ESTIMATION OF AQUIFER TRANSMISSIVITY FROM GEO-PHYSICAL DATA. A CASE STUDY OF COVENANT UNIVERSITY AND ENVIRONS, SOUTHWESTERN NIGERIA

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ABSTRACT: *The combination of geoelectric resistivity layer and thickness in the Da-zarrouk parameters (such as longitudinal conductance and transverse resistance) has been proved to be useful in the evaluation of aquifers transmissivities around Covenant University and its environs. It was observed that the study area is underlain by the unconsolidated to semi-consolidated Coastal Plain Sand (Benin Formation). Geoelectrical resistivity method was used in the study. Sixteen geoelectric soundings known as Vertical electrical Sounding data was acquired in the study area using Schlumberger array configuration at maximum electrode spacing of 420 m. Four (4) geoelectric soundings were carried out in the area that near existing boreholes. Inverse resistivity model software was employed in processing the data. The result showed that the aquifer is shallow at depths that ranged from 30.6 m to 67.6 m, semi-deep at depths ranged from 70.8 m to 95.0 m and deep at depths that ranged from 96.0 m to 107.6 m. The thickness of the aquifers ranged from 14.0 m to 48.0 m. The hydraulic conductivities values ranged from 0.94 m/day to 12.83 m/day and transmissivity values ranged from 13.16 m^2/day to 515.04 m^2/day respectively. It is therefore hoped that this result would help the residents of the study area in terms of groundwater development planning and management.*

Keywords: Da-zarrouk parameters, Covenant University Ota and environs, aquifers.

1.0 INTRODUCTION

The geoelectrical resistivity techniques have been utilized in various ways for groundwater investigation [1-2-3-4-5-6]. Interpretation of true thickness and subsurface layers of aquiferous area measured from resistivity measurements have been made possible through the use of computer modeled interpretation procedure [7-8-9-10-11]. The longitudinal conductance (S) and transverse resistance (R) can be estimated when thickness and resistivity of an aquiferous zone is known. The concept of Da-zarrouk parameters was first introduced by [11]. Since then, this concept has been adopted in geosciences study for estimating hydraulic parameters of aquifers. The estimation of aquifer transmissivity of Ajali sandstone, southeastern Nigeria has been studied using the Da-zarrouk concept [8]. The aquiferous zone transmissivity of middle Imo River basins was investigated through the application of Da-zarrouk parameters [10]. Groundwater resources assessment of Imo River basins was carried out by Uma [12]. He concluded that there are three existence of aquifers in the basins namely; shallow aquifer, which is discontinuous and unconfined, semi-confined to confined with spatial variability in groundwater potential and confined aquifer which has high transmissivity values. Hydrogeophysical study of Njaba River basin was investigated by determining the hydraulic parameters (such as transmissivity, storativity etc) from geoelectric data using electrical resistivity method [13]. The aquifer transmissivity from surface geoelectric data of Owerri and environs have been studied by applying Da-zarrouk concept [13]. Estimation of hydraulic parameters from geophysical parameters (such as resistivity and other properties) has been adjudged as non-invasive and cost effective [14-15]. In this present study, the concept of Da-zarrouk functions has been applied in order to estimate the aquifer transmissivity in Covenant University Ota and its environs.

2.0 BASIC THEORY

The combination of Darcy's equation and differential form Ohm's law has been established [7]. This is to analytical address the relationship between aquifer transmissivity and transverse resistance, and transmissivity and longitudinal unit conductance on the hand.

From Darcy'slaw $Q= KIA$ 1

From Ohm's law $J= \sigma E$ 2

Where k is hydraulic conductivity in m/day, A is cross sectional area perpendicular to the flow of current in m, Q is fluid discharge, I is hydraulic gradient, J is current density, σ electrical conductivity and E is electric field intensity.

Equations (1) and (2) was combined by [7] to get

$T = K\sigma R$ 3

And $T= K/\sigma C$ 4

Where T is transmissivity = (aquifer thickness × hydraulic conductivity), R is transverse resistance (aquifer thickness × resistivity) and C is longitudinal conductance (aquifer thickness × electrical conductivity).

In this present study, equation (3) was used to estimate the aquifer transmissivity in Covenant University Ota and environs.

3.0 THE STUDY AREA AND ITS GEOLOGICAL SETTING

The study area lies between latitudes (6.6668°N - 7.2368°N) and longitudes (3.3100°E - 4.0669°N). It lies within western section of Dahomey basin. The geology of the study area is underlain by Coastal Plain Sands of the Benin Formation as shown in Figure 1.

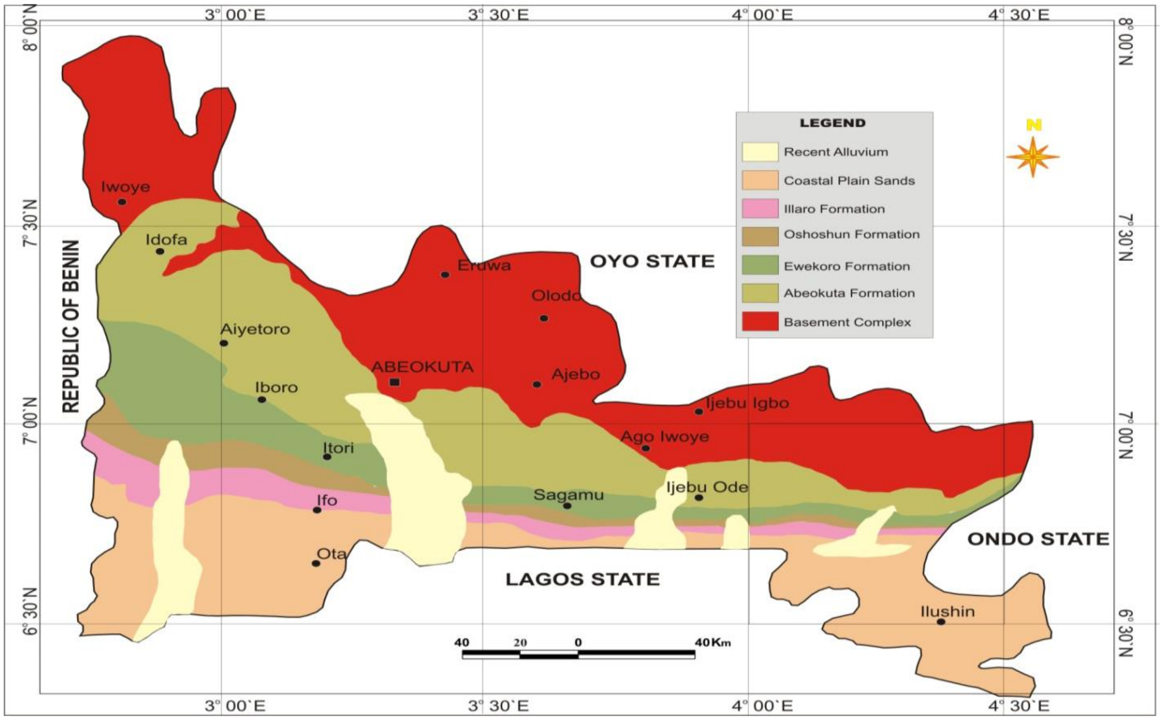


Figure 1. Geological map of Ogun State, Nigeria showing the study area (NGSA, 2006)

Figure 2. Showing geoelectric mapping within Covenant University and environs

4.0 MATERIAL AND METHODS

4.1 Data Acquisition

The locations where geoelectric sounding were taken are shown in Figure 2. Sixteen (16) geoelectric soundings using Schlumberger configuration were made with ABEM 1000/4000 terrameter series. The instrument has capacity of averaging and then recording the measured resistivity value. The maximum electrode spacing separation of 420 m was used. Four geoelectric soundings were taken at the site of existing boreholes for the purpose of comparison in order to establish the interrelationship between the geoelectric sections and subsurface geo-electrical layer. The soundings conducted at existing boreholes stations are around lecture theatre which represent VES 13, female hostel (VES 14), Male hostel (VES 15) and Professor Village borehole stations (VES 16).

4.2 Data Processing

The ABEM 1000/4000 series used in this study measured the apparent resistivity directly and the sounding curves for each geoelectric sounding was obtained by plotting the apparent resistivity against AB/2 (half electrode spacing) on a logrimathic transparent paper. Geophysical parameters such as true resistivity and thickness obtained from the method of asymptotes and partial curve matching were used to input data into computer iterative modeling [1]. Inspection of preliminary interpreted subsurface layer and geoelectric sounding curves gives the idea of resistivities of layers and its extension of areal. The quantitative interpretation of geoelectric soundings data was done using inverse modeling resistivity software.

5.0 RESULT AND INTERPRETATION

Various format such as;

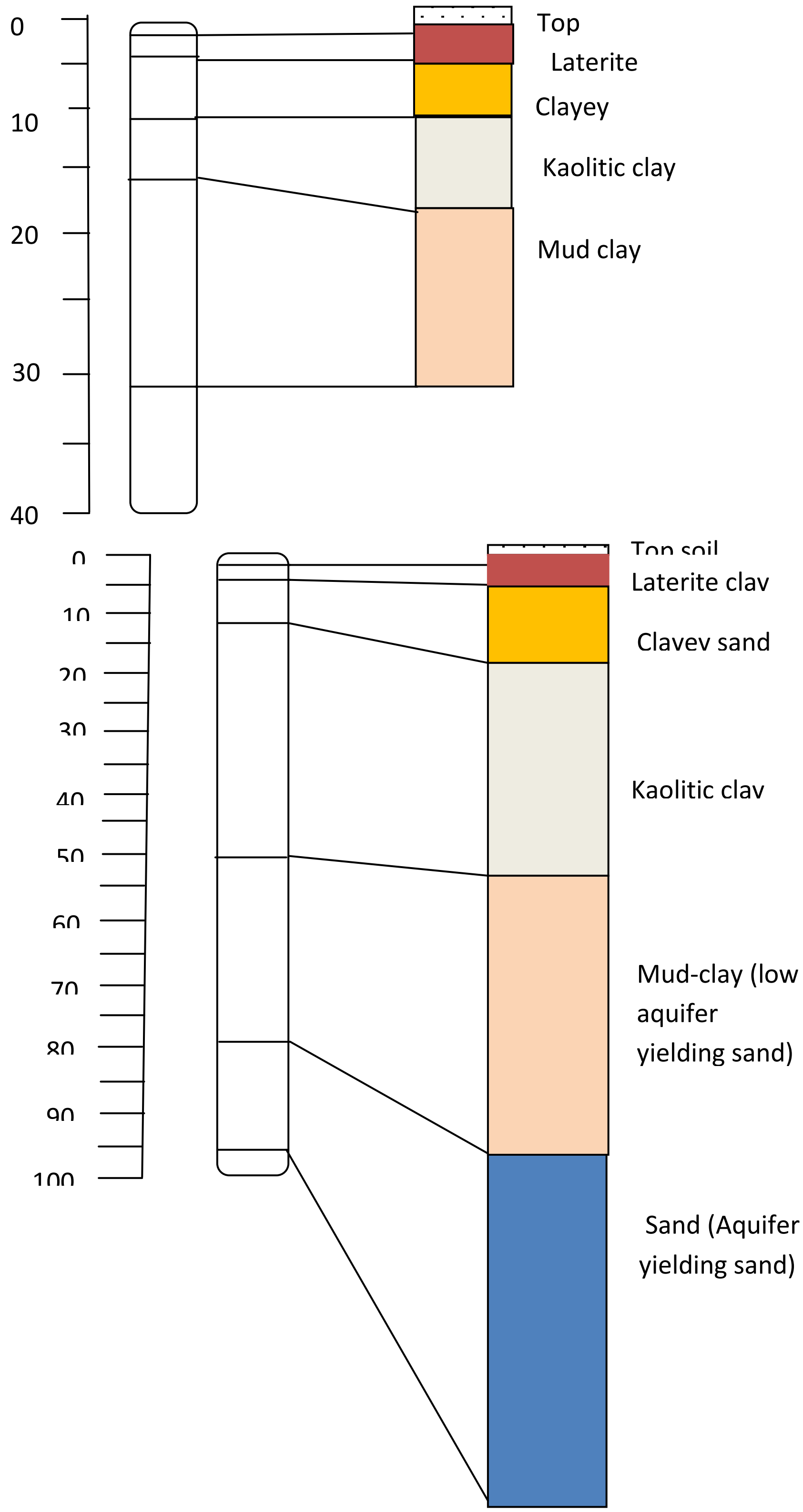
a) Comparison of VES curves and typical geoelectric sections of each sounding stations,
b) 3-D representation of depth to aquifer, Isoresistivity map and contour map for transmissivity
c) These formats above were used in presenting the results.

5.1 Comparison of VES Curves Results and Geoelectric Sections

The lithological layers varies from six (6) to eight (8) with six geoelectric layers dominating the study area except for few sounding stations that has seven and eight layers which may be as a result complexity in the subsurface geology of the area of study. However, with these numbers of layers, the geoelectric sections established five (5) to seven (7) lithologies at close range depths (Figure 3a-b). The first in the series of the lithology is top soil and the resistivity values ranged from 42.1 Ωm to 568.2 Ωm with average resistivity value of 137.1 Ωm. It is light-brown in colour. The second subsurface lithology is lateritic clay (brownish in colour) with resistivity values that ranged from 77.4 Ωm to 898.6 Ωm and it has average resistivity value of 351.49 Ωm. The third layer is termed clayey sand which is brown-reddish in colour and it has resistivity
values that ranged from 116.7 Ωm to 924.5 Ωm with mean resistivity value of 431.41 Ωm. The fourth layer is characterized as kaolitic clay and it is mixture of reddish-ash colour, its resistivity value ranged from 44.8 Ωm to 1781.5 Ωm with average resistivity value of 898.24 Ωm. The high resistivity observed in this layer may be as a result of presence of carbonaceous element in the layer. The fifth layer is characterized as mud-clay which has characteristics of orange accent and it’s designated as low yielding aquifer. Its resistivity values ranged from 116.3 Ωm to 1459.8 Ωm with mean resistivity value of 697.16 Ωm. The corresponding aquifer thickness and depth ranged from 14.0 m to 48.0 m and 30.6 m to 107.6 m respectively. The sixth layer is delineated as high yielding aquifer sand with resistivity values ranged from 38.5 Ωm to 633.5 Ωm (Figure 3a-b).

5.2 3-D Determination of Aquifer Depth

The depth to water table or aquifer was deduced from geoelectric sounding result through interpretation of sounding curves. The deduced depths showed three kinds of aquifer that exist within the study area (Figure 4) namely (a) shallow aquifer (unconfined) (b) semi-deep aquifer and (c) deep aquifer (confined). The depth of shallow aquifer ranged from 30.0 m to 59.9 m and it’s encountered in the southern part of the study area. The semi-deep aquifer ranged from 60.0 m to 80.0 m, this is sensed in the western and partly eastern of the study area. The deep aquifer ranged from 81.0 m to 107.0 m and it’s majorly sensed in the central and eastern part of the study area. Generally, the depth to water table or aquifer increases from southern part of the study area towards eastern part



3(a)

3(b)

Figure (3a-b). Typical geoelectric sections showing the varying depth and lithology

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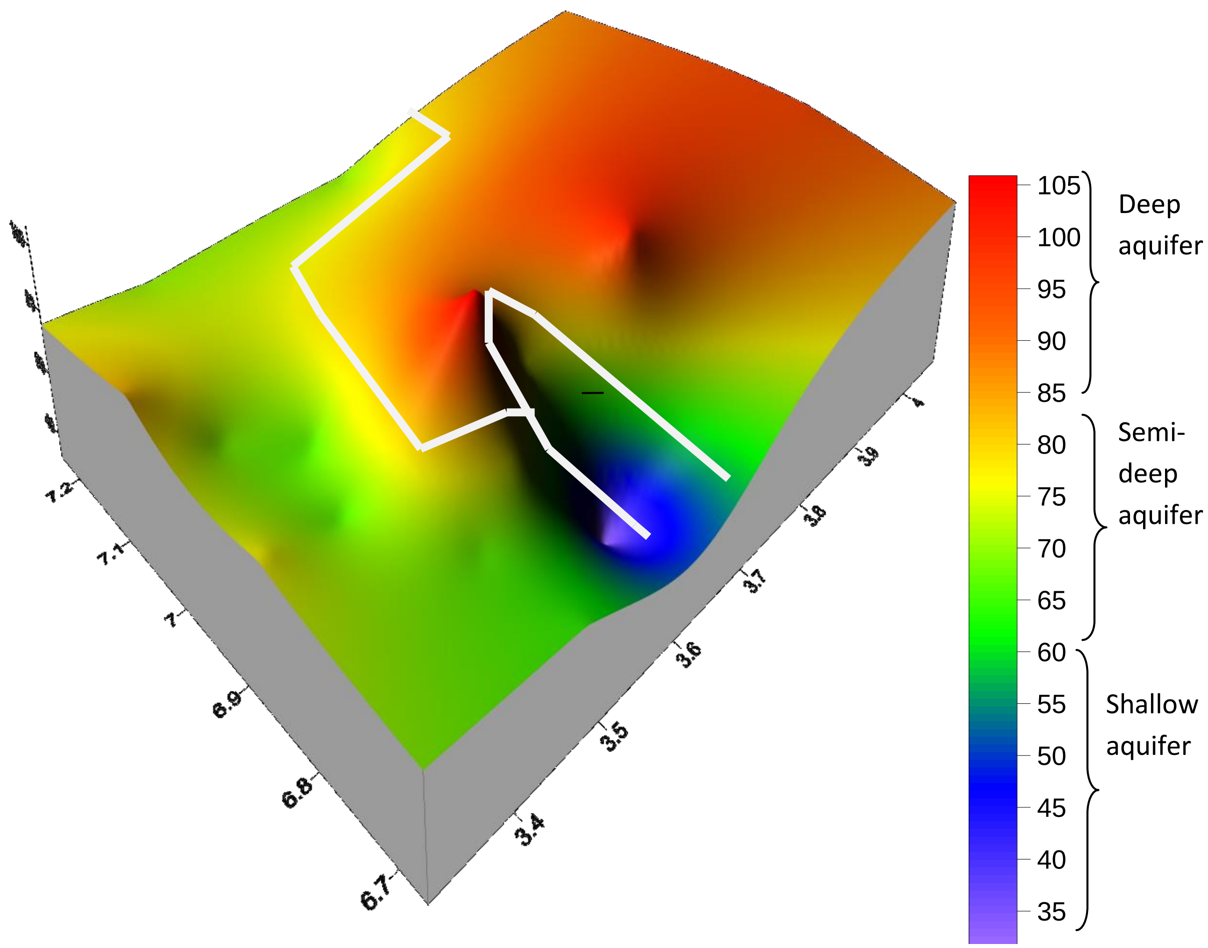

Figure 4. 3-D representation of aquifer depth

5.3 Isoresistivity and Transmissivity Map

The geoelectric sounding result was further interpreted by generating isoresistivity map of the study area (Figure 5). It was observed from Figure 5 that resistivity of the aquifer increases from southern part of the study area towards eastern. The area that has very high resistivity values has very low depth to the aquifer and was described as the shallow aquifer. The resistivity value ranged from approximately 401 .0 Ωm to 800.0 Ωm. The area of semi-deep aquifer has moderate resistivity values that ranged from 250.0 Ωm to 400.0 Ωm and it formed between shallow aquifer and deep aquifer (Figure 5). The area of deep aquifer has very low resistivity and it ranged from approximately 30.2 Ωm to 199.0 Ωm. Comparing the aquifer resistivity and 3-D aquifer representation depth, it was observed that area of low depths (shallow aquifer) has very high resistivity values followed by area of moderate depths (semi-deep aquifer) with moderate resistivity values and very high depths (deep aquifer) with very low resistivity values.

Furthermore, the transmissivity for the all geoelectric sounding stations was determined using equation (5).

$$T = Kb \quad (5)$$

where K is hydraulic conductivity, b is aquifer thickness (obtained from geoelectric sounding interpretation). This was presented in Table 1 and the contouring map which showed the trends of the transmissivity within the study area in Figure 6.

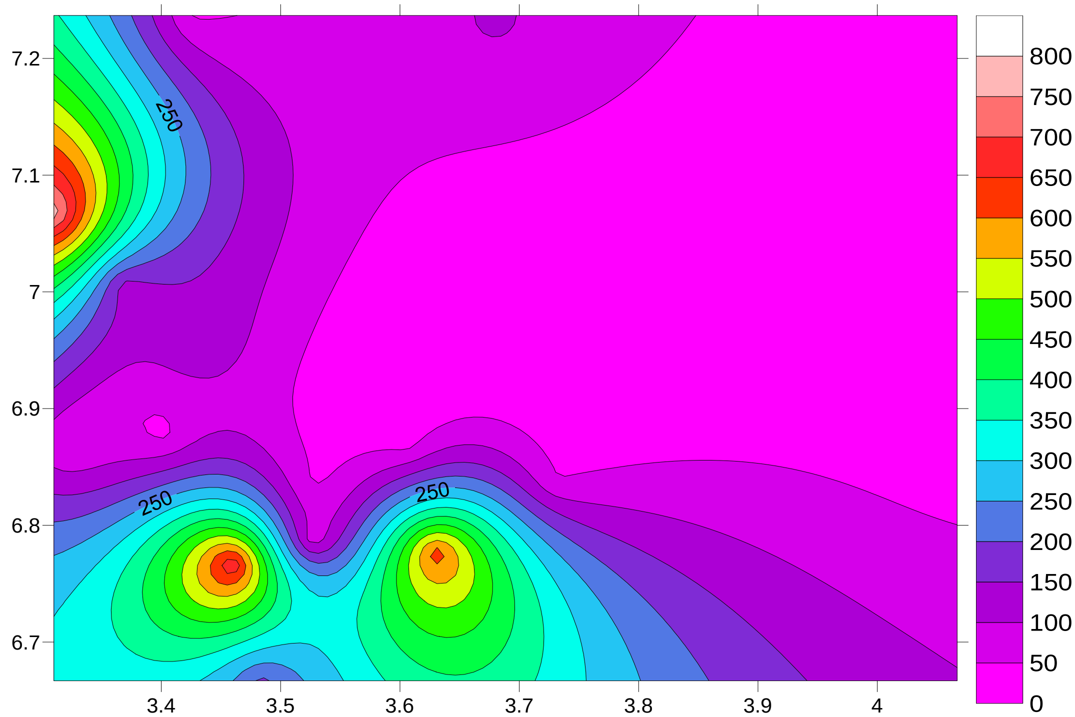

Figure 5. Isoresistivity map showing the distribution of aquifer resistivity within Covenant University and environs.

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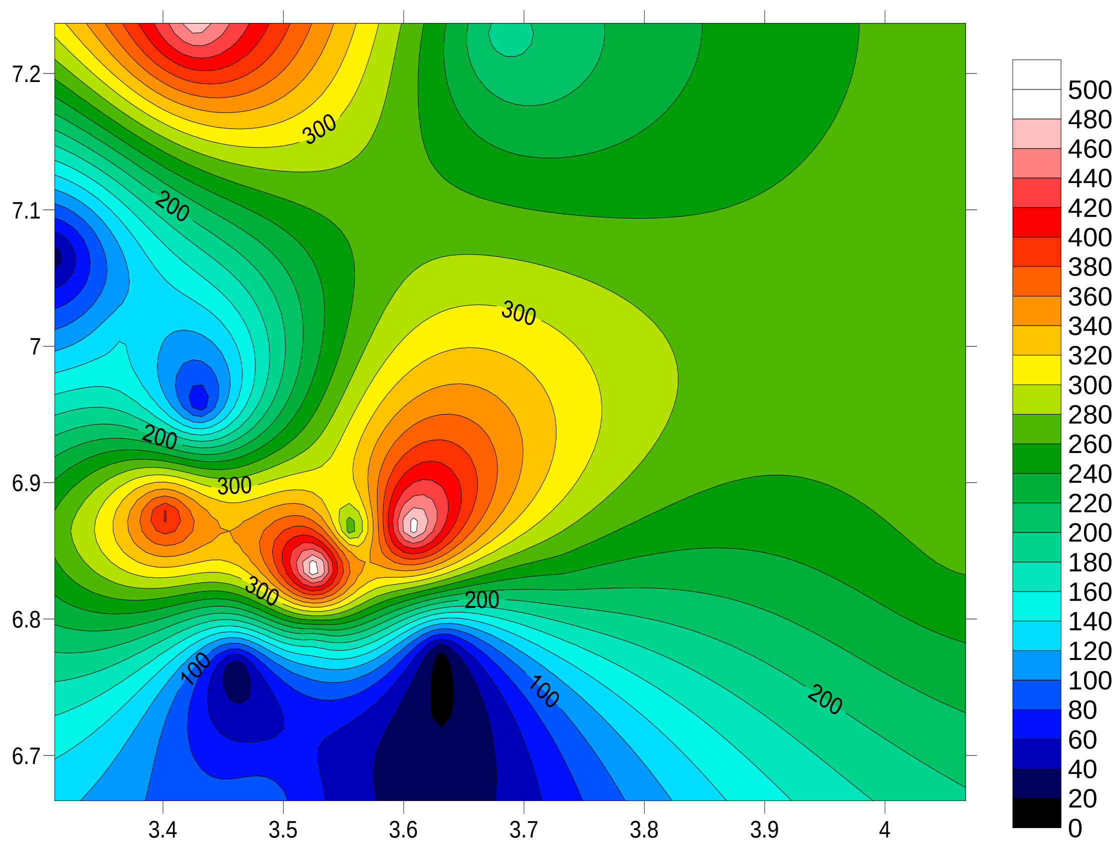

Figure 6. Contour map of transmissivity of Covenant University and environs

The estimated transmissivity values ranged from 13.16 m^2/day to 515.04 m^2/day at sounding stations (VES 1) and sounding station (VES 8) with mean transmissivity value of 230.21 m^2/day. From the study, it was observed that the area with shallow aquifer has lowest transmissivity values and it ranged from 13.16 m^2/day to approximately 119.0 m^2/day. The area with semi-deep aquifer with moderate transmissivity values ranged from 120.0 m^2/day to 280.0 m^2/day. The deep aquifer has the highest transmissivity which ranged from approximately 300.0m^2/day to 515.0 m^2/day. The hydraulic conductivity also varied from 0.94 m/day to 17.86 m/day

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Table 1 Aquifer parameters of the study area

Sounding Stations	Latitude (Deg)	Longitude (Deg)	Depth Aquifer (m)	Aquifer Thickness (m)	Aquifer Resistivity (Ωm)	Hydraulic Conductivity (m/day)	Transmissivity (m^2/day)
1	6.7768	3.6300	30.6	14.0	633.5	0.94	13.16
2	7.2303	3.6802	70.8	38.5	107.8	4.91	189.035
3	6.8667	3.5567	107.6	19.8	38.5	12.83	254.034
4	6.7868	3.5267	73.4	25.6	71.8	7.17	183.552
5	6.8669	3.6068	76.8	41.2	40.7	12.17	501.404
6	7.2368	3.4267	70.8	42.7	44.5	11.20	478.24
7	7.0069	3.3667	69.3	36.5	138.5	3.89	141.985
8	6.8368	3.5267	89.3	48.0	46.6	10.73	515.04
9	6.8667	3.3167	76.7	29.3	53.9	9.37	274.541
10	6.8567	4.0669	95.0	15.1	27.0	17.86	269.686
11	6.8368	3.7300	100.7	26.8	55.0	9.20	246.56
12	6.6668	3.4833	64.5	32.7	185.2	2.96	96.792
13	6.9568	3.4303	67.3	16.8	151.6	3.57	59.976
14	6.8768	3.4017	66.9	32.4	38.9	12.70	411.48
15	7.0667	3.3100	83.5	35.2	780.7	0.77	27.104
16	6.7668	3.4603	67.6	24.1	701.3	0.86	20.726

6.0 DISCUSSIONS AND CONCLUSIONS

The analysis of the geoelectric sounding curves of the study area has revealed the succession in the lithological layers with clays intercalates with the layers. The computer iterative model helped in resolving the true resistivity and thickness of the aquiferous lithological unit. The depth to aquifer was shallow at VES 1 (opposite guest house), VES 12 (at the back Covenant University building), VES 13 (lecture theatre borehole stations), VES 14 (Female hostel borehole stations) and VES16 (Professor Village and new estate borehole stations). The depth ranged from 30.6 m to 67.3 m. The semi-deep aquifer was found at VES 2, VES 4, VES 5, VES 6, VES 7, VES 8, VES 9, VES 10 and VES 11 all these stations are located outside Covenant University environment except VES 15 (male borehole station) at the depth that ranged from approximately 69.5 m to 95.0m. The deep aquifers sensed were located outside Covenant University community at VES 3 and VES 11 (Figure 2).The depth ranged from approximately 96.0 m to 107.6 m. From the result of this investigation, it worth noting that the aquifer system within Covenant University and environs are in three (3) categories namely shallow aquifer system which is discontinuous, unconfined aquifer system and it's regional in nature (semi-deep aquifer) and confined aquifer system (deep aquifer). Most of the boreholes drilled within Covenant University environment were on shallow aquifer except borehole drilled at male borehole station (VES 15) and this may be the reason for occasional groundwater supply shortage usually experienced from the borehole drilled at the Covenant University community. It is advisable that the borehole should be drilled at the minimum depth of semi-deep aquifer (that is from approximately 70.0 m to 95.0 m).

It is however recommended that the authority of the Covenant University community should urgently look into the borehole situation of the community to avoid acute shortage of groundwater supply that can occur as a result of borehole failure due to the shallow aquifer system on which the majority of the boreholes used by community depends on and also for future planning in terms of groundwater development and management. Further investigation is recommended in term of groundwater quality and groundwater recharging systems of the study area to ensure safe and sustainable groundwater development.

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