



Research Paper

Integrating Geoelectrical And Hydrogeological Data in Determining Aquifer Hydraulic Parameters of Ikeduru Area, Southeastern Nigeria

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Electrical resistivity survey, employing Vertical Electrical Sounding (VES) and hydrogeological data were combined to determine the aquifer hydraulic parameters, with a view to evaluating the groundwater potential of Ikeduru area, southeastern Nigeria. Ten (10) VES data were obtained randomly in the study area using Schlumberger electrode configuration, with four of the VES parametrically sounded. A maximum half-current electrode separation of 370 m was used. The data were interpreted using standard resistivity software. Shallow and semi-deep aquifer systems were mapped as the depth to water table in the study area ranges from 26.2 to 71.4 m. The aquifer thickness ranges from 34.1 to 136.9 m. Using diagnostic constant (K_0) value of 0.0018 for the study area, the Hydraulic Conductivity for the area varies from 1.35 to 29.16 m/day with a mean value of 12.25 m/day, indicating a clean sand aquifer material. Transmissivity values range from 314.0 to 2796.8 m²/day, with a mean value of 987 m²/day. The high transmissivity in the area indicates a broad and shallow drawdown which encourages water abstraction to a degree of regional importance. The Storativity value varies from 0.1023 to 0.4107, which is fairly uniform depicting similar geologic setting, hydrochemical facies and water quality. The aquifer Diffusivity varies from 451.2 to 9720.0 m²/day, with a mean value of 7936.9 m²/day which implies quick response of the aquifer to fluid transmission as the hydraulic conditions change from one location to another. The results indicate that the area is suitable for sustainable groundwater development.

Keywords: Hydraulic parameters, Hydraulic conductivity, Transmissivity, Storativity, Diffusivity

Introduction

“Water is the elixir of life, without it life is not possible” (Fetter, 2001). The accuracy of that statement cannot be overstated. With the increased contamination of surface water, the

‘burden’ rests on groundwater to be the panacea for life. In many developed and developing countries there is not only a heavy reliance on groundwater as primary drinking supply source, but also as a supply of water for both agriculture

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and industrial uses. Nigeria is one of such developing countries where the reliance on water has grown dramatically in recent years; there is an ever-increasing demand for fresh water resources to meet the requirements for Industrial, Agricultural and Domestic Sectors. As a result of this, it is important to monitor the available groundwater in Nigeria to ensure that the abstraction of groundwater does not supersede its available quantity. Quite unfortunately, in spite of the fundamental role groundwater plays in human well-being, as well as that of many ecosystems, it is yet to be fully appreciated and adequately managed and protected, especially within Nigeria. It is well-known that groundwater basins are difficult to govern and manage, partly because of poor information, and because of poor visibility of the resource. To manage groundwater effectively the need for reliable data and accurate information is essential to protecting the quantity and quality of available groundwater (Nwankwoala, 2015).

Determination of aquifer hydraulic parameters is essential to the solution of several hydrological and hydrogeological problems. In order to assess groundwater potential in any area and to evaluate the impact of pumping on groundwater regime, it is essential to know the aquifer hydraulic parameters (Kumar, 2010). These parameters are basically; hydraulic conductivity, transmissivity, storativity and diffusivity, but also include aquifer depth and thickness. In the past two decades, a lot of researchers have estimated aquifer hydraulic parameters from Vertical Electrical Sounding (VES) with huge success. Some of these researchers are Kelly (1977), Niwas and Singhal (1981), Onuoha and Mbazi (1988), Ekwe et al. (2006), Igboekwe and Akpan (2011), Ikechukwu and Onu (2012), Opara et al. (2012) and Chukwudi et al. (2013).

The present research is targeted at evaluating the groundwater potential from the calculated aquifer hydraulic parameters of Ikeduru Local Government Area, Southeastern Nigeria with the aid of resistivity survey and information obtained from pumping test data.

The Study Area

The study area is Ikeduru Area in Imo State of Nigeria which lies between latitudes 5°30'N and 5°40'N and longitudes 7°04'E and 7°14'E (Figure 1). Ikeduru has an estimated population of 149,316 people (Onyekakeyah, 2010). It covers a land area of about 1500 km² and is accessible due to good road network except in some parts of Ikembara, Omuomi Uzoagba and Okwu owing to gully erosion arising from the topographic nature and length of slope in the area (Amangabara, 2012). The area is drained by rivers Mbaa and Oramiriukwa. Mbaa River is the main river in the area, which has its source at Ugri community in Isiala-Mbano Local Government Area of Imo State where it flows into Oramiriukwa River (Figure 1). The distributaries and tributaries of these rivers effectively drain the area. These rivers are also characterized by dry valleys, which are usually covered by floodwater during periods of high rainfall. Floodwater infiltration during the rainy season recharges the aquifer.

The area has two seasons, namely rainy and dry seasons. The mean annual rainfall is between 200 mm and 2250 mm and the annual rainfall is usually heavy. On a monthly basis, the rainfall amount at any location is not uniform but exhibits a marked seasonality. The rainfall distribution consists of two minima and two maxima. The first minima are in November and December while the second minimum is in August, which is usually associated with August break. From

February, total rainfall increases sharply to primary maxima in June and July. The second maximum is in September, which increases sharply and subsequently decreases in November and December (NIMET, 2012; Ibeneme et al., 2014).

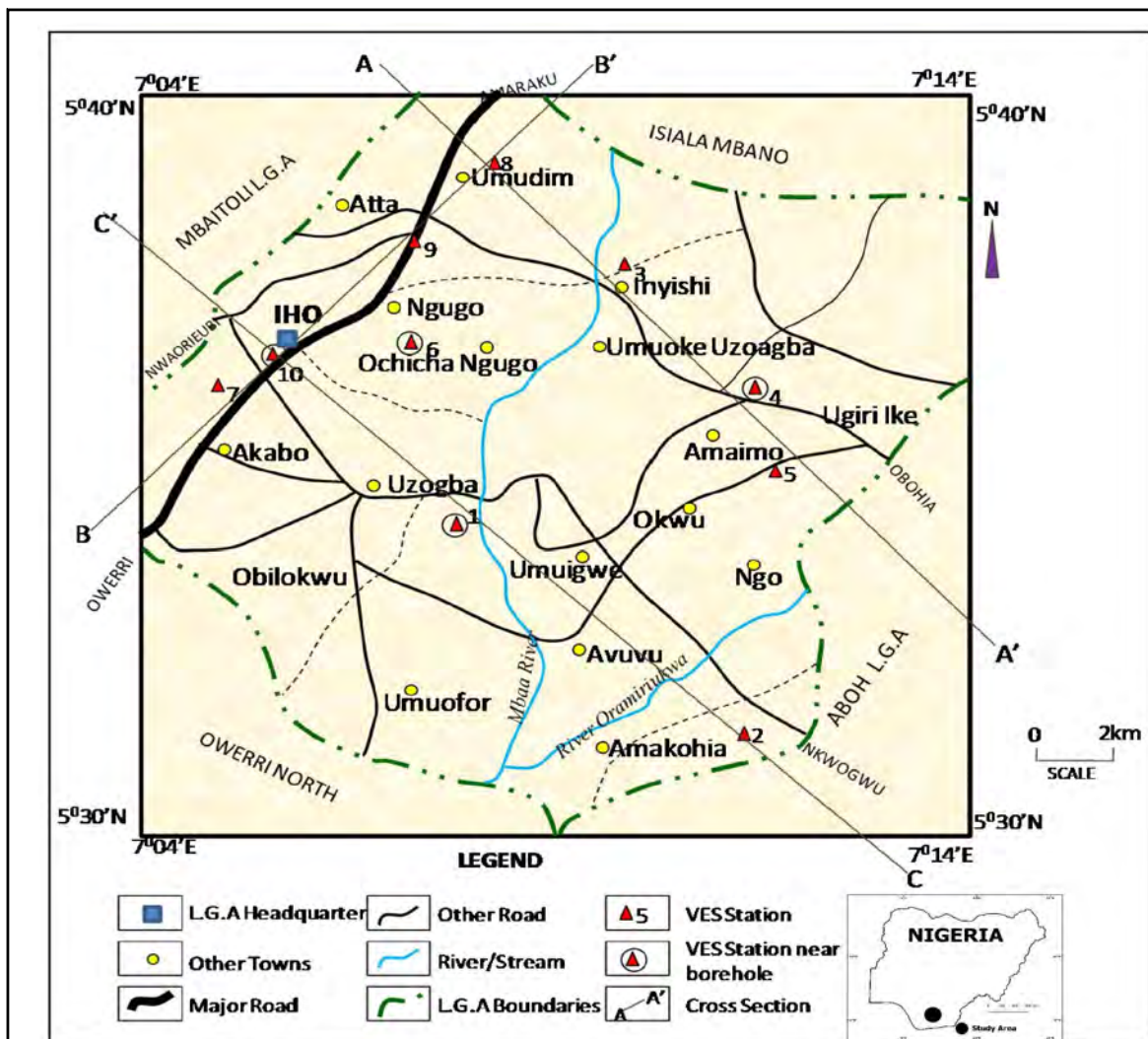
The area lies within the tropical rain forest belt of Nigeria; the natural vegetation in greater part of the area is occupied by oil palm trees, crops such as cassava, pear and other shrubs. The

area is also characterized by tall trees. The vegetation is however, undergoing alteration from constant clearing and fallowing due to farming activities by people of the area.

Geology of the Study Area

The area is part of Benin Formation (Figure 2). The Benin Formation is made up of friable sands and minor intercalation of clay. The sand units are mostly coarse grained, pebbly, poorly sorted

Figure 1: Location Map of the Area Showing VES Points and Borehole Points



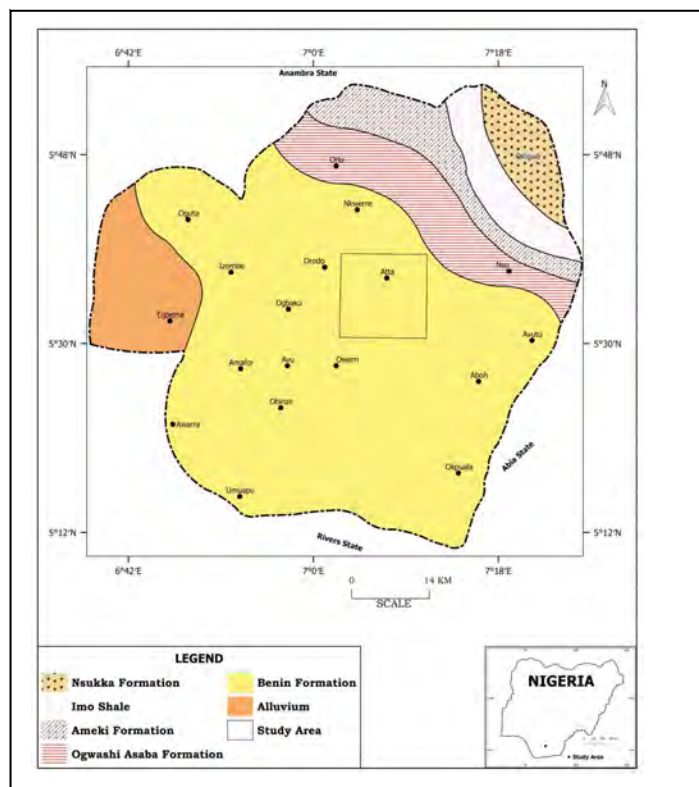
and contain lenses of fine-grained sands (Reyment, 1965). The sediments were deposited during the Late Tertiary to Early Quaternary Period. The age of the Benin Formation is from Miocene to Recent (Onyeagocha, 1980). The formation also contains some isolated units of gravels; the sands and sandstones are coarse to fine and commonly granular in texture and can be partly unconsolidated. The formation has variable thickness ranging from 0 - 2,000 metres. It is a fresh water bearing massive continental sand and gravel deposited in an upper deltaic environment (Onyeagocha, 1980). The sands may represent braided stream point bars and channel fills. The shales are few and thin and may represent back swamp deposits. Benin Formation is underlain by Ogwashi-Asaba Formation (Reyment, 1965).

Ogwashi-Asaba Formation is underlain by the Ameki Formation, which is in turn underlain by Imo shale and Nsukka Formations successively.

Methods

Since the method employed in this study involved incorporating geophysical survey with hydrogeological data, reconnaissance survey was carried out in the study area. This involved visiting sites of the acquired borehole data located at Amaimo, Uzoagba, Iho and Ngugo (Figure 1). This is important because the data obtained from these sites were useful in the determination of the aquifer hydraulic parameters. Geophysical survey involving Vertical Electrical Sounding (VES) using the Schlumberger array with maximum electrode separation of 740m was used in acquiring the resistivity data. Half-current

Figure 2: Geologic Map of Imo State Showing the Study Area (Modified After Okeke, 2001)



electrode spacing (AB/2) values range from 1.5m to 370m, ensuring about 800 feet depth of investigation. Ten different soundings were carried out in the study area; four of the soundings (parametric sounding) were made at the sites of existing boreholes.

The observed field data was converted to apparent resistivity values using equation (1).

$$\rho_a = \left(\frac{\Delta V}{I} \right) K \quad \dots(1)$$

where, "V is the voltage, I is the current flowing into the ground and "V/I is the resistance, R.

$$K = \pi \left\{ \frac{(AB/2)^2}{MN} - \frac{MN}{4} \right\} \text{ or}$$

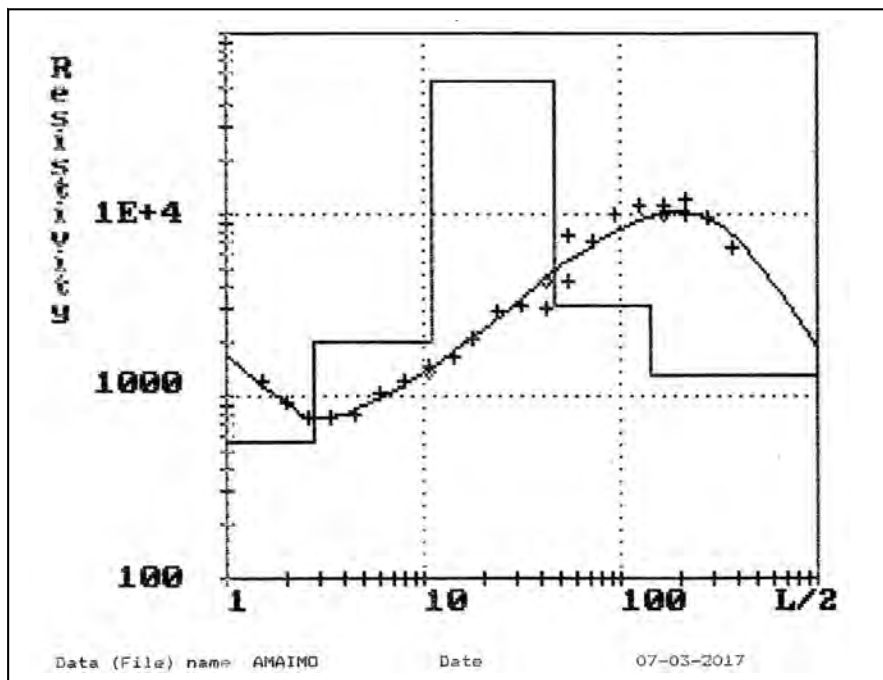
$$K = \pi \left\{ \left(\frac{a^2}{b} \right) - \left(\frac{b}{4} \right) \right\} \quad \dots(2)$$

The factor K in Equation (2) above is called the geometric factor and depends only on the electrode separation or intervals.

Data acquired from Vertical Electrical Sounding (VES) were processed using FORTRAN Resistivity 2D inverse computer program, which is an iterative inversion-modelling program. The VES data were then presented as sounding curves (Figure 3), which were obtained by plotting graphs of apparent resistivity versus half-current electrode spacing, yielding layered earth models composed of individual layers of specified depth and resistivity.

The existing borehole information from pumping test analysis of the study area was obtained using the data provided by Nwosu and Nwosu (2017).

Figure 3: Typical HK Curve Type Observed in the Study Area



Estimation of Aquifer Hydraulic Parameters

Two very relevant equations necessary in using electrical resistivity survey to determine aquifer hydraulic parameters are Transverse Resistance, T_R and Longitudinal Conductance, S_L .

The transverse resistance of the section is a sum of the resistance of the entire layers, given by;

$$T_R = \sum_{i=1}^n \rho_i h_i; \quad i = 1, 2, 3, \dots, n \quad \dots(3a)$$

Generally, the Transverse Resistance of a layer is given by the product of its resistivity, ρ and the thickness, h of that layer.

$$T_R = \rho h = \frac{h}{\sigma} \quad \dots(3b)$$

where, ρ is the resistivity of the layer,

σ is the conductivity of the layer, which is the inverse of resistivity and

h is the thickness of the layer.

Also, the conductance for the current flowing horizontally through the column of each rock is the Longitudinal Conductance, S_L is given as;

$$S_L = \frac{1}{R_i} = \sum_{i=1}^n \frac{h_i}{\rho_i} \quad i = 1, 2, 3, \dots, n \quad \dots(4a)$$

Generally, the Longitudinal Conductance of a layer is given by the product of its conductivity, and the thickness, h of that layer.

$$S_L = \sigma h = \frac{h}{\rho} \quad \dots(4b)$$

These two equations are commonly called Dar-Zarrouk parameters and are very important in hydro-geophysics in obtaining aquifer hydraulic

parameters; hydraulic conductivity, transmissivity, storativity and diffusivity.

Niwas and Singhal (1981) established an analytical relationship between aquifer Transmissivity and Transverse Resistance on one hand, and between Transmissivity and Longitudinal Conductance on the other hand. From Darcy's law, the fluid discharge Q is given by the relationship:

$$Q = -KA I \quad \dots(5)$$

$$\text{And from ohm's law, } J = -\sigma E \quad \dots(6)$$

where, Q is the discharge, K is the hydraulic conductivity, A is the cross sectional area, I is the hydraulic gradient, J is the current density, σ is the conductivity of the medium, E is the electric field intensity.

It is not easy to notice that both are similar forms of equations, but rewriting the equations,

Darcy's law becomes;

$$q = -K \left(\frac{dh}{dl} \right) \quad \dots(7)$$

And ohm's law becomes;

$$J = -\sigma \left(\frac{dV}{dr} \right) \quad \dots(8)$$

where, J is the current density, σ is the electrical conductivity, V is the electrical potential, l and r are both distances distance (metres), q is the specific discharge (discharge per unit area), K is the hydraulic conductivity (or permeability) and h is the hydraulic head. It is also interesting to note that both the hydraulic conductivity, K of the medium and the electrical conductivity, σ depends upon the porosity of the medium (they both increase with increase in porosity and vice versa).

Niwas and Singhal (1981) combined equations for transmissivity (T), transverse resistance (T_R) and longitudinal conductance (S_L) by taking into account a prism of aquifer material having unit cross-sectional area and thickness h .

$$T = Kh \quad \dots(9)$$

where, T is the transmissivity, K is the hydraulic conductivity and h is the aquifer thickness.

Dividing equation (9) by (3) and (4), we obtain;

$$T = K\sigma T_R = \frac{K}{\sigma} S_L \quad \dots(10)$$

where, T is the transmissivity, K is the hydraulic conductivity, σ is the electrical conductivity of the aquifer, T_R is the transverse resistance and S_L is the longitudinal conductance.

Niwas and Singhal (1981) proposed that the quantities ($K\sigma$) or (K/σ) are assumed to remain fairly constant within areas of similar geologic setting and water quality. Thus, knowing the hydraulic conductivity information from at least one point within the study area, and the conductivity values from the sounding interpretation for the aquifer, the transmissivity and its variation from place to place is made possible, including those areas without boreholes.

Using the relationship $K\sigma$, the transmissivity (T) of the area was determined, by combining the conductivity of the aquifer with the hydraulic conductivity (K) calculated from the pumping test data in four locations within the study area. The average value obtained from the four locations is termed the diagnostic constant and is combined with the transverse resistance from each location to obtain the various transmissivity values.

Having obtained the transmissivity values, the hydraulic conductivity, K of each location in the

study area can be obtained by simply modifying Equation (9).

The hydraulic conductivity would therefore be given as;

$$K = \frac{T}{h} \quad \dots(11)$$

where, K is the hydraulic conductivity,

T is the transmissivity and

h is the saturated thickness of the aquifer.

The Storativity (S) is the product of the specific Storage (S_s) and the aquifer thickness (h).

$$S = h * S_s \quad \dots(12)$$

To determine the storativity parameter for confined aquifers, the following rule of thumb proposed by Lohman (1972) is used:

$$S = 3 \times 10^{-6}h \quad \dots(13)$$

where, S and h are the storativity and thickness of the aquifer respectively (Hamil and Bell, 1986).

For unconfined aquifers, storage is termed specific yield, and comparing the least values of storage for both confined and unconfined aquifers, Guideal, et al. (2011) modified equation (13) as;

$$S = 3 \times 10^{-3}h \quad \dots(14)$$

Diffusivity is the ratio of hydraulic conductivity to specific Storage.

$$D = \frac{K}{S_s} \quad \dots(15)$$

where, D is diffusivity,

K is hydraulic conductivity and

S_s is the specific Storage.

The hydraulic diffusivity parameter was estimated using the formula:

$$D = \frac{T}{S} \quad \dots(16)$$

Results and Discussion

The processed data were interpreted qualitatively and quantitatively. In qualitative interpretation, the shape of the field curves is observed to get an idea about the number of layers. The study area is characterised by three major curve types (Table 1). It is observed that the study area is predominantly of a hybrid of HK and KK - type curves. Figure 3 shows a typical curve type of the study area.

The quantitative interpretation involves the numerical aspect of the interpretation, to delineate the depth in relation to the resistivity of each layer, and this proved useful in delineating the aquifer hydraulic parameters as shown in Table 2. Several hydrogeophysical 2-Dimensional distribution maps, which include aquifer depth, aquifer thickness, aquifer hydraulic conductivity, transmissivity, storativity, and hydraulic diffusivity maps were generated from the data presented in Table 2 using Surfer 14 Software.

The geoelectric sections for the various Sounding points were developed using Strata 4 software. The geoelectric sections were then correlated according to those lying along the same profile. This generated three profiles or cross sections along the ten sounding points labelled profiles A – A', B – B' and C – C' (Figure 1).

Profile A – A' runs in Northwest-Southeast direction and cuts across VES 8; (Atta), VES 3 (Inyishi), VES 4 (Amaimo) and VES 5 (Okwu) (Figure 4). VES 8 has six layers comprising of Lateritic soil, clayey sand, clay, dry coarse sand/gravel, saturated sand and medium sand. The fifth layer is the aquifer with a resistivity of 1752Ωm and a thickness of 87.8 metres. VES 3 has six layers comprising Lateritic soil, clay, fine sand, saturated sand and medium sand. The fourth layer is the aquifer with a resistivity of 4110Ωm and a thickness of 37.1 metres.

VES 4 has six layers comprising Lateritic soil, clayey sand, clay, dry coarse sand/gravel, saturated sand and medium sand. The fifth layer is the aquifer with a resistivity of 3175Ωm and a

Table 1: Qualitative Interpretation of the VES Points

VES No.	Locations	Curve Type	Number of Layers
1	Uzoagba	HK	6
2	Owo Amakohia	KK	6
3	Inyishi	HK	6
4	Amaimo	HK	6
5	Okwu	KK	6
6	Ngugo	KHK	6
7	Amii Akabo	KK	7
8	Atta	KHK	6
9	Amaeke Udo Atta	KK	7

Table 2: Aquifer Parameters of the Study Area

VES No.	Location	Aquifer				k Value from Borehole (m/day)	Kσ	Transverse resistance (Ω-m ²)	Longitudinal Conductance (Ω-1)	Hydraulic Conductivity (m/day)	Transmissivity (m ² /day)	Storativity	Diffusivity (m ² /day)
		Depth (m)	Thickness (m)	Resistivity (ωm)	Conductivity (ωm) ⁻¹								
1	Uzoagba	71.4	103.6	2140	0.0004673	4.24	0.00198	221704	0.048411	3.85	399.07	0.3108	1284.000
2	Owo Amakohia	35.4	99.6	15600	0.0000641	-		1553760	0.006385	28.08	2796.77	0.2988	9360.000
3	Inyishi	40.5	37.1	4110	0.0002433	-		152481	0.009027	7.40	274.47	0.1113	2466.000
4	Amaimo	47.1	92.9	3175	0.0003150	3.02	0.00095	294957.5	0.029260	5.72	530.92	0.2787	1905.000
5	Okwu	56.1	136.9	8200	0.0001220	-		1122580	0.016695	14.76	2020.64	0.4107	4920.000
6	Ngugo	44.7	88.3	1980	0.0005051	4.75	0.00240	174834	0.044596	3.56	314.70	0.2649	1188.000
7	Ami Akabo	33.8	53.3	8500	0.0001176	-		453050	0.006271	15.30	815.49	0.1599	5100.000
8	Atta	26.2	87.8	1752	0.0013298	-		66025.6	0.116755	1.35	118.85	0.2634	451.200
9	Udo Atta	65.7	120.3	7410	0.0001350	-		891423	0.016235	13.34	1604.56	0.3609	4446.000
10	Iho	43.1	34.1	16200	0.0000617	29.8	0.00184	552420	0.002105	29.16	994.36	0.1023	9720.000

Table 3: Range of Values of Hydraulic Conductivity and Permeability (after Freeze and Cherry, 1979)

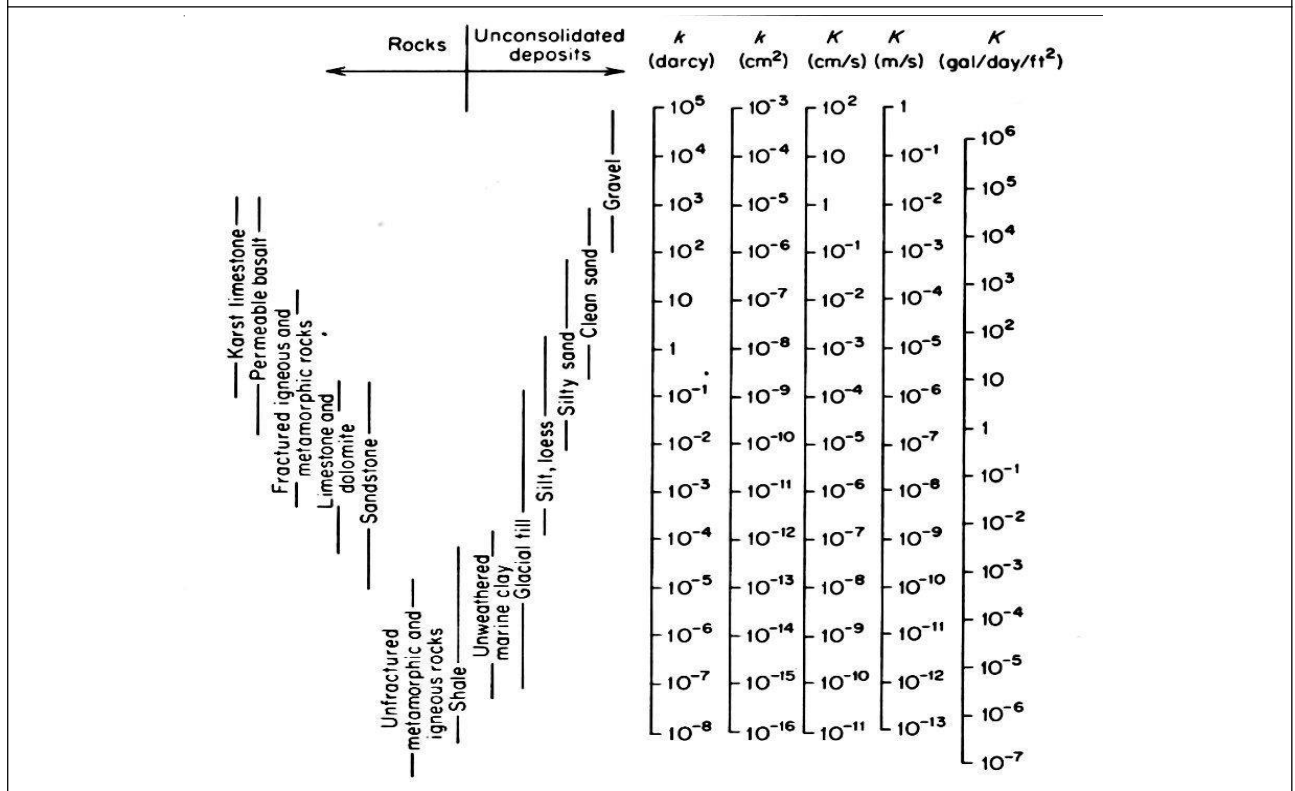


Table 4: Standards for Transmissivity (After Gheorge, 1978)

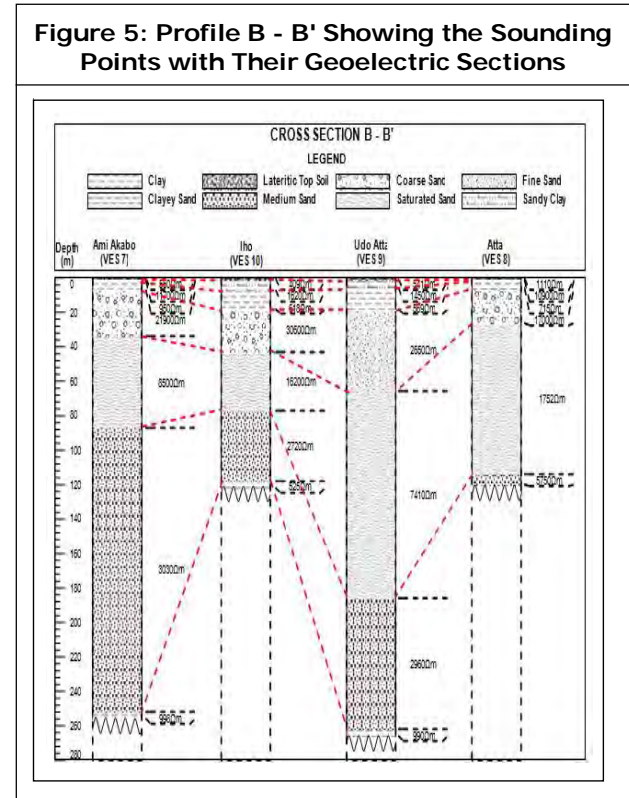
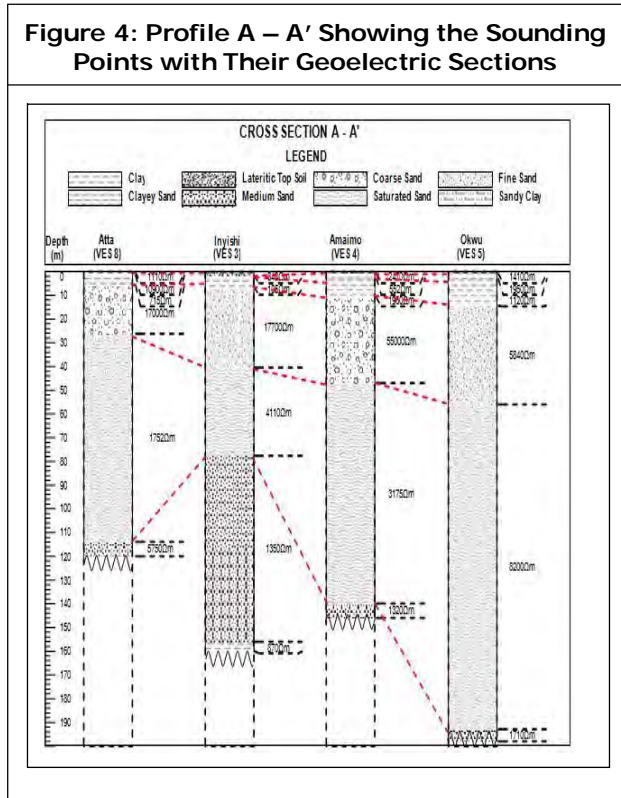
Transmissivity Range (m ² /day)	Transmissivity Potential
> 500	High potential
50 - 500	Moderate potential
5 - 50	Low potential
0.5 - 5	Very low potential
< 0.5	Negligible potential

thickness of 92.9 metres. VES 5 has six layers comprising Lateritic soil, clayey sand, clay, fine sand, saturated sand and medium sand. The fifth layer is the aquifer with a resistivity of 8200Ωm and a thickness of 136.91 metres.

Profile B – B’ runs in Northeast-Southwest direction and cuts across VES 7 (Ami Akabo), VES 10 (Iho), VES 9 (Udo Atta) and VES 8 (Atta) (Figure 5).

Table 5: Standards for Transmissivity (After Krasny, 1993)

Transmissivity(m ² /day)	Designation	Groundwater Supply Potential
> 1000	Very high	Withdrawal of great regional importance.
100 - 1000	High	Withdrawal of lesser regional importance.
10 - 100	Intermediate	Withdrawal of local water supply (small communities, plants, etc.).
1 - 10	Low	Smaller withdrawal for local water supply (private consumption).
0.1 - 1	Very low	Withdrawal for local water supply with limited consumption.
< 0.1	Impermeable	Sources for local water supply are difficult, if possible to ensure.

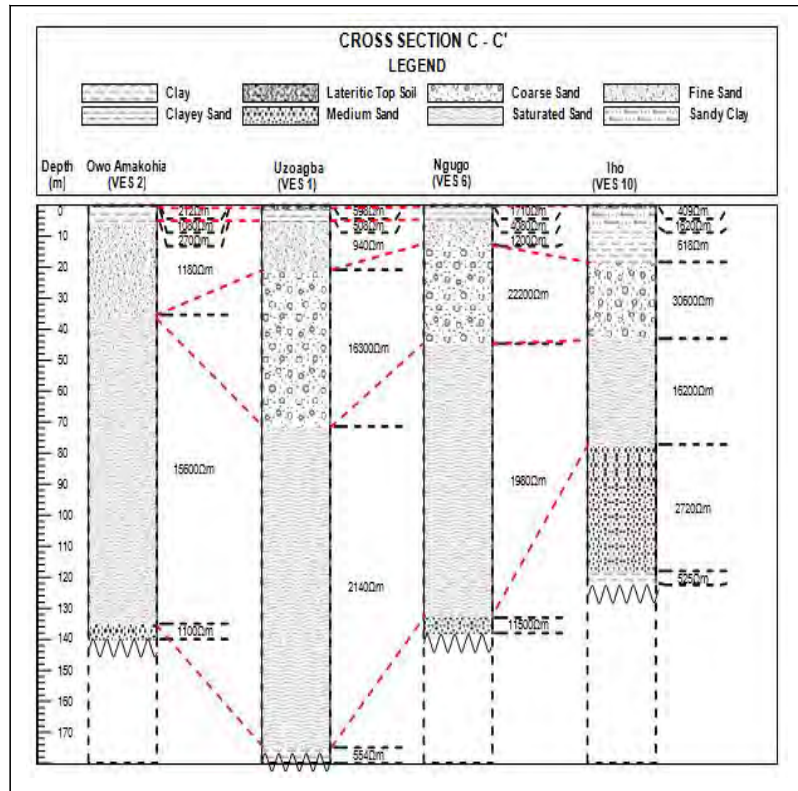


VES 7 has seven layers comprising lateritic soil, clayey sand, clay, dry coarse sand/gravel, saturated sand, medium sand and clay as the final layer probed by the sounding. The fifth layer is the aquifer with a resistivity of 8500Ωm and thickness of 53.3 metres. VES 10 has seven layers comprising lateritic soil, clayey sand, clay, dry coarse sand/gravel, saturated sand, medium sand and clay as the final layer. The fifth layer is the aquifer with a resistivity of 16200Ωm and thickness of 34.1 metres. VES 9 has seven layers comprising lateritic soil, clayey sand, clay, fine sand, saturated sand, medium sand and the final layer probed is clay. The fifth layer is the aquifer with a resistivity of 7410Ωm and thickness of 120.3 metres.

Profile C – C’ also runs in Northwest-Southeast direction and cuts across VES 2 (Owo Amakohia), VES 1 (Uzoagba), VES 6 (Ngugo) and VES 10 (Iho) (Figure 6).

VES 2 has six layers comprising of Lateritic soil, clayey sand, clay, fine sand, saturated sand and medium sand. The fifth layer is the aquifer with a resistivity of 15600Ωm and a thickness of 99.6 metres. VES 1 has six layers comprising of Lateritic soil, clayey sand, clay, fine sand, saturated sand and clay. The fifth layer is the aquifer with a resistivity of 2140Ωm and a thickness of 103.6 metres. VES 6 has six layers comprising of Lateritic soil, clayey sand, fine sand, dry coarse sand/gravel, saturated sand and medium sand. The fifth layer is the aquifer with a resistivity of 1980Ωm and a thickness of 88.3 metres.

Figure 6: Profile C – C’ Showing the Sounding Points with Their Geoelectric Sections



The results indicate that the shallowest aquifer has a depth of 26.2 metres at Atta, while the deepest aquifer has a depth of 71.4 metres at Uzoagba (Figure 7). Hence, shallow and semi-deep aquifers were encountered in the study area.

The configuration of the aquifer depth in the study area was also found to follow similar trend with the topography of the area (Figure 8). Aquifer thicknesses range between 34.1 metres at Iho to 136.9 metres at Okwu (Figure 9).

Figure 7: 2-D Distribution Map of the Aquifer Depth of the Study

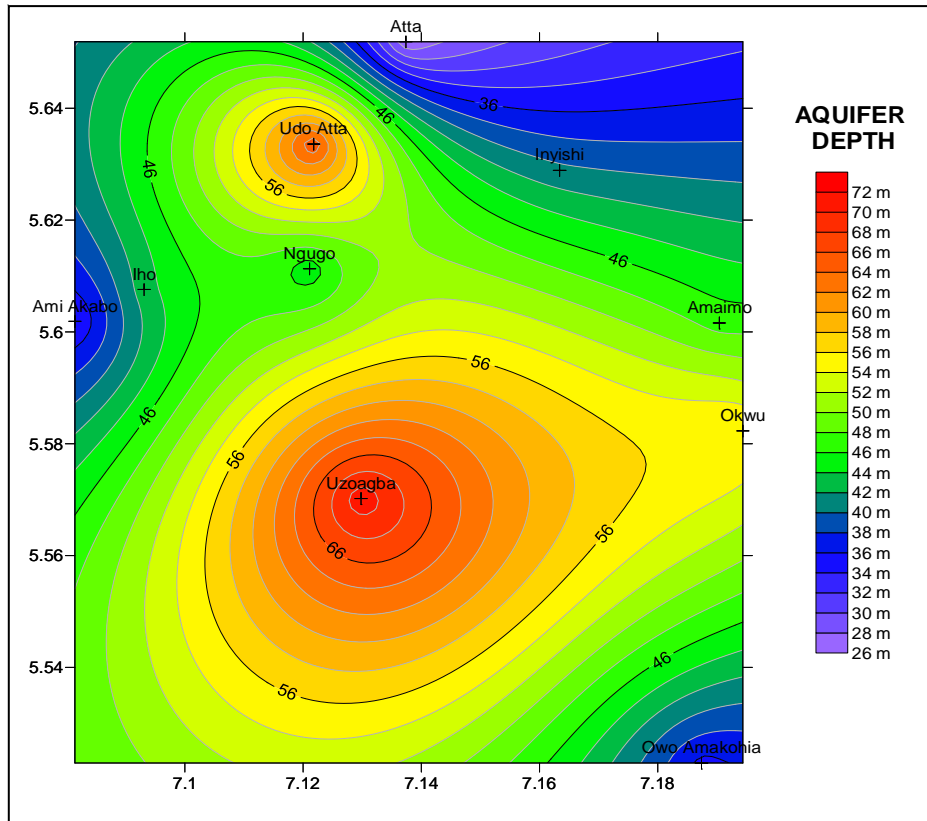


Figure 8: Configuration of Water Table and Topography
 (a) Cross Section A – A' (b) Cross Section B – B' (c) Cross Section C – C'

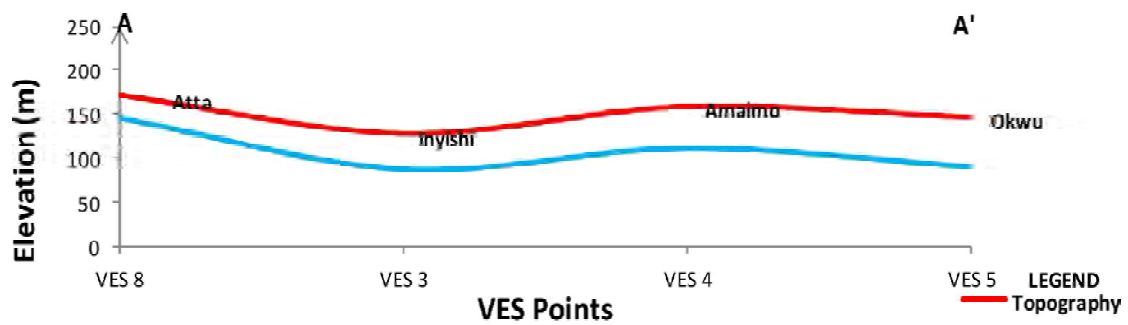


Figure 8 (Cont.)

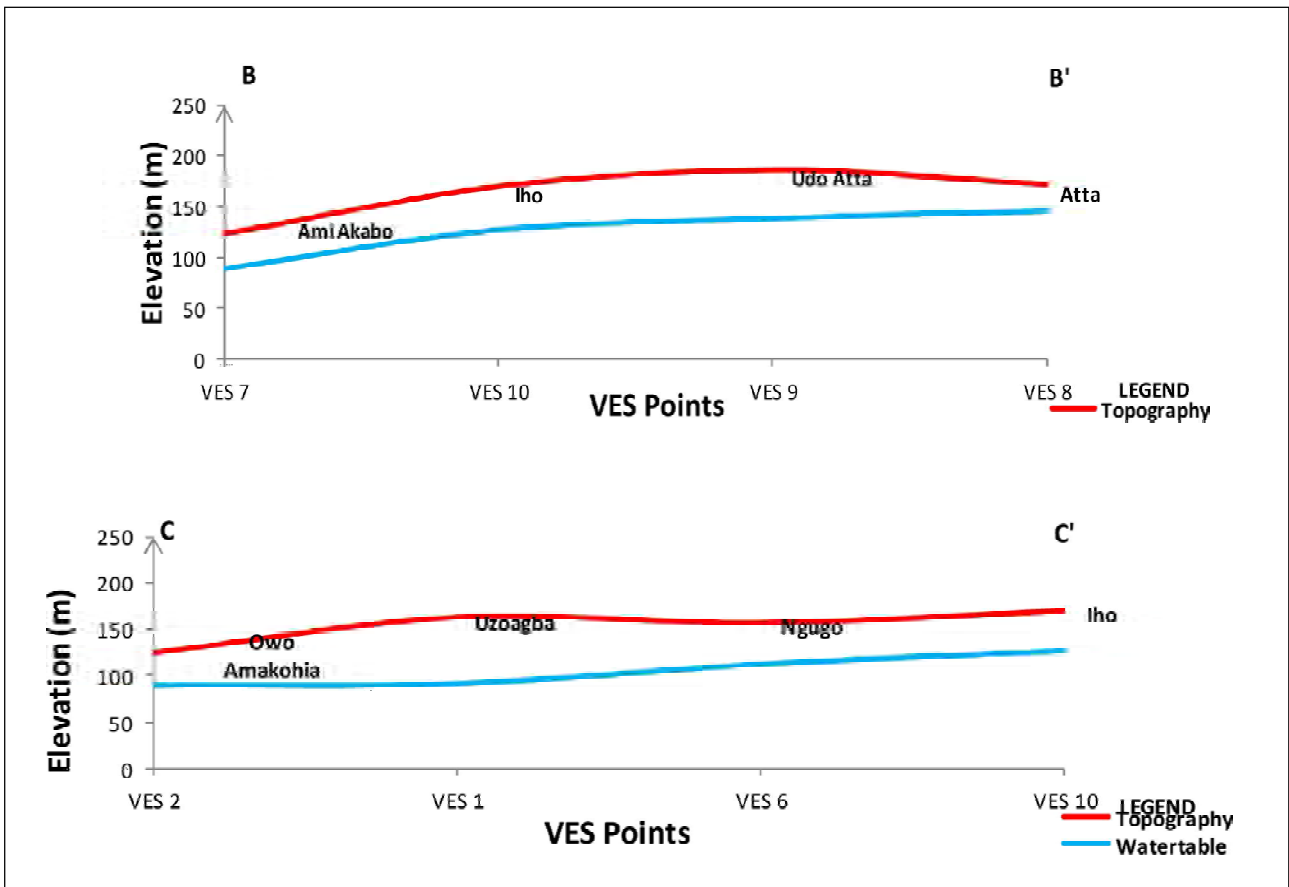


Figure 9: 2-D Distribution Map of the Aquifer Thickness of the Study Area

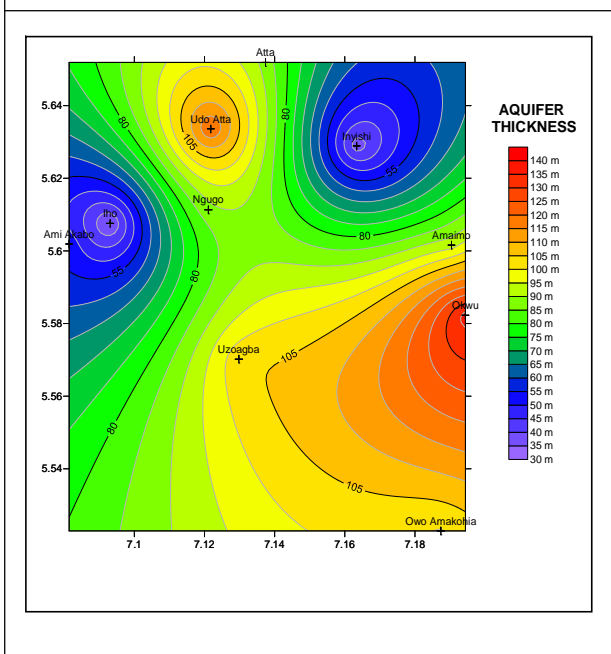


Figure 10: 2-D Distribution Map of the Hydraulic Conductivity of the Study Area

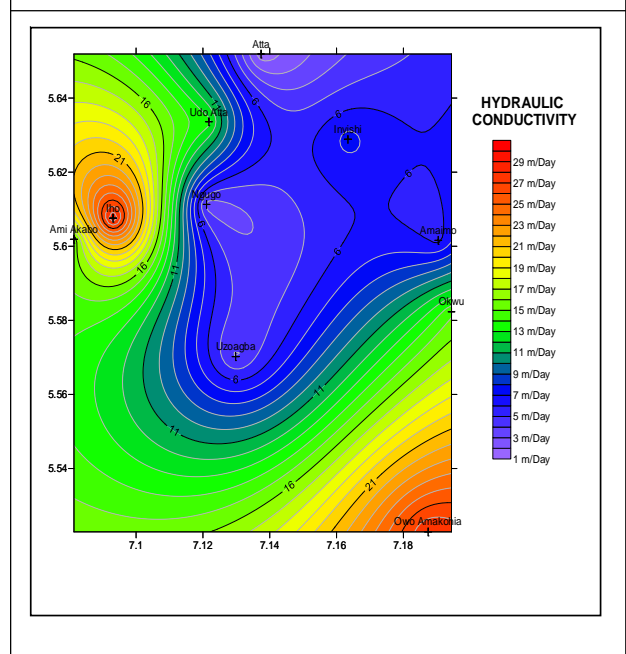


Figure 11: 2-D Distribution Map of the Transmissivity of the Study Area

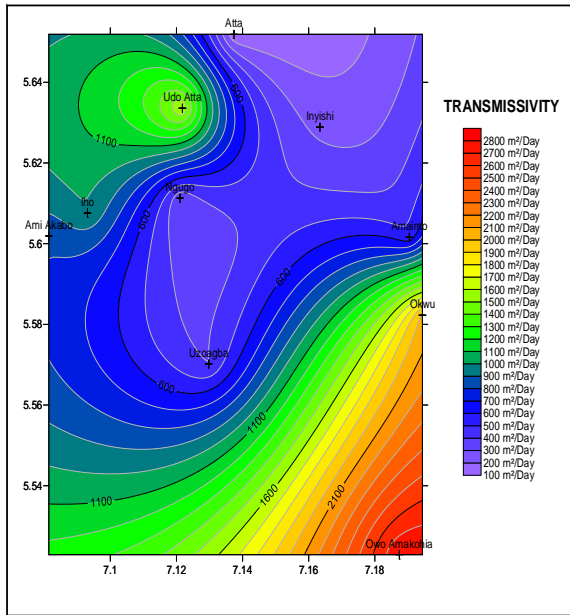


Figure 12: 2-D Distribution Map of the Storativity of the Study Area

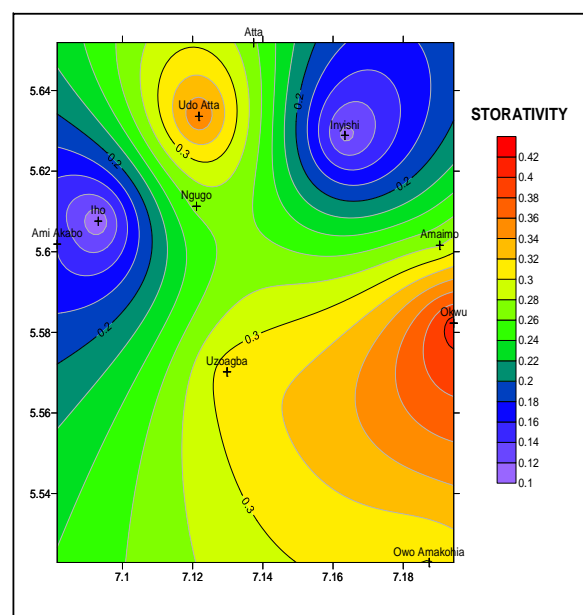
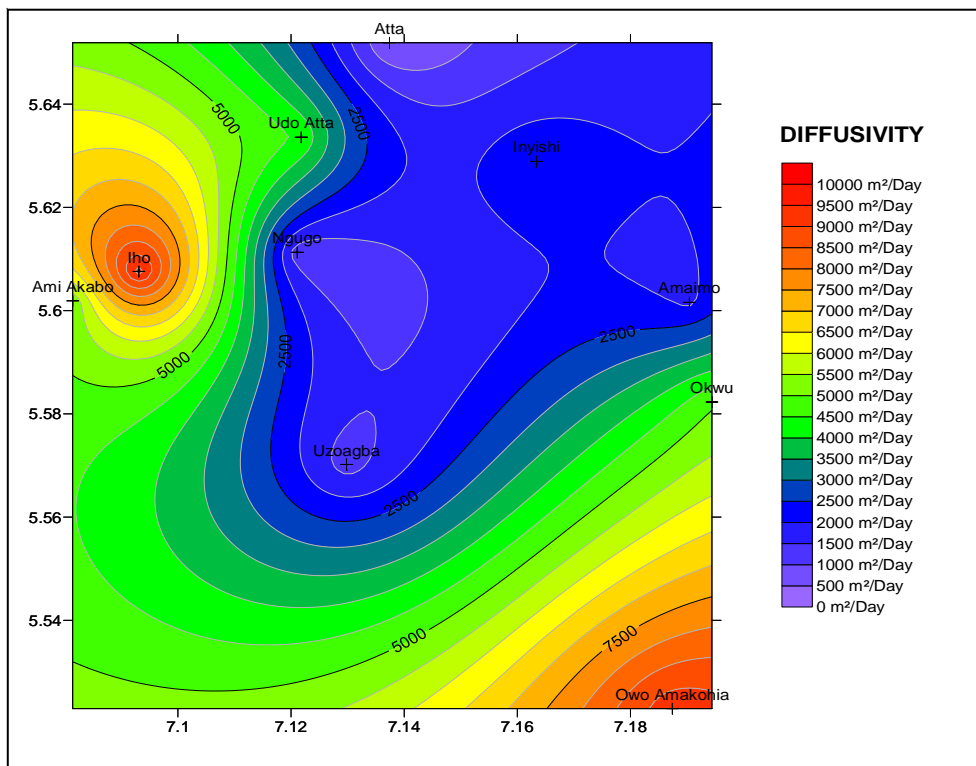


Figure 13: 2-D Distribution Map of the Diffusivity of the Study Area



The various aquifer hydraulic parameters were obtained on the basis of the diagnostic constant (K_0), which was found to be fairly constant in the area ranging from 0.00095 to 0.0024. By taking the average from the four locations, the diagnostic constant, K_0 used to estimate the various aquifer hydraulic parameters of the study area was 0.0018.

Aquifer hydraulic conductivity varies from 1.35 m/day at Atta to 29.16 m/day at Iho (Figure 10), having similar hydraulic conductivity with that calculated from the pumping test data (29.8 m/day at Iho). The mean hydraulic conductivity for the area, K_{mean} is 12.25 m/day. Comparing the values for the hydraulic conductivity in the study area with the range of values of hydraulic conductivity shown in Table 3, shows that the aquifer material in the study area is clean sand, with values between 1.56×10^{-5} m/s (1.35 m/day) to 3.38×10^{-4} m/s (29.16 m/day).

Transmissivity values vary between 314.7 m²/day at Ngugbo to 2796.8 m²/day at Owo Amakohia (Figure 11). High transmissivity values typical of Benin Formation were also recorded at Okwu, Udo Atta and Iho. The mean transmissivity for the area, T_{mean} is 987.0 m²/day.

From Table 4, it can be seen that the aquifers in the study area are in two classes: those with moderate transmissivity potential and those with high transmissivity potential. From Table 5, the aquifers are grouped into two groups: those with very high potential, which is of great regional importance, and those with high potential, which is of lesser regional importance. Transmissivity affects the shape of the drawdown. If the transmissivity is high as is the case in the study area, then the drawdown will be broad and shallow implying high groundwater yield during abstraction.

Aquifer storativity ranges between 0.1023 at Iho to 0.4107 at Okwu (Figure 12); a uniform storativity potential for the area. Aquifer hydraulic diffusivity for the area varies between 451.2 m²/day at Atta to 9720 m²/day at Iho (Figure 13). The mean hydraulic diffusivity for the area is 7936.9 m²/day.

Conclusion

Combination of geoelectrical and hydrogeological data has proved effective in determining the aquifer hydraulic parameters in the study area. Computer modelled interpretation techniques helped to resolve the aquifer thickness, aquifer resistivity and depth to the aquiferous zones. The high resistivity values associated with most locations in the area is possibly due to the presence of loose sand and sand formation, which corresponds to the local geology of Ikeduru Area, which is Benin Formation (coastal plain sands). Using the Dar-Zarrouk concept the hydraulic conductivity, transmissivity, storativity and diffusivity were determined. The obtained hydraulic parameters are indicative that the area is suitable for sustainable groundwater development.

The strength of this method is the possibility and simplicity in estimating the hydraulic parameters of aquifers if pumping test data from a few boreholes in the area is known thereby reducing the additional cost of undertaking pumping tests. The limitation of this method however is its unsuitability in areas with complex geological setting.

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