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Research Article

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Aquifer Delineation and Characterization using Geoelectric Method at Parts of Umuahia, Nigeria

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Abstract Resistivity study was carried at Bende area in Umuahia. The study was able to locate the area within the Ameki Formation. Results from the survey reveals a KH curve with a drilling depth of 50m and above as the indicated by the Resistivity values which is > 1000ohms within the fifth layer. Dar-zarouk Parameters were obtained from the Geoelectric Properties with great inclination of a productive aquifer within the Fifth layer. Transmissivity of 509 m^2/day and Permeability (k) value of 8.5 m/day were obtained by empirical relations, with high correlations from values obtained from Pumping Test data within the area. Longitudinal Conductance>1 mhos of the fourth layer depicts a safe aquifer in terms of surface contamination. The study was also able to the delineate the actual commencement of the Benin formation from the Amachara Region down to the south in Umuahia.

Keywords Aquifer, Conductance, Geoelectric, Permeability, Resistivity, Transmissivity, Umuahia

Introduction

The complex Geological properties and topography of the study area has resulted in the difficult of mining groundwater within the area. The area Isieke, Umuahia North, has being known of its scarcity of groundwater in recent years; thus bringing untold hardship on the residence with respect to water resources. Numerous efforts and studies from Government and Private sectors have being made to abate this trend but little or no recorded success. Study carried out by Amos *et al* [1], Chukwu *et al* [2] shows the many cases of boreholes failure especially in the northern and central parts of the state while the southern part has huge groundwater potentials.

This study is one of such efforts to further divulge the hydrological conditions prevailing in part of the area.

In Ground water exploration/production practice, geophysical survey of the subsurface rock materials are usually carried out to determine the water bearing potentials of the proposed site to assess the viability of the project in the given site by acquiring hydro-geophysical information necessary for a productive borehole construction/installation. Some of the vital information to be obtained from the survey includes:

- Viability of the project at the chosen site
- Estimated drill depth
- Type of geological formations (subsurface materials) to be encountered

Certain aquifer characteristics are useful in assessing the water resources potential of a place [3]. These parameters includes the hydraulic conductivity (K), transmissivity (T), and storativity (S).

These parameters are needed to execute proper water planning and management and also in determining the natural flow of water through an aquifer and its response to fluid abstraction [4-6].

Resistivity measurements were performed at the following predetermined locations at Community Model Secondary School, Bende Road, Isieke Umuahia, Abia State.

Geology of the Study Area

The Geology of the area ($5^o32'56.9868"$ N, $7^o31'31.6632"$E), which is in the North of Umuahia, reflects the geology of the southeastern Nigeria. Nkporo shale of Maastrician age underlies the basin after the santonian tectonic event. This sediment is overlain by the Mamu, Ajali and Nsukka formation respectively. During the Paleoceneage, a regressive phase brought about the sedimentation of the Imo shale, which was subsequently overlain by the Eocene Ameki formation. The Miocene to recent Benin formation overlies the Ameki formation.

Annual rainfall is between 2000 mm and 2250 mm. The maximum daily mean temperature is 29 ^oC (i.e. between 28^o and 30 ^oC) during the month of March and minimum daily mean temperature is 23.5 ^oC (i.e. between 23^o and 24 ^oC) during the month of July. Topographically, the crustal mass distribution for Umuahia is not even [2].

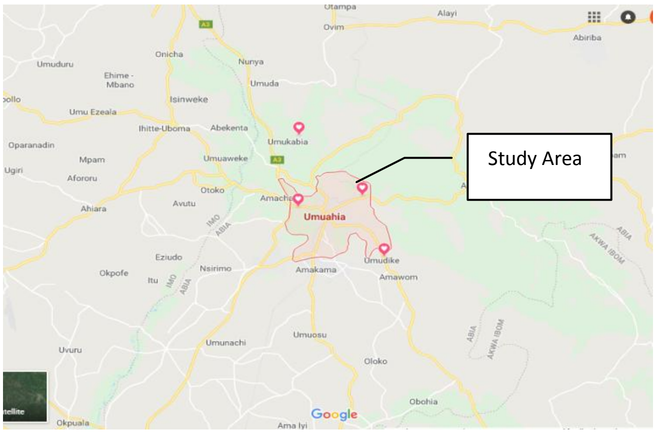

Figure 1: Geology of the area

Materials and Methods

Resistivity Measurement

The geophysical method applied in this survey is the resistivity method, which measures the apparent resistivity of the subsurface, including effects of any or all of the following: soil type, bedrock fractures, contaminants and ground water. Variations in electrical resistivity may indicate changes in composition, layer thickness or contaminant levels.

Soil electrical resistivity indicates the relative capacity of the soil to carry electrical current and is a main indicator in determining the permeability of the soil thereby predicting its water bearing capacity. It is therefore the most important parameters taken into account in groundwater Survey [7].

Basic Principles of Resistivity (DC) Method

Resistivity is measured by passing a current of known value in the ground by means of two electrodes (C_1, C_2) and measuring potential difference between two intermediate points in the ground using another two electrodes (P_1, P_2). As the electrode spread (C_1, C_2) increases, depth of probe increases, thereby, giving a vertical electrical sounding, VES [7]. The equivalent soil resistivity, ρ, is calculated using the relevant formula (derive from ohms law):

$$\rho a = \frac{\pi \Delta v}{4IMN}(AB - MN)(AB + MN) \quad (1)$$

where

$\rho a = apparent\ resistivity$

$\Delta v = voltage$

$I = currrent$

$MN = Potential\ Electrode\ Spacing$

$AB = current\ Electrode\ Spacing$

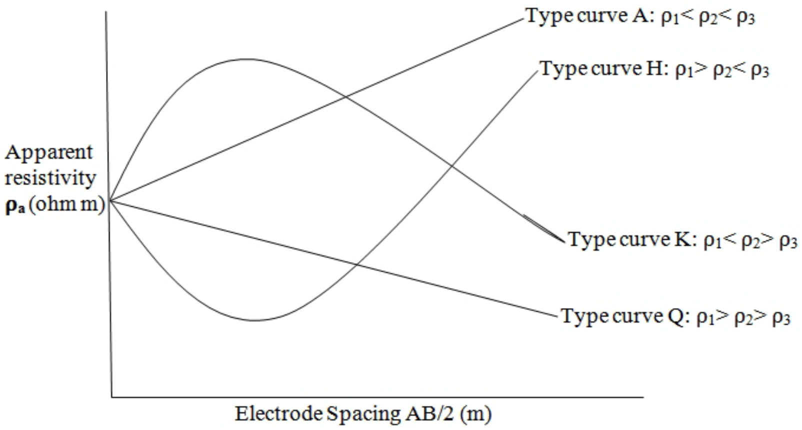

Figure 2: Schematic Diagram of Resistivity type curves for Layered Structures

Data Processing

Raw field data was transferred to computer on completion of Field Work, A forward modelling subroutine was used to calculate the apparent resistivity (*pa*) values, and a non-linear least-squares optimisation technique was used for the inversion routine.

An aquifer can be characterized by its Transmissivity, its quantitative expression of the productivity of an aquifer and Coefficient of Storage, which determines its storage capacity [8]. The combination of thickness and resistivity into single, variables otherwise known as Dar Zarrouk parameters can be used as a basis for the evaluation of aquifer properties [9]. The Dar Zarrouk parameters consists of the Transverse Resistance (*RT*) and Longitudinal Conductance (*Lc*) which is a measure of the impermeability of the rock layer. For a horizontal, homogeneous, and isotropic layer, the Transverse Resistance R_T(Ωm^2) is defined as

$$R_T = \rho h \tag{2}$$

Transverse Resistivity, ρ_t

$$\rho_t = {}^{R_T}/_{h} \tag{3}$$

And the Longitudinal Conductance L_C(mho) is defined as:

$$L_C = {}^{h}/_{\rho} \tag{4}$$

Longitudinal Resistivity, ρ_L

$$\rho_L = {}^{h}/_{L_c} \tag{5}$$

Where h is the thickness of the layer (in metres) and ρ is the electrical resistivity of the layer in ohm-metres.

But aquifer Transmissivity (*T*) is expressed as:

$$T = kh \tag{6}$$

where$k$ is the Hydraulic Conductivity (m/day). These relationship infers the Transmissivity and Coefficient of Storage. Ioannis *et al* [10], proposed the following equation for k;

$$k(10^{-4})m/s = 2.12f - 1.54 \tag{7}$$

Where;

f= Formation Factor

The formation factor can be derived from Archie's Law (1942)

$$f = {}^{R_o}/_{R_w} \tag{8}$$

Where;

R_o= Resistivity of the Formation

$R_w =$ Resistivity of Water

Values of formation factor, f , which is dependent on the aquifer [11], can be deduced from from the formation equation above (equation 8). Amos-Uhegbu, *et al*. [1], stated formation factor, f of 2.61 within the Benin formation around Amizi area, Southern Nigeria, within depth less than 200m. Also Amos-Uhegbu, *et al* [1] stated the Formation factor of 7.67 at Amaoba, about 5km from the study area with depth less than 200m. The outcome of the equation above (equation 7), correlates with the results obtained by Ngah *et al* [12] in parts of the Niger Delta. Niwas and Singhal [9], proposed a relationship between Transverse Resistance, R_T and Transmissivity

$$T = kR\sigma \qquad (9)$$

Where σ=$conductivity$, R_T=$TransverseResi$, T= Transmissivity and k=$Hydrualic\ Conductivity$

Also the Anisotropy, defines the measure of stratified rock which is generally more conductive in the parallel plane than in the perpendicular plane, which also influences flow Direction [13].

$$\text{Anisotropy, } \lambda = {}^{\rho_t}/_{\rho_L} \qquad (10)$$

Results and Discussion

Raw field data was transferred to computer on completion of Field Work, A forward modelling subroutine was used to calculate the apparent resistivity (*pa*) values, and a non-linear least-squares optimisation technique was used for the inversion routine.

Table 1: Field values

S/No	AB/2(m)	MN/2 (m)	Resistivity(Ω)
1	2	0.6	249.2336
2	2.5	0.6	264.744441
3	4	1	322.201855
4	5	1	350.287508
5	8	2	402.124
6	10	2	367.566264
7	12	2	342.006386
8	15	3	287.455668
9	20	3	131.946885
10	25	5	127.627208
11	30	5	82.5610582
12	70	20	41.5632708
13	80	20	53.2814088
14	100	20	68.4042409
15	120	30	64.8424735
16	150	30	91.8915855

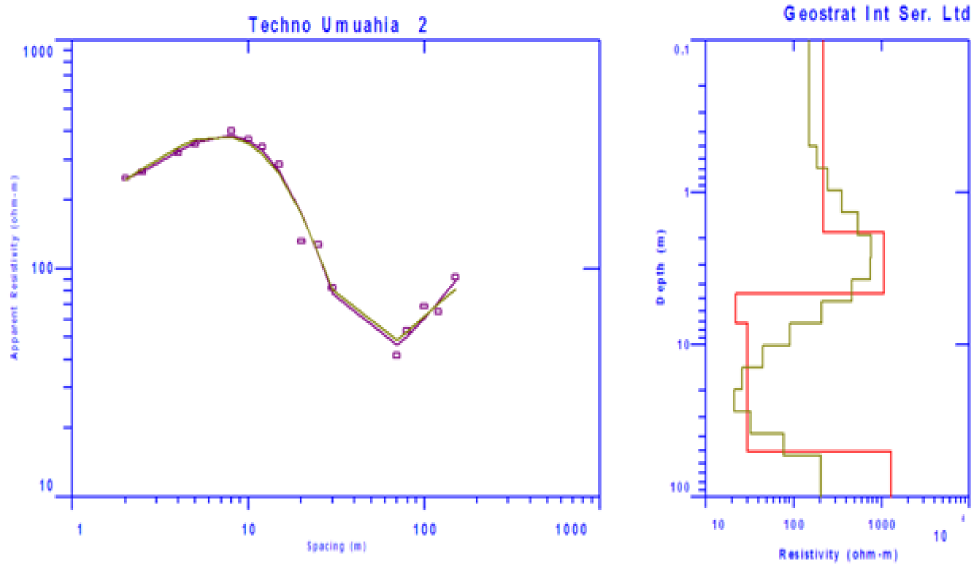

Figure 3: Resistivity Models

Table 2: Layers Properties

Layers	Resistivity (Ωm)	Thickness (m)	Depth (m)
1	216	1.9	1.9
2	1069	2.8	4.7
3	21	2.6	7.3
4	30	43.7	50.9
5	1296		

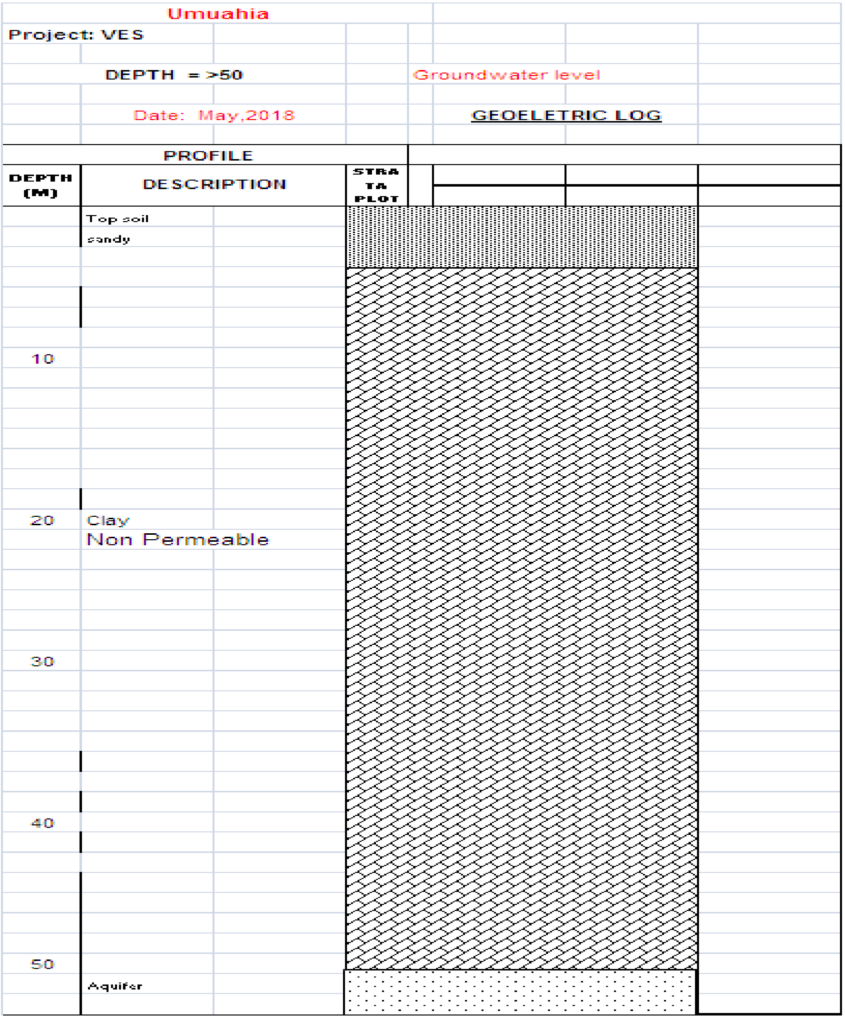

Figure 4: Geoelectrical Section

Table 3: Geoelectric Properties

Layer	Resistivity (Ωm)	Thickness (m)	Depth (m)	Transverse Resistance (Ωm^2)	Longitudinal Conductance (mhos)	Lithology
1	216	1.9	1.9	437.57	0.008250109	sandy
2	1069	2.8	4.7	2993.2	0.00261927	sandy
3	21	2.6	7.3	54.6	0.123809524	shale
4	30	43.7	50.9	1311	1.456666667	shale
5	1296	*10	50.9	12960	0.007716049	Sand-stone

Note: * minimum assumed thickness

Table 4: Aquifer Properties

Layer	Resistivity (ohm-m)	Transverse Resistivity (Ωm)	Longitudinal Resistivity (Ωm)	Anisotrophy	Transmissivity m^2/day	K(m/day)
1	216	230.3	230.3	1		
2	1069	1069	1069	1		
3	21	21	21	1		
4	30	30	30	1		
5	1296	1296	1296	1	509.48352	8.49139

Discussion

The Survey was carried out at Umuahia. The survey has an AB (C1, C2) = 300m with Sounding Depth >45m. The survey, which is a five layer (KH) model, indicates a Top sandy Layer within depth of 5m and resistivity value of about 200 - 1000 ohm.m (Aquiclude) The third and Fourth Layer, with resistivity value of about 30 ohm.m and total thickness of about 46m, indicates a non Permeable, clayey region (aquifuge). The fifth Layer, with resistivity value >1000 ohm.mindicates a Permeable and Porous Aquifer within depth >50m.

The Permeability values were obtained from formation factor value of 1.19 (based on values for Umuobia, a site 2km close to the study area, Igboekwe *et al* [14]. This formation Factor value correlates with values obtained from similar works done within the region. Permeability value of 8.5m/day obtained from the study also relates with the works of Amos-Uhegbu *et al* [1].

The Transverse Resistance within the fifth layer, indicates values that correlates permeable region [7].

The Transmissivity value of 509.5m^2/day obtained within the fifth layer, indicates Intermediate Transmitting capacity for local Water Supply, based on Krasny's Classification [15].

Anisotrophy values shows homogeneity in the lateral and transverse direction as indicated by the calculated values.

From Table 4, Longitudinal Resistance values >1mhos within the fourth layer, shows high protective capacity from surface intrusion of contaminants. This implies the aquifer is safe from surface contaminants.

Table 5: Longitudianl Conductance/Protective Capacity Rating (after Henriet [16])

Total longitudinal unit conductance (mhos)	Overburden protective capacity classification
<0.10	Poor
0.1 - 0.19	Weak
0.2 - 0.69	Moderate
0.7 - 1.0	Good

Work done by Chukwu *et al* [2], shows that within Umudike, amachara, Apumiri and its environs has underground water, while Nkata Alike, Umukabia contains no underground water (figure 5). These indicate that the region with high scarcity of underground water lies within the Imo Shale formation, while the region with high proliferation of underground water lies within the Benin formation.

The study was also able to the delineate the actual commencement of the Benin formation from the Amachara Region down to the south (figure 5). This is exacerbated by the fact that from that region downward the possibility of a productive shallow aquifer is very high. This was also cited in the works of Amos et al [1], which states the Benin Formation as the surface outcrop of Umuahia-South area and also serves as the aquifer for all the boreholes. Also the region northward from the numerous study, shows no possibility of locating an aquifer, this depicts the Imo Shale. Thus, the location of the study area which shows some possibility of locating an aquifer, Portrays the Ameki formation which contains an alternation of shale and sandstone.

Conclusion

The area is located within three geological area, the Imo Shale, Ameki formation and the Benin Fomation. The study w as able to delineate these locations through the use of existing data and Resistivity Survey. Results of the

Geoelectrical study carried out within the study area, reveals the location in the Ameki Formation, with a drill drilling depth > 50m-60m. This depth was confirmed was confirmed by Resistivity values, Trasmissivity value and Permeability Value within the layer. The Longitudinal Conductance r values within the fourth layer reveals a safe aquifer in terms of surface contamination.

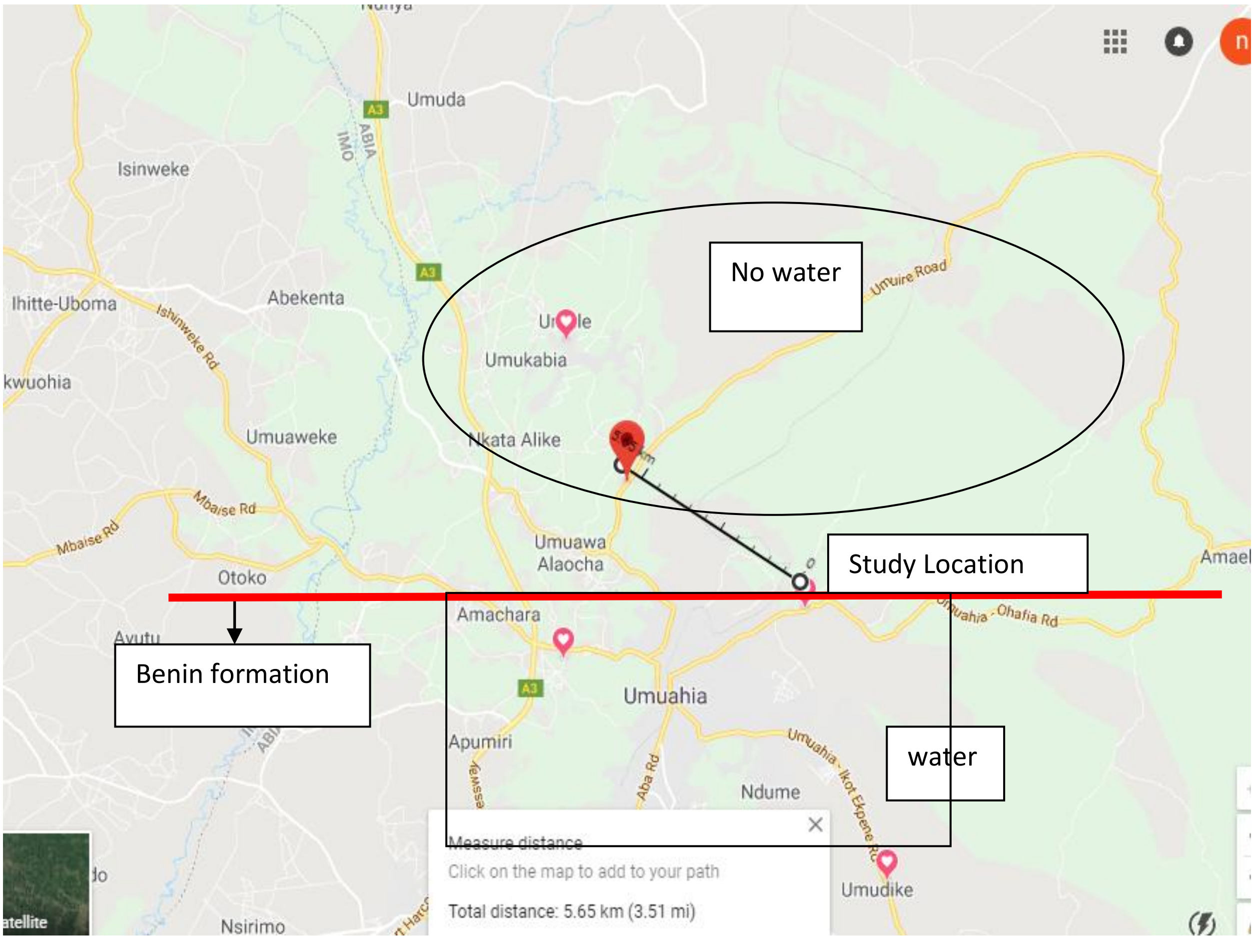

Figure 5: Delineation of Imo shale and Benin formation within the study Area

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