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Geoelectrical Investigation of Groundwater Potential in University of Abuja, Main Campus

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Abstract

Electrical resistivity techniques of geophysical prospecting have been used to evaluate the groundwater potential of the University of Abuja Health Services Centre at the main campus. This research aims to identify suitable locations for productive wells and boreholes, determine the depth of the bedrock, as well as measure resistivity and overburden thickness. The survey employed Vertical Electrical Sounding (VES) along five profiles, comprising fifty (50) VES stations covering the survey area. The resistivity data obtained are analysed using IPI2win software. The analysis of the resistivity data revealed that the survey area can be divided into four geoelectric layers: topsoil, clayey sand, weathered layer, and fresh basement. The resistivity values of these layers range from 38.7-1427 Ωm, 16.2-310 Ωm, 32.1-1714 Ωm and 1007-9528 Ωm respectively. The fresh basement layer was found to have an infinite thickness. Significantly, potential regions with low resistivity values indicating the presence of groundwater were identified at a depth of 18.3 m. Furthermore, the average overburden thickness in the study area was 35 m while the longitudinal conductance of the overburden ranges from 0.04 – 1.87 mho. Results obtained indicate the main aquifer in the area consists of a thick weathered layer of overburden and a weathered basement with relatively low resistivity, suggesting a potentially productive groundwater yield. This information is crucial for future planning and decision-making regarding the siting of wells and boreholes and the sustainable utilisation of groundwater resources in the University of Abuja main campus.

Keywords: Resistivity; Basement; Groundwater potential; Geoelectric layers; Aquifer.

I. INTRODUCTION

The pursuit of water availability is indeed a significant concern in Nigeria, as the country heavily relies on various sources such as springs, rivers, lakes, and rainfall for domestic, industrial, and agricultural activities. However, the goal of achieving reliable access to water throughout the year has not been fully realized in many developing countries, including Nigeria [1].

In areas with basement terrain, aquifers, which are underground layers of permeable rock or sediment that can hold and transmit groundwater, are typically replenished annually by precipitation. However, some aquifers may become depleted and exhausted, reaching saturation thickness before the rainy season begins. This natural occurrence can result in a lack of available groundwater for extraction, which negatively impacts people, economic activities, and industries that rely on groundwater [2, 3]. The quality of groundwater is as important as its quantity since it can be influenced by human activities when contaminants flow into the subsurface. Therefore, it is crucial to conduct site investigations before drilling wells or boreholes and to monitor and maintain the quality of both shallow and deep wells to ensure clean water is available for domestic and irrigation purposes.

In Nigeria, various techniques have been employed to investigate groundwater potentials, with the electrical resistivity method being the most used [4]. This method, specifically Vertical Electrical Sounding (VES), will be utilized in the mentioned study to investigate the thickness of overburden (the layer of soil and rock above the aquifer), depth, and variations in resistivity of the subsurface layers. Electrical resistivity measures the ability of subsurface materials to resist the flow of electric current, which can provide valuable information about the characteristics and potential presence of aquifers. By employing the electrical resistivity method, researchers can gain insights into the subsurface structure, identify potential groundwater-bearing formations, and assess the viability of drilling wells or boreholes in specific locations. This information is vital for efficient and sustainable water resource management in Nigeria, supporting the country's efforts to enhance water availability for various needs.

II. LOCATION AND GEOLOGY OF THE STUDY AREA

The study area is in the North Central Part of the Federal Capital Territory (FCT), Nigeria. Its coordinates lie between latitude 8°58′ 50″ North and longitude 7°10′ 49″ East as seen in Fig.1. University of Abuja, main campus shares its boundaries with Anagada in the north, in the east and southeast by Kuje, in the west by Giri along Abuja airport road and the southwest by Gwagwalada town. The area is easily accessible by good road networks that lead to Abuja cities (Wuse, Area One, Maitama, Gwarinpa) and Gwagwalada area council.

The underlying rock of Abuja (F.C.T) is subdivided into two geological areas similar in structure and lithological characteristics and this is known as the Basement Complex and Sedimentary Rocks. The basement complex rocks are made up of igneous and metamorphic rocks which cover about 48% of the total area while the hills and dissected terrain occupy other places [5]. The geology of the study area is a basement complex which is Precambrian in age. The basement complex is made up of four lithological units and they include the Migmatite-Gneiss Complex (MGC), the Schist belt, older granites and the undeformed acid and basic dykes [6].

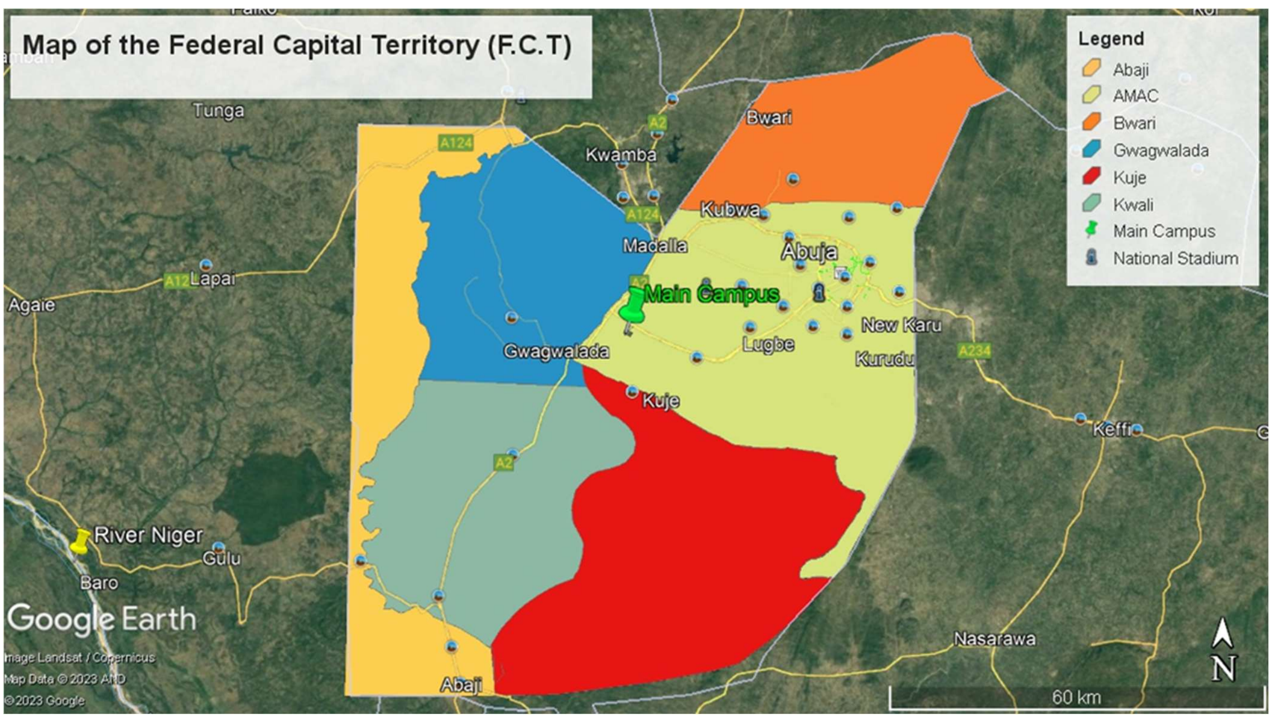

Fig. 1 Map showing the location of the study area.

A. Drainage of the study area

The drainage pattern in the study area is dendritic with undulating topographic features. Abuja has many major rivers namely Gurara and Usuma which rises from the hills and join to form a tributary in river Niger. Other small tributaries that join to the main river Niger include Mangol, Yewu, Bobo, Wuye, Wupa, Itsu, Iku, Tapa, Jabi, and Wosika. They give rise to form the drainage system in the Federal Capital Territory (F.C.T) which can be seen in Fig. 2. The area is fertile for agricultural purposes due to the presence of alluvial materials deposited as well as the availability of water supply for irrigation, hydro-electric power potential and domestic use [7].

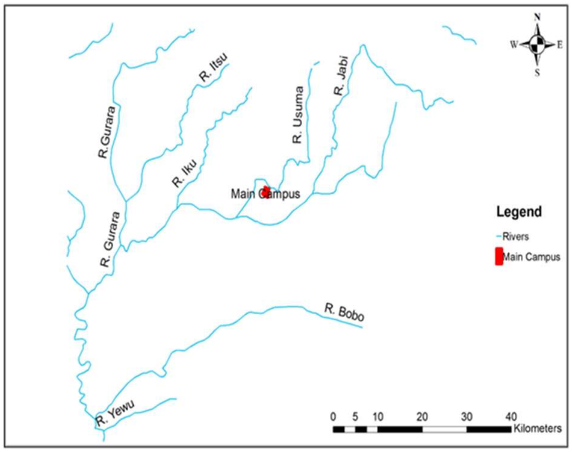

Fig. 2 Map showing the drainage pattern of the Study Area.

B. Climate and Vegetation

The temperature of the study area ranges from 30°C-35°C and the hot humid climate is greatest during the daytime. However, there is a short intermission of harmattan between the two seasons caused by the Northeast trade wind, associated with the features of climate change such as dust, dryness and coldness [8].

The vegetation of the study area is that of the Guinea Savannah which comprises of various species of shrubs and high forest plants [9]. It is characterized by grasses, thorn bushes, and a few deciduous trees and flowers.

III. MATERIALS AND METHODS

A total number of fifty (50) vertical electrical soundings (VES) points are carried out at the University of Abuja's main campus, opposite the University Health Services (U.H.S) using ABEM SAS 300c Terrameter. This survey adopted the use of the Schlumberger array method to determine resistivity measurement of the subsurface earth materials, its thickness, and the depth of the water-bearing zone. However, the layout of the study area was mapped on the field for measurement accuracy and as well as taking and recording coordinates reference point of each VES station as seen in Fig. 3. In this research, the data were analyzed using IPI2WIN (version 1.0) software package for interpreting Schlumberger sounding curves which were obtained from field data. The current electrode spread (AB/2) varied from 1-120 meter(m), and the depth sounding curves were used to illustrate the apparent resistivity data.

During qualitative data analysis, the apparent resistivities (ρ_{α}) which is in ohmmeters (Ω-m) were plotted against the half-current electrode (AB/2) spacing which is in meters(m) on a constant logarithmic scale which yielded the curves. Using the IPI2win software (version 1.0), the partial curve matching method was used to interpret the curves number of layers, average resistivity, thickness and depth. According to [10], when field data are collected, the sounding curves plotted are analyzed to detect the lateral changes in thickness, depth and variations in lithology.

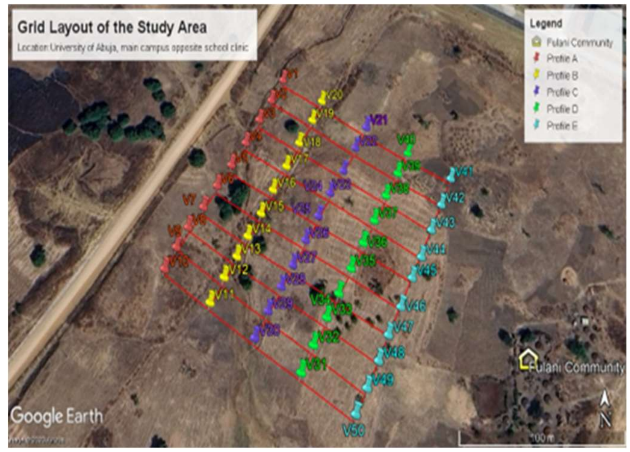

Fig. 3 Map showing the grid layout of the study area.

A. Theoretical Background

The geoelectrical technique, also known as electrical resistivity method, is widely used in groundwater exploration, particularly in basement terrain. It involves the measurement of electrical resistivity to infer the subsurface characteristics and identify potential groundwater resources. The resistivity of consolidated and unconsolidated earth materials, such as rocks and soils, depends on various factors including porosity, temperature, rock type, and texture. Different types of rocks, like sandstone and granite, have different void and fluid content, which affect the flow of electrical current.

In geophysical prospecting and groundwater exploration using direct current, the surface effect produced by the flow of electrical current within the earth is detected. This method involves the insertion of an electrode into the homogeneous medium (earth) to supply direct electric current, while measuring the electrical potential above the surface using another electrode. The resistivities of rocks and soils encountered during the passage of electricity around the electrodes can influence the distribution of the expected electrical potential.

A slight deviation from the expected pattern of electrical potential can indicate variations in the electrical characteristics of the subsurface. By analysing these deviations, valuable information about the subsurface geology, such as the presence of aquifers, lithological boundaries, and potential groundwater reservoirs, can be obtained. This information is crucial for groundwater exploration and resource assessment in basement terrains.

The principle governing the electrical method is embodied in the theory of Ohm's law [11, 12] which is mathematically given by (1).

$$R = \frac{\Delta V}{I} \quad (1)$$

According to[13], the theoretical study of the resistivity of the homogeneous medium can be solved from the measured field values of voltage V, current I, and geometric factor K where the parameter K depends on the type of electrode configuration used in taking the field measurement. In this study, the Schlumberger array of the geometric factor K according to [11] was used to compute the apparent resistivity using (2).

$$\rho_\alpha = K\frac{\Delta V}{I} \quad (2)$$

$$K = \left(\pi\alpha\left(\frac{s}{a}\right)^2 - \frac{1}{4}\right) \quad (3)$$

Where K is the geometric factor "s" and "a" are the maximum spacing between the current $(\frac{AB}{2})$ and potential electrodes (MN) respectively. The potential difference ΔV is measured in volts while the current (I) is in Amperes.

IV. RESULTS AND DISCUSSION

The resistivity sounding curves that were analyzed from the survey area are predominately; HA, AH and QH type. Its significance is to predict likely groundwater prospects found in the survey area. The different curve classification is based on the resulting number of defined layers produced from the true resistivity and thickness values of each VES station plotted, which is graphically represented in a digitized logarithmic scale as seen in Fig. 4, Fig. 5 and Fig. 6 respectively.

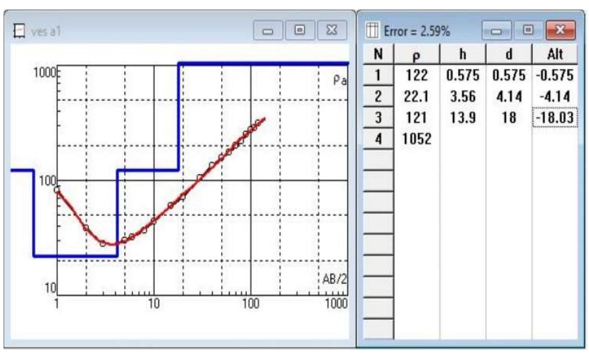

Fig. 4 Graph representation of VES A1.

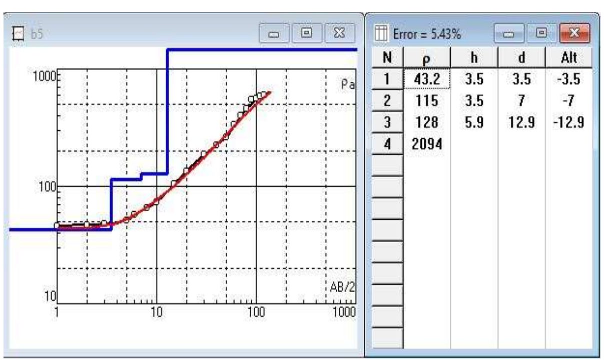

Fig. 5 Graph representation of VES B5.

Fig. 6 Graph representation of VES E7.

The curves illustrate that the study area is underlain into four geoelectric layers namely, the topsoil, clayey layer, weathered and the fresh basement layer. The topsoil resistivity and thickness values range from $38.7 - 1427\ \Omega m$ and $0.17 - 8.8\ m$ respectively. The layer underlain by the topsoil is the clayey sand with resistivity values ranging from 16.2-310 Ωm and the thickness varies from 0.06-8.31 m. The resistivity of the weathered basement ranges from 32.1-1714 Ωm while the thickness value varies between 1.17-124 m. The last layer is the fresh basement, the resistivity values range from 1007-9528 Ωm and have an infinite thickness. The summary of the interpreted resistivity data obtained along five profiles covering the survey area is shown in Table I and this was used to compute the longitudinal conductance of the subsurface layers by combining the interpreted resistivity and thickness value of each layer. The result obtained was used to classify the aquifer protective capacity found in the study area, while the rating model after [14] and [15] was also employed in Table II to obtain the map as shown in Fig. 7. The calculated longitudinal conductance for the study area is presented in Table I and the observed result reveals four distinct zones defined as: poor, weak, moderate and good aquifer protective capacity. Nineteen (19) VES stations have a poor protective capacity which covers 38% in the map as seen in Fig. 7, twenty-one (21) VES stations show weak protective capacity rating which covers about 42% of areas in the map, eight VES station has moderate aquifer protective capacity covering 16% areas in the map while two VES stations have good aquifer protective capacity rating covering 4% areas in the map. High longitudinal conductance corresponds to high aquifer protectivity capacity as shown in Fig. 7, in which information is provided on potential zones that will help water quality improvement.

Table I. Summary of results

VES No	Curve Type	Layer	Resistivity (Ωm)	Thickness (m)	Depth (m)	Lithology	Longitudinal conductance (S= m/ρ)	Groundwater potential rating
		1	122	0.58	0	Sandy topsoil		
A1	HA	2	22.1	3.56	4.14	Clayey sand	0.2807	Moderate
		3	121	13.9	18	Weathered basement		
		4	1052	∞		Fresh basement		
A2	HA	1	520	0.49	0	Sandy topsoil		
		2	133	2.44	2.93	Clayey sand		
		3	438	45.3	48.3	Weathered basement	0.1227	Weak
		4	1976	∞		Fresh basement		
A3	HA	1	433	0.56	0	Sandy topsoil		
		2	83.4	3.72	4.28	Clayey sand		
		3	198	11.3	15.6	Weathered basement	0.1029	Weak
		4	1222	∞		Fresh basement		
A4	QH	1	269	0.48	0	Sandy topsoil		
		2	51.4	3.08	3.56	Clayey sand		
		3	26.6	2.04	5.6	Weathered basement	0.1384	Weak
		4	5192	∞		Fresh basement		
A5	QH	1	537	0.35	0	Sandy topsoil		
		2	101	0.87	1.22	Clayey sand		
		3	60.7	4.86	6.08	Weathered basement	0.0893	Poor
		4	7862	∞		Fresh basement		
A6	HA	1	514	0.33	0	Sandy topsoil		
		2	138	8.31	8.64	Clayey sand		
		3	584	7.99	16.6	Weathered basement	0.0745	Poor
		4	9528	∞		Fresh basement		
A7	HA	1	394	0.47	0	Sandy topsoil		
		2	48.1	0.57	1.04	Clayey sand		
		3	170	8.98	10	Weathered basement	0.0659	Poor
		4	4053	∞		Fresh basement		
A8	HA	1	374	0.57	0	Sandy topsoil		
		2	16.2	0.06	0.62	Clayey sand		
		3	78.8	5.26	5.88	Weathered basement	0.0719	Poor
		4	2056	∞		Fresh basement		
A9	QH	1	1427	0.39	0	Sandy topsoil		
		2	152	1.84	2.24	Clayey sand		
		3	42.9	2.24	4.47	Weathered basement	0.0646	Poor
		4	1380	∞		Fresh basement		
A10	QH	1	696	0.29	0	Sandy topsoil		
		2	119	1.55	1.85	Clayey sand		
		3	24.3	2.32	4.17	Weathered basement	0.1089	Weak
		4	8348	∞		Fresh basement		
B1	HA	1	429	0.55	0	Sandy topsoil		
		2	97.9	5.99	6.54	Clayey sand		
		3	156	3.56	10.1	Weathered basement	0.0853	Poor
		4	6478	∞		Fresh basement		
B2	QH	1	116	8.4	0	Sandy topsoil		
		2	81.6	2.7	11.2	Clayey sand		
		3	84	3.6	14.8	Weathered basement	0.1484	Weak
		4	1007	∞		Fresh basement		
B3	HA	1	278	0.61	0	Sandy topsoil		
		2	45.6	1.44	2.05	Clayey sand		
		3	188	19	21	Weathered basement	0.1348	Weak
		4	4484	∞		Fresh basement		
B4	HA	1	386	0.55	0	Sandy topsoil		
		2	74.7	2.51	3.06	Clayey sand		
		3	432	15.8	18.8	Weathered basement	0.0716	Poor
		4	4478	∞		Fresh basement		
B5	AH	1	43.2	3.5	0	Sandy topsoil		
		2	115.3	3.6	7	Clayey sand		
		3	128	5.9	12.9	Weathered basement	0.1583	Weak
		4	2093.9	∞		Fresh basement		
B6	HA	1	76.5	8.8	0	Sandy topsoil		
		2	55.9	3.2	12	Clayey sand		
		3	192.7	2	14	Weathered basement	0.1827	Weak
		4	2232.1	∞		Fresh basement		
B7	HA	1	371	0.32	0	Sandy topsoil		
		2	31.9	1.23	1.55	Clayey sand		

		3	438	17.3	18.85	Weathered basement	0.0789	Poor
		4	2663	∞		Fresh basement		
B8	HA	1	412	0.97	0	Sandy topsoil		
		2	111	4.46	5.43	Clayey sand		
		3	535	34.6	40	Weathered basement	0.1072	Weak
		4	9152	∞		Fresh basement		
B9	HA	1	569	0.57	0	Sandy topsoil		
		2	98.5	3.21	3.78	Clayey sand		
		3	104	7.74	13.9	Weathered basement	0.1080	Weak
		4	2522	∞		Fresh basement		
B10	QH	1	582.2	0.406	0	Sandy topsoil		
		2	67.46	1.459	1.865	Clayey sand		
		3	100	34.087	39.9	Weathered basement	0.3632	Moderate
		4	1821	∞		Fresh basement		
C1	HA	1	242	0.57	0	Sandy topsoil		
		2	83.3	3.81	4.38	Clayey sand		
		3	420	26.7	31.1	Weathered basement	0.1116	Weak
		4	7427	∞		Fresh basement		
C2	AH	1	38.7	3.3	0	Sandy topsoil		
		2	179.9	1.9	5.2	Clayey sand		
		3	275.1	1.6	6.3	Weathered basement	0.1017	Weak
		4	1012	∞		Fresh basement		
C3	HK	1	707	0.41	0	Sandy topsoil		
		2	7.8	4.53	4.94	Clayey sand		
		3	76.4	13.3	18.3	Weathered basement	0.7554	Good
		4	7558	∞		Fresh basement		
C4	HA	1	165	0.64	0	Sandy topsoil		
		2	20.4	0.75	1.39	Clayey sand		
		3	68.6	5.13	6.52	Weathered basement	0.1154	Weak
		4	2574	∞		Fresh basement		
C5	HA	1	457	0.57	0	Sandy topsoil		
		2	79.3	0.41	0.98	Clayey sand		
		3	171	51.1	52	Weathered basement	0.3052	Moderate
		4	1789	∞		Fresh basement		
C6	QH	1	410	0.48	0	Sandy topsoil		
		2	112	2.16	2.64	Clayey sand		
		3	372	16.8	18.24	Weathered basement	0.0656	Poor
		4	5243	∞		Fresh basement		
C7	QH	1	515	0.39	0	Sandy topsoil		
		2	150	3.76	4.15	Clayey sand		
		3	132	11.1	15.25	Weathered basement	0.1099	Weak
		4	3657	∞		Fresh basement		
C8	QH	1	521	0.39	0	Sandy topsoil		
		2	150	3.86	4.24	Clayey sand	0.1127	Weak
		3	103	8.88	13.12	Weathered basement		
		4	5437	∞		Fresh basement		
C9	HA	1	371	0.55	0	Sandy topsoil		
		2	79.2	3.67	4.22	Clayey sand	0.0726	Poor
		3	428	10.6	14.8	Weathered basement		
		4	8845	∞		Fresh basement		
C10	HA	1	363	0.57	0	Sandy topsoil		
		2	79.2	3.38	3.96	Clayey sand	0.0755	Poor
		3	394	12.3	16.2	Weathered basement		
		4	5254	∞		Fresh basement		
D1	HA	1	364	0.57	0	Sandy topsoil		
		2	79.7	3.42	4	Clayey sand	0.0754	Poor
		3	401	12.4	16.4	Weathered basement		
		4	5265	∞		Fresh basement		
D2	HA	1	335	0.67	0	Sandy topsoil		
		2	47.9	1.54	2.22	Clayey sand		
		3	371	8.96	11.2	Weathered basement	0.0583	Poor
		4	1270	∞		Fresh basement		
D3	QH	1	355	0.49	0	Sandy topsoil		
		2	94.6	1.75	2.25	Clayey sand		
		3	59	9.88	12.1	Weathered basement	0.1873	Weak
		4	1888	∞		Fresh basement		
D4	HA	1	779	0.64	0	Sandy topsoil		
		2	149	6.1	6.74	Clayey sand		
		3	1209	124	130	Weathered basement	0.1443	Weak
		4	6997	∞		Fresh basement		
D5	HA	1	316	0.58	0	Sandy topsoil		

		2	77.1	2.02	2.6	Clayey sand		
		3	394	22.2	24.8	Weathered basement	0.0844	Poor
		4	8892	∞		Fresh basement		
D6	HA	1	335	0.62	0	Sandy topsoil		
		2	137	3.46	4.08	Clayey sand		
		3	1224	90.9	95	Weathered basement	0.1014	Weak
		4	6487	∞		Fresh basement		
D7	HA	1	315.1	0.79	0	Sandy topsoil		
		2	91.79	1.15	1.949	Clayey sand		
		3	321.6	8.64	10.59	Weathered basement	0.0419	Poor
		4	1724	∞		Fresh basement		
D8	HA	1	814	0.37	0	Sandy topsoil		
		2	310	4.84	5.21	Clayey sand		
		3	674	21.7	26.9	Weathered basement	0.0483	Poor
		4	7859	∞		Fresh basement		
D9	QH	1	187	0.52	0	Sandy topsoil		
		2	49.1	4.84	5.36	Clayey sand		
		3	105	9.85	15.21	Weathered basement	0.1952	Weak
		4	3634	∞		Fresh basement		
D10	HK	1	183	0.43	0	Sandy topsoil		
		2	51.4	5.79	6.21	Clayey sand		
		3	1714	5.86	12.1	Weathered basement	0.1184	Weak
		4	3849	∞		Fresh basement		
E1	HA	1	147	0.55	0	Sandy topsoil		
		2	24.4	3.25	3.8	Clayey sand		
		3	256	28.8	32.6	Weathered basement	0.2494	Moderate
		4	3795	∞		Fresh basement		
E2	HA	1	360	0.51	0	Sandy topsoil		
		2	99	3.98	4.48	Clayey sand		
		3	310	9.48	14	Weathered basement	0.0722	Poor
		4	3236	∞		Fresh basement		
E3	HA	1	1171	0.25	0	Sandy topsoil		
		2	273.03	1.98	2.233	Clayey sand		
		3	1028	38.24	40.48	Weathered basement	0.0447	Poor
		4	5024	∞		Fresh basement		
E4	HA	1	73.19	0.6	0	Sandy topsoil		
		2	23.86	2.19	2.799	Clayey sand		
		3	162	25.46	28.26	Weathered basement	0.2571	Moderate
		4	6860	∞		Fresh basement		
E5	QH	1	666	0.33	0	Sandy topsoil		
		2	167	0.92	1.25	Clayey sand		
		3	100	9.39	10.64	Weathered basement	0.0999	Poor
		4	5012	∞		Fresh basement		
E6	HA	1	108	0.87	0	Sandy topsoil		
		2	34.4	2.29	3.16	Clayey sand		
		3	220	46.8	49.96	Weathered basement	0.2874	Moderate
		4	3976	∞		Fresh basement		
E7	QH	1	191	0.52	0	Sandy topsoil		
		2	66.2	2.03	2.55	Clayey sand		
		3	32.1	3.49	6.04	Weathered basement	0.1421	Weak
		4	8349	∞		Fresh basement		
E8	HA	1	58.7	0.73	0	Sandy topsoil		
		2	18.2	5.85	6.58	Clayey sand		
		3	410	53.6	60.18	Weathered basement	0.4646	Moderate
		4	1973	∞		Fresh basement		
E9	HA	1	58.7	0.77	0	Sandy topsoil		
		2	23.2	6.35	7.12	Clayey sand		
		3	350	51.6	58.72	Weathered basement	0.4343	Moderate
		4	2973	∞		Fresh basement		
E10	HA	1	108	0.17	0	Sandy topsoil		
		2	48.4	7.33	7.5	Clayey sand		
		3	282	41.8	49.3	Weathered basement	0.3012	Moderate
		4	1897	∞		Fresh basement		

Table II. Longitudinal conductance/ aquifer capacity rating

Longitudinal conductance	Protective Capacity
>10	Excellent
5 – 10	Very good
0.7 – 4.9	Good
0.2 – 0.69	Moderate
0.1 – 0.19	Weak
<0.1	Poor

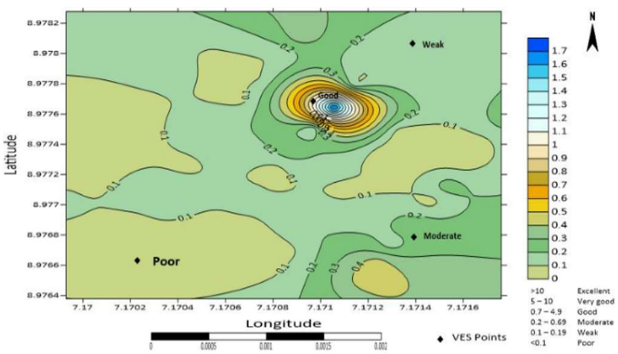

Fig. 7 Longitudinal conductance variations of the study area

A. ISO-Resistivity Map of the Topsoil

The iso-resistivity map of the topsoil was produced to show the various distribution of resistivity values obtained at each VES station using Golden surfer (version 18) software package. The resistivity values from Table I obtained for this layer vary from 38.7 – 1427 Ωm while the thickness varies between 0.17-8.8 m. The software shows different colors to represent the resistivity values of the earth materials as shown in Fig. 8.

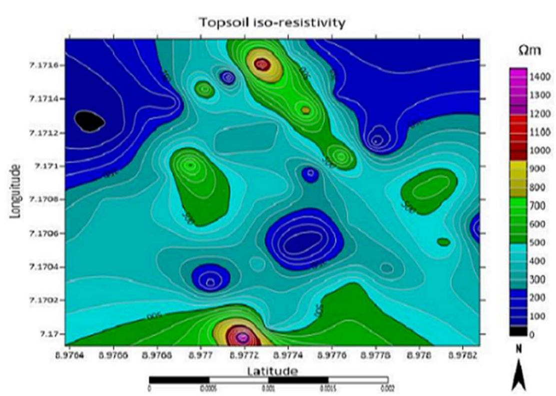

Fig. 8 Iso-resistivity map for layer one.

According to [16, 17], the iso-resistivity map of the first layer reveals that the topsoil constitutes of loose sand, clay, gravels, sandy clay, and organic materials. The resistivity values obtained from the map ranges from 0 – 1400 Ωm and contour interval used is 50 Ωm. The blue color represents sand with resistivity values ranging between 38.7 – 250 Ωm while the sky-blue color signifies gravels and has resistivity value ranging between 269 – 457 Ωm. The green color is characterized by the presence of laterite with resistivity values that ranges from 514 – 707 Ωm while the yellow, red and purple color is represented as deposits of alluvium materials. The resistivity values vary from 750 – 1427 Ωm as obtained from the map.

B. ISO-resistivity map of the second layer

The iso-resistivity map of the second layer in Fig. 9 shows different range of colors that represent various distribution of resistivity values of the earth materials. From the interpreted data, the resistivity values of this layer vary from 16.2 – 310 Ωm while the thickness ranges from 0.06-8.31 m. According to [16, 17], the ISO-resistivity map of the second layer shows that blue color signifies the presence of gravels with resistivity value ranging between 16.2 – 49.1 Ωm while the sky blue corresponds to clay sand with resistivity values that varies between 51.4 – 98.5 Ωm. The green color has resistivity values that ranges from 101 – 167 Ωm and this is represented by the presence of laterite. Alluvium materials is represented as yellow and red color with resistivity values ranging from 160 – 310 Ωm. However, the resistivity values obtained from the map ranges from 0 – 300 Ωm and it is contoured at an interval of 10 Ωm.

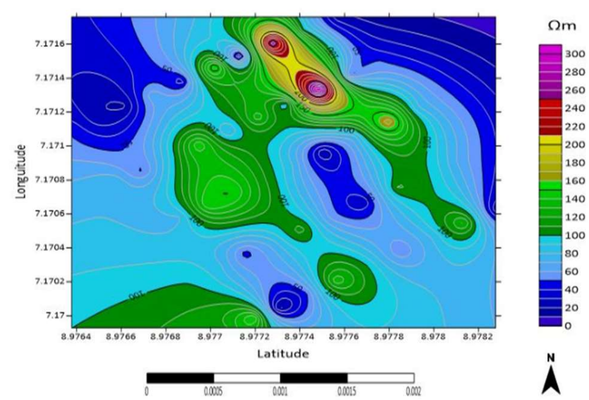

Fig. 9 ISO-resistivity map for the second layer.

C. Iso-resistivity map of the third layer

The ISO-resistivity map of the third layer which is the weathered layer in this study was produced to show the various distribution of resistivity values obtained in each VES station using different colors to represent the various rock materials as shown in Fig. 10. The resistivity values obtained from the map ranges from 0 – 1700 Ωm and it is contoured at an of interval of 100 Ωm. According to [16, 17], the iso-resistivity map of the third layer shows that the blue color represents the presence of clay while the sky blue corresponds to laterite soil, the green color represents the presence of water while the yellow and red color is represented by gravel deposits. The presence of clay in this layer has a resistivity value that varies from 32.1 – 282 Ωm while laterite, groundwater and the gravel deposits have a resistivity value that ranges from 310 – 535 Ωm, 674 – 1028 Ωm and 1224 – 1714 Ωm respectively. The resistivity values from this layer as shown in Table I varies between 7.8 – 1714 Ωm while the thickness value ranges from 1.17-124 m. According to [18], areas based on the weathered layer map where the resistivity ranging from 32.1 – 282 Ωm is classified as high groundwater potential, resistivity zones ranging from 300 – 500 Ωm are classified as medium groundwater potential and areas above 500 Ωm are classified as low groundwater potential groundwater potential can be zoned.

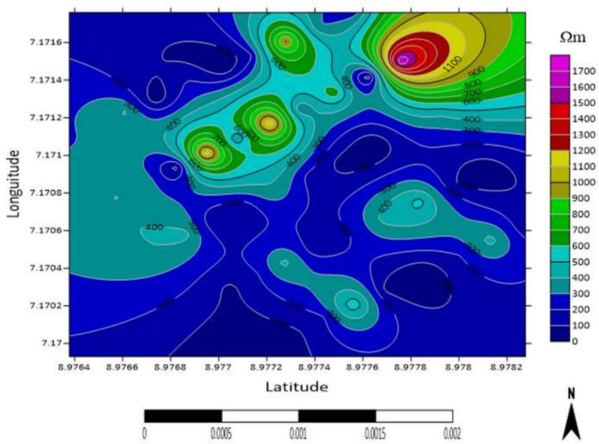

Fig. 10 Iso-resistivity of the third layer.

D. Iso-resistivity of the basement

The iso-resistivity map of the fourth layer which is the fresh basement layer reveals the various distribution of resistivity values obtained at each VES station. The software package shows different colors to represent the resistivity values as shown in Fig.11. According to [16, 17], the iso-resistivity map of the fourth layer shows that the blue color represents the presence of granite while the sky blue corresponds to gneiss, the yellow color is represented by the gabbro rock and the red color is represented by ultramafic rock. The resistivity value of the granite rock ranges from 1000 – 2000 Ωm, while the resistivity value of gneiss rock ranges from 2000 - 3500 Ωm as seen in Fig 11. The resistivity value of gabbro rock ranges from 3500 - 5000 Ωm while the resistivity values of the ultramafic rock ranges from 5000- 9528 Ωm with an infinite depth. However, the resistivity values obtained from the map ranges from 1000 – 9500 Ωm and the contour interval used is 500 Ωm. Rocks with resistivity values < 2000 Ωm support high groundwater yield and this is because the fractured part of the fresh basement is relatively high in permeability [18].

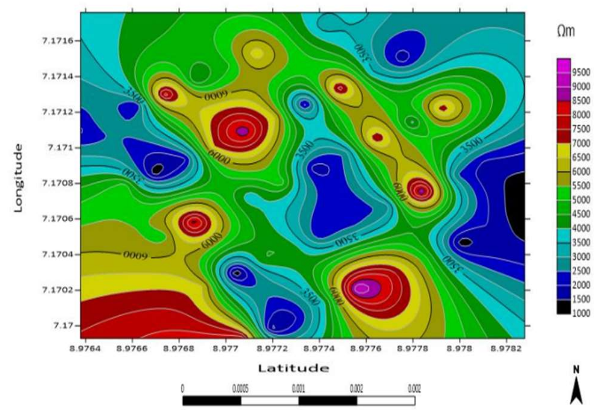

Fig. 11 ISO-resistivity map of the fourth layer.

E. Depth to Basement

The purpose of this map is to observe the general view of the topography and the variation in overburden thickness to establish the deepest and shallowest depths to basement. It is produced by contouring the last depth (that is the interpreted depth to fresh basement) at all the VES point. The contour map suggests that the depth to basement ranges from 5 – 130 m as shown in Fig. 12 contoured with an interval of 5 m. The blue color corresponds to the shallowest part of the study area with depth ranging from 0 – 35m. The areas delineated show possible watering zone because of the low resistivity values and high clay content materials found in these areas. The deepest part of the basement area revealed in the contour map is represented in red colour with depth ranging from 90 – 130 m. These areas depict the presence of low clay content and high resistivity values. In profile D at VES point D4 with depth of 130 m and resistivity value ranging between 779 - 6997 Ωm have an aquifer protective capacity that is weak. The overburden layer at this station constitutes a possible water-bearing zone.

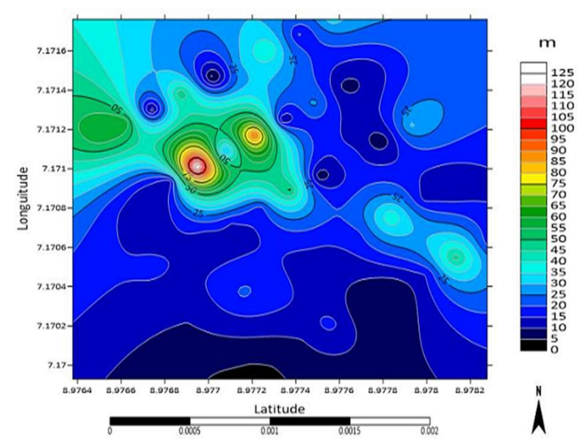

Fig. 12 Depth to basement map.

F. Isopach map of the weathered layer

The isopach map of the weathered layer is produced from the interpreted data of the thickness values obtained from the weathered layer for all the VES stations. This is also referred to as the aquifer thickness contour map. However, the aquifer thickness contour map is similar to the depth to basement map, and this is because they correlate with each other to show the aquifer variation in thickness from one VES station to another and as well as reveal the topography of the fresh basement in the study area. Shallow basement from the map indicates areas corresponding to low thickness values while the deepest part of the basement reveals areas corresponding to high thickness values as shown in the map. The blue color representing the shallowest part of the study area has an aquifer thickness that ranges from 5 – 35 m while the thickness values greater than 35 m shows the deep basement areas. From the three-dimensional map in Fig. 13, the aquifer thickness map varies from 5 – 115 m contoured at an interval of 5 m. However, the average overburden layer of the study area is obtained at $35\,m$. Hence, areas covering the fresh basement have an average overburden layer of about 35 m which is sufficiently thick to store enough water to support groundwater exploitation activities.

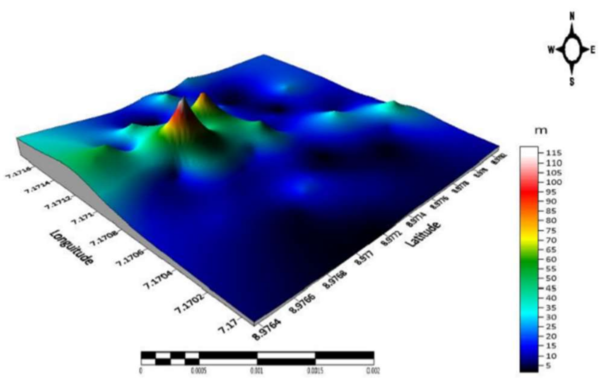

Fig. 13 Isopach map of the weathered layer.

V. Conclusion

A Vertical Electrical Sounding (VES) survey was conducted opposite the school clinic of the University of Abuja main campus to delineate the water-bearing formations within the study area. The resistivity result obtained shows the importance of electrical resistivity survey in delineating subsurface layers, aquifer zones, thickness, depth and longitudinal conductance. The presence of four distinct aquifer capacity zones were delineated which consists of the poor, weak, moderate and good. However, the subsurface geology generally shows a clayey-sandy formation. This investigation has also delineated the areas where groundwater development can be undertaken, as well as vulnerable zones where groundwater withdrawal should be restricted. From the quantitative interpretation of the data collected on the site, it can be inferred from the vertical electrical sounding results those potential regions with poor and weak aquifer protective capacity as shown in Table 1 are vulnerable to contamination arising from polluted water and waste disposal while areas of good and moderate aquifer protective capacity are less vulnerable to contamination. Considering all the geoelectric parameter adopted, it is recommended that VES A1, B10, C3, C5, E1, E4, E6, E8, E9 and E10 accorded with high longitudinal conductance value, low resistivity, depth and an average overburden thickness value of 35 m are potential zones for sitting wells and boreholes.

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