Estimation of Hydrogeological Parameters for Michael Okpara University of Agriculture, Umudike, Southeastern Nigeria.

M.U. Igboekwe*, Ph.D. and A.O. Akankpo, M.Sc.

Department of Physics, Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria.

*E-mail: akankpo@yahoo.com

ABSTRACT

This paper presents results of geoelectric soundings carried out around Michael Okpara University of Agriculture, Umudike and its environs, Southeastern Nigeria. The data of fourteen Schlumberger vertical electrical soundings (VES), with a maximum AB/2 = 500 m were analyzed using the Resist software. The parameters obtained were used to calculate transmissivity (T_r) and Kσ within the study area. Aquifer characterization of the area showed that the aquifer resistivity range is between 804.40 to 8387.60 Ωm. The transmissivity values in the area ranged between 48.00 to 384.80 $m^2 day^{-1}$, while Kσ values ranged between 0.0009 and 0.0099 $(\Omega d)^{-1}$. The sandy aquifer exhibits moderate to high transmissivity values, which reflects the geological setting of a typical sandy formation. Based on the above analysis, potential aquifer has been identified for sustainable groundwater development.

(Keywords: transmisivity, aquifer, Umudike, Kσ, resistivity, vertical electrical sounding)

INTRODUCTION

Groundwater is a natural resource that is of immense importance to life and its characteristics are greatly determined by the properties of the immediate geologic formations. Groundwater is naturally stored in the pores spaces within soil compartments and between unconsolidated formations. Aquifer characteristics are greatly influenced by formation strata and terrain type (Akpokodje and Etu-Efetobor, 1987). Hence, the acquisition of viable deep water wells is mainly dependent on adequate and reliable empirical knowledge of the geology of the area and the depth of aquifer (Okolie et al., 2005).

Groundwater surveying consists of the application of a range of indirect techniques, since groundwater cannot be directly observed or managed from the surface. Successful groundwater exploration depends on the selection of a combination of techniques appropriate to the area under investigation. Numerous investigations have established the usefulness of surface electrical resistivity as a tool in the study of groundwater (Igboekwe et al., 2006).

Excellent examples of the use of surface electrical resistivity as a practical tool in groundwater studies are: determination of lithology (George et al., 2010; Evans et al., 2010), determination of saltwater fresh water interface (Oyedele, 2001; Usen et al., 2007), determination of saline and freshwater interface (Choudhury et al., 2001), delineation of potential aquifer zones (Igboekwe et al., 2006), monitoring of groundwater contamination (Akankpo and Igboekwe, 2011).

The determination of aquifer characteristics in boreholes is characterized on its hydraulic conductivity and transmissivity best made on the basin of data obtained from test pumping well and vertical electrical sounding (Matias, 2002). A reliable data is best obtained when standard packages of pumping and recovery tests are carried out in a strictly controlled way. Vertical electrical sounding (VES) success must rely on the careful interpretation and integration of the results with the other geologic and hydrogeologic data for the site.

This research was conducted in order to determine the hydrogeological parameters and formation strata of Michael Okpara University of Agriculture, Umudike and its environs in consonant with the increasing demand for portable water supply in the area.

GEOLOGY AND HYDROGEOLOGY OF THE STUDY AREA

Michael Okpara University of Agriculture, Umudike (MOUAU) is located in Ikwuano Local Government Area of Abia State, Southeastern Nigeria. It is located within the deltaic marine sediments of Cretaceous to recent age, between latitude 5°28'N and 5°30'N and between longitude 7°31'E and 7°33'E and an elevation range of 60 to 180 m above mean sea level.

The Geology of the area is the deltaic marine sediment of Cretaceous to Recent age. There are two principal Formations in the area namely: the Bende-Ameki and the coastal plain sands otherwise known as the Benin Formation. The Bende-Amaki Formation of Eocene to Oli- gocene age consists of medium to coarse-grained white sandstone, which may contain pebbles, gray-green sandstone, bluish calcareous silt, with mottled clays and thin limestone. Considerable lateral variation in lithology has also been observed. The lower part of the Formation consists of fine-coarse-grained lenses of sandstone with abundant calcarceous shales and thin shelly limestone.

The Bende-Ameki Formation overlies the impervious Imo shale group of Paleocene age, which is characterized by lateral and vertical variations in lithology. The coastal plain sand otherwise known as the Benin Formation overlies the Bende-Ameki Formation and dips south-westward. The Formation sediments were deposited during the late Tertiary-early Quaternary period. The Formation is shallow and has an expected thickness of about 200 m (Igboekwe and Akankpo, 2011). The lithology consists of unconsolidated loosely medium to coarse-grained cross-bedded sands occasionally pebbly with localized clays and shales. Umudike soil is acidic with average pH range of 4.5 - 5.7.

The two principal geological formations: the Bende-Ameki and the coastal plain sands otherwise known as the Benin Formation have comparative groundwater regime. They both have reliable groundwater that can sustain regional borehole production. The Bende-Ameki Formation has little groundwater when compared to the Benin Formation. The high permeability of the Benin Formation, the lateritic overburden earth and the weathered top of this formation as well as the underlying clay-shale member of the Bende-Ameki series provide the hydrologic conditions favoring aquifer formation in the area. The study area has aquifer thickness of about 88.00 m, hydraulic conductivity of about 8.00 m/day and a transmissivity of about 704.00 m2/day (Igboekwe and Akankpo, 2011).

METHODOLOGY

Electrical resistivity technique surveys have been employed for many years in routine hydrogeological investigation. This technique is particularly useful in the area of complex geology (Griffiths and Barker, 1999), in archeology, and in other shallow subsurface investigations (Noel and Walker, 1970). For the geoelectric soundings carried out in this study, an ABEM Terrameter SAS 4000 and its accessories were used. The instrument displays directly the apparent resistivity of the subsurface under probe. It has an in-built dc power source. A total of fourteen vertical electrical soundings (VES) were made using the Schlumberger array with a maximum current electrode separation of AB/2 of 500 m (Figure 1). The resistivity inversion computer program, RESIST was employed in the modeling of the VES data (Igboekwe et al., 2006).

RESULTS AND DISCUSSION

Table 1 shows the summary of the aquifer parameters, aquifer locations and aquifer coordinates in Michael Okpara University of Agriculture, Umudike and its environs. The table consists of primary parameters (resistivity and thickness) of the aquifer used in calculating the secondary parameters known as Dar zarouk parameters (transmissivity, Kσ and longitudinal conductance). Aquifer transmissivity was estimated using the hydraulic conductivity for the area, which is 8.00 m/day (Igboekwe et al., 2006). The corresponding thickness of aquifer was also used in estimating the transmissivity.

The usual high and low resistivities of the Benin Formation caused by changes in lothologies were obtained along with the corresponding thicknesses of aquifer (Table 1). The isoresistivity map shown in Figure 2 was drawn to show the distribution of resistivity in Michael Okpara University of Agriculture. Aquifer resistivity varies from 804.40 Ωm to 8387.60 Ωm. The area has an average aquifer resistivity of 3573.89 Ωm.

Figure 1: Map of the Study Area Showing VES Points

Table 1: Aquifer Characteristics of the Study Area (Tr – transmissivity, σ – electrical conductivity).

VES No	X (m)	Y(m)	Thickness h(m)	Aq Resist ρ(Ωm)	Long. Cond S(Ω^{-1})	Kσ $(\Omega d)^{-1}$	Tr = Kh ($m^2 day^{-1}$)
1	5.4799	7.5422	7.10	2862.80	0.0024	0.0027	56.80
2	5.4794	7.5394	6.00	7147.30	0.0008	0.0011	48.00
3	5.4763	7.5418	30.00	1312.60	0.0229	0.0061	240.00
4	5.4765	7.5398	17.00	3981.20	0.0043	0.0020	136.00
5	5.4768	7.5424	21.62	3894.60	0.0056	0.0021	172.96
6	5.4848	7.5476	2.60	804.40	0.0032	0.0099	20.80
7	5.4803	7.5461	13.70	1716.50	0.0080	0.0047	109.60
8	5.4787	7.5464	48.10	1344.70	0.0358	0.0059	384.80
9	5.4831	7.5451	18.20	7284.60	0.0025	0.0011	145.60
10	5.4878	7.5429	20.90	1104.80	0.0189	0.0072	167.20
11	5.4885	7.5461	10.90	2268.00	0.0048	0.0035	87.20
12	5.4821	7.5426	12.40	3276.10	0.0038	0.0024	99.20
13	5.4816	7.5400	42.20	4649.30	0.0091	0.0017	337.60
14	5.4746	7.5438	23.20	8387.60	0.0028	0.0009	185.60

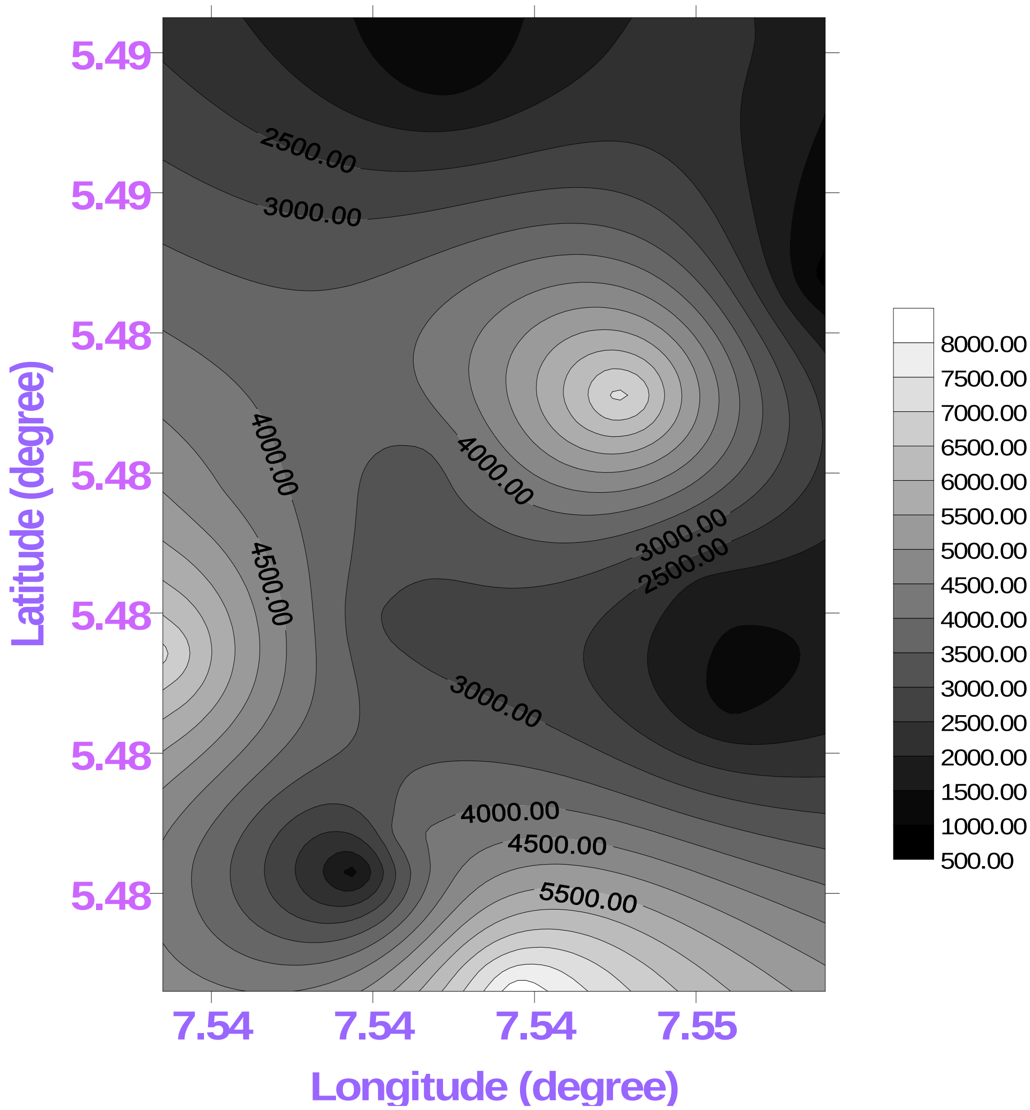

Figure 2: Resistivity Distribution Map in the Study Area.

The prograding of the contour values in Figure 1 indicate that resistivity increases towards the southern part of the area, as well towards the north eastern part of the area. Aquifer thickness also increases towards the southern part of the area, as well towards the north eastern part of the area.

To obtain transmissivity, Tr from resistivity data, two model parameters are necessary. These parameters are total transverse resistance, R and total longitudinal conductance, S. These were first obtained from the relationship:

$$R = \sum_{i=1}^{n} h_i \rho_i \qquad (1)$$

and

$$S = \sum_{i=1}^{n} h_i / \rho_i \qquad (2)$$

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

Also from Equation 2:

$$S_i = \sigma_i h_i \qquad (3)$$

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 and Bisdorf, 1989). It can be determined analytically the relationship between aquifer transmissivity, T_r and R on one hand and between T_r and S on the other hand as follows:

$$T_r = K\sigma R = \frac{KS}{\sigma} = Kh \qquad \textbf{(4)}$$

where K is the hydraulic conductivity.

This relationship was used in this study. In areas where the geology and water quality do not vary much, Kσ values remain fairly constant (Niwas and Singhal, 1981). Equations 1 to 4 were used to generate the values in Table 1.

Transmissivity is directly proportional to horizontal hydraulic conductivity (Kh_i) and thickness. Expressing Kh_i in m/day and the transmissivity (T_r) is found in units m^2/day. The transmissivity is a measure of how much water can be transmitted horizontally, such as to a pumping well. The transmissivity values in the area ranged from 48.00 to 384.80 m^2day^{-1}, with an average transmissivity value of 156.53 m^2day^{-1}. The average transmissivity value shows that the area has moderate aquifer potential. The transmissivity values increases towards the south eastern part of the area, as well as towards the western central area of the area. The values of aquifer transmissivity calculated from the observed values of k and h parameters were used in drawing the contour map showing the distribution of aquifer transmissivity in Figure 3.

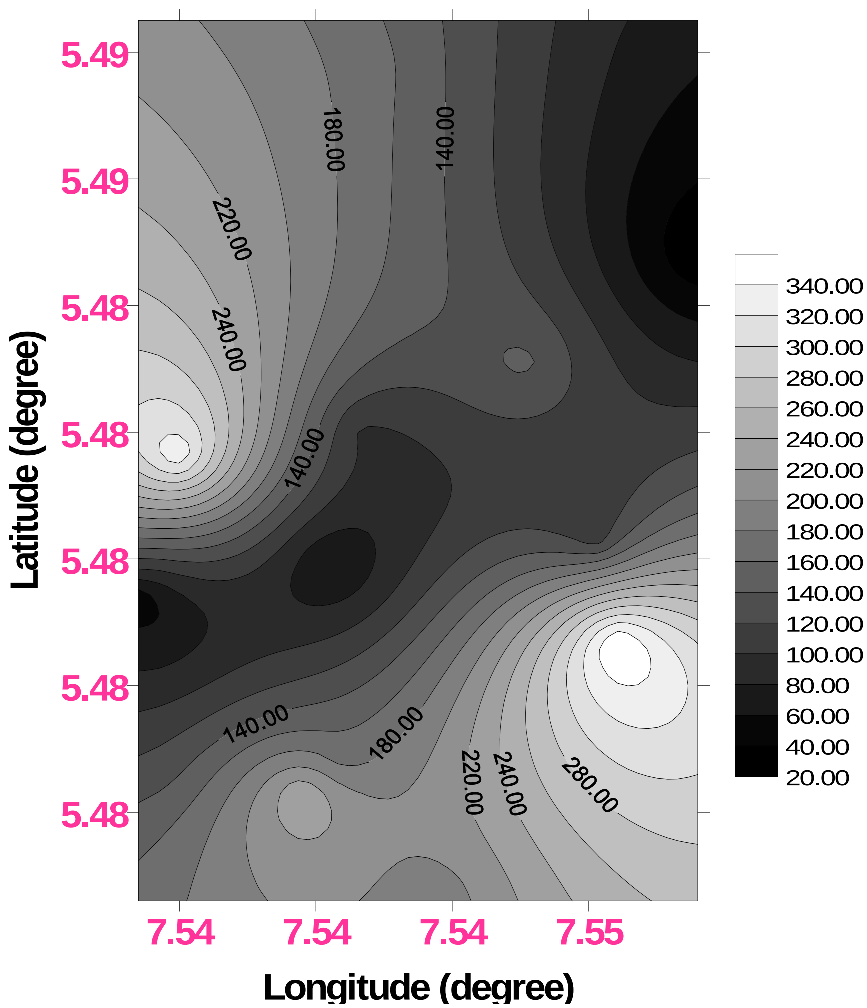

Figure 3: Transmissivity Distribution Map in the Study Area.

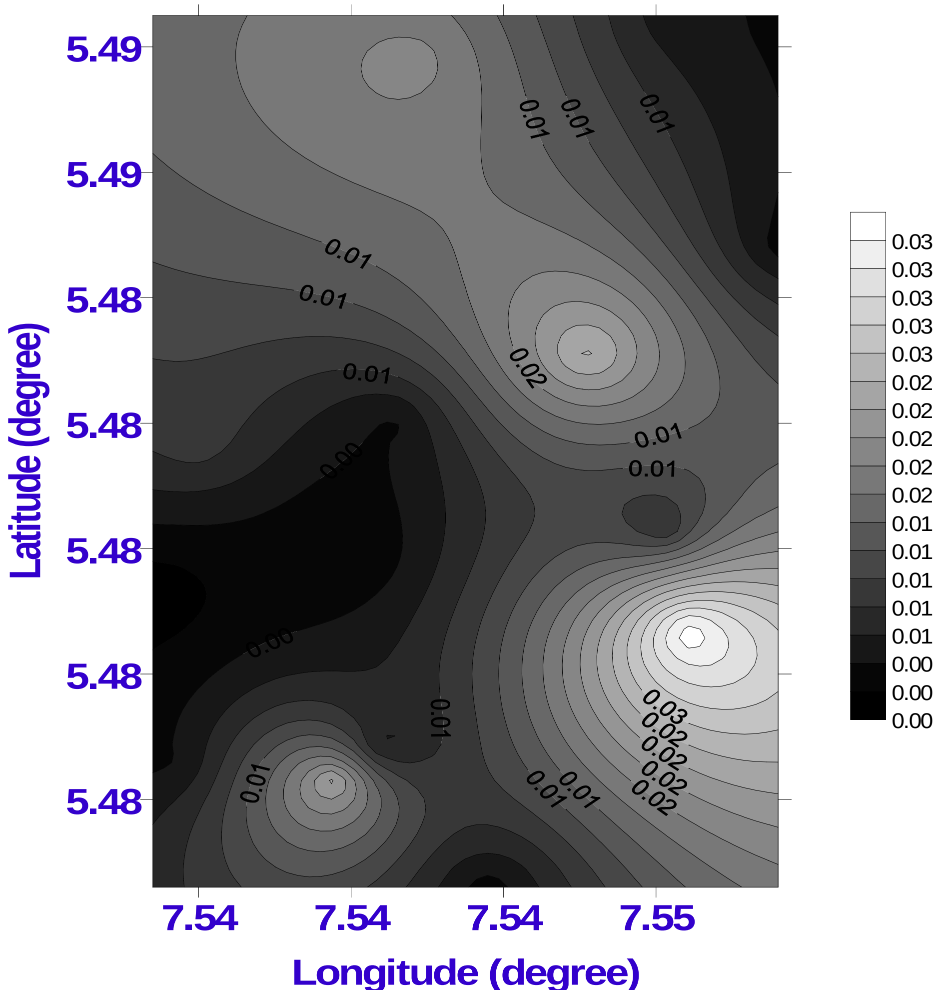

Figure 4: Distribution Map the Product of the Hydraulic Conductivity (k) and Electrical Conductivity (σ) (kσ) in the Study Area.

$K\sigma$ product is another useful parameter as far as characterization of aquifer and water quality are concerned. The distribution of this parameter emphasizes on how fresh or brackish the water in the aquifer is. Generally, high values indicate that the aquifer has fresh water (Umoren, 1999). The $K\sigma$ value distribution is shown on Figure 4. The 0.0009 – 0.0099 $\Omega^{-1}day^{-1}$ $K\sigma$ dominates the area surveyed in Michael Okpara University of Agriculture, Umudike. The range of 0.01 – 0.19 $\Omega^{-1}day^{-1}$ $K\sigma$ value is equally low enough to be classified as area characterized with brackish water. This shows that the area constitutes a brackish water zone.

CONCLUSION

A total of fourteen (14) vertical electrical soundings (VES) were carried out and interpreted. The field data were gotten from Schlumberger electrode configuration and the apparent resistivities were obtained. The hydrogeological studies have helped to delineate aquiferrous zones and characterize the conditions of the groundwater in terms of the transmissivities, aquifer resistivities and kσ of the aquifer in the area.

The sandy aquifer in the study area exhibits moderate to high transmissivity values, which reflects the geological setting of a typical sandy formation. Based on the above analysis, potential aquifer has been identified for sustainable groundwater development.

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SUGGESTED CITATION

Igboekwe, M.U. and A.O. Akankpo. 2012. "Estimation of Hydrogeological Parameters for Michael Okpara University of Agricutre, Umudike, Southeastern Nigeria". *Pacific Journal of Science and Technology*. 13(2):455-461.

Pacific Journal of Science and Technology