Investigation of Groundwater Resources by Determining the Aquifer Parameters around Futa Staff Quarters

C.T. Ibironke, J.R. Adewumi, O.M. Ojo and O.K. Akinmusere
Department of Civil and Environmental Engineering, the Federal University of Technology Akure, P.M.B. 704, Ondo State, Nigeria.
Corresponding E-mail: clementibironke@gmail.com

Abstract: An electrical resistivity survey was conducted at the Federal University of Technology, Akure (FUTA) staff quarters with a view to determine the subsurface layer parameters (velocities, resistivity, and thicknesses) and use same to categorize the ground-water potential and aquifer characteristics of the study area. Fifteen Vertical Electrical Soundings (VES) of the Schlumberger configuration were performed with electrode separation (AB/2) varying from 1 m to 65 m. An Ohmega (Ω) resistivity meter was used in the survey. The geo-electric data obtained were interpreted with partial curve matching and computer iteration using RESIST software. The results shows the presence of five geo-electric layers comprising top soil, weathered layered, partially weathered, fractured basement and fresh basement. The topsoil had resistivity ranging from 104 Ωm- 309 Ωm with a depth of 0.7 m-2.6 m. The weathered layer had resistivity ranging from 53 Ωm- 256 Ωm with a depth of 2.8 m- 19.4 m. The partially weathered had resistivity ranging from 108 Ωm- 645 Ωm with a depth of 6.1m-18.7m. The fractured basement had resistivity ranging from 104 Ωm- 105 Ωm with a depth of 4.7m – 14m while the fresh basement had resistivity ranging from 860 Ωm- 1638 Ωm with a depth of 6m – 16m. The comparison of the various parameters indicates that VES 5 is the preferable point to dig a well in this study area. It is therefore recommended that a good water scheme should be established to serve the residents of the study area.

Key words: Electrical resistivity survey, Resistivity, Schlumberger configuration, Vertical Electrical Soundings, Weathered layer.

1 INTRODUCTION

Common sources of water include rainwater, groundwater and surface water which could be found in form of precipitation, rainfall, river, sea or ocean. Often, surface water found in seas and oceans are not always reliable due to the level of salt in it and contaminants from the surrounding environment. However potable water suitable for human domestic and industrial consumptions exist deep down in the subsurface of the earth. In an attempt to explore and exploit this subsurface water, there is a need for geophysical methods for groundwater exploration. Geophysical methods play a very important and major role in the search for potable water to the society of the world. Surface geophysical survey as a veritable tool in groundwater exploration has the basic advantage of saving cost in borehole construction by locating target aquifer before drilling is embarked upon [1].

The use of the vertical electrical sounding (VES) is aimed at delineating the geo-electric parameters (ground resistivity and thicknesses) as well as aquifer potential over a section of the earth. The vertical electrical method is simple; field logistics are easy and straight forward and the analysis of data is less tedious and economical [2]. There are two major geological terrains that are recognized in Nigeria which are the basement complex and the sedimentary terrain. Ondo State is of the South Western part of Nigeria that comprises of basement complex, sedimentary terrain and the transition zones. The area covered by South Western Nigeria basement complex lies between Latitude 7° N and 7° N and Longitude 3° E and 6° E. In a typical basement complex, it is important to understand the geology of the study area. This will provide an exposure as to the types of rocks and materials underlying the study area which help to a reasonable extent in determining the aquifer characteristics, vulnerability as well as suitability for groundwater development in the environment of investigation.

The resistivity method has been used successfully in investigating groundwater potential. Oseji [3] used the method to investigate the aquifer characteristics and groundwater potential in Kwale, Delta State, Nigeria. VES is commonly used in electrical resistivity surveys to determine the vertical variation between the electrical resistivity below the earth's surface and the potential field generated by the current [4], [5]. This method was also used to determine the groundwater potential in Obiaruku and environs [6]. The technique involves inducing an electric current into the ground by means of two implanted electrodes and measuring the difference in potential between two other electrodes, referred to as the potential electrodes. The electric current used is the direct current provided by a dry cell. Therefore, analysis and interpretation of the geo-electric data are on the basis of direct current.

The resistivity computed from the measurement of induced current and the potential difference is referred to as the "apparent resistivity". This measurement is based on the assumption that the ground is uniform. Therefore, a graph of apparent resistivity against current electrode spacing is used to determine vertical variation in formation resistivity. Interpretation of this graph gives the true resistivity and depth of the geo-electric layers and is also used to ascertain the presence or otherwise of groundwater aquifers in the area. The parameters that are known to affect the estimation of groundwater resources include aquifer thickness and the size and degree of interconnection of pore spaces within the aquifer material [5]. These properties affect the ability of an aquifer to store and transmit groundwater [7]. This same method has also been used to explore for groundwater in a sedimentary environment [8]. The electrical resistivity method is useful in this regard, as it is an efficient and economical method for determining the presence of groundwater [9]. Geophysicists have also used it to determine the thickness of bedrock, clay aquitards, salt water intrusion, the vertical extent of certain types of soil and the spread of groundwater contamination [10], [11]. The electrical resistivity method can be used in a wide range of geophysical investigations, such as exploration for minerals, engineering investigation, geothermal studies, archaeological surveys and geological mapping [5]. The method has been used extensively in Nigeria and other parts of the world to investigate the subsurface.

The purpose of this research work is to determine the aquifer parameters that will help to locate easily access points for groundwater resources around FUTA Staff Quarters.

2 METHODOLOGY

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2.1 Study Area

The study site is located at the staff quarters of the Federal University of Technology, Akure, Ondo State (Fig. 1). Its geographical coordinates spans from 0735330 - 0735070 E along the East and 0808137 - 0808756 N along the North on the WGS 84 system and UTM-31N datum. The study area is readily accessible through the road networks that link the School of Post Graduate Studies (SPGS), School of Earth and Mineral Sciences (SEMS) and School of Management Technology (SMAT).

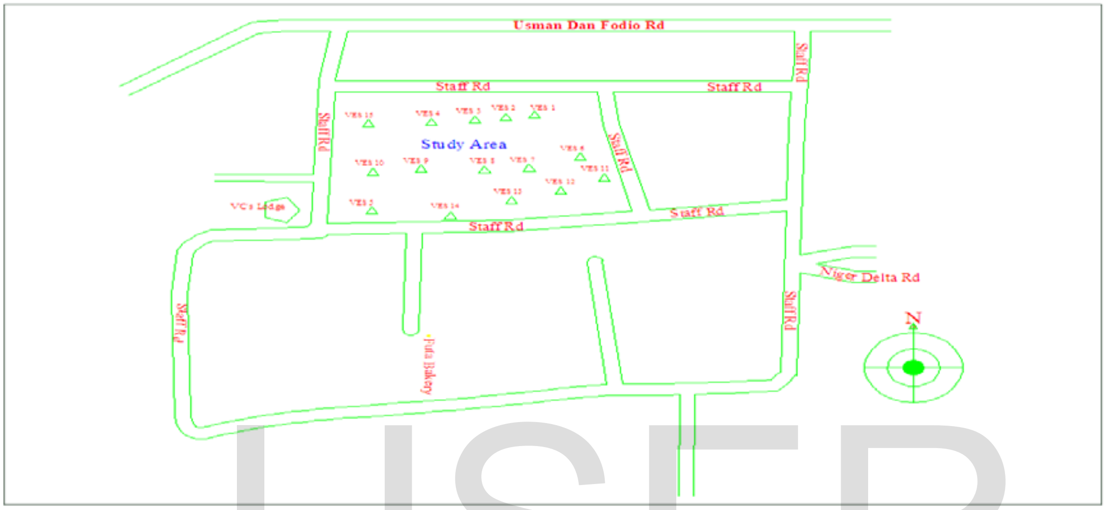

Fig. 1: Map of the Study Area

2.2 Data Acquisition

The geophysical investigation involved the use of electrical resistivity sounding measurements in the developing and accessible area of FUTA staff quarters. A total of 15 sounding points were established and each covered a maximum half spacing (AB/2) of about 50 meters, while the method was adopted for easy resolution and interpretation of the results and also the determination of the geo-electric parameters.

The equipment used for this survey was OHMEGA (Ω) resistivity meter. This equipment has an in-built chargeable battery. The transmitter is capable of accurate measurements over a wide range of applications. It possesses a choice of current settings from 0.5 mA to 200 mA with automatic gain steps, enables measurements to be made between 400 Kohm and 0.001 ohm. It also possesses three (3) square wave frequencies with a choice of up to 16 cycles per measurement.

This was used alongside its four sounding cable reels of 200 m to 500 m, non-polarized electrodes, hammers in driving the electrodes into the ground and clips. The VES was used in measuring vertical variation of ground resistivity. The electrodes are placed in a straight line and the inter-electrode spacing is gradually increased about a fixed center. The orientation of the spread was decided to enhance data quality and to suit the purpose of the investigation. It is applicable in the determination of overburden thickness, structures and resistivity of basement rocks in the subsurface.

Resistivity values (R) were calculated from ΔV/I which were later multiplied with the corresponding geometric factors, K to get the apparent resistivity values.

2.3 Data processing

Processing of the Vertical Electrical Sounding (VES) curve in terms of layer thickness and resistivity was carried out with the aid of computer program (Win Resist) and the corresponding geo-sections were constructed using the Golden Software Surfer® program.

3. RESULTS AND DISCUSSION

This investigation has utilized the different parameters generated and/or calculated to produce Geo-electric sections which were then qualitatively interpreted for an estimate of the groundwater potential. The vertical electrical sounding data were presented in form of tables and sounding curves. The tables below shows both the acquired VES data and parameters for the 15 VES carried out on the field.

Table 1: VES (1-5) Data Parameters

HALF CURRENT SPACING AB/2(m)	HALF POTENTIAL SPACING (M)	GEOMETRIC FACTOR (G)	VES 1 ρ_a (Ωm)	VES 2 ρ_a (Ωm)	VES 3 ρ_a (Ωm)	VES 4 ρ_a (Ωm)	VES 5 ρ_a (Ωm)
1	0.5	6.28	174	199	141	149	185
2	0.5	25.13	166	191	125	91	92
3	0.5	56.55	145	197	131	99	79
4	0.5	100.53	133	194	129	109	82
6	0.5	226.19	125	194	131	118	87
6	1.0	113.10	116	203	131	129	91
8	1.0	201.06	145	193	142	134	100
12	1.0	452.39	113	200	157	136	116
15	1.0	706.86	117	213	170	139	120
15	2.0	353.43	120	197	188	121	122
25	2.0	981.75	177	276	245	162	156
32	2.0	1608.50	237	284	304	167	163
40	2.0	2513.27	309	327	389	198	188

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40	5.0	1005.31	279	340	362	191	187
60	5.0	2654.65	515	-	445	342	-

Table 2: VES (6-10) Data Parameters

HALF CURRENT SPACING AB/2(m)	HALF POTENTIAL SPACING (M)	GEOMETRIC FACTOR (G)	VES 6 ρ_a (Ωm)	VES 7 ρ_a (Ωm)	VES 8 ρ_a (Ωm)	VES 9 ρ_a (Ωm)	VES 10 ρ_a (Ωm)
1	0.5	6.28	279	335	199	163	108
2	0.5	25.13	202	258	195	180	95
3	0.5	56.55	156	257	159	158	81
4	0.5	100.53	146	278	148	158	70
6	0.5	226.19	155	297	144	161	66
6	1.0	113.10	170	275	148	164	71
8	1.0	201.06	184	262	174	185	83
12	1.0	452.39	181	232	220	211	109
15	1.0	706.86	193	236	224	236	139
15	2.0	353.43	184	225	264	230	156
25	2.0	981.75	222	225	397	293	234
32	2.0	1608.50	216	252	276	353	301
40	2.0	2513.27	240	273	268	442	371
40	5.0	1005.31	231	307	331	464	342
60	5.0	2654.65	307	456	450	-	596

Table 3: VES (11-15) Data Parameters

HALF CURRENT SPACING AB/2(m)	HALF POTENTIAL SPACING (M)	GEOMETRIC FACTOR (G)	VES 11 ρ_a (Ωm)	VES 12 ρ_a (Ωm)	VES 13 ρ_a (Ωm)	VES 14 ρ_a (Ωm)	VES 15 ρ_a (Ωm)
1	0.5	6.28	103	146	183	103	324
2	0.5	25.13	73	144	171	63	218
3	0.5	56.55	58	137	164	49	224
4	0.5	100.53	50	109	154	50	233
6	0.5	226.19	42	116	141	55	246
6	1.0	113.10	43	116	149	61	262
8	1.0	201.06	41	111	142	71	266
12	1.0	452.39	43	111	157	82	275
15	1.0	706.86	47	129	174	89	295
15	2.0	353.43	48	144	195	90	276
25	2.0	981.75	79	212	289	124	265
32	2.0	1608.50	125	271	406	150	281
40	2.0	2513.27	169	332	327	166	307
40	5.0	1005.31	165	327	379	180	279
60	5.0	2654.65	272	423	780	220	367

4 DISCUSSION

4.1 Geo-electric Section along ENE –WSW Direction Connecting VES 1, 2, 3 and 4

The geo-electric section is oriented along ENE –WSW direction covering a total length of 520 meters. It comprises of the VES point 1, 2, 3 and 4 as shown in Fig. 2. The first layer is top soil with resistivity value between 113 and 198 Ω-m and with thickness between 2.2 m and 2.6 m. The second layer is the weathered layer

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with resistivity between 76 and 165 Ω-m and with thickness between 4.4 m and 7.5m. The third layer is partially weathered with resistivity between 329 and 573 Ω-m and with infinite thickness. The fourth layer is the fresh basement with resistivity of 1026 ohm-m and with infinite thickness. At VES 1 the fresh basement is closer to the surface with depth of 9.5 m from the topsoil. In this transverse section, VES 1, 3 and 4 are good yield point while VES 2 is a poor yield point.

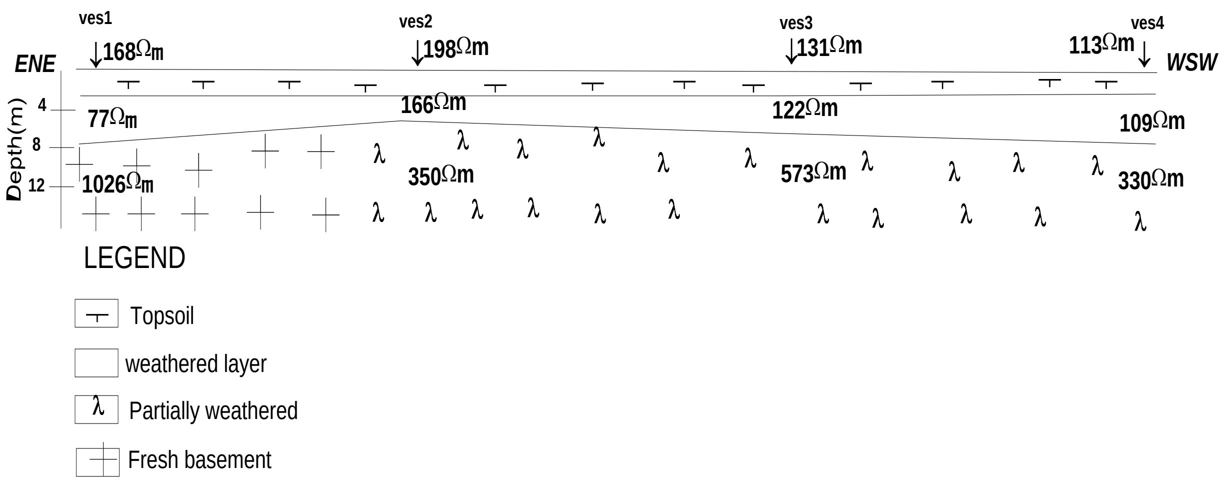

Fig. 2: Geo-electric section of VES 1, 2, 3 and 4

4.2 Geo-electric Section along ENE –WSW Direction Connecting VES 6, 7, 8 and 9

The geo-electric section is oriented along ENE –WSW direction covering a total length of 520 meters. It comprises of the VES 6, 7, 8 and 9 as shown in Fig. 3. The first layer is topsoil with resistivity value between 169 and 329 Ω-m and with thickness between 0.8 m and 1.5 m. The second layer is the weathered layer with resistivity between 92 and 240 Ω-m and with thickness between 2.0m and 3.2m. The third layer is partially weathered with resistivity between 263 – 645 Ω-m and thickness of 3.4m to infinite. The fourth layer is the fracture basement with resistivity ranging from 103 – 105 ohm-m and thickness of 2.7 m - 7.9 m. The fifth layer is the fresh basement with resistivity of 960 Ω-m with infinite thickness. In this transverse section, VES 6 and 9 are poor yield point, VES 7 is a good yield point while VES 8 is the best yield point.

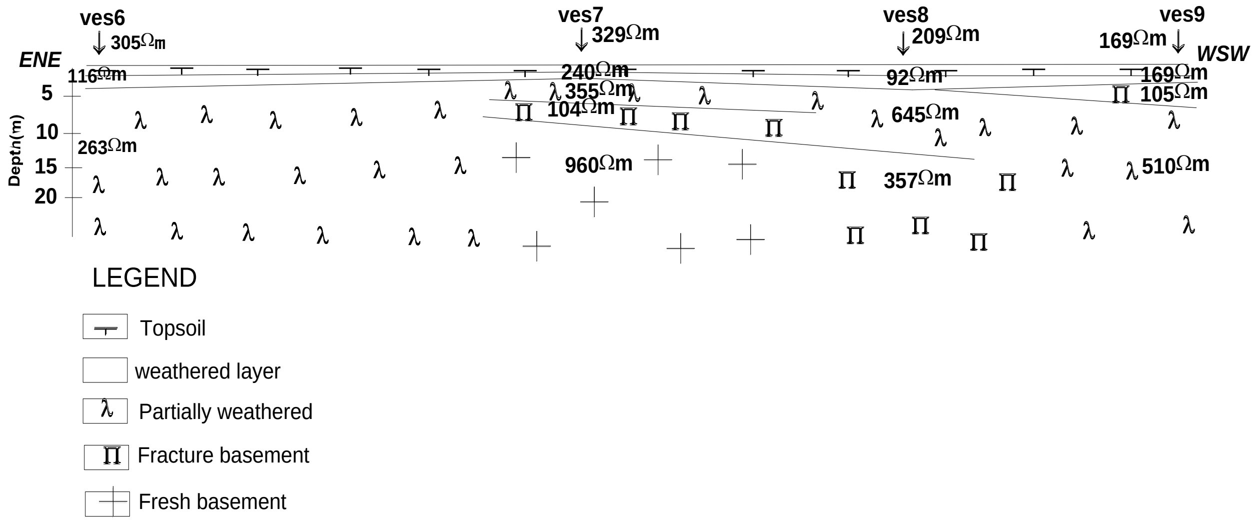

Fig. 3: Geo-electric section of VES 6, 7, 8 and 9

4.3 Geo-electric Section along ENE–WSW Direction Connecting VES 11, 12, 13 and 14

The geo-electric section is oriented along ENE –WSW direction covering a total length of 520 meters. It comprises of the VES point 11, 12, 13 and 14 as shown in Fig. 4. The first layer is topsoil with resistivity value between 104 and 182 Ω-m and with thickness between 0.8 m and 1.9 m. The second layer is the weathered layer with resistivity between 30 and 106 Ω-m and with thickness between 3.3 m and 6.6 m. The third layer is partially weathered with resistivity between 108 – 451 ohm-m and thickness of 5.5 m to infinity. The fourth layer is the fresh basement with resistivity ranging from 953 and 1638 Ω-m and with infinite thickness. At VES 12 and 13 there is a depression because of the stream at that point while the fresh basement is closer to the surface. The overburden thickness of VES 11, 12, 13 is shallow. In this transverse section, VES 11, 12 and 13 are good yield point while VES 14 is a poor yield point.

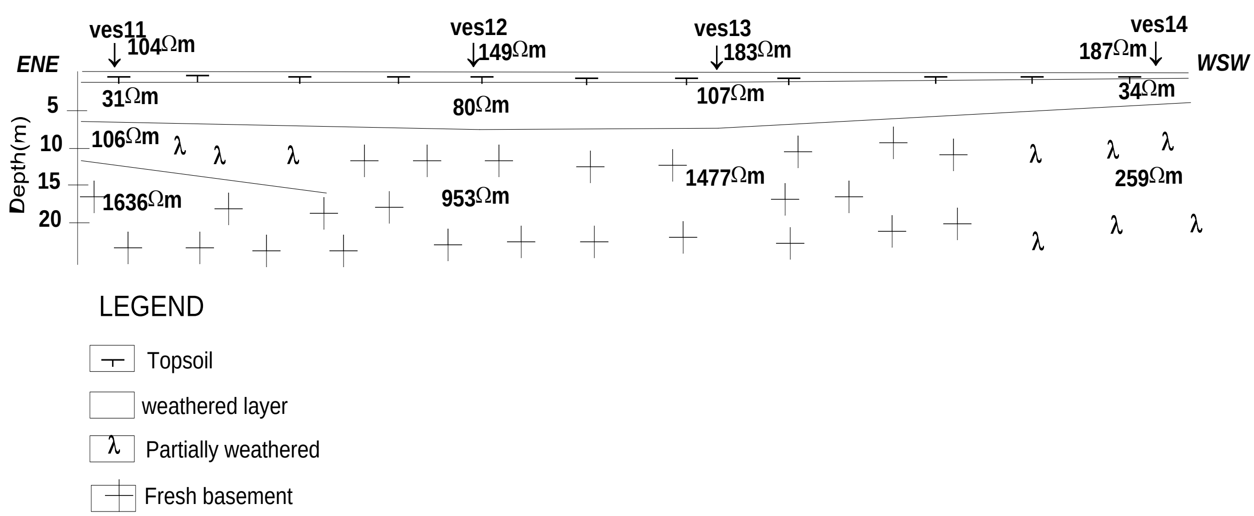

Fig. 4: Geo-electric section of VES 11, 12, 13 and 14

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4.4 Geo-electric Section along N –S Direction Connecting VES 5, 10 and 15

The geo-electric section is oriented along ENE –WSW direction covering a total length of 390 meters. It comprises of the VES point 5, 10 and 15 as shown in Fig. 5. The first layer is top soil with resistivity value between 122 and 251v and with thickness between 0.7m and 2.1m. The second layer is the weathered layer with resistivity between 53 – 255 Ω-m and with thickness between 2.1 m and 17 m. The third layer is partially weathered and fresh basement with resistivity between 190 Ω-m to infinity and with infinite thickness. In this transverse section, VES 10 and 15 are good yield points while VES 5 is the best and most probable yield point.

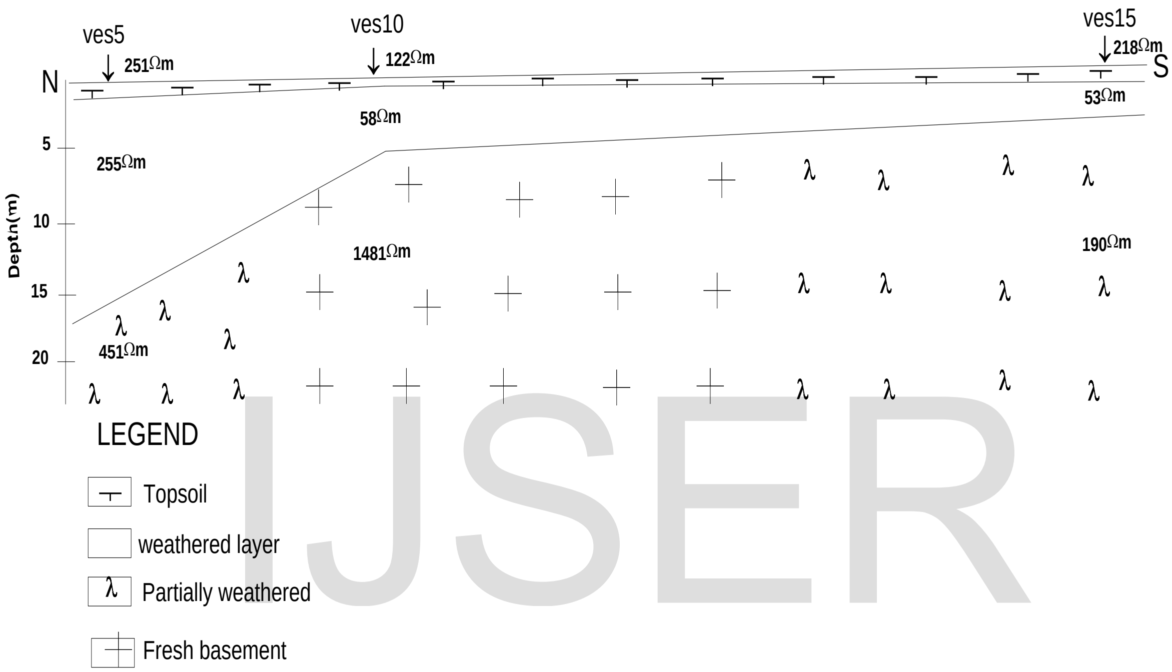

Fig. 5: Geo-electric section of VES 5, 10 and 15

4.5 Summary of Results

A summary of the results obtained are presented in Table 4. VES 5 has a high storability with a relative depth of 17 m within the weathered layer. With a high resistivity of 255 Ωm it is characterized with a high permeability as a result of the partially weathered layer present. Hence, it is the best and most probable yield point. Fig. 6 shows the geo-electric sections for VES 1 to 15, while Fig. 7 shows the columnar section for VES 5.

Table 4: Summary of Results

VES POINT	PROBABLE YIELD	REASON
VES 1	GOOD	Weathered layer lies between the depths of 3.5 m to 8.0 m. The storage coefficient can be achieved at a depth beyond 8.0 m.

VES 2	POOR	Has a shallow depth relative to the top soil and can be affected by runoff and drought.
VES 3	GOOD	Weathered layer lies between the depths of 4.0 m to 10.0 m.
VES 4	GOOD	Weathered layer lies between the depths of 3.9 m to 11.5 m. Which aid the permeability due to the presence of the partially weathered layer.
VES 5	BEST AND MOST PROBABLE YIELD POINT	Has a high storability with a relative depth of 17 m within the weathered layer. With a high resistivity of 255 Ωm it is characterized with a high permeability as a result of the partially weathered layer present.
VES 6	POOR	Has a shallow weathered layer lying between depths of 2.0 m to 3.0m.
VES 7	GOOD	Has a fracture basement of depths 8.7 m to 11.4 m which is characterized by high level porosity.
VES 8	BEST	Has a high rate of transmissibility with a relative depth of 15m within the partially weathered layered.
VES 9	POOR	Has a fracture basement very close to the top soil which ranges between the depth of 4.4 m to 6.0 m
VES 10	GOOD	Has a relative thickness of 5.0m within the weathered layer and a depth of 5.9 m
VES 11	GOOD	Resistivity within the partially weathered layer is 106 Ωm at a depth of 11.3m
VES 12	GOOD	Resistivity within the weathered layer is 80Ωm giving to a high hydraulic conductivity.
VES 13	GOOD	Resistivity within the weathered layer is 107 Ωm giving to a high hydraulic conductivity. Compare to the fresh basement with 1477 Ωm.
VES 14	POOR	Has the weathered layer close to the top soil which is of a depth 5.0m which can be affected by runoff.
VES 15	GOOD	Has an infinite depth and thickness within the partially weathered layer with a resistivity of 190 Ωm.

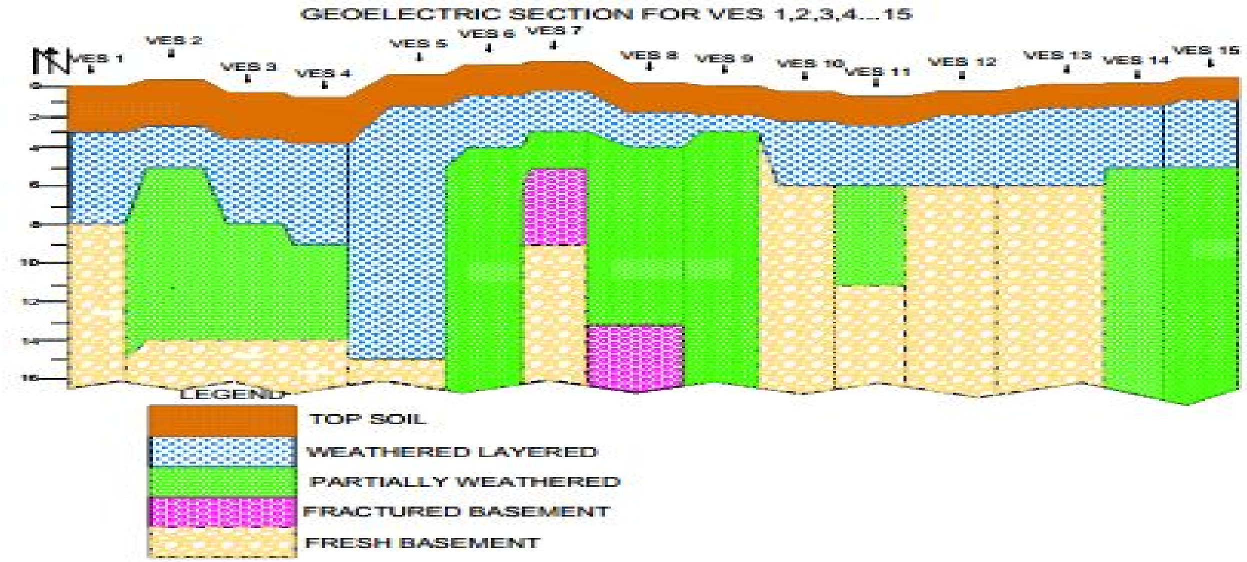

Fig. 6: Geo-electric section for VES 1 to 15.

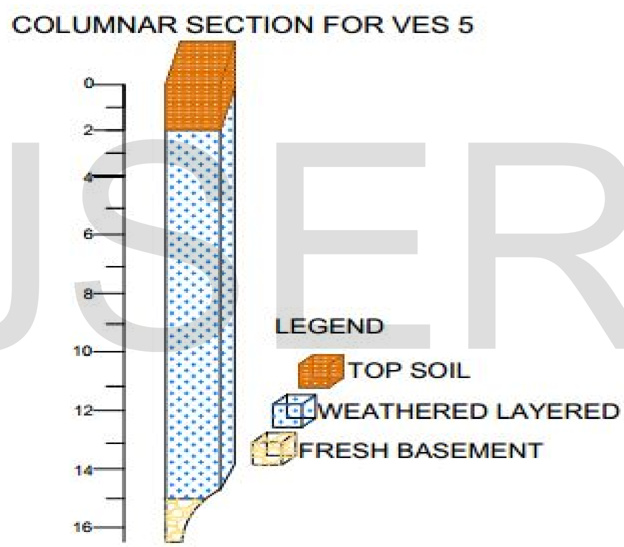

Fig. 7: Columnar section for VES 5.

5 CONCLUSION

From results of geophysical surveys conducted at the study area, VES 5 and 8 are the best suitable points for groundwater exploitation, but in varying compositions as related to groundwater development. However, VES 5 appears more favorable for groundwater development than any other VES point because of the availability of a weathered layer of significance thickness as an aquifer unit, as well as a reasonably high overburden thickness. In VES 7, there is existence of partially weathered rocks as well as a fractured basement. But the thickness of the fractured basement rock(s) is not known. On the other hand, VES 2,6,9, and 14 are not readily suitable for groundwater exploitation because of a thin overburden and a fractured column probably filled with clay, still concealed within two impervious rocks.

The adopted geophysical techniques provided information as related to the suitability of the surveyed area for groundwater development hence, the importance of geophysical methods in groundwater development, especially in a typical basement environment.

The application of geophysical methods for groundwater exploration in determining suitable points for groundwater development cannot be overemphasized. It is recommended that any water well project in FUTA staff quarters should be preceded with a detailed geophysical method. The results obtained from this study can be used as references for further geophysical works on the study area.

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