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Evaluation of Groundwater Potential, Using Electrical Resistivity Method, at Ambursa Modern Market, Birnin Kebbi, Kebbi State

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ABSTRACT
In this study, a total of 36 Vertical Electrical Sounding Stations were occupied using Schlumberger electrodes configuration. An ABEM SAS 300c Terra-meter was used for the Collection of data in the evaluation of Groundwater Potential in Ambursa, modern market, Birnin Kebbi. Data obtained from the field was analysed using Ipi2win and Surfer 12 which gave the interpretation of the resistivity data. Sounding curves obtained from the study area revealed four geo-electric layers, they are slightly thick ironstone and brown clay having the resistivity value ranging from (0.000114Ω m to 877Ω m) with coarse sand/sand stone having resistivity range of (0.000114Ωm to 14179Ω m), underlain with thick sand stone with resistivity (0.285Ω m to 2187Ω m) layering on weathered or fractured zone laterite having resistivity value from (1.03Ωm to3003Ωm), Six curve types have been identified within the study area. These are HK, KQ, QH, AK, KH, and HA, the HK is the predominant, the results showed that the aquifer lie within the intermediate sand stone. The groundwater potential of the area is classified into high, medium and low groundwater potential zone, high groundwater potential zones were found at VES 2, 6, 7 , 8 , 9, 11, 12, 13, 18, 20, 21, 28, 29, 30, 31, 32, 33, 34, and 36 while VES 3, 4, 5, 17, 22, 23, 24, 25, has the medium ground water potential more over VES 1, 10, 14, 15, 16, 19, 27 and 35 has the lowest groundwater potentials.

Key Words: Groundwater, Aquifer, Electrical Resistivity, Vertical Electrical Sounding,

I. INTRODUCTION

Groundwater is the main source of potable water supply for domestic, industrial and agricultural uses, it has been under pressure of degradation and contamination due to urbanization, industrial and agricultural related activities. The impact of this on groundwater is alarming with years of devastating effects on humans and the ecosystem. Water is essential for life. It had been and will continue to be a hot topic in both the political and scientific arenas for years to come (Miller, 2006). Groundwater is said to be contaminated if its unfit for the intended purpose and therefore constitutes nuisance for the user. Expansion of population densities requires greater volume of fresh water and at the same time emphasizes the need to protect and sustain known supplies and sources. The urge to sustain groundwater need by people has strengthened the application of appropriate geophysical/hydro-geologic researches. (Olayinka et al., 1999; Olorunfemi et al., 1999; Lashkaripour, 2003; Batayneh, 2010; Omosuyi, 2010; Anudu et al., 2011) to locate areas of high and reliable groundwater prospect or characterize seasonal changes in the near surface aquifer (Webb et al.,2011). With advances in technology over the last decade, it has come with an exponential increase in the potential number and diversity of viable geophysical applications in the water science.

Electrical methods can give information at locations where neither gravity nor magnetic anomalies can exist for horizontal bedding. Further, the electrical resistivity methods can be used where structure is not complicated. The most probable use of the electrical resistivity survey is in hydrogeological investigation which is in relation to aquifer delineation, lithologic boundaries and geological structures to provide subsurface information (Bose et al., 1973).Maintaining and protecting current water supplies and developing new sources of clean water are essential as modern society expands and civilization continues to develop. Aquifers protection is essential for a sustainable use of the ground water resources protection (Egbai et al.,2015), the key expression for a quantification of aquifers is the vulnerability, which solely indicates weather the physical and biochemical characteristics of the subsurface prevents or favour the transport of pollutant into aquifers.

Transmissivity is a major property of an aquifer and it aids in characterization of rocks as water conducting media. The ability of overburden to retard and filter percolating fluid is a measure of its protective capacity. Exploration for groundwater in sedimentary environments involves locating formations that possess appropriate porosity and permeability, while the location of the permeable clean sands that are capable of yielding useful quantities of water to wells is important (Aweto, 2014). In Electrical Resistivity surveying our goal is to measure the potential difference between two points (Fig.1.1). Figure 1.1 illustrates two potential electrodes, P1 and P2 that are located on the surface with the current electrodes C1 and C2 (Augie et al., 2019).

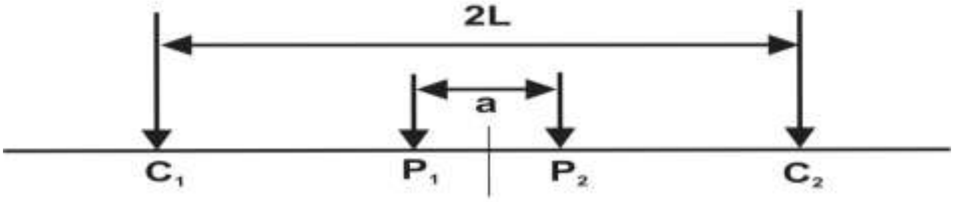

Figure 1.1: Schlumberger array

Two Point Current Electrodes at Earth's Surface

Consider two point current electrodes in which the distance between them is finite figure (1.1). The potential at any new surface point will be affected by both current electrodes and hence the potential due to C_1 and P_1 is

$$V_1 = -\frac{A}{r1} \quad (1)$$

And the potential due to C_2 at P_1 is

$$V_2 = -\frac{A}{r2} \quad (2)$$

Where $A_1 = -A_2 = A$ thus, we have

$$V_1 + V_2 = \frac{I\rho}{2\pi} \{(\frac{1}{r1} - \frac{1}{r2}) \quad (3)$$

Introducing the second potential electrode at the potential difference between the two potential electrodes at P_2 is given by

$$\Delta V = \frac{I\rho}{2\pi} \{(\frac{1}{r1} - \frac{1}{r2}) - (\frac{1}{r3} - \frac{1}{r4}) \quad (4)$$

Birnin Kebbi is located on the Sokoto River and is connected by road to Argungu(45 km north east), Jega (35 km south east) and Bunza 45 km south west) As of 2017 the city had an estimated Population of 125,594, Ambursa area lies in Birnin Kebbi, Kebbi State of Nigeria, and its

Equation (4) gives the potential difference between the two potential electrodes. The electrode layout is referred to as the general four electrode configuration over a homogenous isotropic earth, a variation of which is normally used in electric resistivity measurements.

Apparent Resistivity

From equation (3), the resistivity is given by

$$\rho = \frac{2\pi\Delta V}{I} \frac{1}{(\frac{1}{r1} - \frac{1}{r2}) - (\frac{1}{r3} - \frac{1}{r4})} = (\frac{\Delta V}{I}) K \quad (5)$$

where parameter K, has to do with the electrode geometry. Wherever these measurements are made over a real heterogeneous earth, as distinguished from the fictitious homogenous half space, the symbol is replaced by a. This measured resistivity is called the apparent resistivity since the measured resistivity is usually a composite of the resistivity of several layers.

Location of the Study Area.

geographical co-ordinates are 12°31'0'' North 4°20' 0'' East, the distance between Ambursa and Birnin Kebbi is 16 km. The Study is aimed at evaluating the Groundwater Potentials of the Ambursa Modern Market, Birnin- kebbi, Kebbi State.

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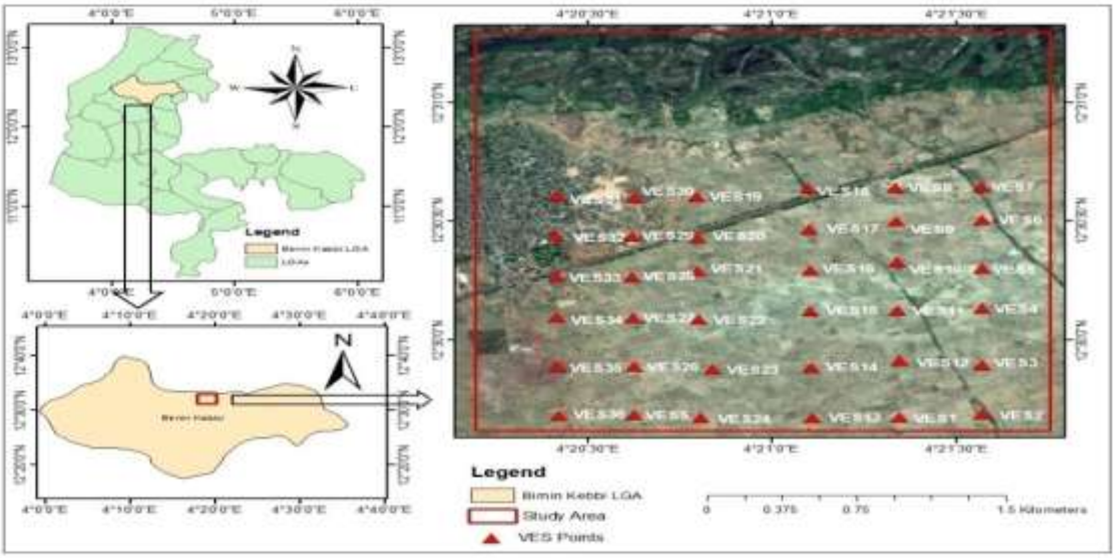

Figure 1.2: Location map of the Study Area showing the Distribution of VES Point.

Geology of the study Area

General Geology of the Study Area : Kebbi State falls within the Sokoto basin which is part of an extensive elongated sedimentary basin underlying most of the North-western Nigeria and Eastern part of Niger Republic. Geologically, the Sokoto basin is divided into two groups, Sokoto group and Rima group. The sokoto consist of Dukamaje formation, Kalambaina formation, Taloka formation, Illo formation and Gundumi formation, while rima group, consist of Gwandu formation, Dange formation and Wurno formation (Sa'adu and Sheik, 2012).

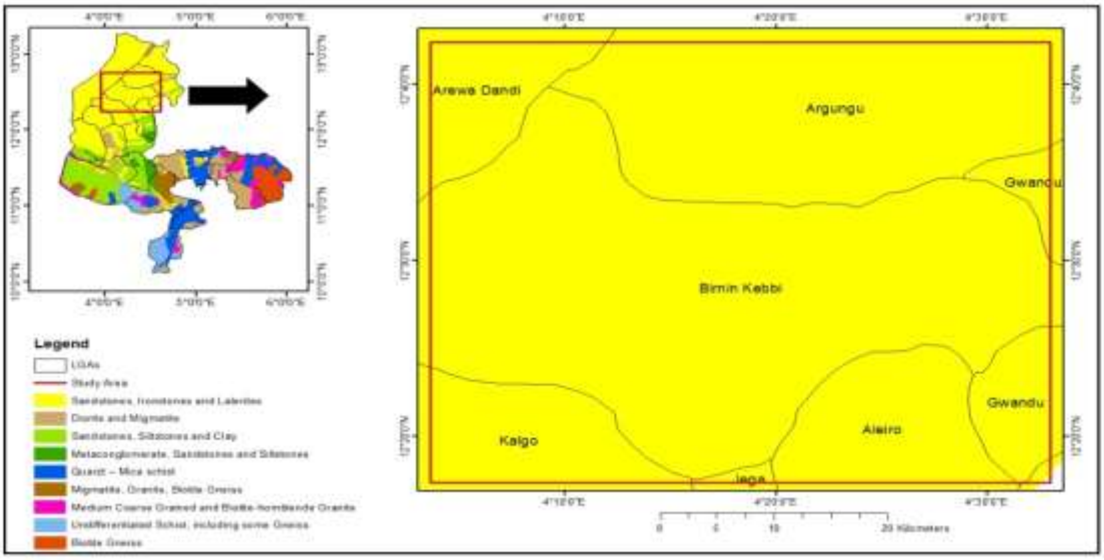

Figure 1.3: geology of kebbi State showing the study area

II. MATERIALS AND METHOD

Materials

The material that was used for the collection of data in the field are: Terra-meter SAS300c, Current and Potential electrodes, Winding Wires, GPS, Battery), Measuring Tape, hammer, Cutlass, Shovel, software such as IPi2win, Surfer 12, mapinfo- Discover etc was used in the interpretation of data.

Method

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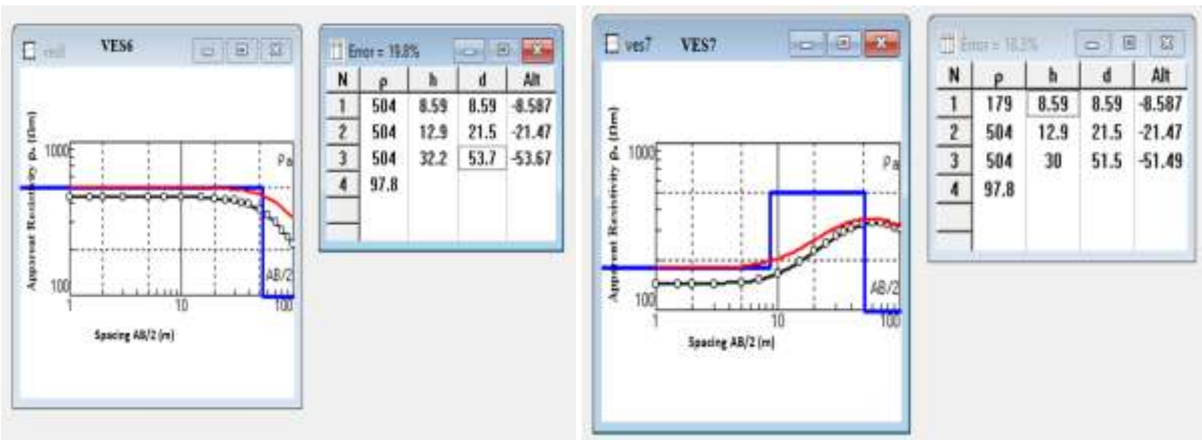
The resistivity data was acquired using ABEM SAS 300C Terra-meter which will check and control all the measurements, current and potential electrodes for the penetration, measuring tape for taking distance, Global Positioning System for taking accurate coordinates of the (VES) points, Hammer for deriving the electrode into the ground, Vertical electrical sounding (VES) employs collinear arrays designed to output a 1-D vertical apparent resistivity versus depth model of the subsurface at a specific observation point. In this method a series of potential differences are acquired at successively greater electrode spacing while maintaining a fixed central reference point. The induced current passes through progressively deeper layers at greater electrode spacing. The potential difference measurements are directly proportional to the changes in the deeper subsurface. Apparent resistivity values calculated from measured potential differences can be interpreted in terms of the depths and thicknesses of subsurface medium. The two most common arrays used for VES are the Wenner array and the Schlumberger array. The Schlumberger array has been adopted for this research work, the electrode spread of AB/2 was to be varied from 1 to a maximum of 100 m on each and every VES Point. Resistivity measurements are associated with varying depths relative to the distance between the current and potential electrodes in the survey, and can be interpreted qualitatively and quantitatively in terms of a lithologic or geo-hydrologic model of the subsurface.

III. RESULTS AND DISCUSSION

Data Interpretation: the VES data obtained were in resistance (Ω), using Terra-meter SAS 300C which were then multiplied by their corresponding geometric factor (k) in order to obtained an apparent resistivity in ohm-meter. Computer software called IPI2WIN was used to processes the data, the apparent resistivity values for each point was plotted against the half current electrode spacing AB/2 on log-graph to obtain sounding curves. The purpose of these curves is to determine the subsurface layers beneath each VES point as well as their thickness and resistivity variation, the results of the analysis of data were correlated with a borehole log data obtained near the study area. Boreholes log data are a necessary and reliable source of data, and electrical resistivity method using vertical electrical sounding (VES) interpretations provide basic information of the area. The log shows an overburden made up of four geologic layers.

The data was processes and analysed using IPI2win version 2.1 Software which gave automatic geo-electric parameters of the study area. The output of VES data is resistivity layer, log resistivity graph and resistivity depth table. Sounding curve obtained from the study area showed four geo-electrical layers as shown in Fig. (3.2) They are the ironstone/brown clay (5 to 1500 ohm-m), sandstone (2400 to 108 ohm-m), coarse sand (2400 to 108 ohm-m) and weathered/fractured basement (9 to 968 ohm-m)



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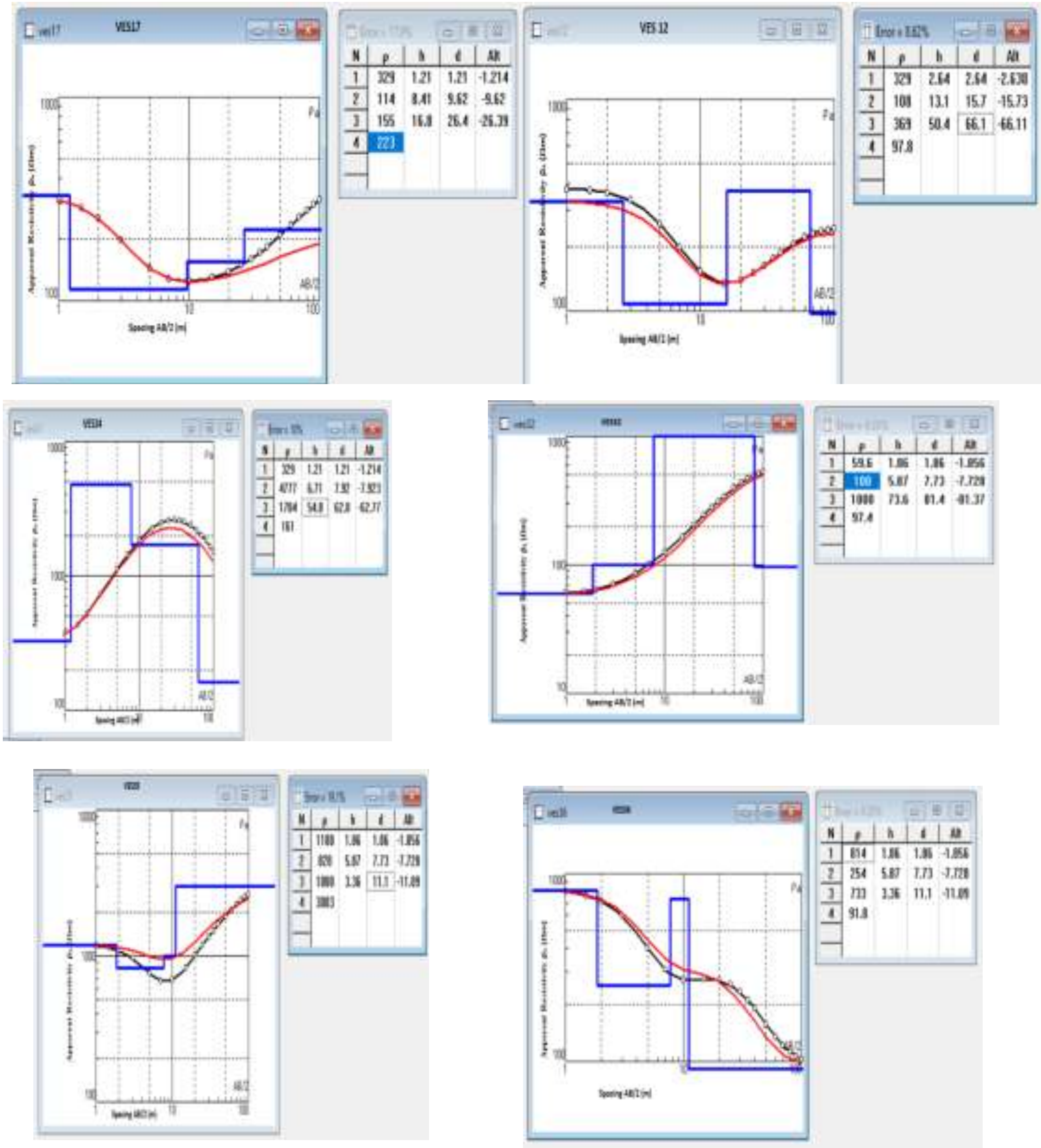

Figure 3.1: Plot of VES Obtained from the Study Area

Observing VES 06, 07, 17 and 12 (Fig.5) A Total of four (4) layers were delineated at these points. The resistivity values range from 98Ωm to 700Ωm while thickness values range from 1m to 51m. First layer of these VES composed of clay and ironstones with resistivity value of 100 Ωm to 600Ωm and thickness 51m. Second layer is corresponding to be coarse sand with resistivity value of 50Ωm to 550Ωm. The third was considered to be sandstone having resistivity values ranging from 130Ωm to 700Ωm. Fourth layer form the aquifer due to its low resistivity (90Ωm to 200Ωm) and thickness value of 50.4m. Its depth is 66.1m (see Table 1 for summary of VES point).

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Table 1: Shows Summary of VES points; Numbers of layer, Resistivity, Thickness and depth of the subsurface

VES NO	Layer 1			Layer 2			Layer 3			Layer 4		
	$\rho_{1(\Omega)}$	$d_{1(m)}$	$h_{1(m)}$	$\rho_{2(m)}$	$d_{2(m)}$	$h_{2(m)}$	$\rho_{3(\Omega)}$	$d_{3(m)}$	$h_{3(m)}$	$\rho_{4(\Omega)}$	$d_{4(m)}$	$h_{4(m)}$
1	3627	1.5	1.5	1134	2.4	0.9	1134	8.9	6.4	1134	-	-
2	$1.1x10^{-4}$	0.468	0.468	$1.1x10^{-4}$	1.17	0.702	0.285	28.7	27.5	1.03	-	-
3	39197	1.005	1.005	14179	1.008	0.00368	21837	1.008	$1.0x10^{-4}$	247.6	-	-
4	3907	1	1	208.1	9.2728	8.728	208.1	22.82	13.09	208	-	-
5	850	0.772	0.772	832	1.02	0.244	909	54.8	53.6	212	-	-
6	504	8.59	8.59	504	21.5	12.9	504	53.7	32.2	97.8	-	-
7	179	8.59	8.59	504	21.5	12.9	504	51.5	30	97.8	-	-
8	179	8.59	8.59	504	21.5	12.9	158	68.8	47.4	97.8	-	-
9	179	8.59	8.59	504	21.5	12.9	347	43.6	22.1	97.8	-	-
10	329	2.64	2.64	251	9.62	6.98	136	41.5	31.9	596	-	-
11	123	2.64	2.64	206	15.7	13.1	369	71.4	55.7	97.8	-	-
12	329	2.64	2.64	108	15.7	13.1	369	66.1	50.4	97.8	-	-
13	329	2.64	2.64	974	15.7	13.1	369	50.4	44.7	07.8	-	-
14	329	2.64	2.64	524	15.7	13.1	244	60.4	44.7	596	-	-
15	329	2.64	2.64	762	9.62	6.98	155	49.7	40.1	596	-	-
16	329	1.21	1.21	114	9.62	8.41	155	26.4	16.8	596	-	-
17	431	5.52	4.3	114	9.62	8.41	155	26.4	16.8	223	-	-
18	329	1.21	1.21	431	5.52	4.3	131	58.1	52.6	97.4	-	-
19	329	1.21	1.21	431	66.1	57.2	845	66.1	57.2	437	-	-
20	329	1.21	1.21	156	8.9	7.69	40.4	58.1	49.2	105	-	-
21	329	1.21	1.21	138	8.9	7.69	339	68.5	59.6	105	-	-
22	329	1.21	1.21	950	5.24	4.02	339	14	8.76	161	-	-
23	329	1.21	1.21	95	5.24	4.02	339	44.84	39.61	161	-	-
24	329	1.21	1.21	4777	7.92	6.71	1704	62.8	54.8	161	-	-
25	329	1.21	1.21	64	11.9	10.7	14.6	50.3	30.4	161	-	-
26	8716	52.1	46.2	842	5.84	3.5	8716	52.1	46.2	1109	-	-
27	472	2.34	2.34	1040	5.84	3.5	120	48.5	42.6	1109	-	-
28	58.1	2.34	2.34	241	7.73	5.39	395	48.5	40.7	97.4	-	-
29	8778	2.44	2.44	241	7.73	5.28	395	67.6	59.9	97.4	-	-
30	217	1.86	1.86	223	7.73	5.28	937	67.6	59.912	97.4	-	-

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31	217	1.86	1.86	117	7.73	5.87	438	81.4	73.6	97.4	-	-
32	59.6	1.86	1.85	100	7.73	5.87	1000	81.4	73.6	97.4	-	-
33	1188	1.86	1.86	2756	7.73	5.87	1000	68.5	60.8	97.4	-	-
34	1180	1.86	1.86	311	7.73	5.87	1000	10	2.27	97.4	-	-
35	11888	1.86	1.86	828	7.73	5.87	1000	11.1	3.36	3003	-	-
36	814	1.86	1.86	254	7.73	5.87	733	11.1	3.36	91.8	-	-

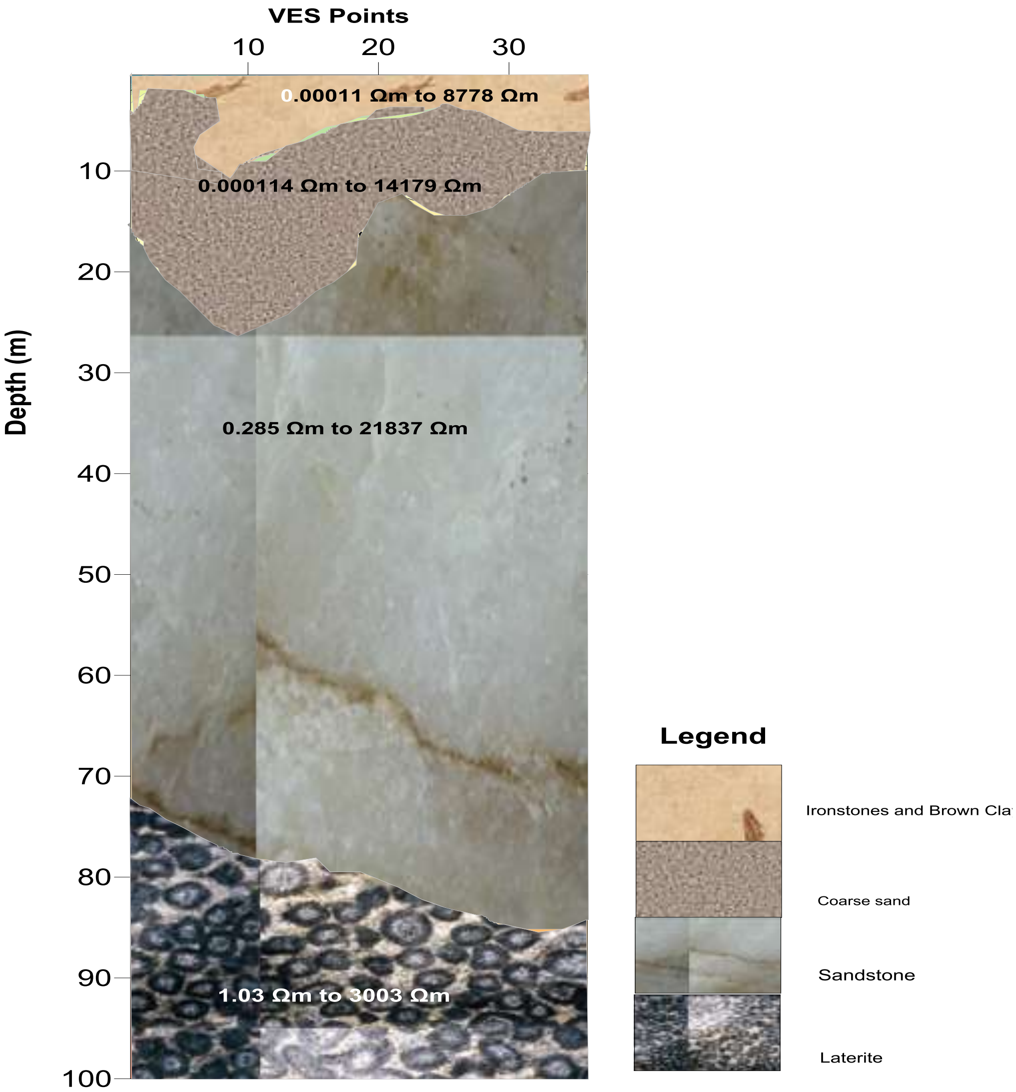

Figure 3.2: Shows the Geo-electric Sections of VES Points

Borehole log showing lithology of the study area was correlated with the geo-electric sections of total VES points (Fig 3.2). The geological interpretation of geo-electrical model for all VES were slightly thick ironstone and brown clay having resistivity values ranging from 0.000114Ωm to 8778 Ωm with coarse sand/sandstones (0.00114Ωm to 14179Ωm) underlain with thick sandstone (0.285 Ωm to 21837 Ωm) layering on weatherd/Fracture zone (Laterite) having resistivity ranging from 1.03 Ωm to 3003 Ωm.

The fourth layer represents the deep seated aquiferous layer in the sandstone/Laterite area. This layer is very important in groundwater accumulation (because it is a sandstone/Laterite area containing high porosity and permeability). In hard rock terrains composite aquifers of the weathered basement zone and fractured basement are known to give the highest groundwater yield

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In this study the value of the apparent resistivity at each sounding point was calculated from the resistance values obtained in the field and presented as sounding curves using IP12win application software. Six curve types have been identified within the study area. These are HK, KQ, QH, AK, KH, and HA, The HK is the predominant among the rest.

IV. CONCLUSION

Groundwater investigation using electrical resistivity method adopted in this study has gave some information in assessing groundwater condition of the study area. From the result of this survey that was carried out with a view to determine the subsurface layer parameters (resistivities, depths and thicknesses) Vertical Electrical Sounding using Schlumberger array method were employed, four distinct geo-electric layers were observed namely; They are the ironstone/brown clay, sandstone, coarse sand and weathered/fractured basement., it is revealed that nature of hydrogeology of the study area contributes in the groundwater potentials. However the result shows that the study area fall under three groundwater potential zones which are high, medium and low groundwater potential zones. High groundwater potential zones were found at VES 2, 6, 7, 8, 9, 11, 12, 13, 18, 20, 21, 28, 29, 30, 31, 32, 33, 34, and 36 the siting of boreholes should be done on these VES while VES 1,10, 14,15,16,19,27 and 35 are low in Groundwater potential also good for building purpose.

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