RESISTIVITY INVESTIGATION OF GROUNDWATER POTENTIAL IN THE CENTRAL PART OF FEDERAL CAPITAL TERRITORY (FCT), ABUJA, NIGERIA.

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Abstract
A resistivity survey was carried out in order to investigate the groundwater potential in parts of Gwagwalada Area council. The geo-electrical method used in the survey was Vertical Electrical Sounding, which was used to determine the groundwater potential of the study area. Twenty-five (25) Vertical Electrical Soundings were established using ABEM Terrameter SAS 300C using the Schlumberger configuration with a maximum current electrode spread of 100 m. The results revealed that the area was underlained by three to four geo-electric layers. The top lateritic soil has resistivity values ranging from 686 Ωm to 6364 Ωm and thickness of 0.8 m to 16.3m, the second layer is composed of sand/clay intercalation with resistivity values varying between 62 Ωm and 471 Ωm and thickness varying between 0.2 to18 m, while the partly weathered/fresh basement layer has resistivities ranging from 2084 Ωm to 11978 Ωm with thickness varying between 0.3 m to 16.5 m. Overburden thickness contour map was established across the whole 25 VES stations and average thickness value of the overburden was 10 m. The thickness and resistivity of the aquifers for twelve VES selected for the Geoelectric section have good potential for groundwater accumulation due to their overburden thickness which is mainly weathered basement with low resistivity value.

Keywords: Resistivity, Aquifer, Schlumberger Array, Overburden thickness.

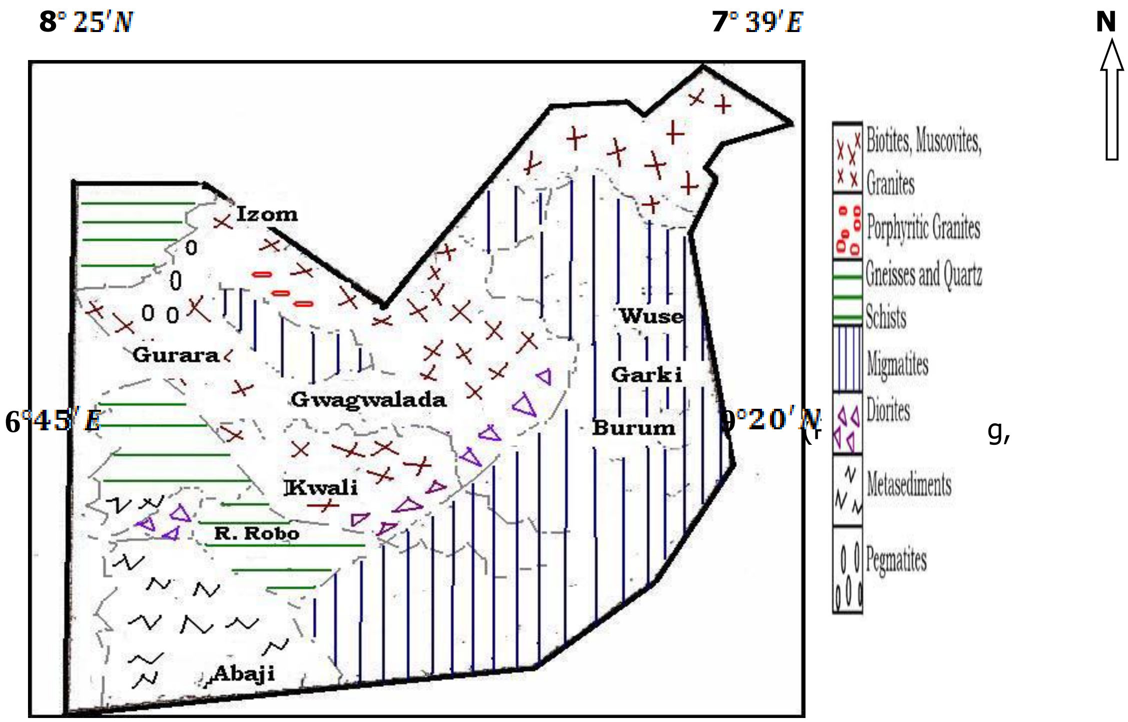
Introduction
Geophysics as its name indicates has to do with the physics of the earth and its surrounding atmosphere. In applied Geophysics several approaches maybe made to determine more accurately the exact location of a structure or deposit. It measures the apparent resistivity of soils and rocks as a function of depth or position, according to (Geovision, 2000).

According to (Telford, *et al* 1976),the purely scientific investigation of such subjects as the rate of evaporation of water from lakes, the chemical constitution of different rocks and waters from streams and ponds the measurement of natural earth currents, potential variation and impurities in the atmosphere all have definite influence on methods of locating deposits which applied geophysicist seeks.

Before any further geophysical work such as drilling can be carried out on an area surveyed by the airborne method, a confirmation has to be made using ground survey. This is because in airborne survey, geological indications tend to merge into one another thus giving an impression of only one indication (Parasnis, 1986).

Location and Geology of the Study Area
Abuja the Federal Capital Territory (FCT) in fig 1.0, lies within the longitude 6°27′00″E and 7°23′24″E and the latitude of 8°15′00″N and 9°12′00″N (Ideh and Sanni, 1998). Almost predominately are high grade metamorphic and igneous rocks of the Precambrian age (Mamman and Oyebanji, 2002). Generally the North North East (NNE) and South South West (SSW) of the FCT are made of gneiss, migmatities and granites which characterize the Northern Nigeria. The outcrop of schist belts is found along the Eastern margins of the Area the belts broadens as one moves southwards and maximum size is found to the South Eastern region of the FCT. The geology of the FCT is same as that of Gwagwalada, central part of FCT. The population grew from 80,841 to 157,770 between 1991and 2006 (NPC, 2006) and (Uzodinma, 2004).The area like most Northern Nigeria region is underlain by basement complex. The central part of FCT,

Gwagwalada consist of granite, gneiss, diorites, horn blende schist, mica schist, feldspathic, quartz schist and migmatities. While some rock outcrops are found in various places around, some are concealed by a thin weathered layer, underlying the FCT almost predominately are high grade metamorphic and igneous rocks of Precambrian age (Mamman and Oyebanji, 2002),. Gwagwalada enjoys higher rainfall total than the more southerly region of the FCT. The FCT experience heavy rainfall occurrence during the months of July, August and September .These three month contribute about 60% of the total rainfall in the region (Dawam, 2000).



Materials and MethodTheory of Method

Consider a continuous current flowing in an isotropic homogeneous medium. If δA the element surface and J the element density in ampere/meter², then the current passing through δA is $J.\delta A$. The current density J and the electric field E are related through Ohm's law:

$$J = \sigma E \qquad (1)$$

Where E is in volts/meter and σ is the conductivity of the medium in Siemens per meter (s/m).
The electric field is the gradient of a scalar potential,

$$E = - \nabla V \qquad (2)$$

Where V is in volts.Thus we have

$$J = -\sigma \nabla V \qquad (3)$$

If charge is conserved (no current sources or sinks) within a volume enclosed by a surface A, we can write

$$\int_A J.dA = 0 \qquad (4)$$

Gauss's theorem states that the volume integral of the divergence of current throughout a given region is equal to the total charge enclosed, so that in this case,

$$\int_V \nabla.J dV = 0$$

Taking V as an infinitesimal volume enclosing a given point, we get for this point

$$\nabla.J = \nabla. \nabla (\sigma V) = 0$$

Hence,

$$\nabla\sigma. \nabla v + \sigma \nabla^2 V = 0 \qquad (5)$$

INSTRUMENTATION

The ABEM Terrameter SAS 300C was used in this research work for data collection in Gwagwalada. The four electrode Schlumberger array with a maximum current electrodes spacing AB/2 of 100m was used for this survey. A rod was hammered into the ground where the site is located, which serves as the mid point from which AB/2 (half spacing between current electrodes) can be measured in both directions by means of measuring tape with respect to the required spacing from 0.3m to 5m for MN/2 (half spacing between potential electrodes).

The current and potential electrodes were then driven down into the ground at the desired spacing as indicated along the measuring tape. The rechargeable 12V battery was connected to a SAS 300CTerrameter. The current and potential electrodes are connected to an ABEM Terrameter SAS 300C with the four short cables by their clips to connect the positive and the negative terminals on the Terrameter to the two potentials reels and current cables.
AB/2 was measured in both directions from 1.0m to 100m using the reference point. Similarly MN/2 was also measured on both sides with values varying from 0.3m to 5m.

Data Analysis and Interpretation
According to Todd (1980), the electrical resistivity method of all the surface geophysical methods has been applied most widely in groundwater exploration studies; this is because it can clarify the zone and it is inexpensive (Mazac *et al* 1985). The electrical resistivity method can be best employed to estimate the thickness of the overburden and also the thickness of weathered/fractured zones with reasonable accuracy (Zohdy *et al*, 1974.)

From Table 1.0, it is evident that the only type of three layer VES sounding curve obtained in this area is the H-type, however their also exist few number of 4-layered type of VES curve namely (QH, HK- types) in basement complex terrains, the intermediate layer of the H-type is commonly water saturated and often characterized by low resistivity, high porosity, low specific yield and low permeability (Jones, 1985)

Table 2, shows the typical view of the parameter of the subsurface as obtained from the interpreted result of the study area. If the curve is taken to be one with three layers, it can be determined if it falls into one of the four types of VES curves.

1. Type H curve ($\rho_1>\rho_2<\rho_3$)
2. Type K curve (($\rho_1<\rho_2>\rho_3$)
3. Type A curve (($\rho_1<\rho_2<\rho_3$)
4. Type Q curve(($\rho_1>\rho_2>\rho_3$)

where there are more than three layers we have combination curves, for n-2, for example, a four- layer curve has a 2-letter combination like HA ($\rho_1>\rho_2<\rho_3>\rho_4$) cited by Koefoed (1984).

Data Presentation.
Table 1 shows the measured resistivity, and their corresponding apparent resistivity values for VES 1,VES 2 and VES3 collected from different parts of Gwagwalada Area council, the AB/2 ranges from 1m to 100m respectively while the MN/2 ranges from 0.3m to 5.0m respectively and the K value was calculated using eqn (3). The results of the remaining 22 VES in presented in Appendix A. The resistivity value of each of the VESwas gotten via the Terrameter and the apparent resistivity was calculated for each of the VES using eqn (4).

$$\rho a = \frac{\pi\{(\frac{AB}{2})^2 - (\frac{MN}{2})^2\} R}{MN} \qquad (6)$$

Data Interpretation

Fig 2.0 shows the Map of the survey area indicating the number of VES points, their locations and lines of profile of each of the data interpreted.

Fig 3.0 shows the interpretation obtained for VES 1, VES 2 and VES 3 .The data was interpreted using the convectional curve matching and (WinResist) computer iteration method. Each of the resistivity plots, shows number of layers, resistivity, thickness and depth of the area.

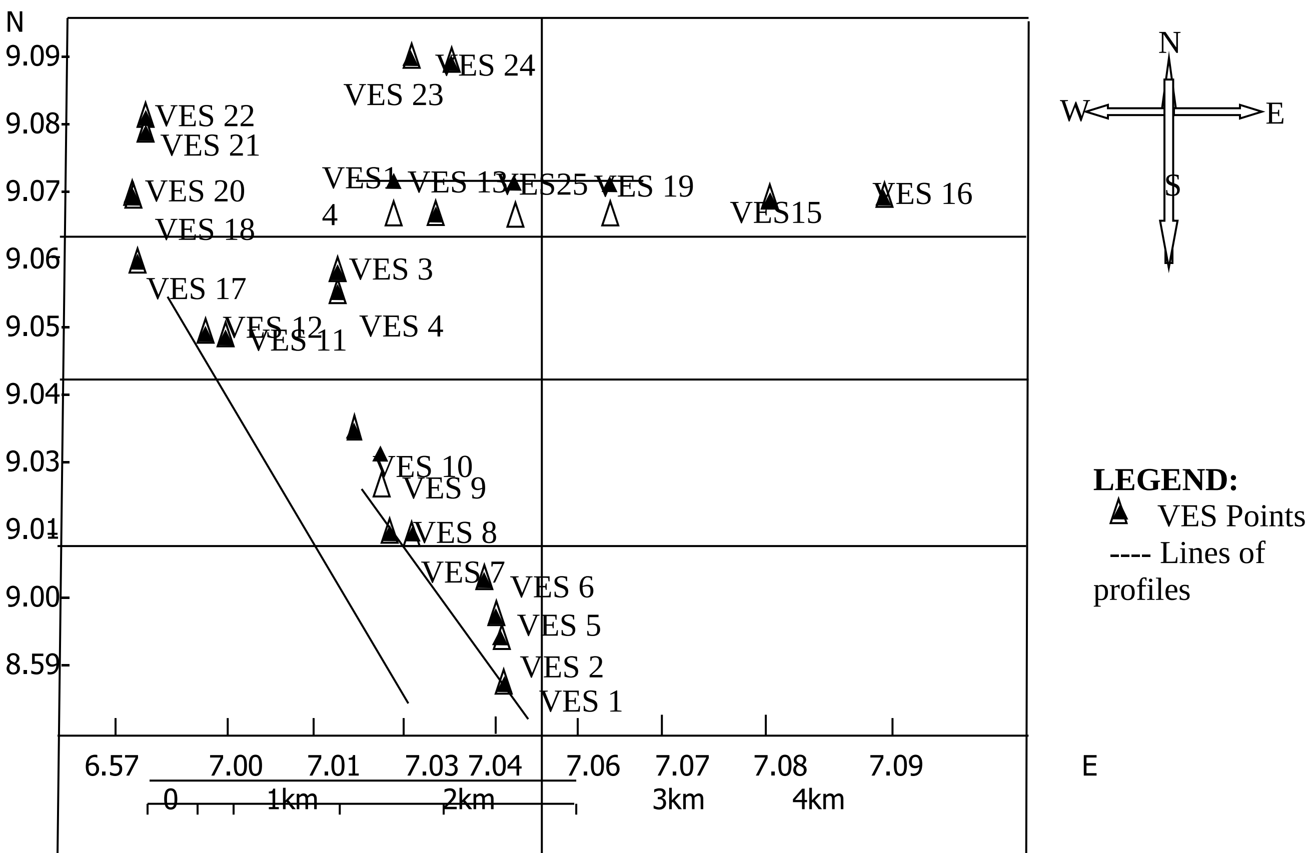


Fig 2.0: Location Map showing VES points and lines of profile.

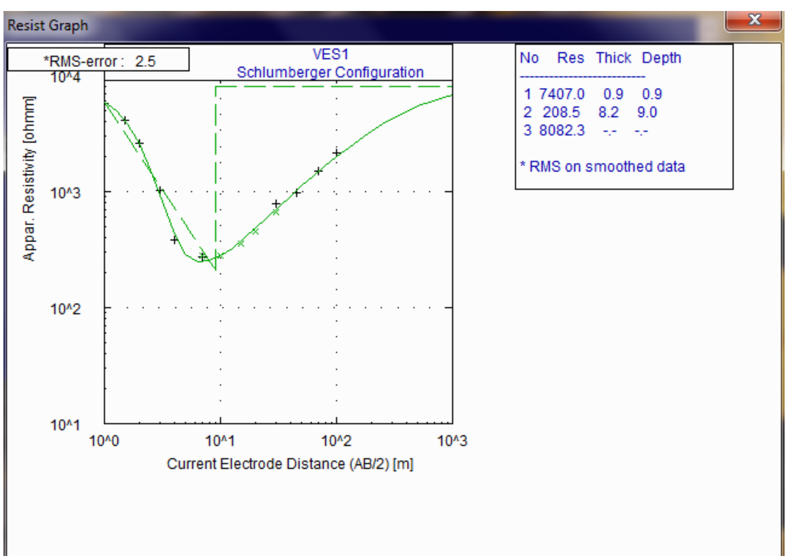
Table 1: Result of VES 1, VES 2 and VES3

S/NO	AB/2	MN/2	K	VES 1 LATITUDE N08°59′255″ LONGITUDE E07°04′848″		VES 2 LATITUDE N08°59′341″ LONGITUDE E07°04′911″		VES 3 LATITUDE N09°06′849″ LONGITUDE E07°01′164″	
				R (Ω)	ρ(Ωm)	R (Ω)	ρ(Ωm)	R(Ω)	ρ(Ωm)
1	1.00	0.3	4.76	1211.56	5767.0	549.37	2615.0	175.08	833.4
2	1.50		11.31	359.78	4069.1	143.15	1619.0	37.82	427.7
3	2.00		20.52	128.45	2635.8	68.81	1412.0	12.70	260.6
4	3.00		46.69	21.78	1016.9	10.82	505.2	3.83	178.8
5	4.50		105.54	3.61	381.0	3.03	319.8	1.57	165.7
6	7.00		256.09	1.07	274.0	0.59	151.1	0.66	169.0

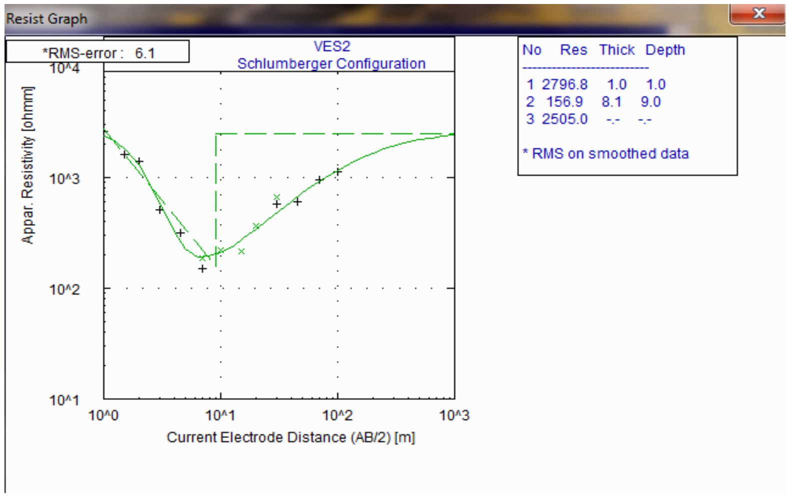
7	7.00	1.0	75.36	3.72	280.3	2.46	185.4	2.27	171.1
8	10.00		155.43	1.80	279.7	1.44	223.8	1.22	189.6
9	15.00		351.68	1.02	358.7	0.61	214.5	0.68	239.1
10	20.00		626.43	0.73	455.7	0.58	363.3	0.48	300.7
11	30.00		1411.43	0.47	663.4	0.47	663.4	0.31	437.5
12	30.00	5.0	274.75	2.84	780.2	2.12	582.5	1.99	546.8
13	45.00		628.00	1.56	979.7	0.96	602.9	1.02	640.6
14	70.00		1530.75	0.99	1515.4	0.62	949.1	0.63	964.4
15	100.0		3132.15	0.69	2161.2	0.36	1127.6	0.43	1346.8

Table 2: Interpretation of VES 1, VES 2 and VES 3.

VES STATION	LATITUDE (E)	LONGITUDE(N)	RESISTIVITY (ΩM)	THICKNESS (M)	DEPTH (M)	LAYER TYPE	CURVE TYPE
1	8.59255°	7.04848	7407.0	0.9	0.9	Topsoil	H-Type
			208.5	8.2	9.0	Weathered layer	
			8082.3	__	_	Fresh basement	
2	8.59341	7.04911	27 96.8	1.0	1.0	Topsoil	H –Type
			156.9	8.1	9.0	Weathered layer	
			2505.0	_	_	Fresh basement	
3	9.06849	7.01164	1403.3	0.5	0.5	Topsoil	H-type
			145.0	7.9	8.4	Weathered layer	
			3152.3	-	-	Fresh basement	



(a)



(b)

(c)

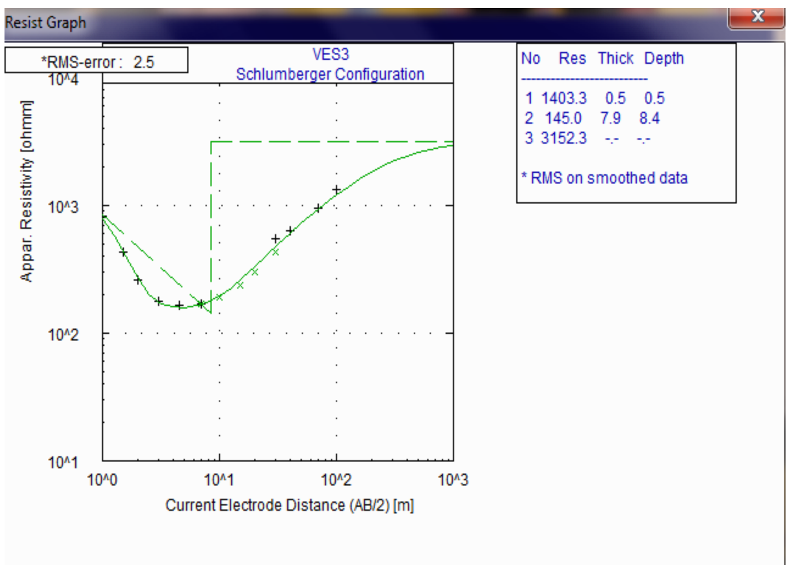


Fig. 3.0 Resistivity plot for (a) VES 1, (b) VES 2 and (c) VES 3

Deductions and Conclusions

The result of the VES interpretations was used to generate various basement maps such as 3D, the overburden thickness and the topsoil resistivity map. Fresh basement is characterized by high resistivity value which is close to 1000 Ωm in almost all the locations. The overburden is assumed to include all materials above the presumably fresh basement.

The shape of the VES curves depends on three factors: the thickness of each layer, the number of layers in the subsurface and the ratio of the resistivity of the layer.

Analysis of Geoelectric Section in each Profile:

The Geoelectric sections are shown in figures 4a, 4b, and 4c. Generally, the section revealed 3 subsurface layers. The topsoil thickness is relatively thin along this section (figure 4a, 4b, 4c).

The geo-electric characteristics give the respective layer resistivity values and thickness. The sections identified a maximum of three geologic subsurface layers. The study of this layer shows that the resistivity value of fresh bedrock often exceeds 1000 Ωm, but where it is fracture /sheared and structured with fresh water, the resistivity often reduces to below 1000 Ωm (Olayinka and Olorumfemi, 1992).

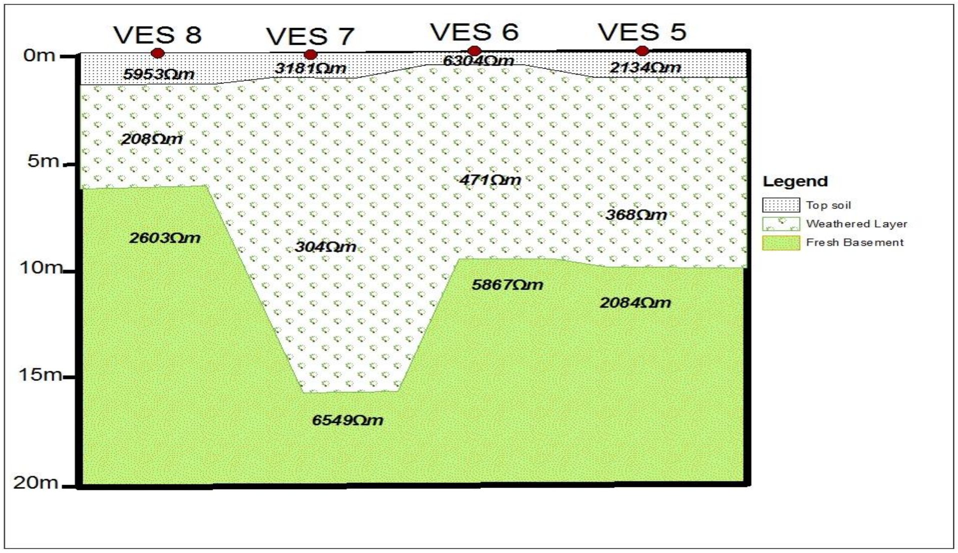


Fig 4.0a Profile1: Geoelectric section across VES 8, 7, 6, 5

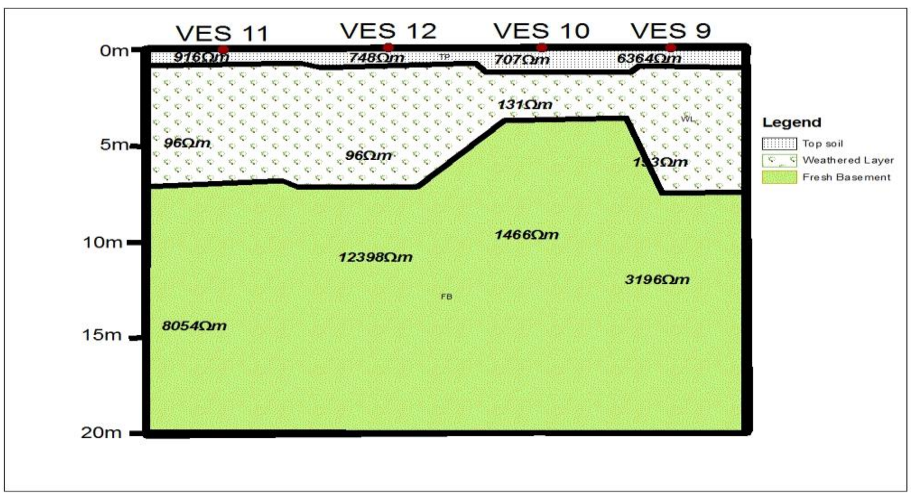


Fig 4.0b Profile 2: Geoelectric Section across VES 11, 12, 10, 9

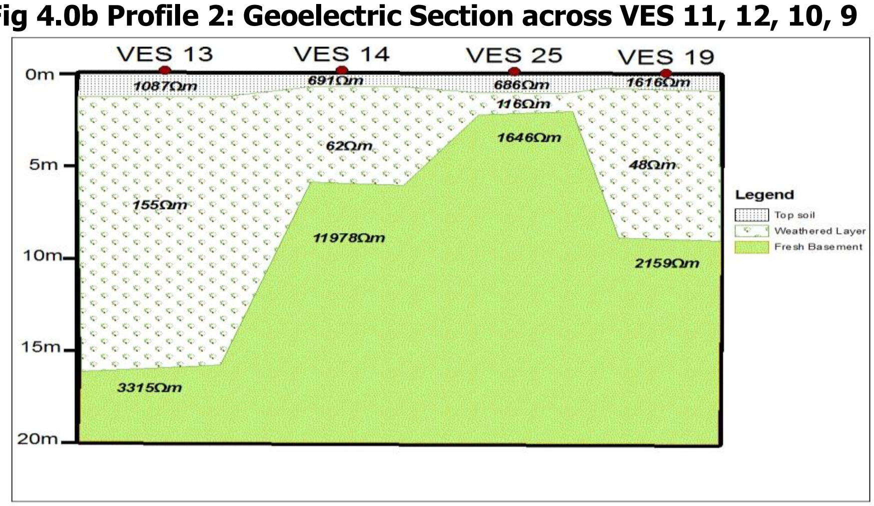


Fig 4.0c Profile3: Geoelectric section across VES 13, 14, 25, 19

The Overburden Thickness Contour Map

The overburden is assumed to include all materials above the presumably fresh basement. The depth to the bedrock varies from 3.5m to 16.5m and the average depth to the bedrock is 10.0m (fig 5.0).

The overburden thickness contour map (Figure 5.0) shows that the weathered basement has an increasing thickness values towards the north-eastern and north-western axis which suggests the presence of an aquiferous zone.

Thickness

(m)

Fig 5.0: The Overburden Thickness Contour Map

The Topsoil Resistivity Contour Map

The map reveals the heterogeneity in the composition` of topsoil, whose composition varies from sandy clay to laterite. The topsoil resistivity varies from 500Ωm to 7500Ωm (fig 6.0).

From fig (6.0) it can be observed that the region with topsoil resistivity values ranging from 3000 Ωm to 7000 Ωm with thickness value ranging from 6.8m to 7.2m i.e. the northwest region with a constant resistivity value of 3000 Ωm, shows that the topsoil is characterized by high resistivity value.

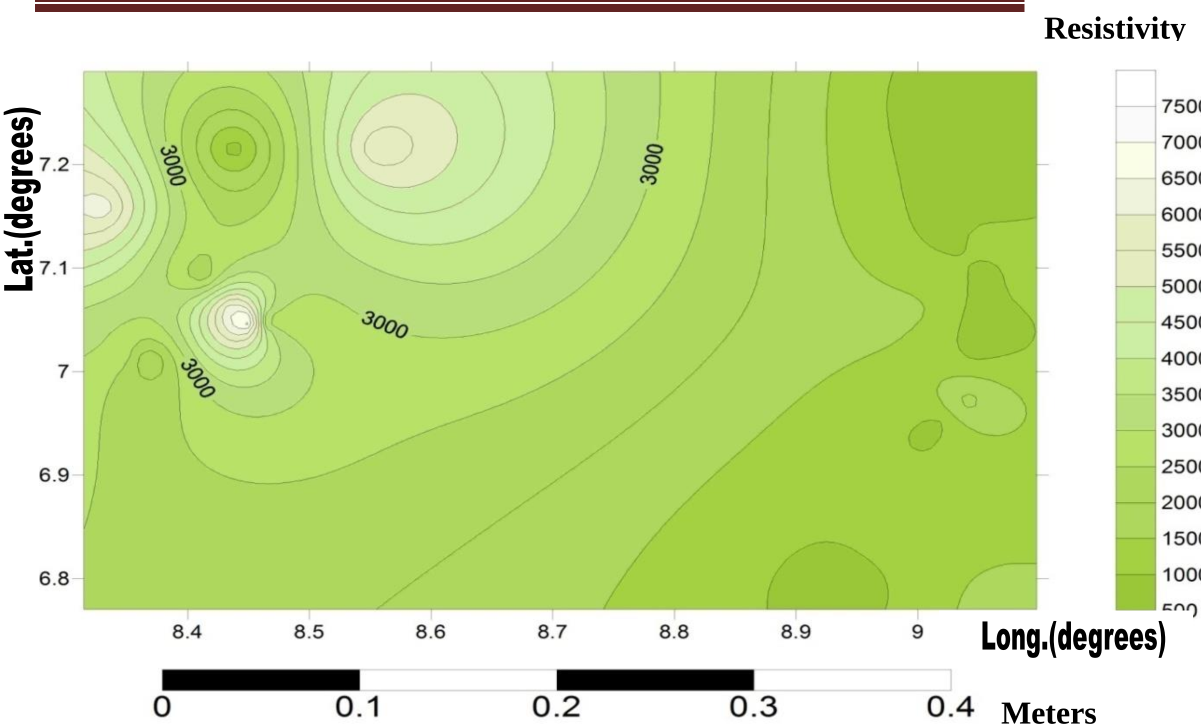


Fig 6.0: The Topsoil Resistivity Contour

Conclusion

The result presented in this work has attempted to define the sub-surface lithology and geo-electric response underlying formations in part of the Gwagwalada area council Abuja, Nigeria. The area is underlain by three to four layers of different lithological units such as topsoil, weathered layer, fractured layer and fresh basement; the aquifer thickness varies from 3.5m to 16.5m. The resistivity value of the weathered basement varies from 57.9Ωm to 471.1 Ωm.

The depth to the bedrock varies from 3.5m to 16.5m and the average depth to bedrock is 10m. It has also been established from this study that Overburden thickness contour map was suited for estimating thickness of the subsurface layering (Fig 5.0). The presence and development of weathered layer underlain by fractured basement are components of aquifer system and zone of groundwater accumulation in the study area. It can therefore be conclude that low resistivity and significantly thick weathered rock and fractured basement constitute the aquifer in this area. It can be concluded based on all the findings made in the interpretation of the VES data, 12 VES Points 5,6,7,8,9,10,11,12,13,14,19,and 25 are strongly recommended as most viable locations for the development of groundwater resources in the study area.

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