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Application of Geoelectric Methods for Groundwater Depths in Igbogbo, Ikorodu, Lagos State, Nigeria

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Authors' contributions

The research work was carried out in collaboration among all authors. Author SMK wrote the manuscript and analysed the data. Author ST designed the study. Author RSL and SOR carried out the field survey. All authors read and approved the final manuscript.

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ABSTRACT

This paper presents the result of the geophysical investigation carried out at Igbogbo Ikorodu, Lagos, Nigeria. The geophysical investigation was done using the Vertical Electrical Sounding (VES) and 2D electrical resistivity imaging techniques, with the aim of accessing the groundwater potential and delineate the subsurface layers of the study area. A total of twenty-four (24) VES were conducted at different points along four (4) traverses using Schlumberger electrode configuration with half-current electrode spread (AB/2) varying from 1 to 270 m. In the 2D electrical resistivity imaging, Wenner electrode configuration was adopted. Geoelectric sections made from the sounding curves revealed three geoelectric layers with resistivity values ranging from 53Ωm to 764 Ωm. These resistivity ranges were lithologically inferred to be topsoil, sand and sandy-clay, clayey-sand, dry-sand with corresponding Q, H and K – curve type. The first geoelectric layer represent the topsoil with resistivity values varying from 117 Ωm to 825 Ωm and thickness of 1.0 m to 2.0 m, the aquiferous unit was represented as the second geoelectric layer composed of sand with electrical resistivity values ranging from 130 Ωm to 238Ωm with thickness of 12.8 m to 30.7 m

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having a depth of 14.1 m to 31.8 m, while the third geoelectric layer represent sandy-clay, clayey-sand and dry-sand with resistivity values from 53 Ωm to 764 Ωm. The geophysical results shows that good aquifer unit is located in the sand layer of the study area with a depth range of 14.1 m to 31.8 m.

Keywords: Geoelectric layer; aquifer; electrical resistivity imaging; vertical electrical sounding.

1. INTRODUCTION

The most common geophysical method is the electrical resistivity method which can be used to probe the subsurface for potential groundwater accumulation; and its quantity can be estimated from the measured resistivity values. Though the determination is not in absolute term but relative through interpretation of inverted electrical resistivity values compared with established resistivity values of some common substances [1]. The electrical method is a versatile geophysical tool in hydrogeology, besides its application in exploration, engineering and environmental geophysics and in delineating lithofacies. In resistivity method, Wenner configuration discriminates between resistivity of different geoelectric lateral layers while the Schlumberger configuration is used for the depth sounding [2].

The geoelectric techniques has been successfully used in investigating groundwater potential in various geological setting even in areas of complex geology in different parts of the world [3,4,5]. The most usual parameters are the porosity, the permeability, the transmissivity and the conductivity [6].

The quality of the groundwater in any area is a function of physiochemical parameters which are greatly influenced by geological formations and anthropogenic activities of the area. Assessing quality groundwater is important to ensure sustainable safe use of these resources. However, describing the overall water quality condition is difficult due to the spatial variability of multiple contaminants and the wide range of indicators (chemical, physical and biological) that could be measured.

2. GEOLOGY OF THE STUDY AREA

The study area is located at Igbogbo area, Ikorodu, Lagos State. Igbogbo is one of the major towns in Ikorodu Local Government Area of Lagos State, Nigeria and is located within latitudes $6^0$34'N and $6^0$35'N and longitudes $3^0$34'E and $3^0$32.5'E. The area is accessible from Ikorodu to the north and has easy access to the lagoon through its immediate neighbouring towns (Ibese, Ososun, Offin and Ijede). The study area (Fig. 1) is a sedimentary terrain underlain by the Nigeria arm of the Dahomey Basin. The Dahomey Basin is one of the passive margin basins of the West African Atlantic Coast. Its origin is closely related to the rifting and separation of the African and South American plates during the Late Jurassic and Early Cretaceous [7,8,9]. The basin is characteristically long, narrow and parallel to the coastline. It stretched from South-Eastern Ghana through Togo and Benin republics to the Western margin of the Niger Delta. The Dahomey Basin is structurally well defined. It is bounded to the west by faults and other features associated with the landward extension of the Romanche fracture zone. Its eastern limit is marked by Benin Hinge line, a fracture zone which marks the western margin of the Niger Delta Basin. This is regarded by most authors as the landward extension continuation of the Chain Fracture Zone. The basin is bounded to the North and northeast by the crystalline Basement Complex [10]. The basin of high economic value as it is greatly endowed with mineral of high commercial quantities such as bitumen, tar sand, industrial rocks and minerals such as limestone and clay deposits [8].

3. MATERIALS AND METHODS

The geophysical survey was carried out using the PASI Resistivity meter, its accessories are:12V-battery (60 Ampere-Hour battery), one Global Positioning System(GPS), measuring tape, four metal electrodes, four reel of cables and four pieces of hammer. Twenty four (24) Vertical Electrical Sounding Stations were sounded along four traverses (T_1, T_2, T_3 and T_4), using Schlumberger electrode configuration (shown in Fig. 2). The Schlumberger current electrode separation (AB/2) was varied from a minimum of 1.0m to a maximum of 270m at each VES station. Two parallel N–S oriented traverse (T_3 and T_4) were surveyed 50m apart. As a follow up to the observed results, another two traverses (T_1 and T_2) were surveyed along the E–W direction, at the 55m point on N–S line, to determine the lateral extent of an observed low resistivity region.

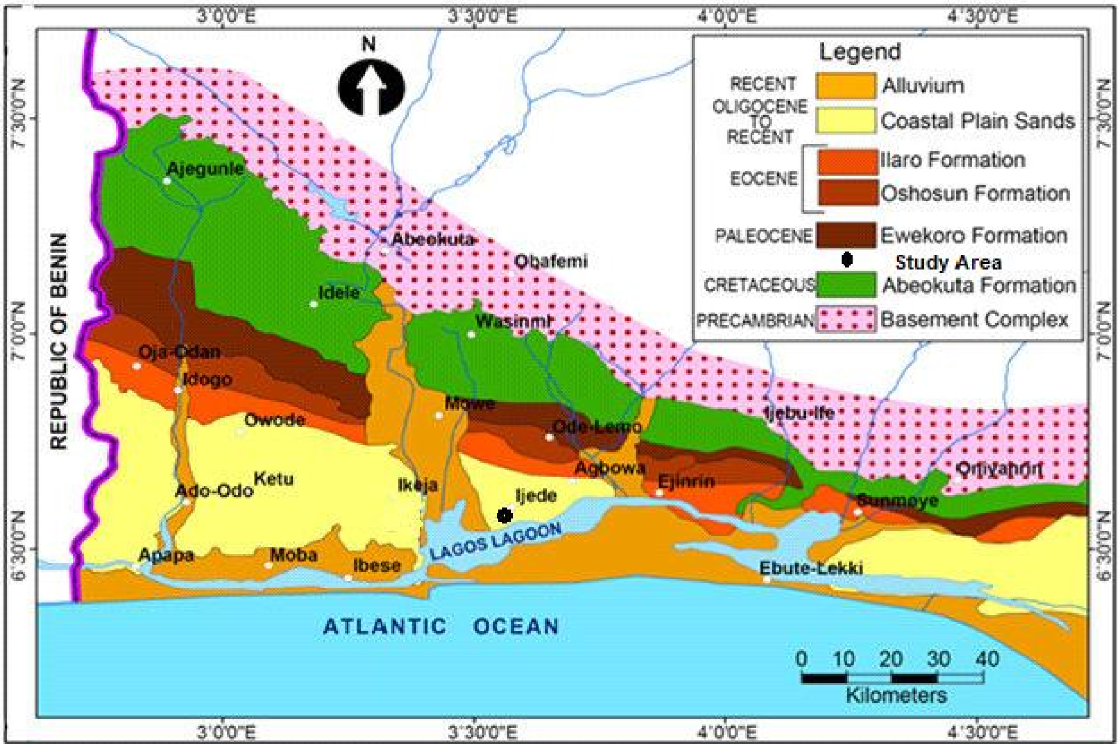

Fig. 1. Geological map of the Eastern Dahomey Basin showing the study area (adopted from [11])

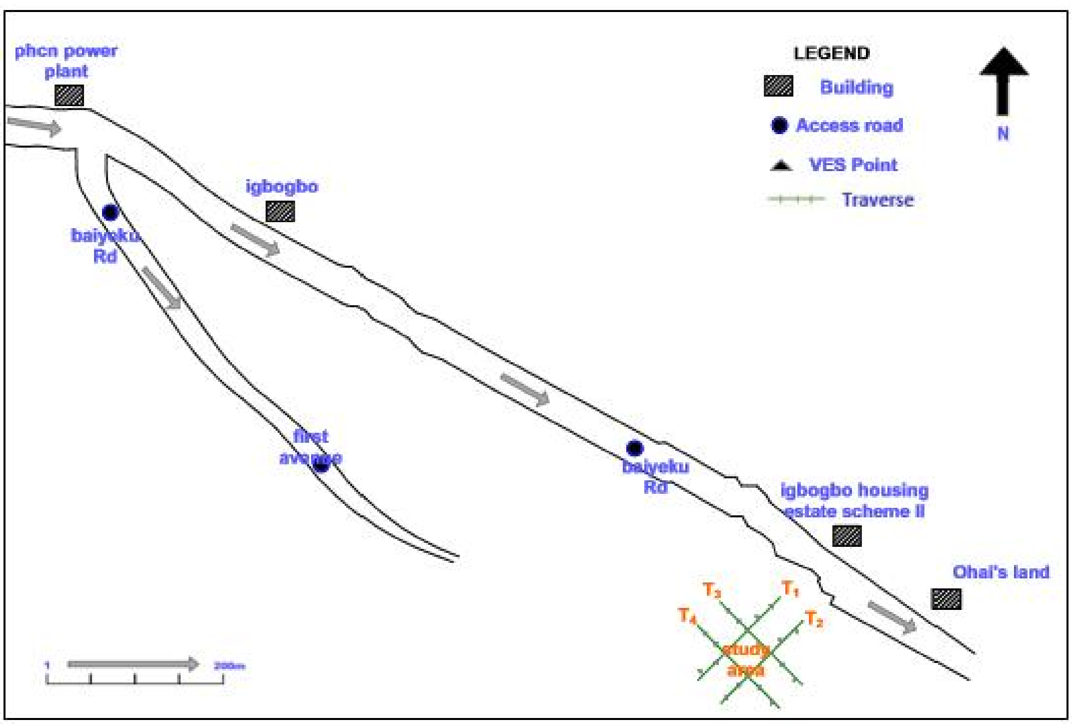

Fig. 2. Map of the study area showing the traverses

The profile A-A' (T_1), B-B' (T_2), C-C' (T_3), and D-D' (T_4) are having (6) VES points each. The 2D imaging survey was carried out using Wenner array for the four traverses. The total length survey for each station was (250 m), and the electrode spacing was (10 m, 20 m, 30 m, 40 m, 50 m and 60 m).

The VES data were processed by partial curve matching and later subjected to computer iteration techniques using the Winresist software (version 1.0) while the constant spacing traverse (CST) was processed with Dipro software (version 4.0).

4. RESULTS AND DISCUSSION

The VES data were plotted using Winresist software (shown in Fig. 3) and the result obtained were presented in Table 1. The VES interpretation identified three distinctive layers with curve Q, H and K types. Fig. 4 shows the geoelectric section of the features beneath the study area while Figs. 5 and 6 shows the lateral extent of the materials beneath the study area.

The geoelectric section of the AA' profile (Traverse 1) comprising of VES 1 to 6, has three layers with Q type curve. The first, second and third layer represent the topsoil, sand, sandy clay or clayey sand with resistivity values varying between 180 Ωm to 384 Ωm, 138 Ωm to 207 Ωm, 55 Ωm to 83 Ωm and with thickness of 1.0 m to 2.0 m, 22.1 m to 29.1 m and greater depth respectively.

The geoelectric section of the BB' profile (Traverse 2) comprising of VES 7 to 12 also has three layers with K and Q type curve. The first, second and third layer represent the topsoil, sand, sandy clay or clayey sand with resistivity values varying between 117 Ωm to 466 Ωm, 169 Ωm to 178 Ωm, 53 Ωm to 62 Ωm and with thickness of 1.2 m to 1.5 m, 14.1 m to 21.8 m and greater depth respectively.

The geoelectric section of the CC' profile (Traverse 3) comprising of VES 13 to 18, has three layers with H type curve. The first, second and third layer represent the topsoil, sand and dry sand with resistivity values varying between 319 Ωm to 487 Ωm, 130 Ωm to 162 Ωm, 649 Ωm to 764 Ωm and with thickness of 1.1m to 1.2 m, 27.6m to 30.7m and greater depth respectively.

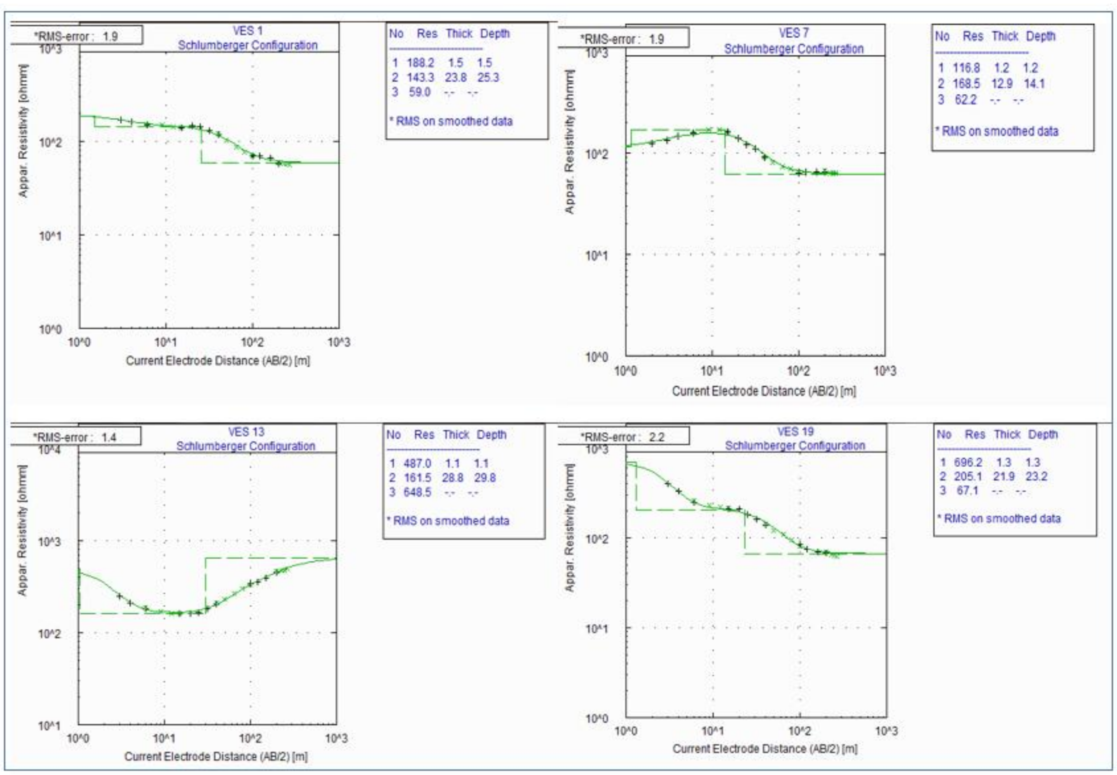

Fig. 3. Resistivity curve for VES 1, 7, 13 and 19 respectively

Table 1. Summary of interpreted results for the study area

	Resistivity ρ (Ωm)			Thickness h (m)			Overburden longitudinal conductance$(1/\Omega)$	Protective capacity ratings
VES station	ρ_1	ρ_2	ρ_3	h_1	h_2	Curve type	$\sum_{i=1}^{n}\frac{hi}{\rho i}$	
1	188	143	59	1.5	25.3	Q	0.184	Weak
2	180	140	55	1.8	28.5	Q	0.213	Moderate
3	184	139	56	1.9	28.5	Q	0.215	Moderate
4	186	138	55	1.9	29.1	Q	0.22	Moderate
5	182	139	59	2	28.7	Q	0.216	Moderate
6	384	207	83	1	22.1	Q	0.109	Weak
7	117	169	62	1.2	14.1	K	0.093	Poor
8	122	169	62	1.3	14.4	K	0.093	Poor
9	461	174	57	1.3	20.4	Q	0.12	Weak
10	421	177	58	1.4	20.4	Q	0.118	Weak
11	446	174	56	1.3	20.2	Q	0.118	Weak
12	334	179	53	1.5	21.8	Q	0.126	Weak
13	487	162	648	1.1	29.8	H	0.186	Weak
14	422	147	692	1.2	30	H	0.206	Moderate
15	407	145	707	1.2	28.8	H	0.201	Moderate
16	372	130	737	1.2	29.9	H	0.233	Moderate
17	367	135	739	1.1	31.5	H	0.235	Moderate
18	319	136	764	1.1	31.8	H	0.236	Moderate
19	696	205	67	1.3	23.2	Q	0.114	Weak
20	682	208	71	1.2	23.8	Q	0.112	Weak
21	698	225	78	1.2	23.3	Q	0.104	Weak
22	712	238	90	1.1	23.1	Q	0.098	Poor
23	761	237	89	1.1	23.7	Q	0.101	Weak
24	825	238	90	1.1	23.1	Q	0.257	Moderate

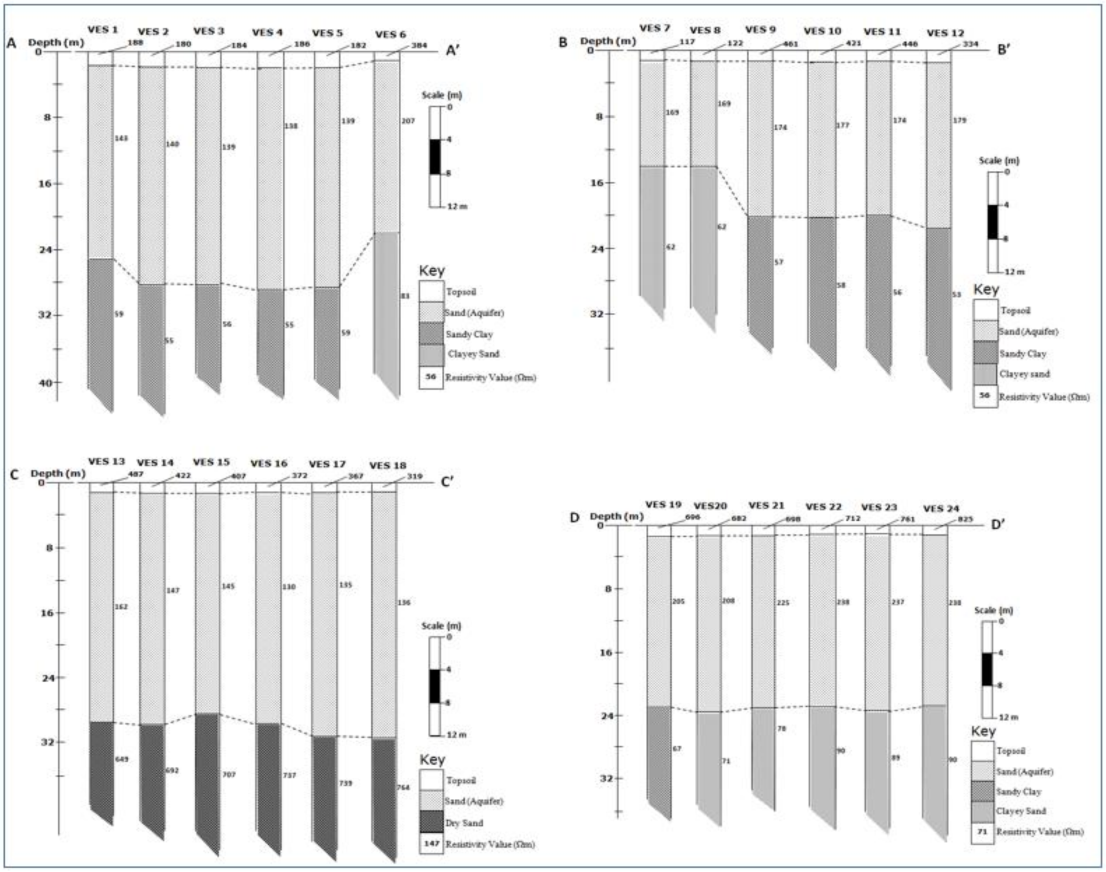

Fig. 4. Geoelectric section of traverse T_1, T_2, T_3 and T_4 respectively

The geoelectric section of the DD' profile (Traverse 4) comprising of VES 19 to 24, has three layers with Q type curve. The first, second and third layer represent the topsoil, sand, sandy clay or clayey sand with resistivity values varying between 682 Ωm to 825 Ωm, 208 Ωm to 238 Ωm, 67 Ωm to 90 Ωm and with thickness of 1.1 m to 1.3 m, 21.9 m to 22.6 m and greater depth respectively.

The study area is characterized with protective capacities of poor, weak and moderate, with logitudinal conductance value of 0.093 Ω^{-1} to 0.257 Ω^{-1}. The lowest longitudinal conductance was observed at VES 7 and 8 along traverse T_2 (0.093 Ω^{-1}), while the highest longitudinal conductance was observed at VES 24 along traverse T_4 (0.257 Ω^{-1}).

4.1 2-D Resistivity Imaging along Traverse One

The 2D inverted resistivity section along the four profile lines are presented in Figs. 5 and 6 having resistivity values that range from 31 - 5078Ωm. However, the first geoelectric layer represents the topsoil with electrical resistivity values that range from 55 to 928 Ωm within the depth range of about 2 m to 3 m. The second geoelectric layer represents sand with electrical resistivity values that range from 170 to 928 Ωm within the depth range of about 2 m to 28 m. The sand layer represent the aquifer unit for groundwater development. This sand delineated as the second geoelectric layer correspond to the sand layer delineated as the second geoelectric layer beneath the VES points. The third geoelectric layer represents clay, sandy clay and clayey sand with electrical resistivity values that range from 31 to 96 Ωm within the depth range of about 25 m to 50 m. However, within this layer at lateral distance of 155 m to 230 m constitute sand.

4.2 2-D Resistivity Imaging along Traverse Two

Fig. 5 shown below reveal that the first geoelectric layer represents the topsoil with electrical resistivity values that range from 170 to 928 Ωm within the depth range of about 2m to 3m. Beneath the topsoil, the sand package extends down to depth of about 50 m beneath the surface within the second and third geoelectric layer. The sand layer represent the aquifer unit for groundwater development. This sand delineated as the second geoelectric layer correspond to the sand layer delineated as the second geoelectric layer beneath the VES points. However, at lateral distance of 80 to 150 m within the depth range of about 22 to 50 m constitute clay, sandy clay and clayey sand having resistivity values that vary between 31 to 96 Ωm.

4.3 2-D Resistivity Imaging along Traverse Three

Fig. 6 represent the 2D inverted resistivity profile along traverse three running in East-West direction. The first geoelectric layer represents the topsoil with electrical resistivity values that range from 1636 to 5079 Ωm within the depth range of about 2 – 3 m. Beneath the topsoil, the sand package extends down to depth of about 50 m beneath the surface within the second and third geoelectric layer having resistivity values that vary between 170 to 1636 Ωm. The sand layer represent the aquifer unit for groundwater development. This sand delineated as the second geoelectric layer corresponds to the sand layer delineated as the second geoelectric layer beneath the VES points. However, at lateral distance of 200 to 230 m within the depth range of about 12 – 50 m constitute clay, clayey sand having resistivity values that vary between 31 – 96 Ωm.

4.4 2-D Resistivity Imaging along Traverse Four

Fig. 6 represent the 2D inverted resistivity profile along traverse four running in East-West direction. The first geoelectric layer represents the topsoil with electrical resistivity values that range from 135 to 2157Ωm within the depth range of about 2 – 3m. Beneath the topsoil, the sand package extends down to depth of about 50m beneath the surface within the second geoelectric layer. The sand layer represents the aquifer unit for groundwater development. However, at lateral distance of 20 to 40m and 195 to 230 m within the depth range of about 18 – 50m constitute clayey sand having resistivity values that vary between 40 – 74 Ωm.

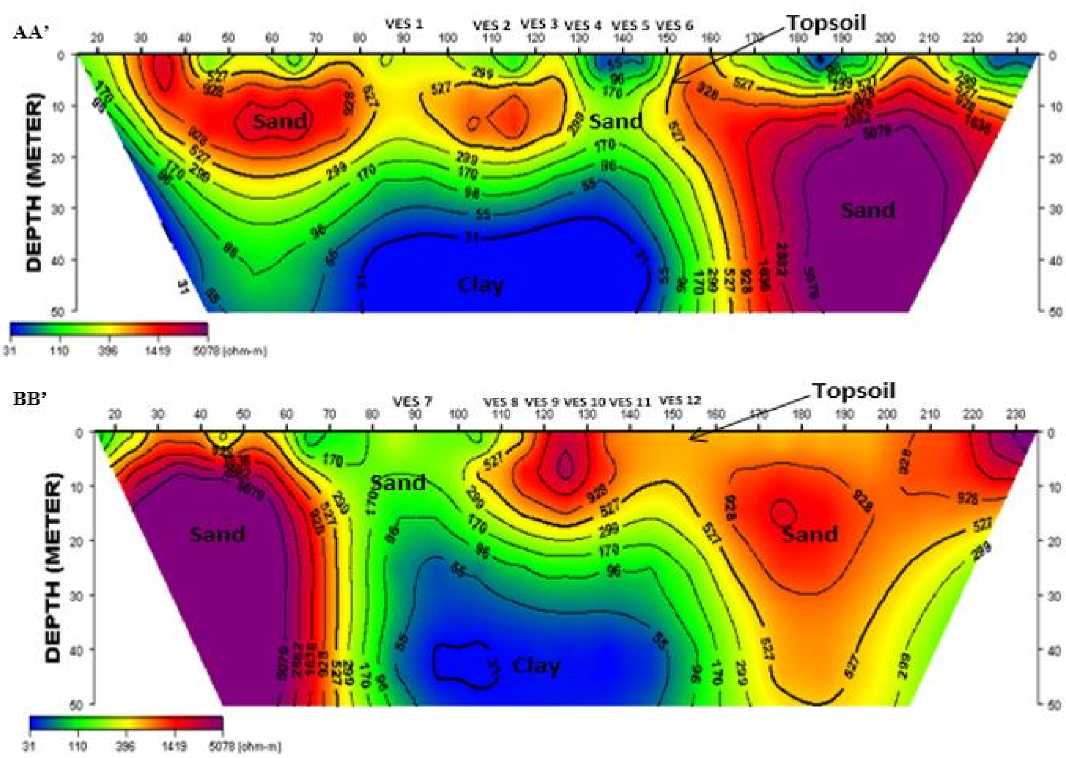

Fig. 5. 2-D Inverted resistivity psuedo-section along traverse T_1 and T_2

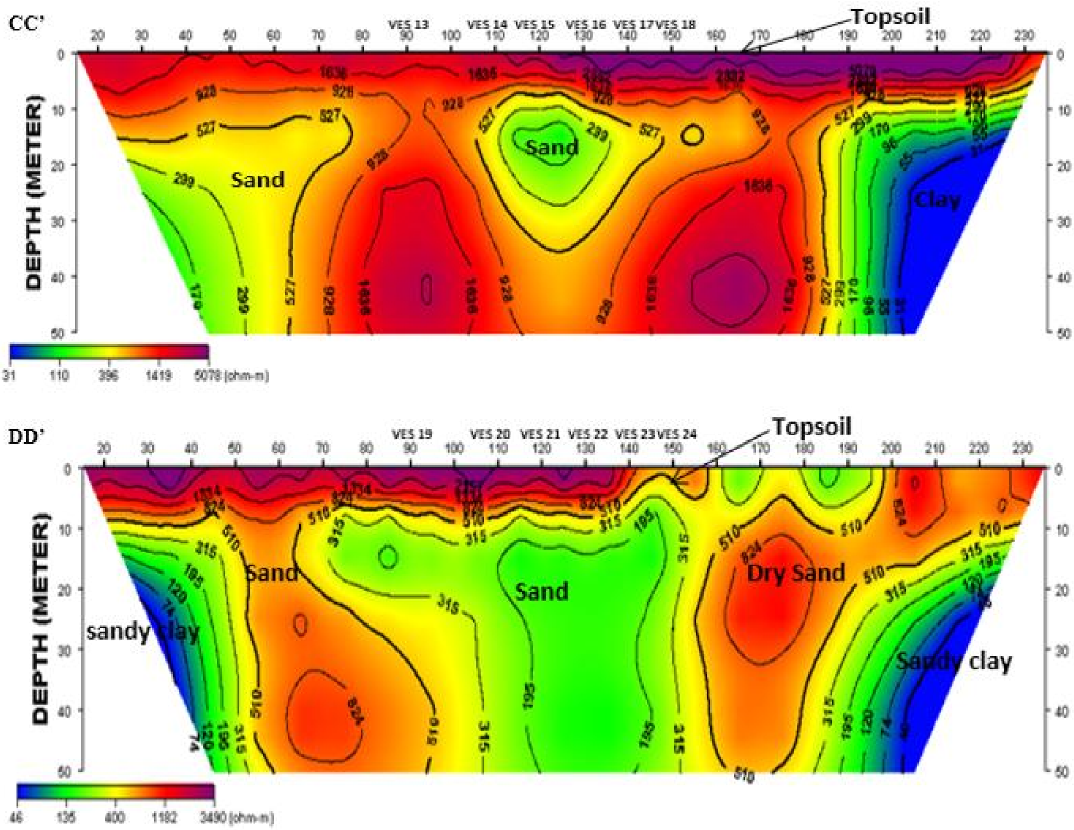

Fig. 6. 2-D Inverted resistivity psuedo-section along traverse T_3 and T_4

5. CONCLUSION

From the Vertical Electrical Sounding (VES), 66.7% of the sounding resistivity curves acquired shows Q -type curve, 25% shows H – type curve and 8.3% represent the K–type curve. The geoelectric sections reveal the sub-surface variation in electrical resistivity and attempts to correlate the geoelectric sequence across the profiles. Integration of both the Vertical Electrical Sounding and Constant Separation Traversing delineate the first geoelectric layer as the topsoil with resistivity values that vary between 117 – 825Ωm with thickness ranges from 1.0 – 2.0 m. The second geoelectric layer composed of sand with electrical resistivity values which range from 130 - 238Ωm and thickness values of 12.8 – 30.7 m within the depth range of 14.1 – 31.8 m. The layer represents the aquifer unit and can be sited for borehole water. The third geoelectric layer represent clayey sand, sandy clay and sand with resistivity values that range from 53 - 764Ωm. Good ground water yield was found, clay and sand layers causes low and high resistivity anomalies.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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