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HYDRO-GEOPHYSICS OF IKWUANO FROM GEOELECTRICAL DRILLING AND GPS MEASUREMENTS

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ABSTRACT
Partial or non-availability of water has been a consistent preoccupation of the inhabitants of Ikwuano local government area. The need to boost the water supply system here is becoming very necessary in recent times. Geophysical measurements were carried out in this vicinity between January and April 2010. Using Schlumberger configuration, vertical electrical sounding (VES) and global positioning system (GPS) measurements were taken to study and verify the hydro geological and hydro geophysical nature, depth and thickness of the aquiferous zone in the area. Results of the study reveal that the study areas traverse two major geological units of Bende-Ameki and Benin Formations. Owing to variations in the subsurface crustal materials and the tectno-stratigraphic facies changes in this sedimentary terrain, the total drill depth (TDD) of boreholes, aquifer thickness and static water level (SWL) vary and were all determined. Boreholes thrive better in Benin Formation with thickness range of 18.4-163.4 meters than in Bende-Ameki Formation with aquifer thickness of 29.1-88.6 meters.
Keywords: sedimentary rock, hydro-geophysics, aquifer, borehole, total drill depth, Ikwuano

INTRODUCTION

In a place where sources of water supply are not steady and guaranteed, the inhabitants pre- occupy themselves with problems emanating from water scarcity. This assertion is true of Ikwuano, (a typical rural community with her adjoining settlements) whose population was 137,993 people by 2006 census (NBS, 2009). The dependence of surface water supply system (rivers/streams, ponds and rainfall) for this essential resource is becoming more excruciating particularly within the six-month spell of dry season (November to April). The search for water within this period inflicts untold hardships to the rural dwellers and this necessitates a viable alternative to ameliorate their sufferings. This viable alternative is the development of groundwater supply system i.e. drilling of boreholes (Goni, 2006). Successful boreholes cannot be accomplished without geophysical studies and this where hydro-geophysics/hydro-geology come in. We have chosen to carry out electrical drilling of the sub-surface in order to locate appropriate sites for boreholes. Resistivity data were acquired using vertical electrical sounding (VES) technique with the Schlumberger arrangement of electrode spacing (Zohdy, 1969). The parameter resistivity is a good layer/lithology discriminator and the study area being a sedimentary terrain, resistivity survey is quite significant and justified for such a study. Also, global positioning system (GPS) data were incorporated in the measurements to enhance the data acquisition requirements. The data were processed and analyzed with the aim to determine the nature, depth and thickness of aquiferous zone in the subsurface. It is necessary and relevant since groundwater development is apparently the next viable alternative option to surface water system.

Location and Geology

Ikwuano is geographically located within Latitude 5^o 22ˊ-5^o 30ˊN and Longitude 7^o 25ˊ-7^o 35ˊE in the east-central portion of Abia State of Nigeria about ten (10) kilometers from Umuahia along the Umuahia-Ikot Ekpene federal highway. It has a thick vegetation cover of rainforest with sparse effluent streams of dentritic drainage. The mean annual rainfall here is between 2000 and 2250 mm with an ambient

temperature of about 29.5^{o}C. The topography is highly undulating with minimum and maximum elevations of 29 and 169 meters above mean sea level respectively from our study.
Geologically, the study area and its environs are within the Tertiary Niger delta sedimentary basin. Specifically, the area traverses two major geological units, namely: Benin Formation and Bende-Ameki Formation (Kogbe, 1976; GSN, 1985). The Bende-Ameki constitutes the main bulk of Middle Eocene strata made up of a series of highly fossiliferous grayish-green sandy-clay with calcareous concretions and white clay sandstones. As a sedimentary origin, the strata consist of alternating shale, sandy shale, mudstone, clayey sandstone and fine-grained argillaceous sandstone. The inter-bedded sandstone, in some places can attain a thickness of 33 meters and the beds dip gently between 5^{o} and 7^{o}S. The age of Bende-Ameki Formation is generally considered to Lutetian to Lower Bartonian age (Kogbe, 1976).
The Benin Formation otherwise referred to as coastal plain sands (CPS) is one of the subsurface stratigraphic units in the modern Tertiary Niger delta. It is coarse-grained, gravely, locally fine-grained and poorly sorted. The formation is a continental deposit of probable upper deltaic depositional environment. It ranges from Miocene to Recent consisting of sands and clay lithology with intermittently variable lignite seams (Kogbe, 1976; GSN, 1985 and Short and Stauble, 1967) and is more extensive than the Bende-Ameki Formation.

MATERIALS AND METHODS

Materials: ABEM Terrameter (SAS) 300B instrument was used to carry out electrical drilling measurements otherwise called vertical electrical sounding (VES) in the study area. Prior to this, a topographic map of the area from map of Nigeria was culled up and superimposed on the geological map of same area, this was the initial material needed for the study. This arrangement was to make it possible to relate the borehole or location sites of data acquisition succinctly to the actual geological formation. Thus, we generated a good geographical information system (GIS) apparatus on which the importation of global positioning system data could be actualized (GSN, 1995; Woodfine, 1995). A total of one hundred and twenty-two VES data sets were used in the study. With ABEM Terrameter and the Magellan GPS 310 instrument, thirty VES sets of data and GPS measurements were procured through surface geophysical data acquisition within the area of study. The other eighty-four (84) sets were obtained from some government agencies and non-governmental organizations (NGOs). GPS measurements were made in-situ at every VES/borehole site irrespective of the source of acquisition and they were effectively applied as they give information on geophysical coordinates and elevation.
Methods: For accurate assessment of the potentiality and sustainability for groundwater in any place, it is not proper to rely on one technique or approach. Maps alone can be wrong, community information/discussion may be misleading and as such geophysical surveys could not be interpreted properly unless the geological environment known before hand. An approach that has been used successfully in many groundwater projects applies a combination of maps, observations and geophysics. MacDonald et al., (2002) refer this combination approach to as "geological triangulation" (Figure 1).

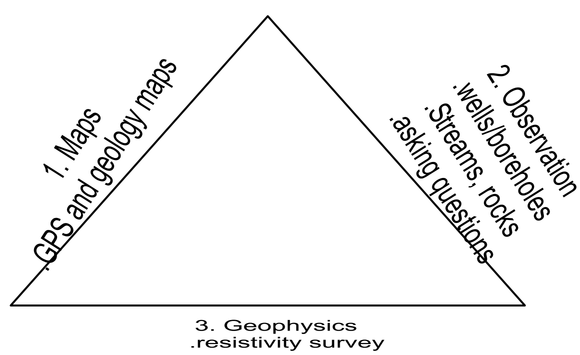

Fig.1: The geological triangulation (after MacDonald et al., 2002)

In essence, the geological triangulation (GT) approach begins and involves the production of appropriate field maps whereby a geological map of an area is cartographically superimposed unto a topographic map of same area and of same scale. Surface location of measurement sites could be clearly seen on the map. Impliedly, position coordinates of global positioning system have been incorporated into the data already acquired thereby generating a workable GIS. The second phase of the GT requires keen observation of geologic features and note-worthy facts/histories. The local geology is adequately taken into account and examined with care as discussed with local community. The nature of the rocks was keenly taken note of through trip-stops, road construction marks, gully erosion scars and fresh outcrops. Local wet and dry season sources of water were observed. All the water boreholes/wells as well as the rivers/streams visited and relevant questions asked. These pre-investigation surveys proved very useful during the actual survey.

The last phase involved the application of geophysics to mirror the subsurface of the area. The type of geophysical survey chosen here was resistivity method since the area is a sedimentary environment characterized by layers. Electrical resistivity is a powerful layer/lithology discriminator based on the resistivity contrast of the subsurface materials. Any geophysical method that measures a certain physical property of rocks depends on the physical parameter(s) to be measured. The measurements do not directly detect the presence of water rather there are features that can lend credence to the presence of water in the subsurface. The entire do is to help interpret what type of rocks there is in the area or detect fractured rocks (MacDonald et al., 2002; Dobrin and Savit, 1988; Telford et al., 1990).

The actual electrical drilling concerned the determination of variation resistivity in geologic formations with depth, this was done by passing electric into the ground by means of two electrodes to measure the potential difference between a second pair of electrodes placed linearly with the first pair using the Schlumberger arrangement (Lowrie, 1997; Zohdy, 1969). The assumed or apparent resistivity was computed from the knowledge of potential difference, current and electrode spacing with the geometric factor duly incorporated. The basic modeling parameters needed for this study are total transverse resistance, R and total longitudinal conductance, S which are expressed in these formulas:

$$R = \Sigma h_i \rho_i \qquad \ldots 1$$

and

$$S = \Sigma hi/\rho_i \qquad \ldots 2$$

where h_i and ρ_i are the layer thickness and resistivity of the i^{th} layer in the seetion respectively.

Also, from equation (2),

$$S = \sigma_i h_i \qquad \ldots 3$$

where σ is layer conductivity.

R and S are referred to as Dar Zarrouk parameters and they have shown to be powerful interpretational aids in groundwater surveys (Zohdy et al., 1974; Mbonu et al., 1991). Niwas and Singhal (1981) determined analytically the relationships between aquifer transmissivity (T_r) and R on one hand and between T_r and S on the other hand as stated in equation (4) as follows:

$$T_r = K\sigma R = KS/\sigma = Kh \qquad \ldots 4$$

where K is hydraulic conductivity or permeability.

According to Niwas and Singhal (1981), in area where the geology and water quality do not vary much, $K\sigma$ remain fairly constant. The geo-electrical drilling measurements generated from equations 1 to 4 and the GPS data acquired during the survey were used to obtain the values in Table 1.

Table 1: Aquifer characteristics of some functional boreholes in the study area

VES /BH		Co-ordinates		Thickness	SWL	Aq.Res	Long. Cond	Hyd.Cond	K σ	Tτ=Kh
No	Location	Lat. °N	Long. °E	h(m)	(m)	ρ(Ωm)	S(Ω^{-1})	K(m/d)	$(\Omega d)^{-1}$	(m^2/d)
04	Oloko	5^0 22.530′	$7^0$32.222′	201.0	27	549.0	0.3660	7.40	0.0135	1487.4
05	Isiala	$5^0$24.345′	$7^0$34.088′	216.4	38	667.0	0.3243	7.88	0.0118	1705.2
13	Amawom	$5^0$27.570′	$7^0$33.531′	139.0	32	1338.0	0.1039	8.10	0.0060	1125.9
18	Umuariaga	$5^0$26.760′	$7^0$32.886′	89.1	29	720.0	0.1238	8.00	0.0111	712.8
20	Nnono	$5^0$26.028′	$7^0$32.797′	97.5	28	1026.0	0.0950	8.00	0.0078	780.0
21	GCU	$5^0$29.951′	$7^0$32.274′	326.0	30	847.0	0.3849	8.20	0.0097	2673.2
30	Isi court	$5^0$29.199′	$7^0$29.041′	296.0	39	827.0	0.3580	8.65	0.0105	2560.4
32	Mgbarakuma	$5^0$28.324′	$7^0$25.160′	195.5	46	491.0	0.3981	10.8	0.0219	2111.4
34	Itaja	$5^0$28.132′	$7^0$30.526′	290.0	41	707.0	0.0120	8.45	0.0119	2450.5
46	Mouau	$5^0$28.995′	$7^0$32.921′	98.1	30	710.0	1.1321	8.00	0.0113	784.8

Source: Present study

NOTE: SWL = static water table
Aq.Res = aquifer resistivity
Long.Cond. = longitudinal conductance
Hyd.Cond. = hydraulic conductivity

RESULTS AND DISCUSSION

The field data were initially plotted manually using bi-logarithmic graph sheets and thereafter fed into the computer using the resistivity inversion computer program software named RESIST. Typical computer-generated curves were as shown in Figure 2. Also, typical hydro-geoelectrical model is also in Figure3.

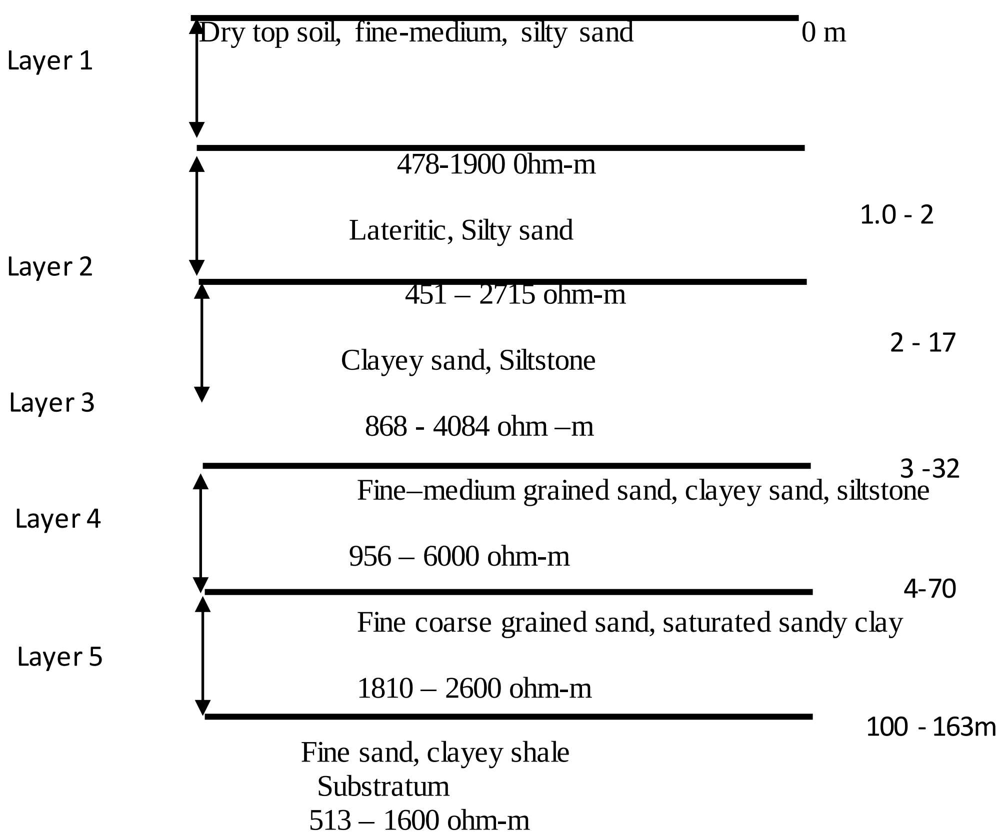

Fig 3: A typical hydro-geoelectrical model from the survey

The computer plots and iterations were correlated with the lithological logs from boreholes drilled at some location sites within the study area from which some reasonable inferences were obtained. The sands in the Benin Formation vary conspicuously in color. In the unsaturated zone, the sand colors are brown and light brown whereas in the saturated zone the color changes to grey and white. Generally, the sands range from fine- to coarse-grained and are poorly-sorted to well-sorted in size.

There are, however, some peculiarities in the various VES sites as depicted from drill or core cuttings (Chukwu, 2010). For instance, the sands observed at Obugwu (VES 03) and Ekpiri ala-ala (VES 02) for the unsaturated zone were characterized with reddish- brown ferrugineous sandstone with cement of haematite ore (iron oxide) forming thin coating to the grains of quartz. This is a clear indication that the area is an ironstone district. The change in color is due to weathering as the iron oxide changes from ferrous (Fe^{2+}) to ferric (Fe^{3+}) ions. Similarly, it was keenly observed from a freshly drilled functional borehole at Oloko (VES 04) whose TDD was 116 m had saturated glassy-white coarse-grained sand that was reflecting and refracting light waves. The characteristics of the different lithological units with respect to resistivity values and sand distribution can be seen.

Geo-electric cross sections were constructed to reveal the true subsurface geology with reference to the layering pattern and distribution of crustal materials within this sedimentary environment. The profile CC′ in Fig.4 shows that the top soil thickness ranges from 0.5 to 0.7 m and is made up of unsaturated dry sand while the second layer (laterite) is between 2.5 and 15.9 meters thick. The aquifer thickness here varies considerably among the VES/borehole points. As can be observed, it is about 32.4 m at Oloko (VES 04), 15.1 m at Amawom (VES 13), 81.6 m at Michael Okpara University of Agriculture, Umudike (MOUAU) and 35.6 m at Ajata Okwuru. Also, the resistivity varies from point to point.

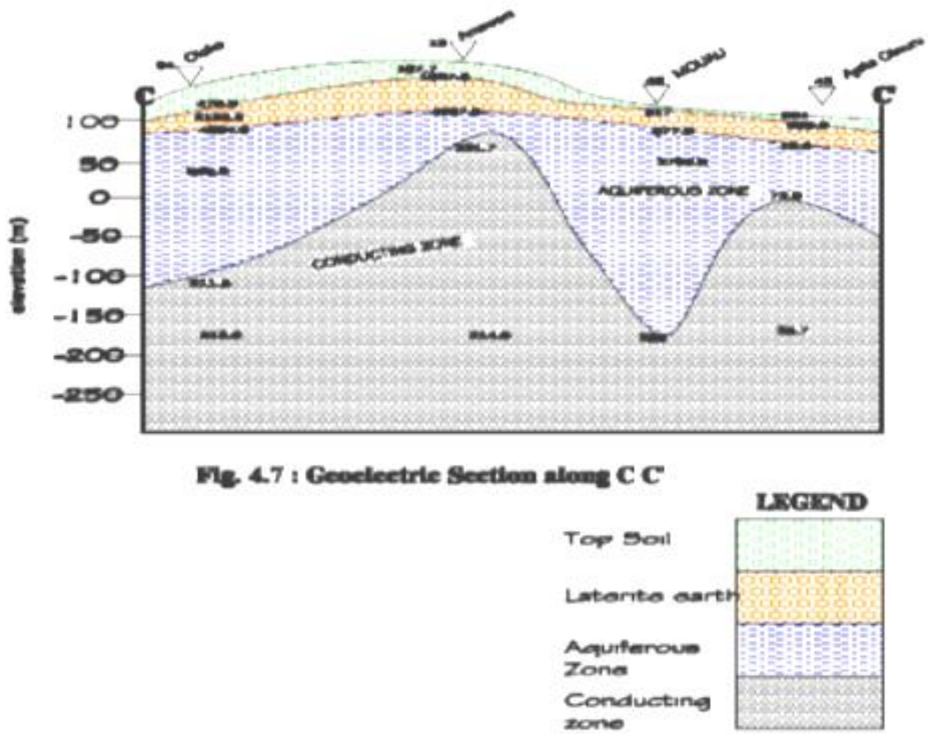

Fig 4 Geoeletric cross-section along CC ′

Another profile DD´ (Fig.5) shows a top soil which is mainly gravel/laterite at Itunta (VES 06) of thickness 0.1 m and very dry unsaturated sand layer at Iyila (VES 08), Isiala Oboro (VES 05) and Oloko (VES 04) of thickness 0.7 m, 0.6 m and 0.5 m respectively. For the second layer which is lateritic zone, the thicknesses are Itunta 3.1 m, Iyila 5.3 m, Isiala 5.7 m and Oloko 15.9 m. The third layer constitutes the broad aquiferous zone which is almost absent at Itunta. Closer observation reveals that Itunta belongs to Bende-Ameki Formation while the others in this

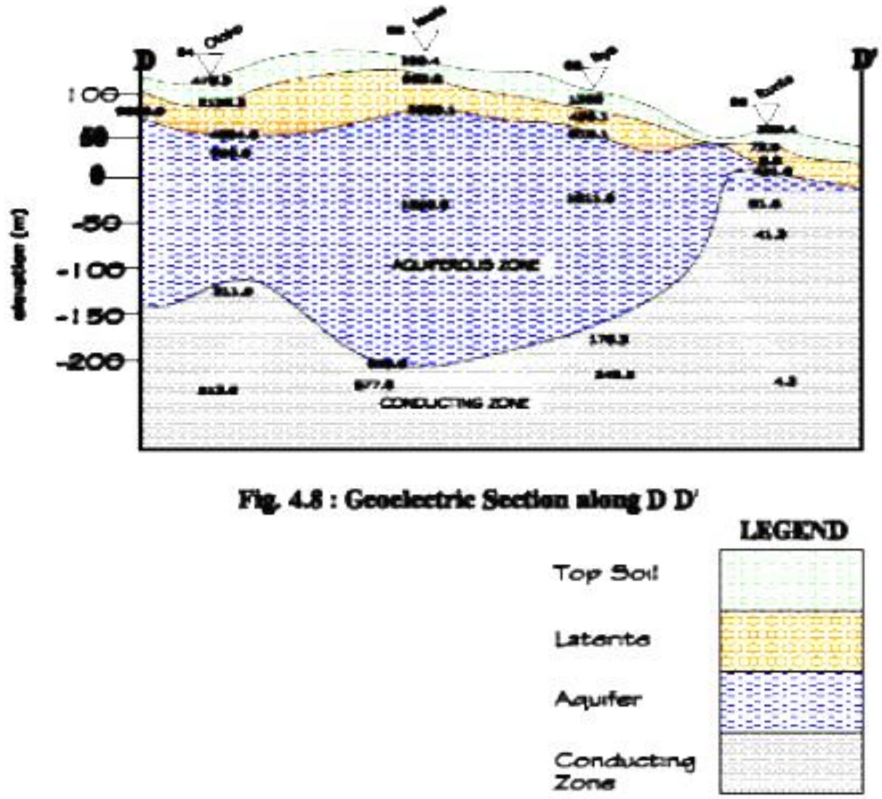

Fig 5 Geoeletric cross-section along DD´

traverse are in Benin Formation. The geo-electrical drilling measurements are actually revealing the subsurface for us to make meaningful inferences. The resistivity range of the aquifer is 1011 – 4084 Ω m. The perennial Akwu stream between Itunta and Elemaga recharges the aquiferous zone during the rainy season and it not hard to observe that this stratum appears to a geological pinchout before reaching Itunta if one is moving from D (near Oloko in Benin Formation) to D´ (near Itunta in Bende-Ameki Formation).
Yet, another profile EE´ in Fig.6 runs through four VES/borehole stations. These stations are Obohia (VES 56), Ariam ala-ala (VES 52), Obugwu (VES 03) and Ekpiri ala-ala (VES 02) all located within the Benin Formation. Their top soil which is mainly fine – medium grained dry.

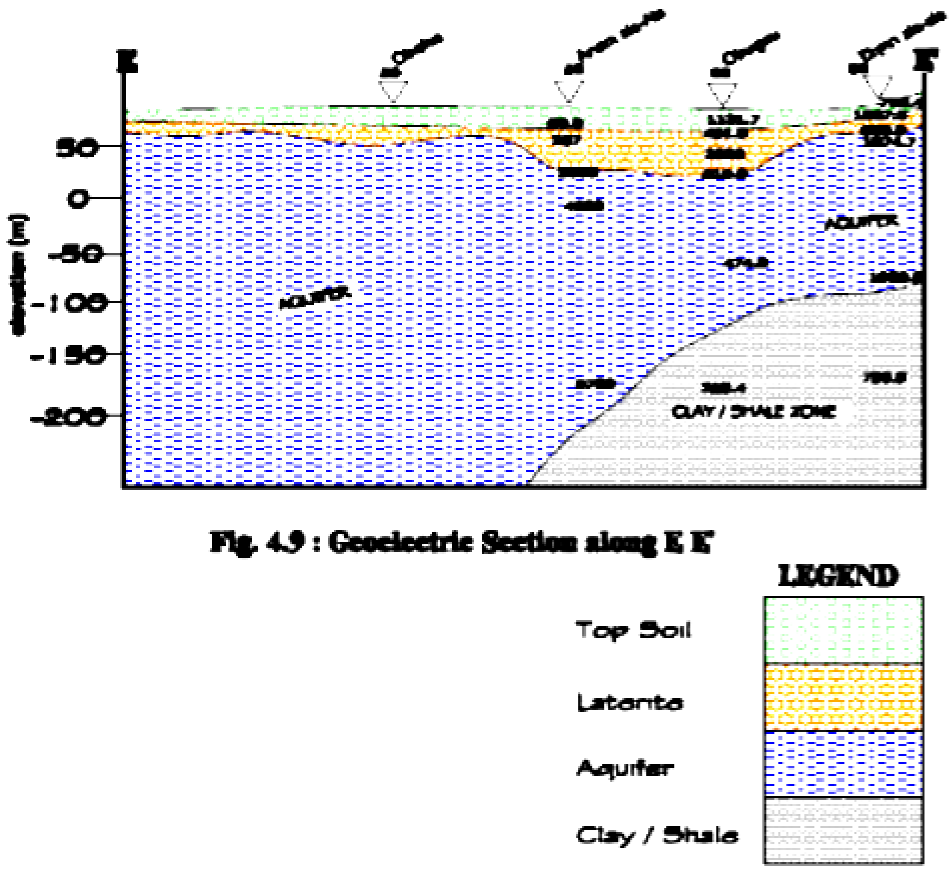

Fig 6 Geoeletric cross-section along EE´

sand varies in thickness between 0.4 and 0.7 m with apparent resistivity value range of 80.0-1121.7 Ω m. The second layer resistivity ranges from 276.0 to 1087.5 Ω m with corresponding thickness of 1.9 to 8.0 meters. The aquiferous layer at Ekpiri ala-ala has a thickness of about 163.4 meters, 16.0 meters in Obugwu and it appears to confined by a clay/shale aquitard below. At Ariam ala-ala, it is more than 68.0 meters in thickness but un-confined. The clay/shale thickness variation here seems to be as a result of the structural/tectonic settings and adjustments of the depositional sedimentary regime of the Quarternary era. Another interesting aspect of the study is the distribution of two product values of Kh and Kσ. The product of hydraulic conductivity, K (also called permeability) and aquifer thickness, h as well as hydraulic conductivity, K and electrical conductivity, σ (also referred to as the inverse resistivity) were estimated and recorded as shown in Table 1. The estimation of Kh values termed transmissivity, T_r is 712.6 m^2/day (minimum) for Umuariaga and 2673.2 m^2/day (maximum) for Government College, Umuahia. The total sum of transmissivity values becomes 16391.6 which give a mean transmissivity of 1639.16 m^2/day. The Kσ values range from 0.0060 for Amawom to 0.0219 $(\Omega.d)^{-1}$ for Mgbarakuma and the sum total of Kσ estimations is 0.1155 $(\Omega.d)^{-1}$. By all standards, the transmissivity values within the area are high though not homogeneous in respect the aquiferous or water-bearing zone. This high transmissivity value has given rise to two implications. It shows and confirms that aquifer materials are made up of porous un-consolidated fine-medium coarse grained sands which have earlier been stated. Secondly, the subsurface areas with thick aquiferous materials are characterized by higher transmissivity values than subsurface areas with thin aquiferous materials. This is very true since transmissivity is highly dependent on aquifer thickness (Igboekwe et al., 2006).

CONCLUSION/RECOMMENDATIONS

Hydro geophysics has been a very powerful tool through which we can 'view' and 'mirror' the subsurface of the Earth beneath our feet and decipher much information about its hydrological attributes. This work has been aimed at studying the hydro-geophysics of Ikwuano with a view to un-ravel the hydro-geological and hydro-geophysical facts which would, in turn, be used to determine the nature, depth and aquifer thickness in the area (Miller, 2006; Okereke et al., 1995).

Geological triangulation approach was adopted in this geophysical investigation which involved GPS/GIS data with geological maps; keen observation of boreholes, streams, rocks, and question-and-answer interactions with inhabitants and then the application of geophysics using resistivity survey or geoelectrical drilling.

Geoelectric drilling data as well as GPS data were acquired processed and interpreted which enable us to have a better knowledge of the hydro-geological and hydro-geophysical perspective of Ikwuano. The nature of the aquifer is mainly un-confined sand/sandstone over-burden aquifer with varying static water levels from place to place owing to undulating topography of the area. The aquiferous zone thickness ranges between 15.1 and 163.4 meters. Another important result is that Ikwuano is laterally traversed by two major geologic formations of Benin and Bende-Ameki Formations.

It is pertinent to state here that application of global/regional geophysics to solve local problem can give rise to un-successful results. The authors therefore suggest, from experience in this study, that solution to a local problem using a global or regional geophysics be avoided. This is because the subsurface is practically inhomogeneous and demands that each borehole location or site should be treated on its own merits based on pre-drilling findings. Using generalized regional/global geophysics to tackle a local issue, many a time, end up with obscure results and therefore should not be encouraged.

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