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Geo-electrical investigation of subsurface water resources in Kutunku, Gwagwalada Area Council, Abuja, Nigeria.

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Abstract: *In this study, data obtained with the aid of an ABEM Terameter (SAS 300C), from twenty-five (25) Vertical Electrical Soundings (VES) stations in Kutunku, with maximum half-current electrodes spacing AB/2, of 170m and maximum half-potential electrodes spacing MN/2, of 7.5m for most of the profiles, were analysed with IPI2Win software. The analysis indicated 3 to 5 geo-electric layers where the former was predominant and the lithologic units were interpreted to consist of sandy top soil, clay/clayey sand, lateritic sand, compact laterite, weathered/fractured basement and fresh basement. Layer resistivity ranges were 1.95 - 1360Ωm, 0.4 - 1723Ωm, 7.7 - 180000Ωm and 71 - 44878Ωm for the first, second, third and fourth layers respectively. In the same vein, layer depth ranged from 0.6 - 4.3m, 1.1 – 47.3m, 3.9 – 56.9m and 31.1m to undetermined depth. The second layer in most of the profiles showed conductive zones with low resistivity values ranging from 0.403Ωm to 151Ωm. In most of the profiles, the third layer manifested as the last layer, predominantly with high resistivity readings of the order of 10^3Ωm to 10^5Ωm with unknown depths suspected to be fresh basement rocks. In the few profiles where four geo-electric layers were detected, with the exception of VES 18, the resistivity values (in Ωm), obtained for the last layer, were of the order of 10^3 and above, with unknown depth suspected to be fresh basement rocks. Amongst the second, third and fourth layers, the second layer mostly constitute the aquifer unit in the area with weathered/fractured basement rock type. The stations of highest groundwater potential were found to be VES 2, VES 5, VES 8, VES 14, VES 21, VES 24 and VES 25 because of the thicknesses of the layers interpreted as weathered or fractured zones which ranged from 25m to 55m.*

Keywords: *Resistivity, Terameter, Kutunku, geo-electric layers, aquifer.*

I. Introduction

Water is vital for life sustenance as it is deployed by man for several uses such as drinking, sanitation, cooking, industrial processing, hydropower generation, agriculture, fishery, ecosystem support. Water exists in different forms in the biosphere, atmosphere, lithosphere including ice cap, glaciers, ground surfaces and underground. However, surface and ground water sources are more readily available for abstraction if its quality is not compromised. According to Savenije and Van der Zaag (2002), Integrated Water Resource Management (IWRM) involves the consideration of all physical aspects of water resources including groundwater, at different temporal and spatial scales of the hydrological cycle and the related quality aspects. Unlike saline ocean or sea waters, groundwater is fresh, thus it is a finite resource (Van der Gaal and Savenije, 2011). According to a United Nations world water development report of 2003, groundwater is approximately 0.76% of water on earth. The same report indicates that it is about 30.1% of the world's freshwater resource. Groundwater can be found in both sedimentary and basement complex terrain.

In basement geology, groundwater occurs in weathered mantle, joints and fracture system in the unweathered rocks (Olorunfemi and Olorunniwo, 1985; Ako and Olorunfemi, 1989; Olayinka and Olorunfemi, 1992; Mallam and Emenike, 2008; Amadi *et aI*., 2015) and it is most often localized (Adiat et al., 2009). The zones of possible high groundwater yield in basement terrain are strata often characterized by fractures, relatively low resistivity and thick overburden (Olorunfemi and Fasuyi, 1993). Thus, there is an encouraging trend of the use of geophysical studies prior to the drilling of boreholes for groundwater exploration (Mallam, 2004). Although the use of geotechnical and hydrogeological techniques, remote sensing, geographical information systems, and multicriteria analysis for delineating groundwater potential zones lack the precision of an in-situ analysis (Adiat *et al*., 2012; Madrucci *et al*., 2008), the electrical resistivity method is usually preferable because of the resistivity contrasts obtained when the groundwater zone is reached (Ishola *et al*., 2013). Electrical Resistivity method has become increasingly applied in groundwater prospecting in basement complex terrain (Olayinka and Olorunfemi, 1992; Olorunfemi *et aI*., 1999; Omosuyi, 2000; Eduvie *et al.*, 2003; Lateef, 2012; Okafor and Mamah, 2012; Dikedi, 2012; Abdulsalam and Ologe, 2013; Ishola *et al*., 2013; Odeyemi, 2014; Akinrinade and Olabode 2015; Amadi *et al.*, 2015) and in sedimentary basin (De Beer and Blume, 1985; Mbonu *et aI*., 1991; Emenike, 2000; Okolie *et al*., 2007; Oseji, 2009; Oseji and Ujuanbi, 2009; Oseji, 2010; Alile *et al.*, 2011; Anomohanran, 2013). Apart from being non-invasive, the resistivity method is less expensive and time efficient when compared with test drilling and stratigraphy analysis which are other ways of determining aquifer locations and characteristics (Todd, 1980; Fetter, 1994; Adiat *et al*., 2013; Ishola *et al*., 2013). In this paper, the groundwater potential and lithology in Kutunku is investigated using geo-electrical method. The result of the processed Vertical Electrical Sounding (VES) resistivity data and borehole lithology logs were integrated in order to assess the groundwater development prospect at the study area.

II. Physiography Of The Study Area

The study area is Kutunku in Gwagwalada Area Council, Federal Capital Territory (FCT), Nigeria. It lies within latitudes 8°55′00″N and 8°56′30″N, and between longitudes 7°03′30″E and 7°05′00″E. Gwagwalada is a suburb of the FCT, situated along Abuja-Lokoja road, about 55km South-west of Abuja City centre, between latitude 8°49' and 9°04' North and longitudes 6°50' and 7°06' East (Abuja Guide, 2002). According to a publication of the Nigerian Geological Survey Agency (2006), FCT lies within latitudes 8°22'N and 9°26'N and longitudes 6°42'E and 7°43'E.

The study area is within the tropical savannah vegetation zone. River Usuma and its tributaries drain the area. The map in figure 1 shows the topographic variation in elevation, VES stations and other physical features in the study area.

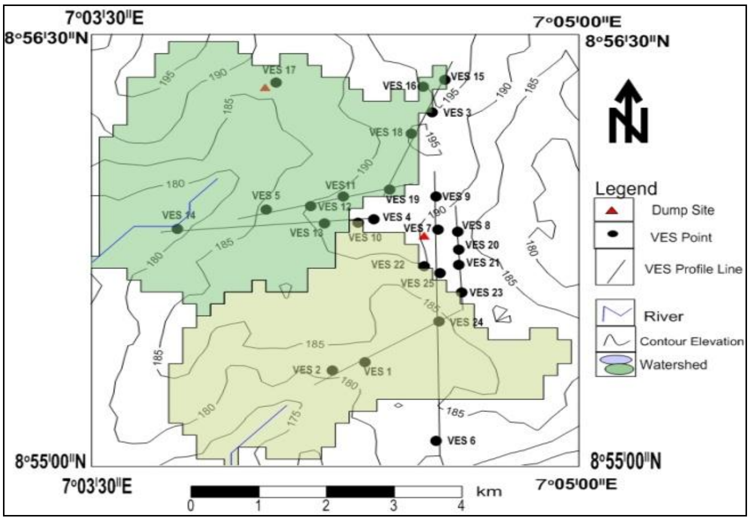


Figure 1: Location map of the study area.

III. Geology Of The Study Area

FCT is predominantly underlain by the Nigerian Basement Complex rock of the Precambrian age (Mamman and Oyebanji, 2000). Figure 2 shows the geologic map of FCT indicating the basic geologic formations. The rocks include different textures of granites, gneiss, migmatites, diorites, metasediments and pegmatites (Eduvie et al., 2003; Dikedi, 2012). Dikedi (2012) documented that the geology of the FCT is same as that of Gwagwalada. Groundwater is found mainly in the variable weathered/transition zone and in fractures, joints and cracks of the crystalline basement while sparse amount of water can be obtained in the freshly unweathered bedrock below the weathered layers (Eduvie et al., 2003).

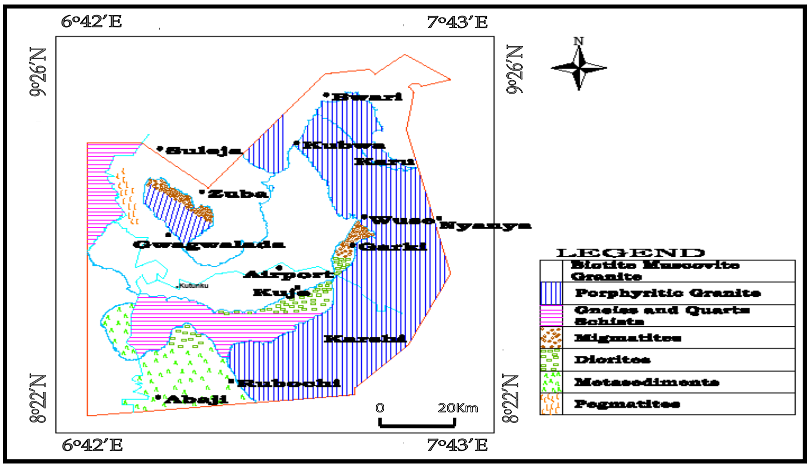


Figure 2: Geologic map of FCT (Adapted from: Dikedi, 2012)

IV. Materials And Method

An Abem Terameter SAS 300c, batteries, two pairs of electrodes, insulated multi-strand copper cables, non-conducting measuring tape, Megellan Triton 300 GPS (WP001) device, hammer and four crocodile clips were deployed to the field to aid in data acquisition.

The principle of operation of resistivity method depends on the fact that any subsurface variation in conductivity alters the form of current flow within the earth and this in turn affect the distribution of electric potential. Thus, it is possible to have information about the subsurface formations from potential measurements made at the surface. The microscopic form of ohm's law is the fundamental formula used in resistivity measurements. That is,

$$E = J\rho \text{ ....(1)}$$

The Vertical Electrical Soundings (VES) were carried out using the Schlumberger electrode configuration described by Zohdy *et al.*, (1974). The arrangement of electrodes is illustrated in figure 3. L is half the distance between the current electrodes and ɭ is half the spacing between the potential electrodes. The potential electrodes indicated by P_1 and P_2 are kept fixed and the current electrode separation is varied to obtain the changes in subsurface resistivity at greater depth. The field procedure was implemented by taking soundings with successive increase in the distance between current electrodes (AB) along the profile while the distance between potential electrodes (MN), was kept fixed. At the point when the measuring capability of the Terrameter tended to be overwhelmed as a result of a decreasing potential difference across MN, a new value for MN larger than the preceding value was taken and the survey was continued.

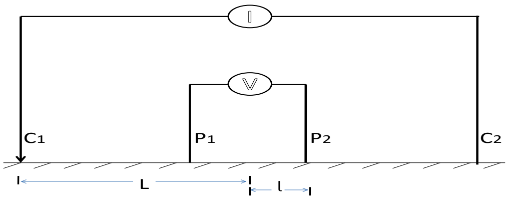


Figure 3: Diagram of Schlumberger array

The apparent resistivity equation for the Schlumberger array is given by

$$\rho_a = \text{л}\left(\frac{L^2}{2l} - \frac{2l}{4}\right) R \text{ ....(2)}$$

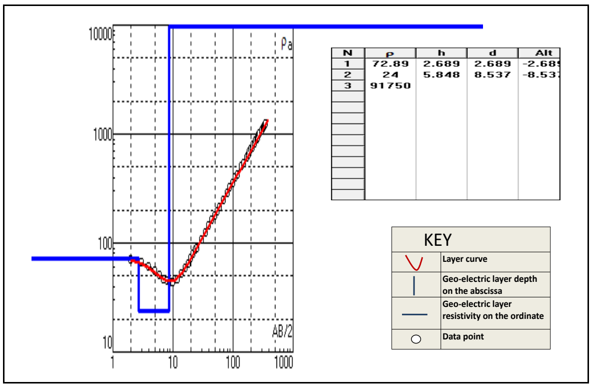
where, the geometric factor, G

$$G = \text{л}\left(\frac{L^2}{2l} - \frac{2l}{4}\right) \text{ ....(3)}$$

Vertical Electrical Soundings (with AB/2, ranging between 2m and 500m, and MN/2, ranging between 0.5m and 45.5m) were carried out at twenty-five VES stations and resistivity data were obtained. The coordinate locations and elevations above sea level were obtained with GPS device. Borehole lithology logs for two locations near the study area were obtained to aid in result interpretation.

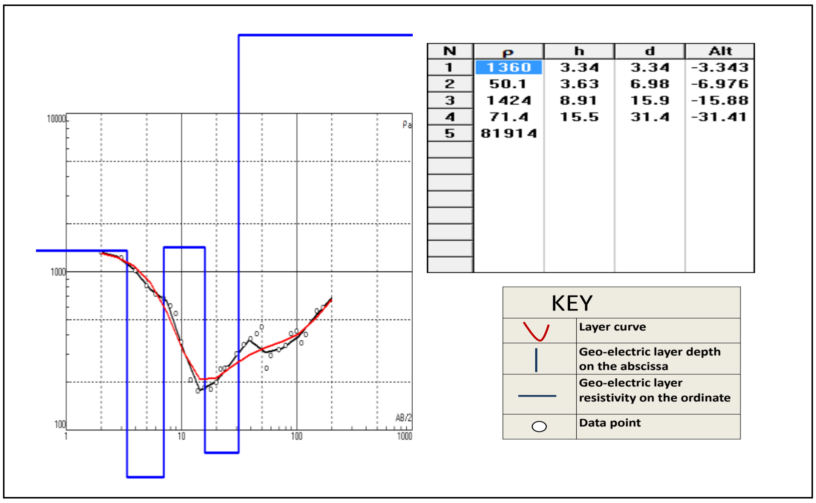
V. Results And Discussion

The resistivity data were processed with IPI2Win software and the layer curve characteristics identified include H, HKH, HA, KH and HK-type. H-type curve characteristics was however predominant. Typical curve types are shown in figures 4a to 4e. The result of geo-electric parameters obtained is presented in table 1. Two borehole lithology logs as shown in figure 4f obtained near the area aided as geologic reference in the result interpretation.



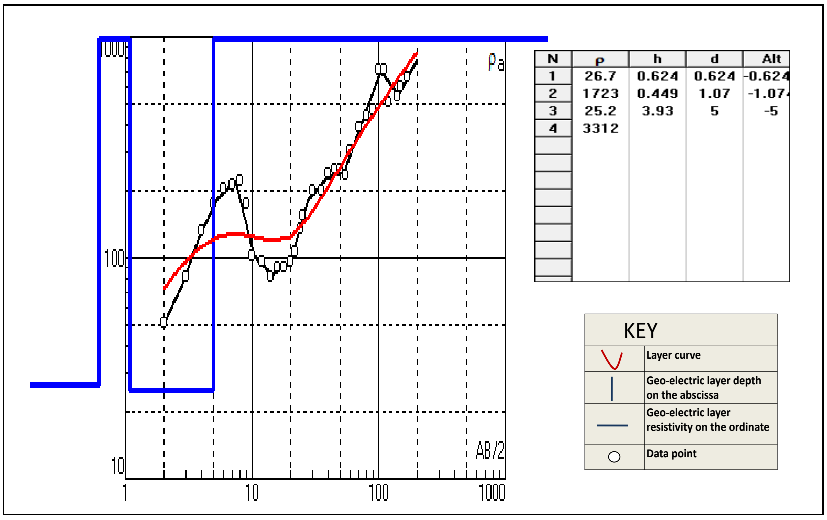
N	ρ	h	d	Alt
1	72.89	2.689	2.689	-2.68
2	24	5.848	8.537	-8.53
3	91750			

Figure 4a: Layer curve and interpretation for VES 1.



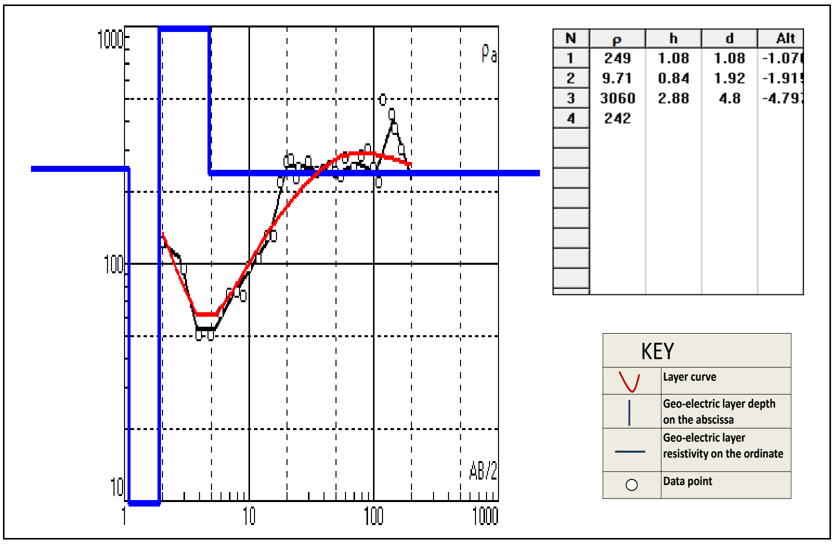
N	ρ	h	d	Alt
1	1360	3.34	3.34	-3.343
2	50.1	3.63	6.98	-6.976
3	1424	8.91	15.9	-15.88
4	71.4	15.5	31.4	-31.41
5	81914			

Figure 4b: Layer curve and interpretation for VES8.



N	ρ	h	d	Alt
1	26.7	0.624	0.624	-0.624
2	1723	0.449	1.07	-1.07
3	25.2	3.93	5	-5
4	3312			

Figure 4c: Layer curve and interpretation for VES 17.



N	ρ	h	d	Alt
1	249	1.08	1.08	-1.07
2	9.71	0.84	1.92	-1.91
3	3060	2.88	4.8	-4.79
4	242			

Figure 4d: Layer curve and interpretation for VES 18.

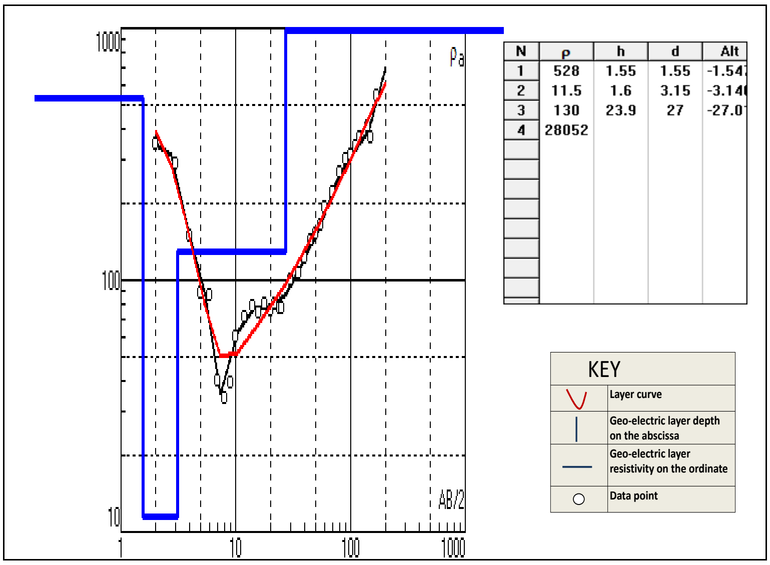
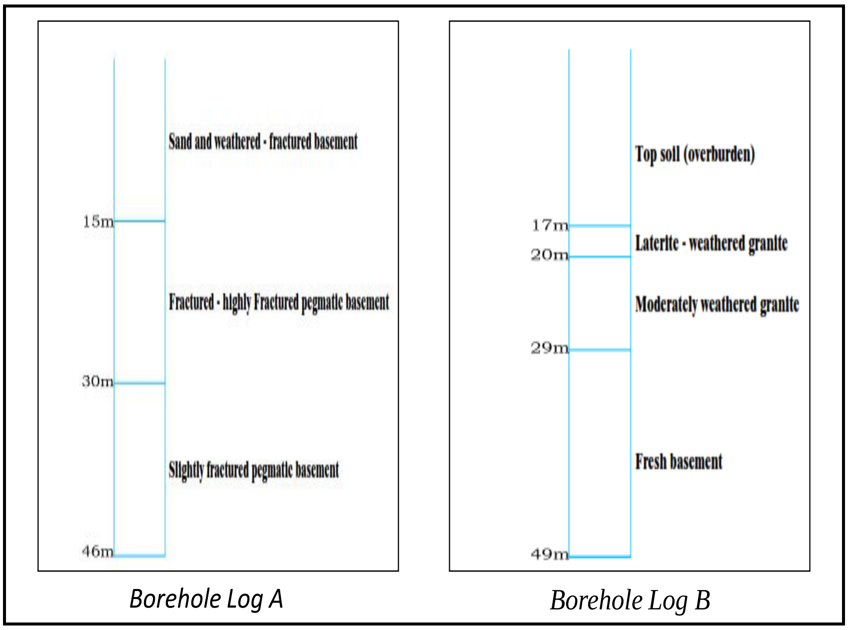


Figure 4e: Layer curve and interpretation for VES 21.



Borehole Log A *Borehole Log B*

Figure 4f: Borehole lithology logs obtained near the study area.

TABLE 1: Summary of the VES interpretation result

VES No.	Curve Type	Layer (l)	Resistivity (Ωm)	Thickness (m)	Overburden Thickness (m)	Lithological equivalence	Groundwater Potential
1	H	l_1	72.8	2.6	2.6	Sandy top soil	Very Low
		l_2	24.0	5.4	8.5	Clay/Clayey sand	
		l_3	91750.0	--	--	Fresh basement	
2	H	l_1	553.9	0.6	0.6	Sandy top soil	Moderate
		l_2	77.9	30.5	31.1	Weathered/fractured basement	
		l_3	97325.0	--	--	Fresh basement	
3	H	l_1	202.8	0.7	0.7	Sandy top soil	Poor
		l_2	37.6	18.9	19.7	Weathered/fractured basement	
		l_3	58133.0	--	--	Fresh basement	
4	H	l_1	475.9	3.0	3.0	Sandy top soil	Poor
		l_2	33.4	9.2	12.2	Weathered/fractured basement	
		l_3	47501.0	--	--	Fresh basement	
5	H	l_1	396.3	2.2	2.2	Sandy top soil	Moderate
		l_2	56.9	45.1	47.3	Weathered/fractured	

						basement	
		l_3	5692.0	--	--	Fresh basement	
6	H	l_1	288	1.44	1.44	Sandy top soil	Very Low
		l_2	10.3	4.08	5.52	Clay/Clayey sand	
		l_3	17927	--	--	Fresh basement	
7	H	l_1	1.95	0.719	0.719	Sandy top soil	Very Low
		l_2	0.403	1.31	2.03	Clay/Clayey sand	
		l_3	1729	--	--	Fresh basement	
8	HKH	l_1	1360	3.34	3.34	Sandy top soil	Moderate
		l_2	50.1	3.63	6.98	Weathered basement	
		l_3	1424	8.91	15.9	Compacted laterite	
		l_4	71.4	15.5	31.4	Weathered/Fractured basement	
		l_5	81914	--	--	Fresh basement	
9	H	l_1	477	1.01	1.01	Sandy top soil	Very Low
		l_2	6.68	1.57	2.58	Clay/Clayey sand	
		l_3	15125	--	--	Fresh basement	
10	H	l_1	244	2.58	2.58	Sandy top soil	Poor
		l_2	72.4	15.4	18	Weathered/fractured basement	
		l_3	110000	--	--	Fresh basement	
11	H	l_1	456	4.34	4.34	Sandy top soil	Low
		l_2	81.3	5.63	9.97	Weathered/fractured basement	
		l_3	180000	--	--	Fresh basement	
12	H	l_1	72.4	1.38	1.38	Sandy top soil	Very Low
		l_2	2.52	1.31	2.69	Clay/Clayey sand	
		l_3	12167	--	--	Fresh basement	
13	H	l_1	452	2.26	2.26	Sandy top soil	Poor
		l_2	53.3	10.1	12.4	Weathered/fractured basement	
		l_3	36023	--	--	Fresh basement	
14	H	l_1	246	1.29	1.29	Sandy top soil	Moderate
		l_2	62.3	25.6	26.9	Weathered/fractured basement	
		l_3	65752	--	--	Fresh basement	
15	H	l_1	473	1.47	1.47	Sandy top soil	Poor
		l_2	92.7	18.5	20	Weathered/fractured basement	
		l_3	120000	--	--	Fresh basement	
16	H	l_1	243	1.96	1.96	Sandy top soil	Low
		l_2	22.6	2.04	4.0	Weathered/basement	
		l_3	806	--	--	Fractured basement	
17	KH	l_1	26.7	0.62	0.62	Sandy top soil	Low
		l_2	1723	0.45	1.07	Compacted laterite	
		l_3	25.2	3.93	5.0	Weathered/fractured basement	
		l_4	3312	--	--	Fresh basement	
18	HK	l_1	249	1.08	1.08	Sandy top soil	Low
		l_2	9.71	0.84	1.92	Clay/Clayey sand	
		l_3	3060	2.88	4.8	Compacted laterite	
		l_4	242	--	--	Weathered/fractured basement	
19	H	l_1	194	4.1	4.1	Sandy top soil	Low
		l_2	29.2	3.99	8.09	Weathered basement	
		l_3	668	--	--	Fractured basement	
20	H	l_1	291	2.32	2.32	Sandy top soil	Poor
		l_2	53.2	14.0	16.3	Weathered/fractured basement	
		l_3	1574	--	--	Fresh basement	
21	HA	l_1	528	1.55	1.55	Sandy top soil	Moderate
		l_2	11.5	1.6	3.15	Lateritic sand	
		l_3	130	23.9	27.0	Weathered/fractured basement	
		l_4	28052	--	--	Fresh basement	
22	H	l_1	173	3.44	3.44	Sandy top soil	Very Low
		l_2	16.4	2.91	6.36	Laterite sand	
		l_3	1296	--	--	Fresh basement	
23	KH	l_1	116	0.595	0.595	Sandy top soil	Very Low
		l_2	1024	1.52	2.12	Compacted laterite	
		l_3	7.67	1.8	3.92	Laterite sand	

		l_4	1834	--	--	Fresh basement	
24	HA	l_1	190	1.38	1.38	Sandy top soil	High
		l_2	19.7	1.17	2.55	Clayey sand	
		l_3	335	54.4	56.9	Weathered/fractured basement	
		l_4	44878	--	--	Fresh basement	
25	H	l_1	241	1.97	1.97	Sandy top soil	Moderate
		l_2	151	34.8	36.8	Weathered/fractured basement	
		l_3	79606	--	--	Fresh basement	

VI. Geo-Electric Sections

Six geo-electric sections were produced showing the subsurface sequence along the established profiles (figures 5a to 5f). Geo-electric layers detected comprised topsoil, clay/clayey sand, lateritic sand, compact laterite, weathered/fractured basement and fresh basement.

The topsoil had resistivity values ranging from 1.9Ωm to 1360.0Ωm and depth ranging from 0.59m to 4.34m. The clay/clayey sand layer had resistivity range of 0.4Ωm to 24Ωm while lateritic sand varied 7Ωm to 16Ωm. Compact laterite showed resistivity range of 1024Ωm to 3060Ωm.

The weathered/fractured basement had resistivity values ranging from 22Ωm to 806Ωm while the detected basement rocks were highly resistive, of the order of 10^3Ωm to 10^5Ωm with unknown depths. Figures 5c and 5f are characterised by structural deformation at respective depths of 8.0m and 4.8m.

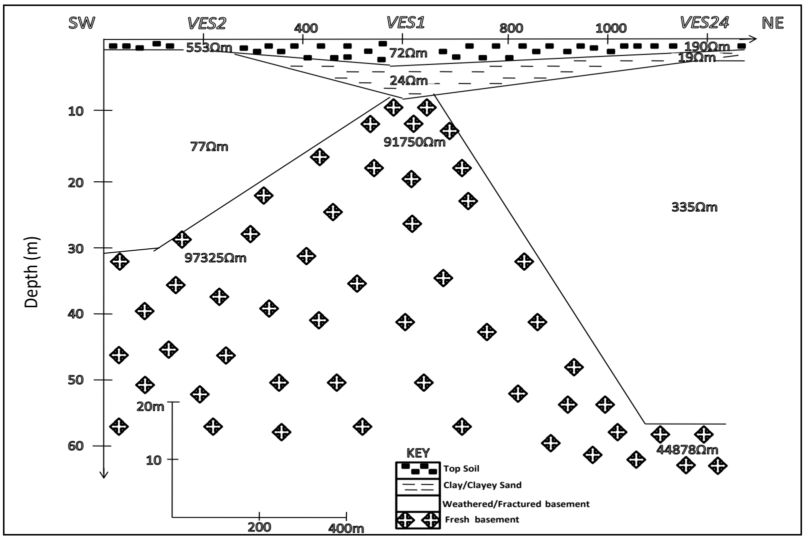


Figure 5a: Geo-electric section of the profile along VES 2, 1 & 24.

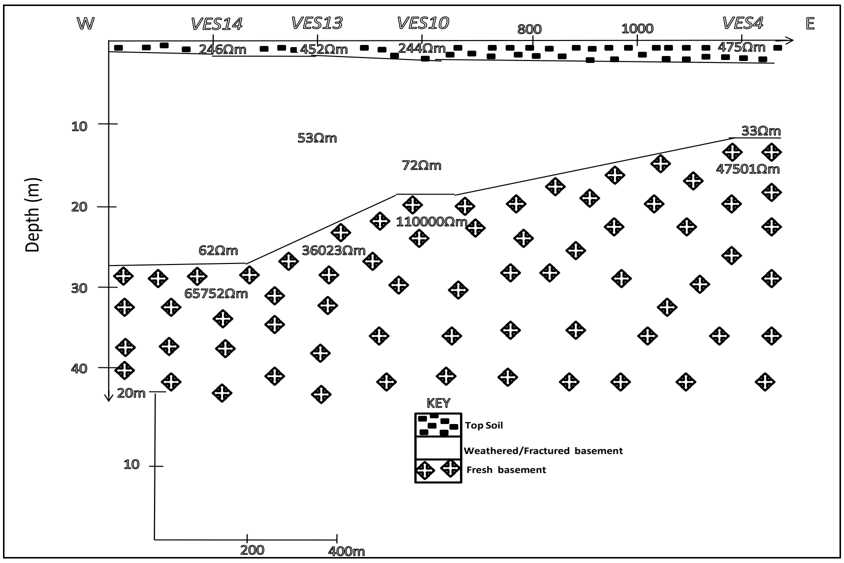


Figure 5b: Geo-electric section of the profile along VES 14, 13, 10 & 4.

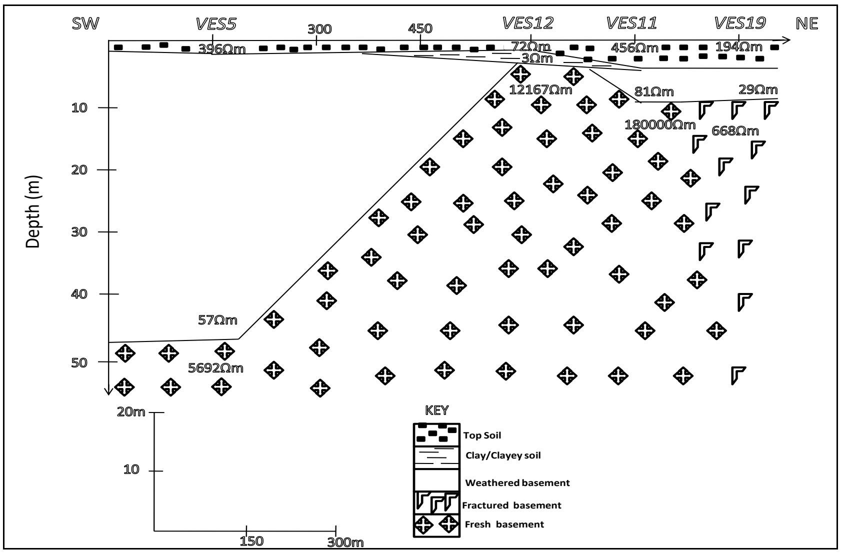


Figure 5c: Geo-electric section of the profile along VES 5, 12, 11 & 19.

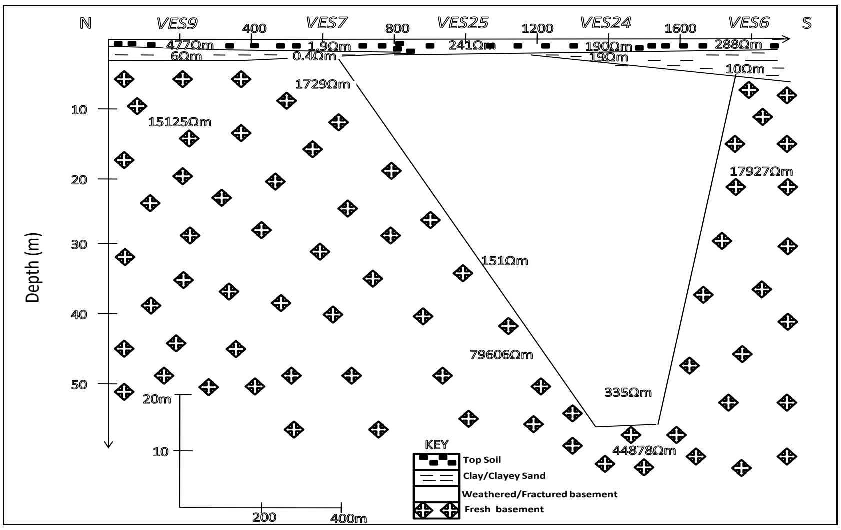


Figure 5d: Geo-electric section of the profile along VES 9, 7, 25, 24 & 6.

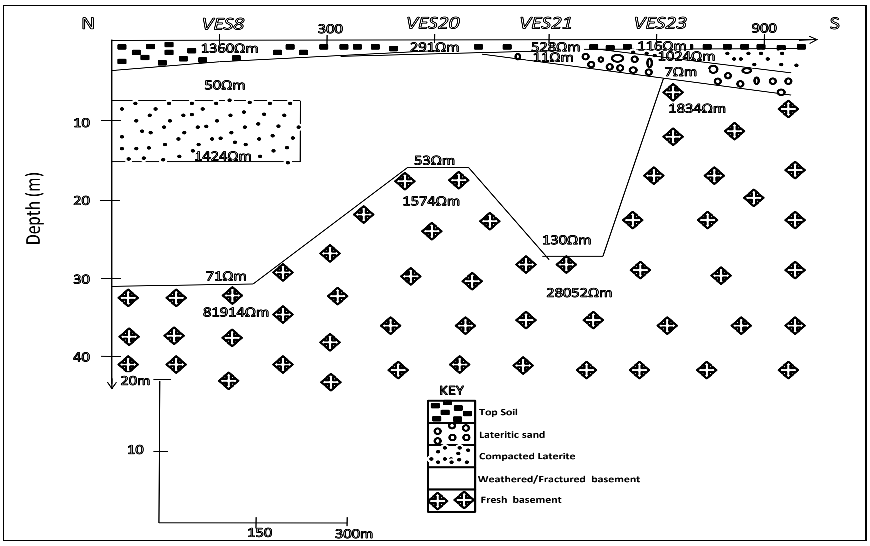


Figure 5e: Geo-electric section of the profile along VES 8, 20, 21 & 23.

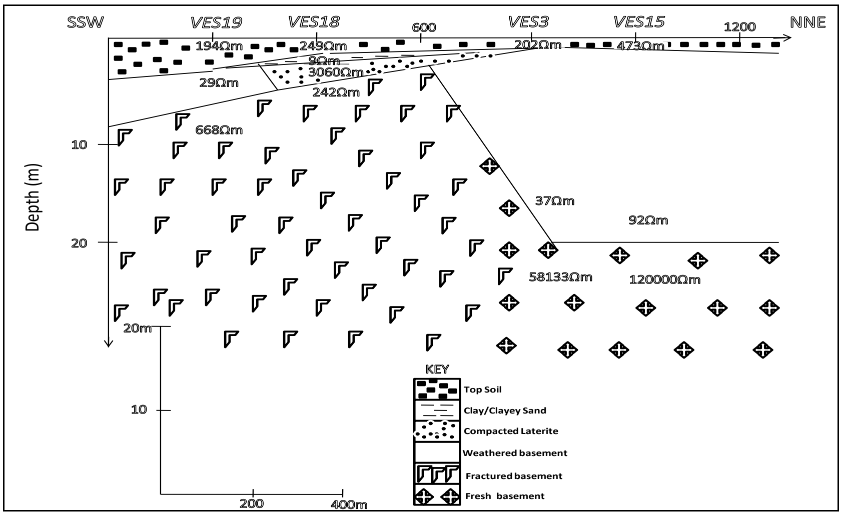


Figure 5f: Geo-electric section of the profile along VES 19, 18, 3 & 15.

VII. Conclusion And Recommendation

The method of investigation adopted by this study has helped in the identification of the aquiferous units and has provided an understanding of the thickness of the aquifer layers and other geo-electric layers, ground water potential and lithologic units within the study area. The second layer mostly constitutes the aquifer units in the investigated area with weathered/fractured basement rocks although a few layers amongst the third and fourth strata were interpreted as conduits for groundwater. The thicknesses of the weathered/fractured basement of VES 2, VES 5, VES 8, VES 14, VES 21, VES 24 and VES 25 (stations) were observed to be approximately 30, 45, 28, 25, 25, 55 and 34 metres respectively which make these seven stations rank topmost for ground water potential within the investigated area. The underground water potential rating of five (5) VES stations were rated low, seven (7) VES stations were rated very low while six (6) VES stations were rated poor. With the classification of the groundwater potential of the study area, the problems of drilling dry holes could be minimized.

From the results of this research, the recommended sites for development of viable boreholes are stations VES 2, VES 5, VES 8, VES 14, VES 21, VES 24 and VES 25. It is therefore suggested that groundwater development through borehole construction in the study area as well as other basement complex terrain should be preceded by geophysical investigation. This will minimize the problems of drilling dry holes and enhance access to groundwater resource in Basement Complex terrains.

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