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Geophysical Delineation of the Groundwater Potentials in a Basement Complex Terrain: A Case Study of Imope and Environs, Southwestern Nigeria.

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Abstract

Vertical Electrical Sounding (VES) has been used as a tool to study the groundwater potentials exploration pattern of Imope, Igaran, Aparaki and Idofe villages, in southwestern Nigeria. A total number of eighty VES stations were established on the study areas covering 4,375,000m^2 using the schlumberger configuration with electrodes spacing varying from 50 to 120m. The surveys were carried out on equal grids of 250 by 250m.

Two to four lithological sections were inferred from the study areas. These are the Top soil, Lateritic Horizon, Clayey/sandy clay Horizon, and Weathered/Fresh Basement. The thicknesses of these horizons vary from 0.4-1.5m, 0-17.5m, 0 -39.1m for the top soil, lateritic layer and the clayey/sandy clay horizon respectively. The resistivity values range from 15.2-1,700 Ohm-m for top soil, 271-2,769.1 Ohm-m for lateritic horizon, 1.8-197.4 Ohm-m for the clayey/sandy clay horizon, and 337-15,300 Ohm-m for the weathered/fracture/fresh basement. Isoresistivity map of the basement and Isopach map of the overburden were plotted. Areas with thick overburden and fractured basement have been identified with high potentials for groundwater exploration.

Introduction

Water is one of the most important ingredients to the survival of live. Groundwater has always been important supplement to the non availability of surface water which has become a scarce resource in most areas of Nigeria. Surface water where available are usually seasonal and prone to contamination by human beings and animals (Bello and Makinde, 2007). Imope and its surrounding villages are not left out as some residents especially women and children travel miles to collect water for their daily needs from the seasonal streams that drain the environment while others depend on shallow hand-dug wells. As a result, the need to explore the groundwater potentials as better alternatives and to supplement the water supply especially in the dry season is but imperative. This study was aimed at providing detailed exploration pattern for the groundwater potentials of these areas.

The successful exploration of groundwater in the basement complex terrain requires a proper understanding of its hydrogeological characteristics as a result of the discontinuous nature of basement aquifers (Satpathy and kanugo, 1976). Geoelectrical surveys provide an effective way to image the subsurface and the groundwater zone without a large number of observation wells (Prasanna et. al., 2008). VES determines the thickness and resistivity of different horizontal or low-dipping subsurface layers, including the aquifer zone (Choudhury and Saha, 2004). Aquifer zones often characterized by relatively low resistivity values in the basement complex terrains are either fractures such as joints and faults or the weathered basements (DuPreez and Barbar, 1965; Olayinka and Olorunfemi, 1992; Olorunfemi and Olorunniwo, 1985).

Description of the Study Area

The study area lies within the crystalline basement complex of southwestern Nigeria. It is located within longitude and latitude $3^0$56.6' and 3^0 59' and 7^0 53.7'and 7^0 55.2' respectively (Fig.1). It comprises the village of Idofe, Iganran, Imope, Falafanmu and part of Aparaki. The area extent is about 30 square kilometers. It is accessible through Ijebu Ode- Oru Road and it is about 4km south to the overhead bridge linking Ago-Iwoye and Oru. The settlements are linked by one major road and several minor roads and footpaths. The major road cuts across Idofe, Iganran, Imope, Ipari Oke and extends to Atan, Southwest, Nigeria.

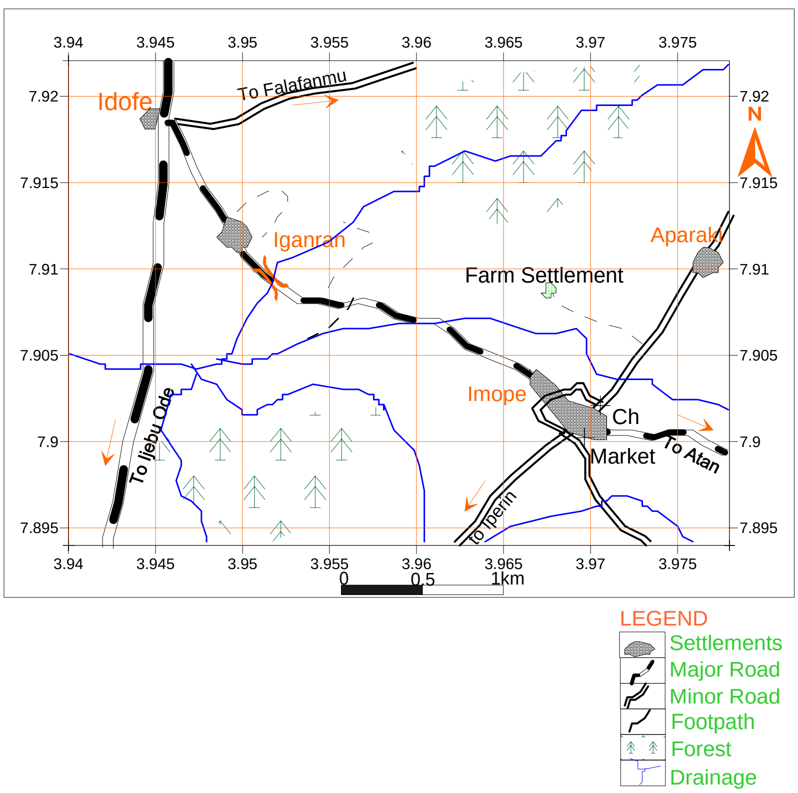


Fig. 1: Map of the Study Area Showing Accessibility, Drainage Pattern and Vegetation.

Materials and Method

The study area was divided into seventy square grids of 250 by 250m on the existing topography sheet of the Federal Survey of Nigeria Sheet 280 and 280A (Ijebu Ode) using Golden Software Surfer 8. The grids were located on the field using handheld Garmin GPS 76 receiver.

Eighty VES involving Schlumberger electrode array were carried out. The electrode spacing AB/2 was varied between 50m and 120m based on the depth to the basement. The VES data are represented as curves in Fig.3a and b. The curves were interpreted quantitatively by partial curve matching and computer iteration with WINRESIST software. The iteration program uses the results of the partial curve matching as starting models.

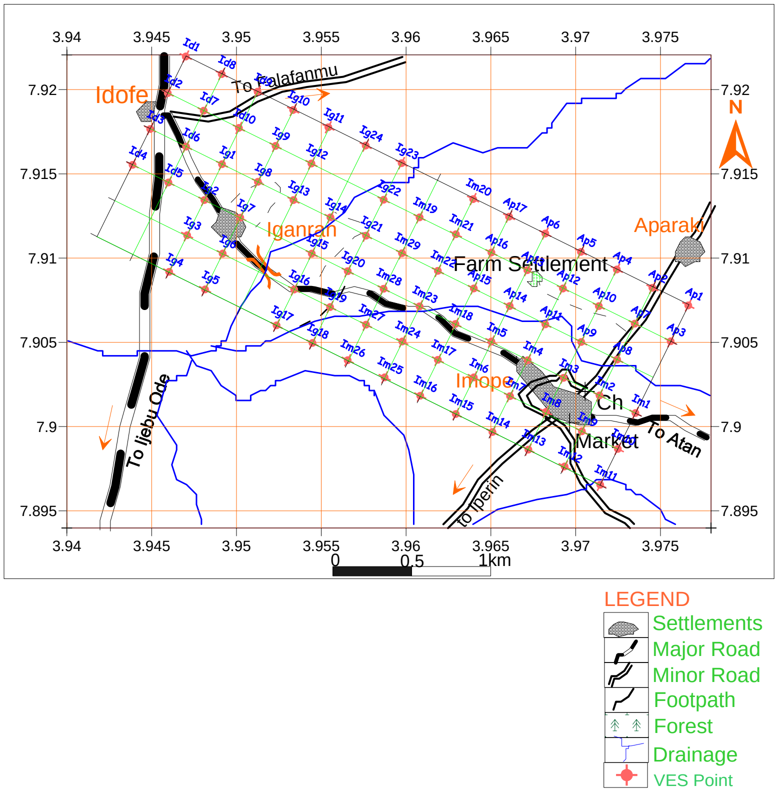
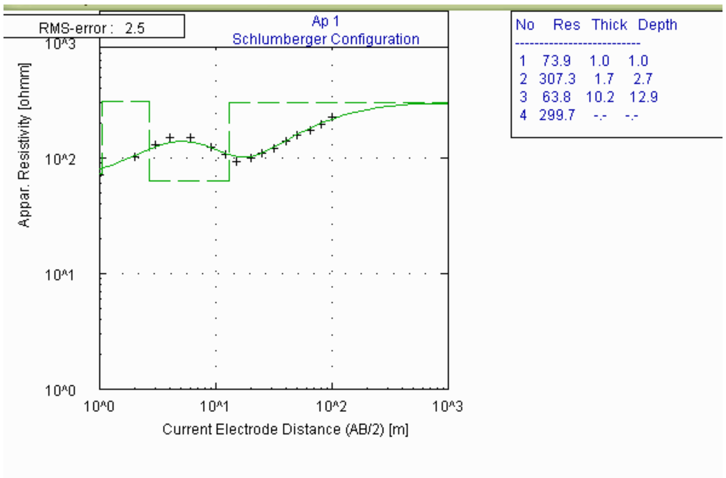


Fig. 2: Map of the Study Area showing the 70 square grids and 80 VES points.

(a)



(b)

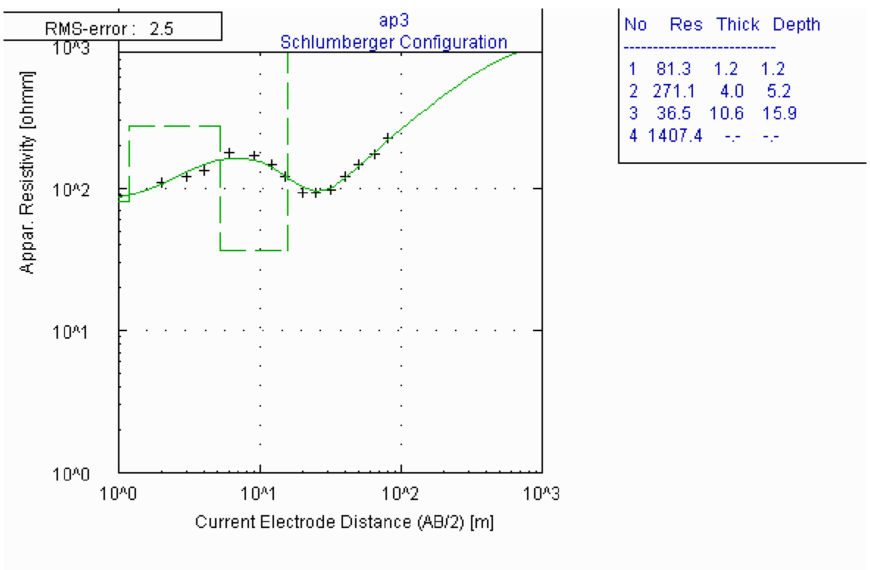


Fig 3a and b: Typical Schlumberger depth sounding curves of the study area.

Results and Discussion

The results of the Electrical Resistivity survey is presented in table 1. Two to four lithological sections were inferred. These are the Top soil, Lateritic Horizon, Clayey/sandy clay Horizon, and Weathered/Fresh Basement. The thicknesses of these horizons vary from 0.4-1.5m, 0-17.5m, 0 -39.1m for the top soil, lateritic layer and the clayey/sandy clay horizon respectively. The resistivity values range from 15.2-1,700 Ohm-m for top soil, 271-2,769.1 Ohm-m for lateritic horizon, 1.8-197.4 Ohm-m for the clayey/sandy clay horizon, and 337-15,300 Ohm-m for the weathered/fresh basement. Table 1 show the quantitative interpretation of the VES results. An isoresistivity map of the basement plotted shows the area with relatively low resisitivity values which corresponds to weathered or fractured basement and areas with relatively high resistivity values interpreted as fresh basement (Fig. 4). The isopach map of the overburden details the area with high overburden thicknesses which corresponds to basement ridges and areas with low overburden thicknesses that correspond to basement highs (Fig. 5).

The basement complex rocks in their unaltered stage lack porosity and permeability and are thus very poor aquifers. Their ability to store and transmit groundwater effectively depends on secondary structures such as joints and faults. According to Olorunfemi and Olorunniwo (1985), the highest groundwater yields are found in areas where thick overburdens overlie fractured zones. In order to ensure maximum and perennial yield boreholes are best sited in areas where the regoliths could be maximally penetrated. Based on these stacked maps of the basement resistivity values and the overburden thicknesses (Fig. 6) were used to produce fig. 7 which is the groundwater potential map of the study area.

Conclusion

The geophysical delineation of Imope and its environs in the southwestern part of Nigeria has revealed the major geologic units. The thicknesses and resistivity values of the aquifers have been identified. Areas where relatively thick overburden overlies fractured or weathered basement have been identified as having the highest potentials for groundwater. Whereas areas with either thick overburden or weathered and or fractured basement are delineated as having medium potentials for groundwater while areas with thin overburden and high resistivity values which correspond to fresh basement have been delineated as low groundwater potential zones.

Western and central Imope, northeastern part of Iganran and Aparaki and the western part of Idofe have been delineated for highest ground water yield in the study area.

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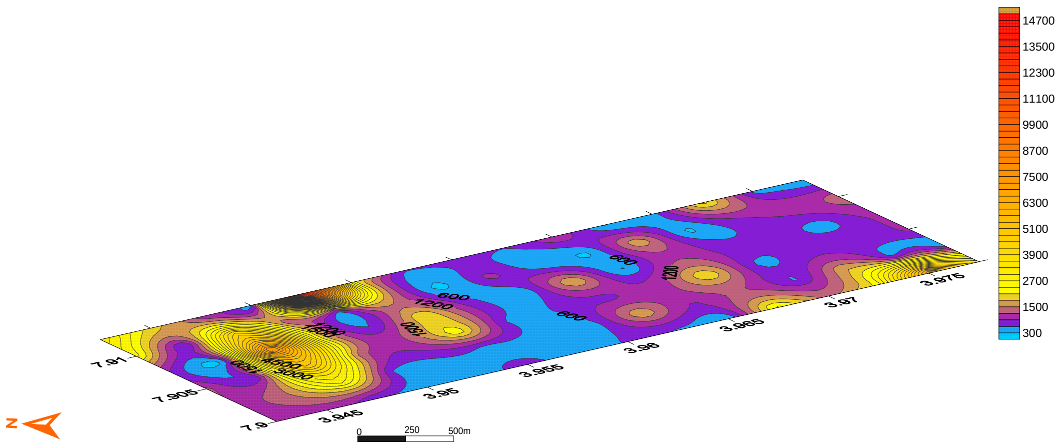

Fig. 4: Isoresistivity map of the weathered, fractured and fresh basement

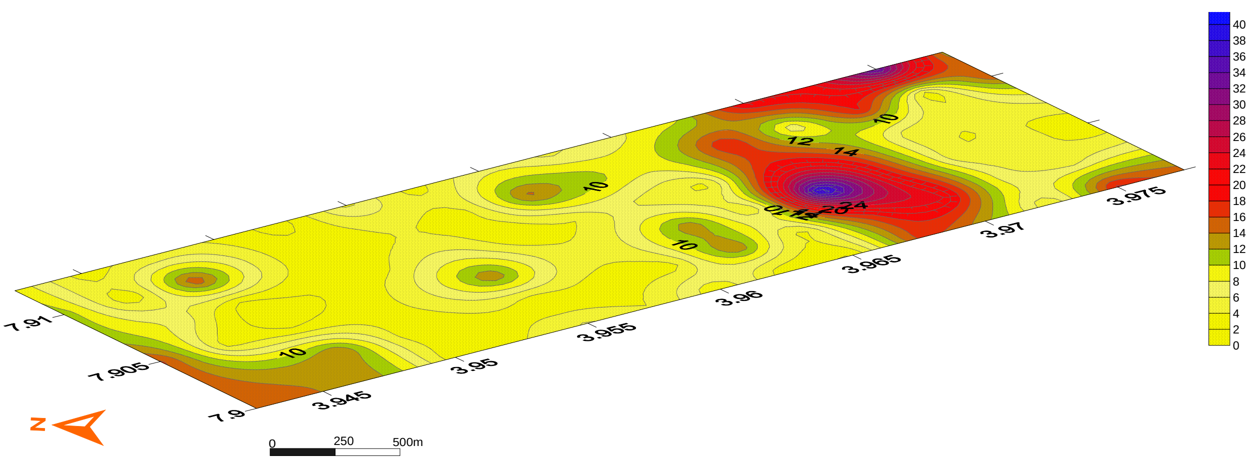

Fig. 5: Isopach map of the overburden

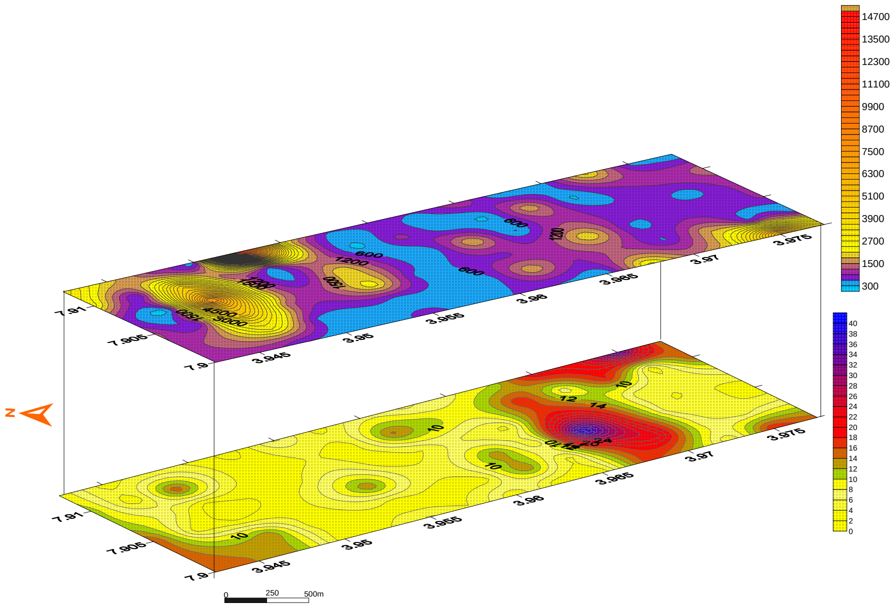

Fig. 6: Stacked isoresistivy and isopach map of the study area

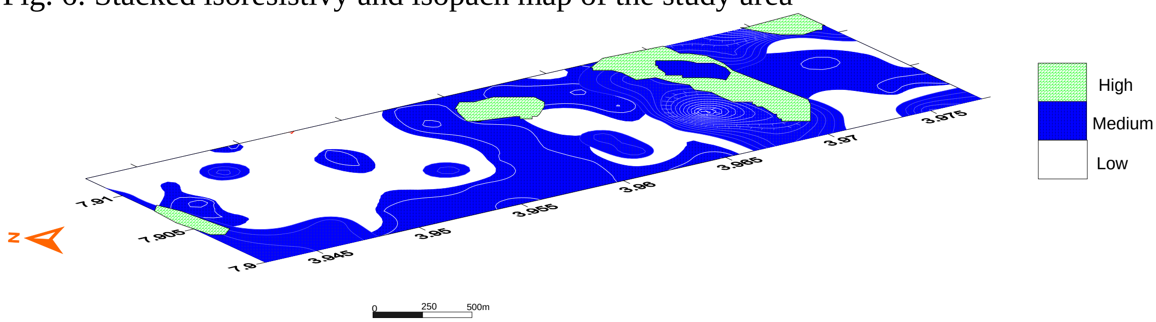

Fig. 7: Combined basement resistivity and overburden thickness map showing high, medium and low groundwater potentials

Table 1: The quantitative interpretation of the VES results

S/N	VES Stations	Layers	Resistivity (ohm-m)	Thickness(m)	Depth(m)	Inferred Lithology
1	Id1	1	160.4	0.7	0.7	Top Soil
		2	23.8	9.2	9.9	Clay Horizon
		3	3244.9			Fresh Bedrock
2	Id2	1	321	1.1	1.1	Top Soil
		2	600.5	1.2	2.2	Lateritic Horizon
		3	92.2	9.1	11.4	Sandy Clay
		4	2585.1			Fresh Bedrock
3	Id3	1	356.1	1.2	1.2	Top Soil
		2	39.9	9.8	11	Clay Horizon
		3	836			Fractured Bedrock
4	Id4	1	490.6	1	1	Top Soil

S/N	VES Stations	Layers	Resistivity (ohm-m)	Thickness(m)	Depth(m)	Inferred Lithology
		2	70.2	15.5	16.5	Clay Horizon
		3	1301.9			Fresh Bedrock
5	Id5	1	549.6	1.1	1.1	Top Soil
		2	27.2	2	3.1	Clay
		3	635.1			Fractured/weathered Bedrock
6	Id6	1	39	0.7	0.7	Top Soil
		2	1652.5	6.9	7.6	Lateritic Horizon
		3	197.4			Fractured/weathered basement
7	Id7	1	15.2	0.6	0.6	Top Soil
		2	7.4	1.6	2.2	Clay
		3	514			Fresh Bedrock
8	Id8	1	258.4	0.8	0.8	Top Soil
		2	41.8	4.2	5	Clay
		3	1964			Fresh Bedrock
9	Id9	1	586.9	1.1	1.1	Top Soil
		2	33	3	4.1	Clay
		3	1033			Fresh Bedrock
10	Id10	1	98.6	0.9	0.9	Top Soil
		2	1604.1	3.1	4	Lateritic Horizon
		3	133.3	12.2	16.2	Sandy Clay
		4	4448.3			Fresh Bedrock
11	Ap 1	1	73.9	1	1	Top Soil
		2	307.3	1.7	2.7	Lateritic Horizon
		3	63.8	10.2	12.9	Clay
		4	299.7	-		Weathered/Fractured Bedrock
12	Ap 2	1	44.2	1.1	1.1	Top Soil
		2	104.7	11.7	12.8	Lateritic Horizon
		3	17.7	22.6	35.4	Clay
		4	512.1	-		Weathered/Fractured Bedrock
13	Ap 3	1	81.3	1.2	1.2	Top Soil
		2	271.1	4	5.2	Lateritic Horizon
		3	36.5	10.6	15.8	Clay
		4	1407.4	-		Fresh Bedrock
14	Ap 4	1	583.9	1.1	1.1	Top Soil
		2	1049.6	6.6	7.7	Lateritic Horizon
		3	63.2	13.4	21.0	Clay
		4	2261.3	-		Fresh Bedrock
15	Ap 5	1	549.6	1.6	1.6	Top Soil
		2	1594.3	2.6	4.2	Lateritic Horizon
		3	20.7	16.1	20.3	Clay
		4	479.3			Weathered/Fractured Bedrock

S/N	VES Stations	Layers	Resistivity (ohm-m)	Thickness(m)	Depth(m)	Inferred Lithology
16	Ap 6	1	247.1	1.3	1.3	Top Soil
		2	628.0	8.4	9.7	Lateritic Horizon
		3	253.8	-		Fractured Bedrock
17	Ap 7	1	108.2	1.3	1.3	Top Soil
		2	19.8	1.1	2.4	Clay
		3	1120.9	-		Fresh Bedrock
18	Ap 8	1	171.3	2.5	2.5	Top Soil
		2	3.9	2	4.5	Clay
		3	438.9	-		Weathered/Fractured Bedrock
				-		
19	Ap 9	1	229.4	1.1	1.1	Top Soil
		2	18.0	3.9	5.0	Clay
		3	730	-		Fresh Bedrock
20	Ap 10	1	549.1	1.1	1.1	Top Soil
		2	824.3	17.3	18.4	Weathered Bedrock
		3	7537.4	-		Fresh Bedrock
21	Ap11	1	251.1	1	1	Top Soil
		2	1006.8	17.5	18.5	Lateritic Horizon
		3	5.0	-		Clay
22	Ap12	1	496.6	1.2	1.2	Top Soil
		2	796.0	5.0	6.2	Lateritic Horizon
		3	191.9	13.1	19.3	Fractured Bedrock
		4	6665.3	-		Fresh Bedrock
23	Ap13	1	169.6	1.1	1.1	Top Soil
		2	273.7	10.5	11.6	Lateritic Horizon
		3	14.0	6.6	18.2	Clay
		4	1832.4	-		Fresh Bedrock
24	Ap14	1	372.5	1.3	1.3	Top Soil
		2	1393.6	4	5.3	Lateritic Horizon
		3	24.2	-		Clay
25	Ap15	1	305.9	1.2	1.2	Top Soil
		2	501.8	2.1	3.3	Lateritic Horizon
		3	217.2	51.5	54.8	Fractured Bedrock
		4	4117.2	-		Fresh Bedrock
26	Ap16	1	836	1.3	1.3	Top Soil
		2	1516	8.2	9.5	Lateritic Horizon
		3	222	-		Fractured Bedrock
27	Ap17	1	344.3	0.9	0.9	Top Soil
		2	1164.5	3	3.9	Lateritic Horizon
		3	107.1	3.3	7.2	Sandy Clay
		4	1176	-		Fresh Bedrock

S/N	VES Stations	Layers	Resistivity (ohm-m)	Thickness(m)	Depth(m)	Inferred Lithology
28	Ig1	1	420	0.7	0.7	Top Soil
		2	7980			Fresh Bedrock
29	Ig2	1	260	1	1	Top Soil
		2	4940			Fresh Bedrock
30	Ig3	1	185	0.8	0.8	Top Soil
		2	734.3	7.8	8.6	Lateritic Horizon
		3	132.3	5.2	13.8	Sandy Clay
		4	2863.3			Fresh Bedrock
31	Ig4	1	126.2	0.8	0.8	Top Soil
		2	65.8	10.9	11.6	Clay
		3	594.8			Weathered/Fractured Bedrock
32	Ig5	1	96.1	1	1	Top Soil
		2	17.8	1.2	2.2	Clay
		3	366.7			Weathered/Fractured Bedrock
33	Ig6	1	204	0.7	0.7	Top Soil
		2	10.1	2.1	2.8	Clay
		3	563.3			Weathered/Fractured Bedrock
34	Ig7	1	122.8	0.9	0.9	Top Soil
		2	13.4	2.1	3	Clay
		3	1451			Fresh Bedrock
35	Ig8	1	121.4	1	1	Top Soil
		2	9.7	1.3	2.2	Clay
		3	2069.7			Fresh Bedrock
36	Ig9	1	144.2	0.5	0.5	Top Soil
		2	35.8	4.6	5.1	Clay
		3	1312.2			Fresh Bedrock
37	Ig10	1	114.7	0.8	0.8	Top Soil
		2	18.5	2.8	3.6	Clay
		3	381			Weathered/Fractured Bedrock
38	Ig11	1	1700	1.15	1.15	Top Soil
		2	15300			Fresh Bedrock
		3				
39	Ig12	1	475.7	0.8	0.8	Top Soil
		2	12.1	1.3	2.1	Clay
		3	596.4			Weathered/Fractured Bedrock
40	Ig13	1	488	0.8	0.8	Top Soil
		2	21.5	2.3	3.1	Clay
		3	604.3			Weathered/Fractured Bedrock

S/N	VES Stations	Layers	Resistivity (ohm-m)	Thickness(m)	Depth(m)	Inferred Lithology
41	Ig14	1	421.9	1.3	1.3	Top Soil
		2	20.9	2.3	3.6	Clay
		3	2124.8	-		Fresh Bedrock
42	Ig15	1	500	0.7	0.7	Top Soil
		2	2769.1	0.7	1.4	Lateritic Horizon
		3	130.2	12.7	14.1	Sandy Clay
		4	2358.4	-		Fresh Bedrock
43	Ig16	1	209.5	1.5	1.5	Top Soil
		2	4.4	0.7	2.2	Clay
		3	309.6	-		Weathered/Fractured Bedrock
44	Ig17	1	432.3	0.3	0.3	Top Soil
		2	21.9	6.1	6.4	Clay
		3	828.7	-		Fresh Bedrock
45	Ig18	1	118.5	1.3	1.3	Top Soil
		2	8	2.7	4.0	Clay
		3	301.3	-		Weathered/Fractured Bedrock
46	Ig19	1	58.7	1.0	1.0	Top Soil
		2	11.0	2.0	3.0	Clay
		3	450.5	-		Weathered/Fractured Bedrock
47	Ig20	1	58.8	1	1	Top Soil
		2	26.2	4.3	5.3	Clay
		3	527.3	-		Weathered/Fractured Bedrock
48	Ig21	1	44.2	0.7	0.7	Top Soil
		2	13.2	1.3	2.0	Clay
		3	760.9	-		Weathered/Fractured Bedrock
49	Ig22	1	164.9	1	1	Top Soil
		2	7.8	2.3	3.3	Clay
		3	198.5	-		Weathered/Fractured Bedrock
50	Ig23	1	338.1	1	1	Top Soil
		2	20.7	2.1	3.1	Clay
		3	611.8	-		Weathered/Fractured Bedrock
51	Ig24	1	344.2	1	1	Top Soil
		2	105.7	7.7	8.7	Sandy Clay
		3	2233.9	-		Fresh Bedrock
52	Im1	1	15.4	0.5	0.5	Top Soil
		2	231	1.8	2.3	Lateritic Horizon
		3	989.4			Fresh Bedrock
53	Im2	1	71.6	1.2	1.2	Top Soil
		2	18.1	3.9	5.1	Clay

S/N	VES Stations	Layers	Resistivity (ohm-m)	Thickness(m)	Depth(m)	Inferred Lithology
		3	848.6	-		Fresh Bedrock
54	Im3	1	374.8	0.4	0.4	Top Soil
		2	41.2	4.3	4.7	Clay
		3	797.9			Fresh Bedrock
55	Im4	1	83	1	1	Top Soil
		2	55	18	19	Clay
		3	495			Fractured Bedrock
56	Im 5	1	76.2	1.3	1.3	Top Soil
		2	22.6	39.1	40.4	Clay
		3	2166.4	-		Fresh Bedrock
57	Im 6	1	130.6	1.3	1.3	Top Soil
		2	59.8	16.5	17.8	Clay
		3	1199	-		Fresh Bedrock
58	Im 7	1	71.3	2	2	Top Soil
		2	9.4	21.2	23.2	Clay
		3	529.3	-		Weathered/Fractured Bedrock
59	Im8	1	139.8	1.5	1.5	Top Soil
		2	62.4	6.3	7.7	Clay
		3	1727.4	-		Fresh Bedrock
60	Im9	1	1064	1.3	1.3	Top Soil
		2	100	3.7	5.0	Sandy Clay
		3	571	-		Weathered/Fractured Bedrock
61	Im 10	1	489.1	0.9	0.9	Top Soil
		2	83	6.1	7.0	Sandy Clay
		3	405.2	-		Weathered/Fractured Bedrock
62	Im 11	1	210.2	1.0	1.0	Top Soil
		2	1049.1	2.4	3.4	Lateritic Horizon
		3	115.6	11.6	15.0	Sandy Clay
		4	3414.1	-		Fresh Bedrock
63	Im12	1	491.2	1.2	1.2	Top Soil
		2	793.6	4.9	6.1	Lateritic Horizon
		3	196.7	12.6	18.7	Sandy Clay
		4	6783.6	-		Fresh Bedrock
64	Im13	1	378.9	1.4	1.4	Top Soil
		2	71.9	2.5	3.9	Sandy Clay
		3	2224.8	-		Fresh Bedrock
65	Im 14	1	579.7	1.2	1.2	Top Soil
		2	44.9	11.3	12.5	Clay
		3	1354.8	-		Fresh Bedrock
66	Im15	1	284.2	2.5	2.5	Top Soil
		2	116.3	14.2	16.7	Sandy Clay
		3	2582.3	-		Fresh Bedrock

S/N	VES Stations	Layers	Resistivity (ohm-m)	Thickness(m)	Depth(m)	Inferred Lithology
67	Im16	1	195.4	1.5	1.5	Top Soil
		2	26	0.4	1.9	Clay
		3	246.5	-		Weathered/Fractured Bedrock
68	Im17	1	410.7	0.8	0.8	Top Soil
		2	16.4	2.4	3.2	Clay
		3	878.2	-		Fresh Bedrock
69	Im18	1	259.6	0.8	0.8	Top Soil
		2	16.8	3.7	4.5	Clay
		3	981.7	-		Fresh Bedrock
70	Im19	1	325.4	1.6	1.6	Top Soil
		2	27.6	13.3	14.9	Clay
		3	1018.8	-		Fresh Bedrock
71	Im20	1	276.8	1.2	1.2	Top Soil
		2	25.9	4.2	5.4	Clay
		3	587.1	-		Weathered Bedrock
72	Im21	1	52.2	0.9	0.9	Top Soil
		2	6.7	10.2	11.1	Clay
		3	331.5	-		Weathered/Fractured Bedrock
73	Im22	1	105.9	1.2	1.2	Top Soil
		2	14.9	4.3	5.5	Clay
		3	1911.7	-		Fresh Bedrock
74	Im23	1	635.7	1.3	1.3	Top Soil
		2	37.9	12.2	13.5	Clay
		3	768.8	-		Fresh Bedrock
75	Im24	1	1003	0.7	0.7	Top Soil
		2	46.2	13.4	14.1	Clay
		3	1834.7	-		Fresh Bedrock
76	Im25	1	499.5	1.0	1.0	Top Soil
		2	18.3	1.5	2.5	Clay
		3	566.7	-		Weathered/Fractured Bedrock
77	Im26	1	536.9	1	1	Top Soil
		2	67.2	9	10	Clay
		3	644.2	-		Weathered/Fractured Bedrock
78	Im27	1	712.3	0.8	0.8	Top Soil
		2	28.8	2.2	3.0	Clay
		3	425.6	-		Weathered/Fractured Bedrock
79	Im28	1	1109.1	1.1	1.1	Lateritic Top Soil
		2	46.1	4.8	5.9	Clay
		3	650.1	-		Weathered/Fractured Bedrock
80	Im29	1	221.9	1.1	1.1	Top Soil

S/N	VES Stations	Layers	Resistivity (ohm-m)	Thickness(m)	Depth(m)	Inferred Lithology
		2	21.7	2.9	4.0	Clay
		3	337	-		Weathered/Fractured Bedrock