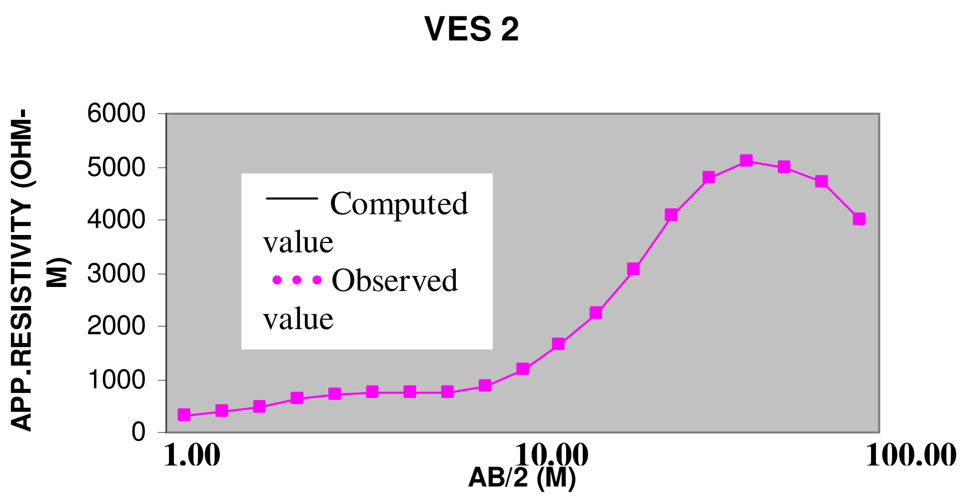

Figure 3. Plate II.

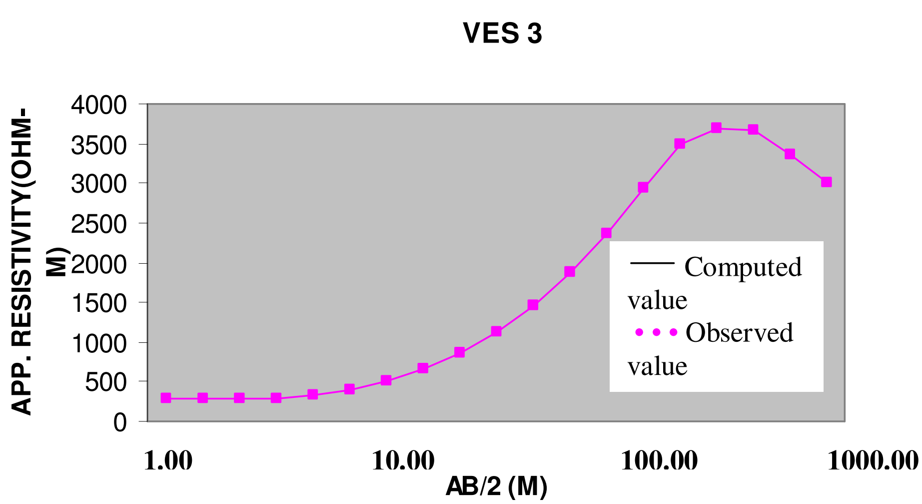

Figure 4. Plate III.

Table 1a. Plate I. Observed (field) and computed (theoretical) data.

$\frac{AB}{2}(m)$	$\rho_a(ohm-m)$ OBSERVED VALUE	$\rho_a(ohm-m)$ COMPUTED VALUE
1.00	1150.00	1000.00
1.47	1085.92	1085.92
2.15	1016.39	1150.00
3.16	1078.77	1200.00
4.64	1245.47	1245.47
6.81	1341.87	1341.87
10.00	1501.04	1400.00
14.70	1485.00	1600.00
21.50	1582.05	2000.00
31.60	3136.28	2550.00
46.40	3152.12	3100.00
68.10	3787.25	3800.00
100.00	471.19	4600.00
147.00	6247.42	5100.00
215.00	7260.49	5300.00
250.00	5678.89	5000.00
300.00	4567.90	4300.00
400.00	3447.89	3447.89
500.00	2567.67	2500.00

Field measurements and data interpretations by Alile Owens.

Table 1b. Plate I. Model parameters.

Geoelectric Layer	Resistivity (ohm-m)	Thickness (m)	Cumulative Thickness(m)
1	1120.00	5.70	5.70
2	2990.00	31.10	36.80
3	23900.00	36.10	72.90
4	12500.00	41.10	144.00
5	9600.00	51.30	165.30
6	17800.00	86.60	251.90
7	2050.00	108.00	359.90
8	1170.00	169.00	528.90
9	767.00	Infinity	Infinity

RMS Error (%): 1.57

Table 2a. Plate II. Observed (field) and computed (theoretical) data

$\frac{AB}{2}(m)$	$\rho_a(ohm-m)$ OBSERVED VALUE	$\rho_a(ohm-m)$ COMPUTED VALUE
1.00	301.06	303.20
1.47	369.88	380.34
2.15	464.84	490.04
3.16	629.11	613.40
4.64	756.74	713.29
6.81	770.92	753.26
10.00	607.94	735.13
14.70	1484.99	739.34
21.50	1001.48	875.89
31.60	2759.93	1185.60
46.40	825.36	1643.62
68.10	2257.78	2251.33
100.00	3795.58	3045.05
147.00	6738.35	4090.77
215.00	7654.67	4800.00
250.00	7698.89	5100.00
300.00	6789.12	5000.00
400.00	4987.32	4700.00
500.00	4500.00	4000.00

Field measurements and data interpretations by Alile Owens

Table 2b. Plate II. MODEL PARAMETERS

Geoelectric Layer	Resistivity (ohm-m)	Thickness (m)	Cumulative Thickness(m)
1	219.00	0.67	0.67
2	1400.00	3.30	3.97
3	316.00	9.10	13.07
4	2190.00	15.20	28.27
5	30700.00	60.60	88.87
6	4460.00	91.80	180.67
7	666.00	123.00	303.67
8	668.00	173.00	476.67
9	657.00	Infinity	Infinity

RMS Error (%): 4.40

Weather: Cool.
State: Edo.

Plates I, II and III showed the variation in the resistivity within the soil profiles of the locations. The three locations from the study area showed a maximum drill depth of 528.90 m for Ekpoma, 476.67 m for Irrua and 495.96 m for Uromi. These values have a close correlation with the hydrogeological values of Ishan Plateau of the study area. There is a relation between the location and the relief, with the highest (528.90 m) depth obtained in Ekpoma where the resistivity was 1170.00 Ohm-m. This location is the highest in the relief position of the study area.

It is possible for fresh water flow under ordinary condiions in soil as a steady state phenomenon and ignores

Table 3a. Plate III. Observed (field) and computed (theoretical) data.

$\frac{AB}{2}(m)$	$\rho_a (ohm-m)$ **OBSERVED VALUE**	$\rho_a (ohm-m)$ **COMPUTED VALUE**
1.00	302.08	288.46
1.47	276.74	277.95
2.15	271.68	279.72
3.16	232.66	297.03
4.64	362.60	331.04
6.81	262.28	392.90
10.00	375.24	499.11
14.70	718.77	657.18
21.50	478.97	863.85
31.60	1097.70	1129.17
46.40	845.07	1462.90
68.10	1966.46	1872.90
100.00	4083.66	2360.41
147.00	4412.43	2939.26
215.00	7260.85	3500.00
250.00	7234.90	3690.78
300.00	7176.45	3660.34
400.00	7389.89	3360.00
500.00	7023.67	3000.00

Field measurements & data interpretations by Alile Owens

forces or accelerations. The flux of water under these conditions (Plates I, II, and III above) is proportional to the gradient of water potential and the conductivity in a way similar to the flux of electricity being proportional to the electrical potential difference in a circuit and electrical conductivity (ohm's law). However, the nature of the forces that give rise to the potential varies in soil water systems and the kind of forces involved have an important bearing upon the way that flow takes place. The soil profile in the field is a very dynamic and complex system.

It is important to consider first the water balance of the entire soil profile in terms of individual process which is precipitation, applied irrigation water and surface runoff. Hydrologist must know how much of the precipitation will result in direct runoff and in deep percolation to ground water.

It might be inferred that aquifer layers are depending mostly on topography and areas on higher locations, would experience difficulties to reach the aquifer layers. The heat of radiation from the sun would dry the profile and moisture become insufficient within the soil. The presence of solid materials makes the water table not to be easily accessible. Therefore more soil horizons have to be penetrated to meet aquifer layers.

Table 3b. Plate III. Model parameters.

Geoelectric Layer	Resistivity (ohm-m)	Thickness (m)	Cumulative Thickness(m)
1	280.00	2.30	2.30
2	253.00	3.40	5.70
3	569.00	6.00	11.70
4	2030.00	35.60	47.30
5	9600.00	80.60	127.90
6	6310.00	85.00	212.90
7	4350.00	115.06	327.96
8	4203.00	168.00	495.96
9	840.00	Infinity	Infinity

RMS Error (%): 2.35

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