ELECTRICAL RESISTIVITY SURVEY FOR GROUNDWATER POTENTIALS IN SHAKWATU, NIGER STATE, NIGERIA

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Abstract
Schlumberger configuration of the electrical resistivity method was employed to investigate the groundwater potential in Shakwatu, part of Minna Sheet 164. The area is a part of the crystalline basement complex of Nigeria. A total of 36 VES points was established along six profile lines employing the SAS 4000 Terameter. The maximum current electrode spacing (AB/2) was 100 m while potential electrode separation (MN/2) was set at 15m maximum. Three curve types were noticed from the geoelectric curves; these includes the HA, A and AK curves. Almost all the geoelectric sections of the six profiles are composed of three geoelectric layers. The apparent resistivity of the first and second geoelectric layers ranges from 18 Ωm to 695 Ωm and 11 Ωm to 1782 Ωm respectively with a thickness range of 0.5 m to 1.6 m and 1.1 m to 16.4 m for the first and second layers. The depth to the first layer ranges from 0.5 m to 1.6 m and 1.9 m to 17.5 m for the second geoelectric layers. The third geoelectric layer shows a resistivity range of 493 Ωm to 5631 Ωm which extends to an infinite depth. The potential VES points for groundwater exploitation in the study area includes P2V2 which indicates low to moderate resistivity at greater depth. VES points P6V1 and P1V3 which indicates a fairly thick overburden material are also considered as potential points for groundwater exploitation.

Keyword: Schlumberger, Electrical Resistivity, Shakwatu, Groundwater, Overbuden

Introduction
The ever-increasing demand for water made groundwater exploration more important in Nigeria. Most water from streams, rivers and oceans in Nigeria are highly polluted. The alternative to this polluted water is groundwater described as "water in the zone of saturation" and from which wells, springs and underground run-off are supplied. It underlies the surface of the earth almost everywhere. It is not accessible or fresh enough for use without treatment; and it is sometimes difficult to locate or measure. The communities and individuals of Shakwatu mostly drink water from polluted streams, rivers and wells, which infects them with water related diseases like typhoid, rashes, dysentery and cholera. In response to this and because of the intimate relationship between water and life, there is need for research work of this nature to identify ground water potential points for the community.

Geographical Location of the Study Area
The study area, which covers an area of 500 meters by 500 meters, is part of Shiroro local government area of Niger state, North-central Nigeria. It is located between latitude $9^{0}40^{/}10.2^{//}$ to $9^{0}40^{/}21.8^{//}$ and longitudes $6^{0}42^{/}02.1^{//}$ to $6^{0}42^{/}13.4^{//}$ (Figure 1). It is accessible and bounded to the South by Shakwatu-Gunu road, to the west by Shakwatu-Gunudna road, to the North by Gunudna and to the east by Gunu-She road.

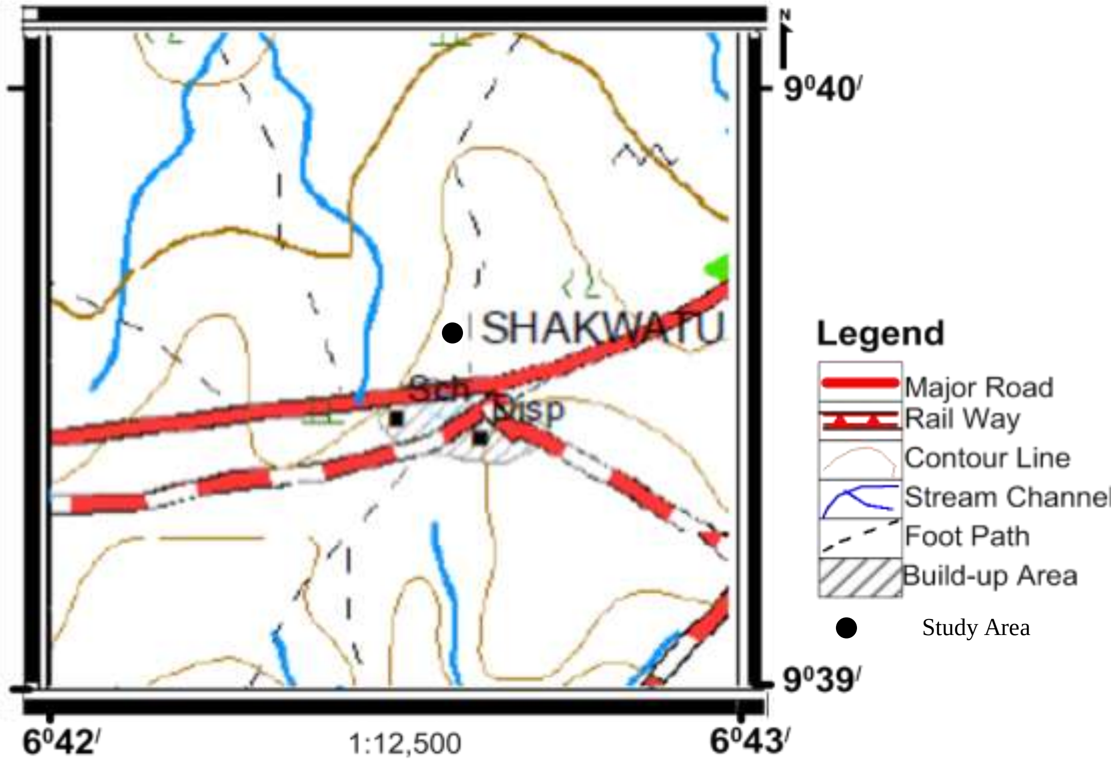

Figure 1: Geographical Map of the Area (Office of the Surveyor General of the Federation, 2018)

Geology of the Study Area

Shakwatu is located 7 km East of Minna and is underlain by basement complex rocks consisting of medium-grained biotite granite inter banded with coarse-grained leucocratic granite and intruded in places by quatzo-feldspar pegmatite dykes. The dykes strike parallel to the strike of the foliation and they range from 0.5 km to 3.5 m in diameter. Out crops are found along the river valleys as flat laying bodies. They range in sizes from 3 x 5m to about 8 x 15m. Pinkish feldspar (i.e., potassium feldspar) is the dominant mineral in the granite gneiss and the pegmatite. The rock types present in the area are part of the old granite suite which are mostly exposed along the stream channels (Udensi *et al.*, 2005). The major rock type is porphyritic, medium to fine grained granite (Adesoye, 1986) and (Adeniyi *et al.*, 1988). The rocks are found in East-West (E-W) trending quartz; this is in contrast to the porphyritic granite that are found in the North-South (N-S) trending quartz and aplitic veins ranging in length from 2 m to about 15m. The medium to fine grained granite rocks are broken into boulders in some places and they show the effect of weathering in the form of colour change, and loose rock fragments (Adesoye, 1986).

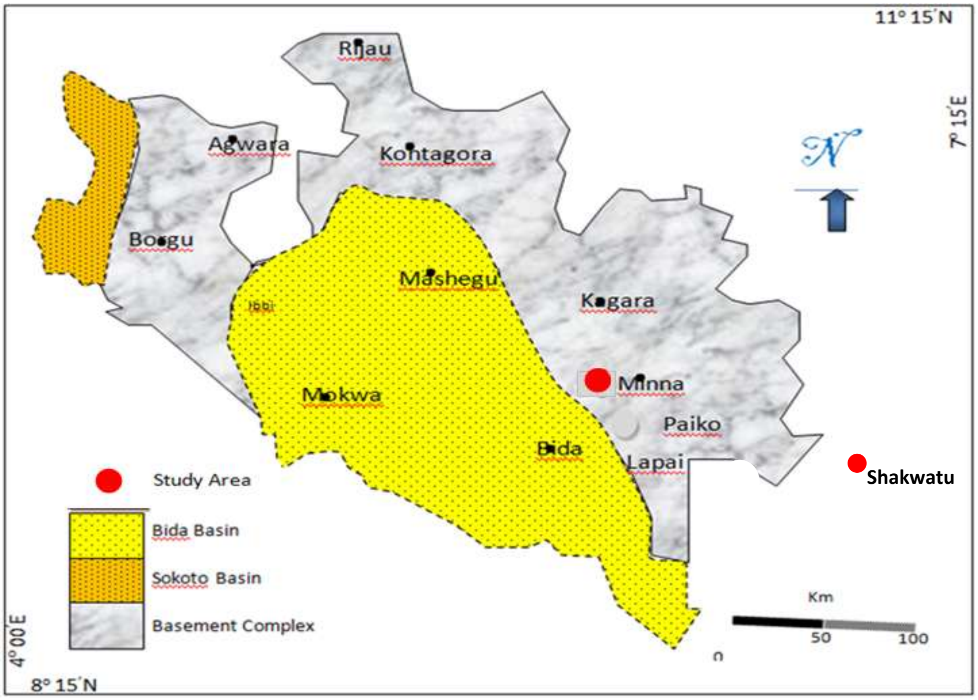

Figure 2: Geological Map of Niger State (Amadi *et al.,* 2012)

Materials and Method

Materials

In this survey, a number of instrument and equipment were used for data acquisition. The major one was Abem Terrameter SAS 4000 which was used for collecting earth resistivity and Global positioning system that was used for taking the coordinate of each VES point.

Methodology

An extensive preliminary field survey was carried out to ascertain the total area coverage and also to clear off rugged terrains in the site. 36 VES points were investigated in all, with 6 VES points on each profile for a total number of 6 profiles as shown in Figure 3.

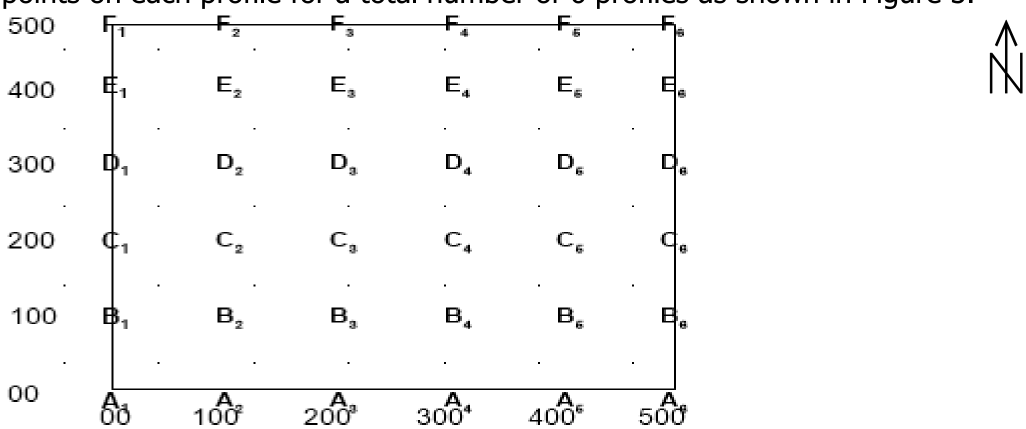

Figure 3: Profile layout.

The method involves the use of two potential electrodes, M and N fixed about the centre O while current electrodes, A and B are moved in steps collinearly with M and N as shown in Figure 4.

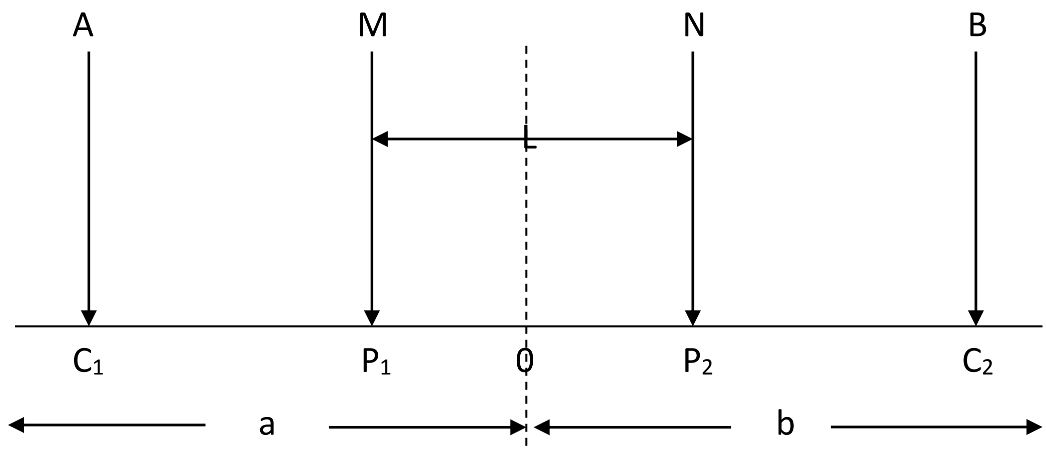

Figure 4: Schlumberger Array

A total of thirty-six (36) VES points were sounded on six (6) profiles, each profile has six (6) VES points hence 0.5 km long. All earth resistance data were recorded on recording sheets at the field. In all cases, the obtained values from the terrameter were used to estimate the apparent resistivity values. A Table of the apparent resistivity values with electrode separation were produced for each VES point.

Electrical Resistivity

Electrical Resistivity is a form of geophysical survey that aids in imaging the subsurface by utilizing the resistivity contrast of the subsurface materials and layers, It is based on the principle of Ohms law. When current (I) was introduced into the ground, a potential difference (V) is created and the earth's resistance (R) is given by the ratio of the potential difference to the current.

$$R=V/I \quad (1)$$

In-field practice, direct current is passed into the ground through two outer electrodes (current electrodes), and the resultant potential difference is measured across two inner electrodes (potential electrodes) that are arranged in a straight line, symmetrically about a centre point.

The ratio of the potential difference to the current is displayed by the Terrameter as earth resistance.

To increase the depth of investigation, the current electrode separation was increased while the potential separation remained constant. The sensitivity of the potential electrode measurement decreases as the current electrodes spacing increases, therefore, at some point, it was necessary to increase the potential electrode spacing.

A geometric factor ***K*** in metres is calculated as a function of the electrode configuration adopted, for schlumberger array,

$$K = \pi \quad (2)$$

Then the apparent resistivity (ρ_a) values were obtained by multiplying K with the resistance (R) values

$$\rho_a = KR \quad (3)$$

Also, the apparent resistivity values obtained was plotted against the inter current electrode spacing (AB/2) using winResist software and from the plots; the resistivity, depth and thickness of each of the subsurface layer were obtained.

Table 1: Ranges of resistivity of various rocks component in basement complex (Esimai, 2017).

Rock Type	Range of Resistivity (Ω m)
Famada loam	30-90
Weathered laterite	150-900
Fresh laterite	900-3500
Granite	$300\text{-}10^5$
Alluvium and sand	10-800
Quartzite (various)	$10 – 2 \times 10^8$
Weathered basement	20-500
Fractured basement	500-1000
Fresh basement	> 1000

Results and Discussion

VES Data Curves and Geo-Electric Parameters

The corresponding geo-electric layers with the respective curve type for each profile have been shown in Table 2. The geometry of the geoelectric curves shows that the effect of anisotropy, equivalence and topography is evident in the results, as the resistivity values are changing with directional response to the subsurface anomalies.

The plotting and interpretation of the VES data using the inversion software revealed that the generated curves are predominantly made up of three geoelectric layer HA-type curve with 58% ($\ell_1 > \ell_2 < \ell_3$) were ℓ_1, ℓ_2 and ℓ_3 represent the resistivity of the first, second and third layers respectively. 41% of the curves is made up of three geoelectric layers A-type curve ($\ell_1 < \ell_2 < \ell_3$).

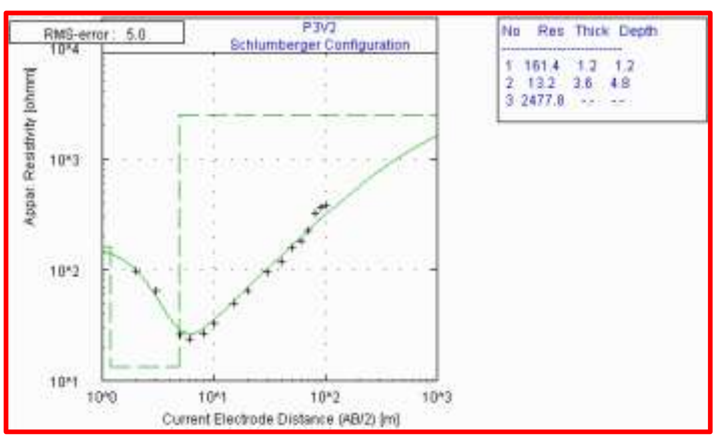

Figure 7: A Typical HA-Curve Type

Table 2: Resistivity Thickness, Depth and Curve Types of the VES on the Profiles

VES POINTS	APPARENT RESISTIVITY (Ωm)			THICKNESS (m)			DEPTH (m)			CURVE TYPE
	ℓ_1	ℓ_2	ℓ_3	h_1	h_2	h_3	d_1	d_2	d_3	
1	40	31	892	0.9	2.5	∞	0.9	3.3	h_3	A
2	65	36	2451	0.8	2.1	∞	0.8	2.8	∞	A
3	109	61	1348	1.3	8.8	∞	1.3	10.1	∞	HA
4	80	40	1173	0.9	4.3	∞	0.9	5.2	∞	HA
5	67	14	2086	0.5	2.1	∞	0.5	2.6	∞	HA
6	119	23	656	0.5	5.1	∞	0.5	5.6	∞	HA
7	181	15	5631	0.6	2.7	∞	0.6	3.3	∞	HA
8	205	21	799	1.0	5.5	∞	1.0	6.5	∞	HA
9	44	11	1375	0.7	3.0	∞	0.7	3.7	∞	HA
10	48	25	1085	0.7	5.6	∞	0.7	6.3	∞	A
11	178	15	3234	0.6	3.3	∞	0.6	3.9	∞	HA
12	49	39	1517	1.0	5.0	∞	1.0	6.0	∞	A
13	278	36	2283	1.2	4.1	∞	1.2	5.3	∞	HA
14	161	13	2478	1.2	3.6	∞	1.2	4.8	∞	HA
15	39	15	888	0.7	3.9	∞	0.7	1.5	∞	HA
16	61	21	844	0.7	4.5	∞	0.7	5.2	∞	HA
17	695	1782	1104	0.8	13.0	∞	0.8	13.8	∞	K
18	56	25	715	1.2	7.4	∞	1.2	8.6	∞	HA
19	159	76	1951	0.9	6.8	∞	0.9	7.7	∞	HA
20	41	52	493	1.0	3.9	∞	1.0	4.9	∞	A
21	62	53	1514	1.0	4.5	∞	1.0	5.5	∞	A
22	141	49	1165	1.0	6.9	∞	1.0	7.8	∞	HA
23	18	13	893	1.2	4.3	∞	1.2	5.5	∞	A
24	181	30	1474	1.6	7.0	∞	1.6	8.6	∞	HA
25	93	59	2952	0.9	5.6	∞	0.9	6.5	∞	A
26	41	55	2644	1.1	6.7	∞	1.1	7.8	∞	A
27	60	1263	826	1.2	52.7	∞	1.2	53.9	∞	AK
28	127	37	1436	0.8	3.4	∞	0.8	4.3	∞	HA
29	117	21	1893	0.8	4.7	∞	0.8	5.5	∞	HA
30	323	23	1323	1.1	9.8	∞	1.1	10.9	∞	HA
31	226	112	1873	1.0	16.4	∞	1.0	17.5	∞	HA
32	133	118	3833	1.1	3.4	∞	1.1	3.4	∞	HA
33	55	69	1004	1.0	2.0	∞	1.0	3.0	∞	A
34	119	100	1389	1.0	4.6	∞	1.0	5.6	∞	A
35	137	34	1535	1.2	6.2	∞	1.2	7.4	∞	HA
36	74	28	2994	1.0	4.0	∞	1.0	5.1	∞	HA

Geologic Section for Profile One

The Geologic parameters of profile 1 (Figure 8) shows that from the surface there is a relatively low to moderate resistivity range of 40Ωm to 109Ωm with relatively shallow layers of top soil which correspond to the unsaturated zones. This is followed by a low resistive layer of variable thickness which corresponds to the weathered/fractured layer, the base of which depth ranges from 2.6 m to 10.1 m. The geoelectric layers terminate at the bedrock which is characterized by relative rise in the resistivity range from 892 Ωm to 2451 Ωm, its thickness extends to infinity.

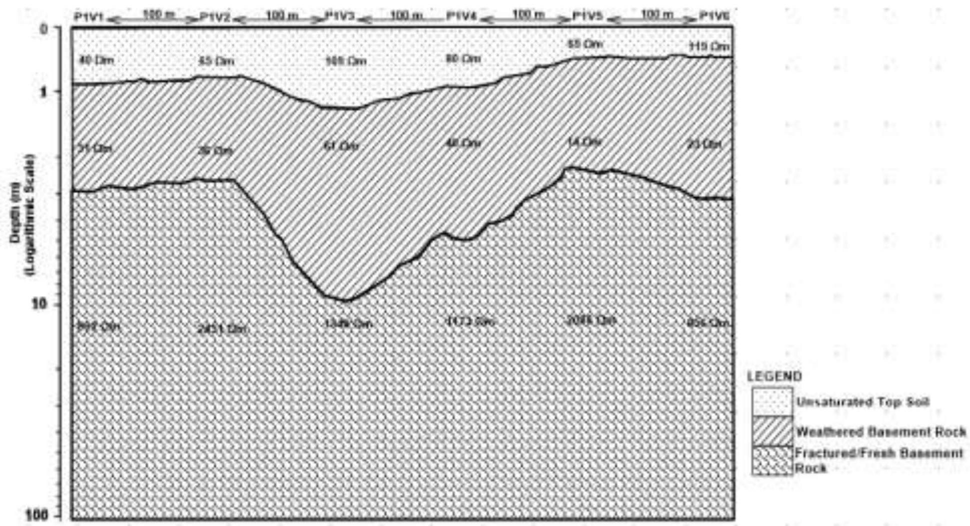

Figure 8: Geoelectric/Geologic Section of Profile one

Geologic Section for Profile Two

The Geologic section along profile two (Figure 9) revealed that the first layer is the top soil made of loose, loamy and clay/sandy materials. The resistivity of these layers ranges from 44 Ωm to 205 Ωm. The second layer has a resistivity range from 11 Ωm to 39 Ωm, layer thickness range from 2.7 m to 5.5 m while the depth varies from and 3.3 m to 6.5 m. The third layer has a resistivity range of 799 Ωm to 5631 Ωm extending to an infinite thickness and depth.

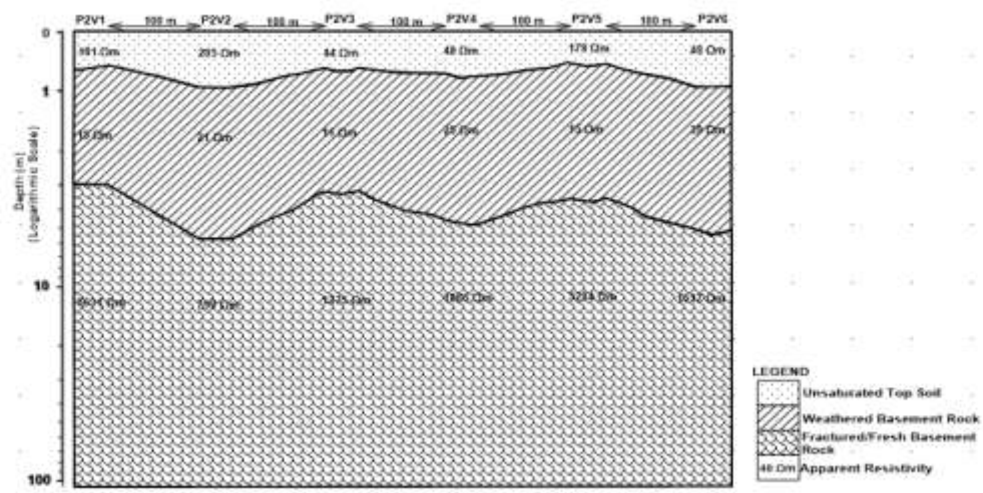

Figure 9: Geoelectric/Geologic Section of Profile Two

Geologic Section for Profile Three

The geologic section along profile three (Figure 10) indicates that the top layers of the sounded points on the profile shows variability of resistivity values, ranging from as low as 39Ωm to 695Ωm. The thickness and depth range of this profile ranges from as shallow as 0.7 m to1.2 m. The second layer on the profile indicates a resistivity range of 13 Ωm to 1782 Ωm and a thickness and depth range of 3.6 m to 13.0 and 4.8 13.8 m respectively. The third layer shows an infinite extent of thickness and depth with a resistivity range of 715 Ωm to 2283 Ωm.

Geologic Section for Profile Four

Along profile four (Figure 11), the geologic section reveals a resistivity range of 18 Ωm to 181 Ωm with a relative shallow depth of 0.9 m to 1.6 m for the first geoelectric layer. The second geoelectric layers on the profile shows a low resistivity range of 13 Ωm to 76 Ωm, attributed to the depth range of 4.9 m to 7.7 m. The thickness of the second layer on the fourth profile ranges from 3.9 m to 6.8 m. the third layer on the profile indicate a resistivity range of 493 Ωm to 1951 Ωm with an infinite thickness and depth extend.

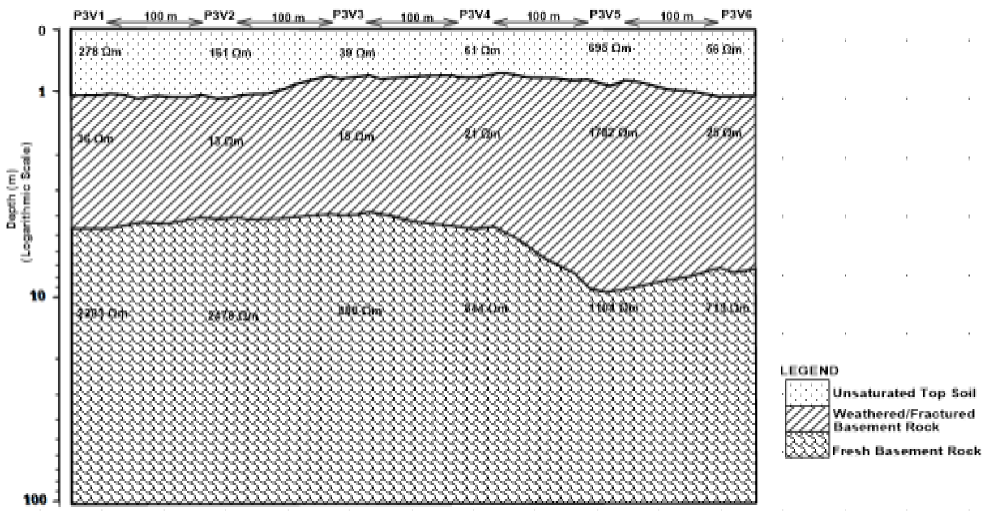

Figure 10: Geoelectric/Geologic Section of Profile Three

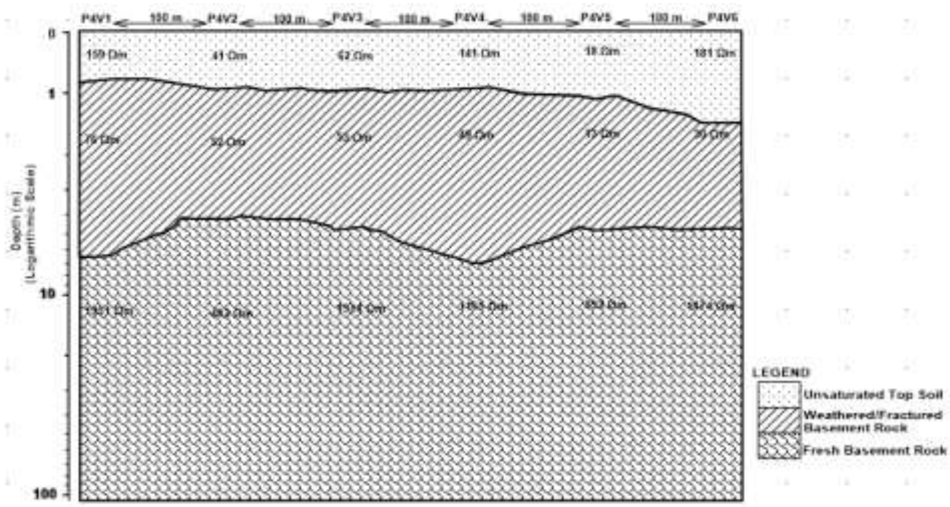

Figure 11: Geoelectric/Geologic Section of Profile Four

Geologic Section for Profile Five

Profile five geologic section (Figure 12) indicates a thin thickness and depth of the first layers ranging from 0.8 m to 1.1 m with resistivity attributes of 41 Ωm to 232 Ωm. The second geoelectric layer on the profile shows a resistivity range of 21 Ωm to 165 Ωm with a thickness and depth range of 1.1 m to 9.8 m and 1.9 m to 10.9 m respectively. The third layer is attributed with a high resistivity range of 1323 Ωm to 2952 Ωm.

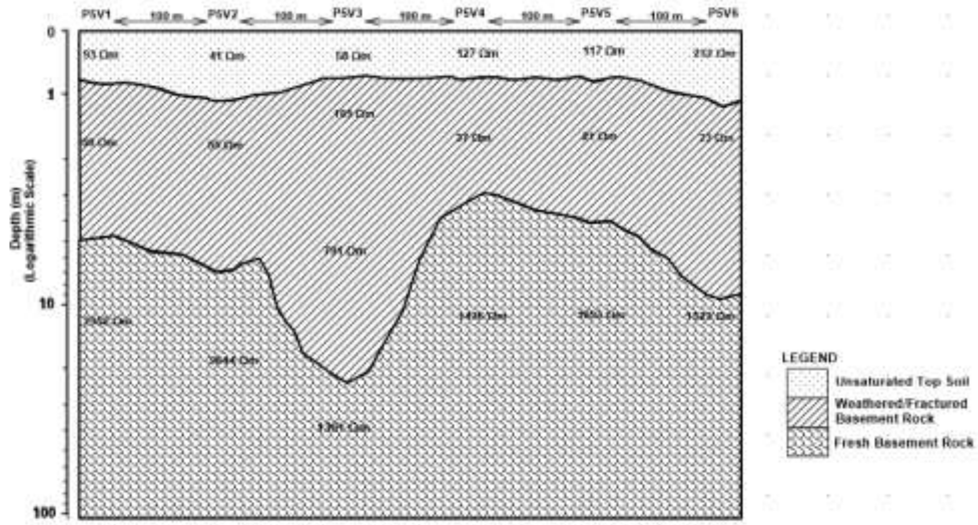

Figure 12: Geoelectric/Geologic Section of Profile Five

Geologic Section for Profile Six

The geologic section of the sixth and final profile (Figure 4.11) indicates a moderate resistivity range of 55 Ωm to 226 Ωm to a depth and thickness range of 1.0 m to 1.2 m. The second geoelectric layer is characterized with a thickness and depth ranges of 2.0 m to 16.4 m and 3.0 m to 17.5 m respectively with resistivity range of 18 Ωm to 112 Ωm. The third layers which extend to an infinite depth show a resistivity range of 1004 Ωm to 3833 Ωm.

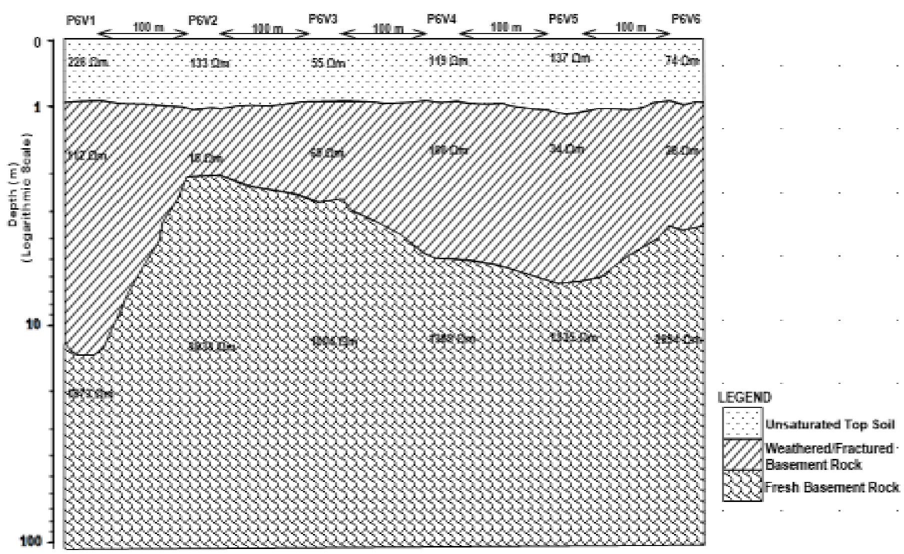

Figure 13: Geoelectric/Geologic Section of Profile Six

Isopach Map of the Second Geoelectric Layer

The northern portion of the layer indicates the shallower thickness to the basement rock, which implies that at that portion the basement rock is intruded to the earth’s surface. The thickness of this geoelectric layer ranges from one to seventeen meters across the mapped area. A slight portion of the north-west and the eastern portion of the area indicate moderate thickness of the layer.

Table 3 contains the VES points delineated as aquifer potential of the study area, the range of resistivity; depth and thickness of these aquifers are 21 to 112 Ωm, 6.5 to 17.5 m and 5.5 to 16.4 m respectively.

ES ations	No. of Layers	Layer Resistivity ρ (Ωm)			Layer Depth (m)			Layer Thickness (m)			Curve Type
		$\rho 1$	$\rho 2$	$\rho 3$	$d1$	$d2$	$d3$	$h1$	$h2$	$h3$	
V_3	3	109	61	1348	1.3	10.1	∞	1.3	8.8	∞	HA
V_2	3	205	21	799	1.0	6.5	∞	1.0	5.5	∞	HA
V_1	3	226	112	1873	1.0	17.5	∞	1.0	16.4	∞	HA

Table 3: Delineated aquifer potentials of the study area

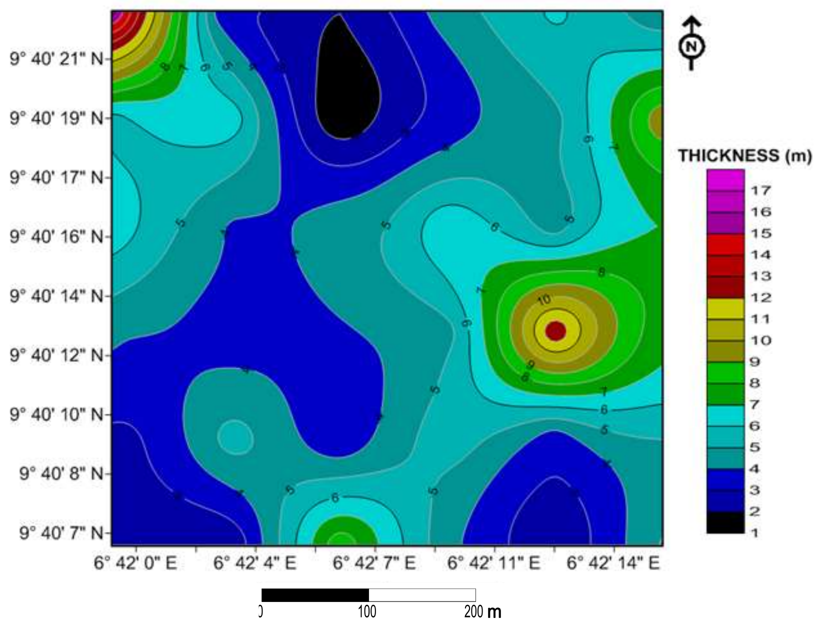

Figure 14: Iso-Pach (Thickness) map of the Second Layer

Conclusion

Geophysical investigation for groundwater potential employing the electrical resistivity method was carried out in part of Shakwatu, Niger State, Nigeria. The study area falls under the basement complex of Nigeria which is characterized with lithologies such as granite, migmatite-gniess and schist. The field layout consists of the distribution of a total of thirty-six (36) VES carried out along six (6) established profiles. The distance between VES points and the distance between profile lines were set at 100 m. The maximum current electrode spacing (AB/2) was set at 100 m while the maximum potential electrode separation (MN/2) was set at 15m.

A multidimensional approach which includes model geoelectric curves, pseudo-sections, geoelectric sections and iso-resistivity plots were adopted for data interpretation. The interpretation of the data sets employing various approaches has made the study both very qualitative and quantitative which have necessitated a justifiable conclusion.

The apparent resistivity of the first and second geoelectric layer ranges from 18 Ωm to 695 Ωm and 11 Ωm to 1782 Ωm respectively with a thickness range of 0.5 m to 1.6 m and 1.1 m to 16.4

m for the first and second layers. The depth to the first layer ranges from 0.5 m to 1.6 m and 1.9 m to 17.5 m for the second geoelectric layers. The third geoelectric layer shows a resistivity range of 493Ωm to 5631 Ωm which extends to an infinite depth.

The study therefore, recommended that Government or individuals who wish to site boreholes within the study area should consider VES stations P_1V_3, P_2V_2, and P_6V_1.

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