Evaluation of Soil Resistivity Characteristics forSubstation Grounding: a Case Study of a University Campus in South-West Zone, Nigeria

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Abstract

There are numerous transmission and distribution problems encountered in the development and operation of electrical power systems. A number of interference and protection problems arise due to unavoidable interaction of such systems with nature and each other. These interactions arise because the earth is involved as a return conductor for both types of systems, either during normal or abnormal operation typified by system faults. It is essential to determine the soil resistivity and maximum grid current to design a substation grounding system. This work provides the soil resistivity values with the type of soil at various locations, which serve as the best reference point for safe grounding system for electrical power substations, communication base substations and transmitter tower antennas.

Keywords: Soil resistivity, Vertical electrical grounding, Substation, University

I. Introduction

Beginning from generating station to the final distribution station, electrical power passes through number of different kind of substations. To ensure that substations are safe and reliable, the substation must have a properly designed grounding system. Grounding deals with the problems relating to conduction of electricity through earth (Gupta, 1991). Lightning and thunder are the most significant cause of interferences in electrical power distribution systems. In order to reduce incidence of fault to a minimum protection schemes are put in place. Power systems grounding is very important, particularly since a large majority of faults involve ground or are caused by thunderstorm/lightning strikes.Grounding system plays vital role in satisfactory operation of a substation. It provides place for connecting system neutral points, equipment body and support structures to the earth (Baleva, 2012 and Markovic, 1994).

According to Francis (1993) earthing or grounding a component means making a connection between the component and the general mass of the earth to ensure an immediate and safer discharge of energy.The main importance of grounding is to provide a discharge path for lightning strikes and hazardous fault current, for safety to avoid shock of individual in the vicinity, to minimize hazards from transferred potential. This helps to maintain proper functioning of the electrical system.The factors that influence the grounding resistance of an electrode or combination of electrodes are the:

a) composition of the soil in the immediate neighbourhood;
b) temperature of the soil;
c) moisture content of the soil; and
d) depth of electrode.

A good grounding system provides a low resistance to remote earth in order to minimize the ground potential rise (GPR). For transmission substations and large distribution substations, the ground resistance is usually about 1 ohm or less. In smaller distribution substations, the usually acceptable range is from 1 ohm to 5 ohms, depending on the local conditions.

In this work, the soil resistivity value of four locations within Federal University of Technology in Akure (FUTA) was obtained.

a) Location A: University Library Area
b) Location B: Ogomudia Laboratory Area
c) Location C: Educational Trust Fund (ETF) Area
d) Location D: 33/0.415kV FUTA Power Substation Area.

II. Methodology

Measurement techniques are widely employed to monitor the effectiveness or otherwise of the earth termination network. Such measurements of grounding electrode resistance and soil resistivity are necessary periodically in order to assess the effectiveness of the protective schemes for vulnerable communications and electric utility facilities against thunderstorm and lightning strikes. In this work, Wenner four pin method was adopted to obtain the soil resistivity values. Four electrodes were driven into the ground in a straight line and equally spaced. The two outer electrodes are current electrode (C1 and C2) while the two inner electrode are potential electrode (P1 and P2) as shown in figure 1.

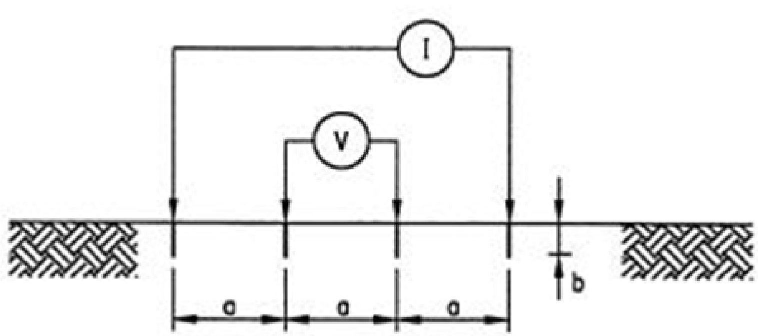

Figure 1: Wenner Four Pin Method (Wenner, 1915)

The two outer electrodes were used to inject current into ground. There was voltage dropped as the current flows through the earth. This voltage dropped was measured between the two inner electrodes (P1 and P2). The amount of current indicated by the meter was recorded as the current flowing through the earth and the voltage drop across inner electrodes. The resistance obtained from the Megger meter was used to determine the soil resistivity by using equation 1. The soil resistivity values are shown in table 1to 20

$$\rho = 2\pi aR \quad (1)$$

where ρ is the resistivity of the local soil (Ω-m), a is distance between probes (m) and R is resistance determined by the testing device or instrument (Ω).

III. Results and Discussion

Good soil models are the basis of all grounding designs. The test results obtained are shown in Table 1 to 20 while the corresponding plots are shown in Figure 1 to 20 using WINRESIST software. The WINRESIST software helps to determine the depth, number, thickness and resistivity of each soil layers. The apparent resistivity is plotted on the vertical axis against the electrode spacing on the horizontal axis. To investigate changes in resistivity with depth, the size of the electrode array is varied. The apparent resistivity is affected by material at increasingly greater depths (hence larger volume) as the electrode spacing is increased. In view of this effect, a plot of apparent resistivity against electrode spacing can be used to indicate vertical variations in resistivity.

Table 1: 33kV Substation Area Resistivity Values (Sounding 1)

GPS CORDINATES(UTM): 73°59"54N : 80°74''87E : 394m				
REMARK : I = 2mA				
S/N	a (m)	K = 2πa	R (Ω)	ρ_a = K x R (Ω-m)
1	0.25	1.571	38.480	60.45
2	0.50	3.142	23.470	73.74
3	1.00	6.283	12.040	75.65
4	1.50	9.425	7.756	73.10
5	2.00	12.566	5.777	72.59
6	2.50	15.708	4.776	75.02
7	3.00	18.850	3.613	68.11
8	4.00	25.133	2.184	54.89
9	6.00	37.699	1.551	58.47
10	8.00	50.265	1.255	63.08
11	10.00	62.832	1.092	68.61
12	12.00	75.398	1.019	76.83

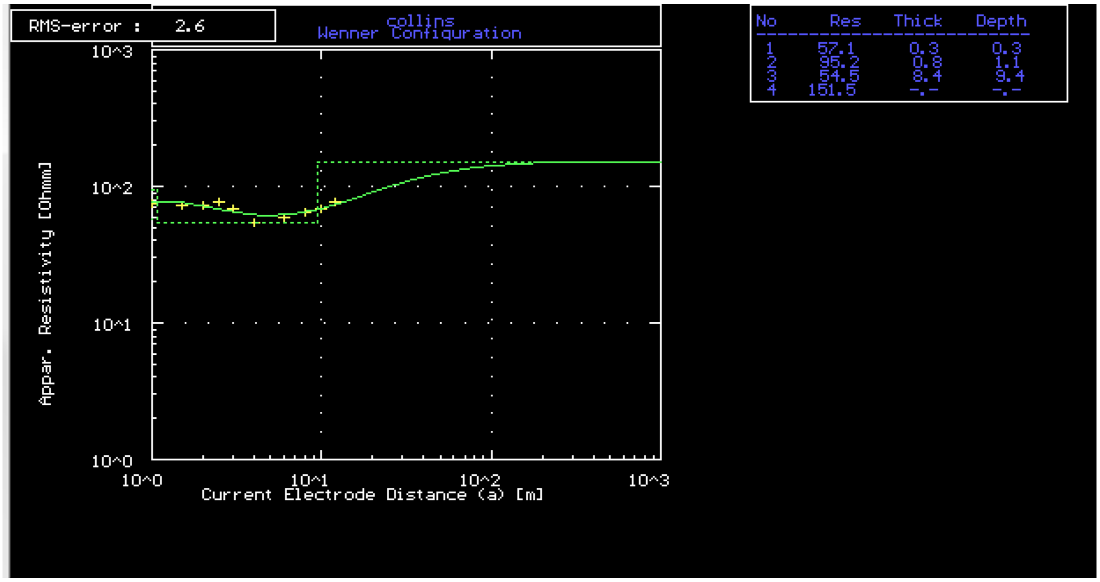

Figure 2: Graph of apparent resistivity (ρ_a) against electrode distance (m)

Table 2: 33kV Substation Area Resistivity Values (Sounding 2)

GPS CORDINATES(UTM): 73°59"62N : 80°74"87E: 385m				
REMARK : I = 2mA				
S/N	a (m)	K = 2πa	R (Ω)	ρ_a = K x R (Ω-m)
1	0.25	1.571	93.08	146.23
2	0.50	3.142	46.23	145.25
3	1.00	6.283	24.39	153.24
4	1.50	9.425	16.84	158.717
5	2.00	12.566	12.65	158.96
6	2.50	15.708	9.706	152.46
7	3.00	18.850	8.032	151.40
8	4.00	25.133	4.970	124.91
9	6.00	37.699	2.592	97.72
10	8.00	50.265	1.837	92.33
11	10.00	62.832	1.653	103.86
12	12.00	75.398	1.428	107.67

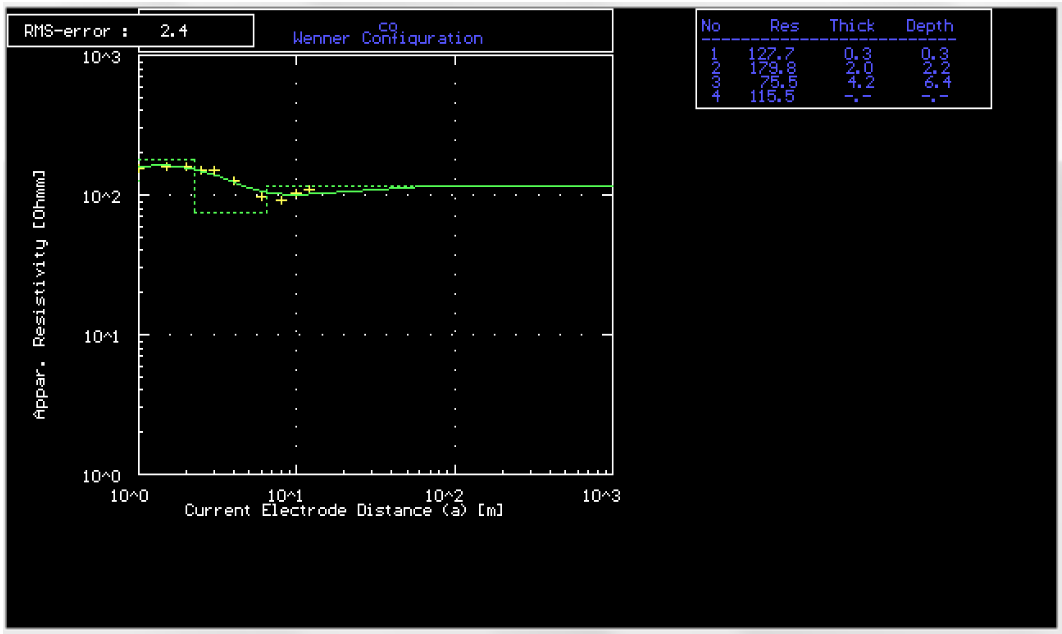

Figure 3: Graph of apparent resistivity (ρ_a) against electrode distance (m)

Table 3: 33kV Substation Area Resistivity Values (Sounding 3)

GPS CORDINATES(UTM): 73°59"65N : 80°74"84E: 376m				
REMARK : I = 2mA				
S/N	a (m)	K = 2πa	R (Ω)	ρ_a = K x R (Ω-m)
1	0.25	1.571	94.21	148.00
2	0.50	3.142	62.67	196.91
3	1.00	6.283	33.78	212.24
4	1.50	9.425	19.28	181.71
5	2.00	12.566	12.24	153.81
6	2.50	15.708	10.92	171.53
7	3.00	18.850	5.879	110.82
8	4.00	25.133	3.592	90.28
9	6.00	37.699	2.592	97.72
10	8.00	50.265	2.133	107.22
11	10.00	62.832	1.918	120.51
12	12.00	75.398	1.990	150.04

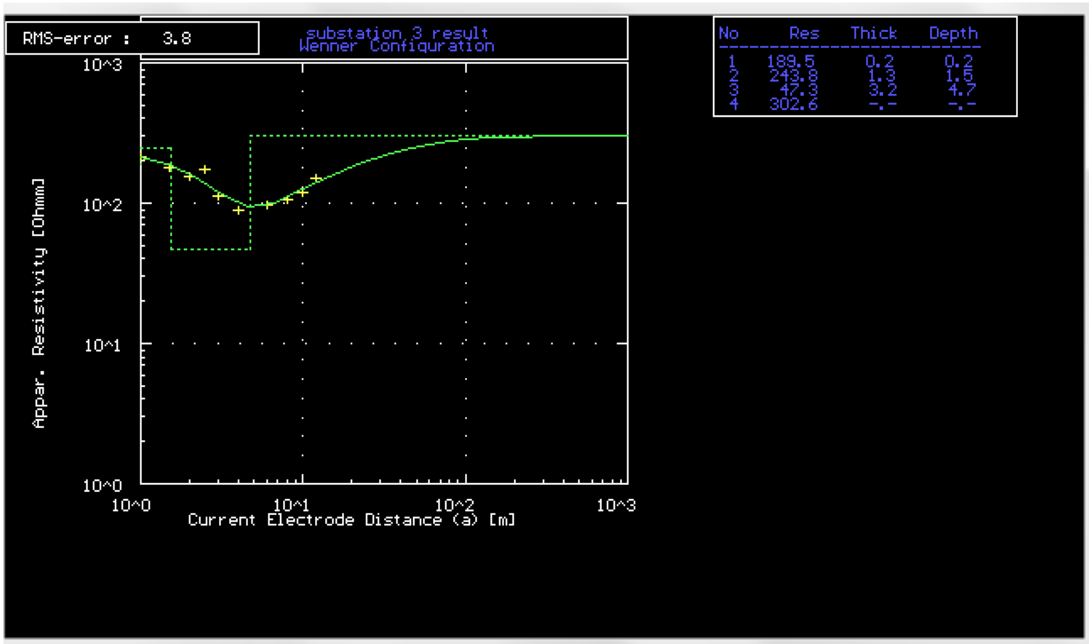

Figure 4: Graph of apparent resistivity (ρ_a) against electrode distance (m)

Table 4: 33kV Substation Area Resistivity Values (Sounding 4)

GPS CORDINATES(UTM): 73°59"56N: 80°74"80E: 379m				
REMARK : I = 2Ma				
S/N	a (m)	K = 2πa	R (Ω)	ρ_a = K x R (Ω-m)
1	0.25	1.571	84.71	133.08
2	0.50	3.142	71.24	223.84
3	1.00	6.283	26.23	164.80
4	1.50	9.425	15.41	145.24
5	2.00	12.566	11.73	147.40
6	2.50	15.708	7.706	121.05
7	3.00	18.850	5.920	111.59
8	4.00	25.133	2.776	69.77
9	6.00	37.699	2.174	81.96
10	8.00	50.265	1.745	87.71
11	10.00	62.832	1.816	114.10
12	12.00	75.398	1.867	140.77

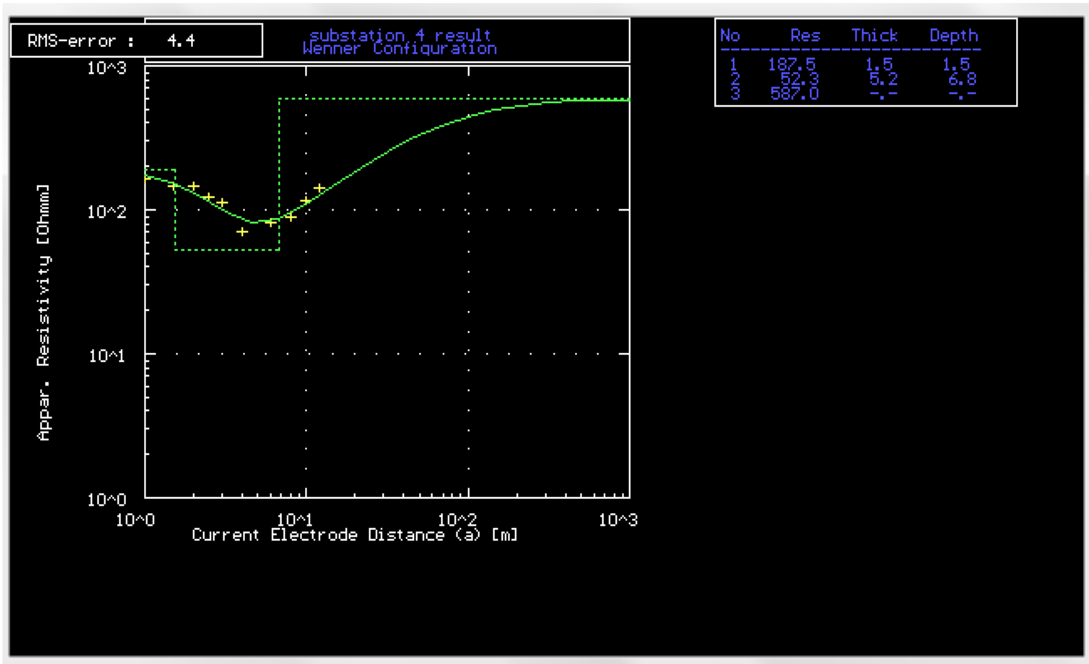

Figure 5: Graph of apparent resistivity (ρ_a) against electrode distance (m)

Table 5: 33kV Substation Area Resistivity Values (Sounding 5)

GPS CORDINATES(UTM): 73°59"63N : 80°74"88E: 375m				
EQUIPMENT USED : Ohmega digital earth tester				
REMARK : I = 2mA				
S/N	a (m)	K = 2πa	R (Ω)	ρ_a = K x R (Ω-m)
1	0.25	1.571	65.93	103.58
2	0.50	3.142	40.41	126.97
3	1.00	6.283	20.00	125.66
4	1.50	9.425	12.86	121.21
5	2.00	12.566	9.533	119.80
6	2.50	15.708	7.455	117.10
7	3.00	18.850	5.582	105.22
8	4.00	25.133	3.225	81.05
9	6.00	37.699	1.724	64.99
10	8.00	50.265	1.428	71.78
11	10.00	62.832	1.367	85.89
12	12.00	75.398	1.367	103.07

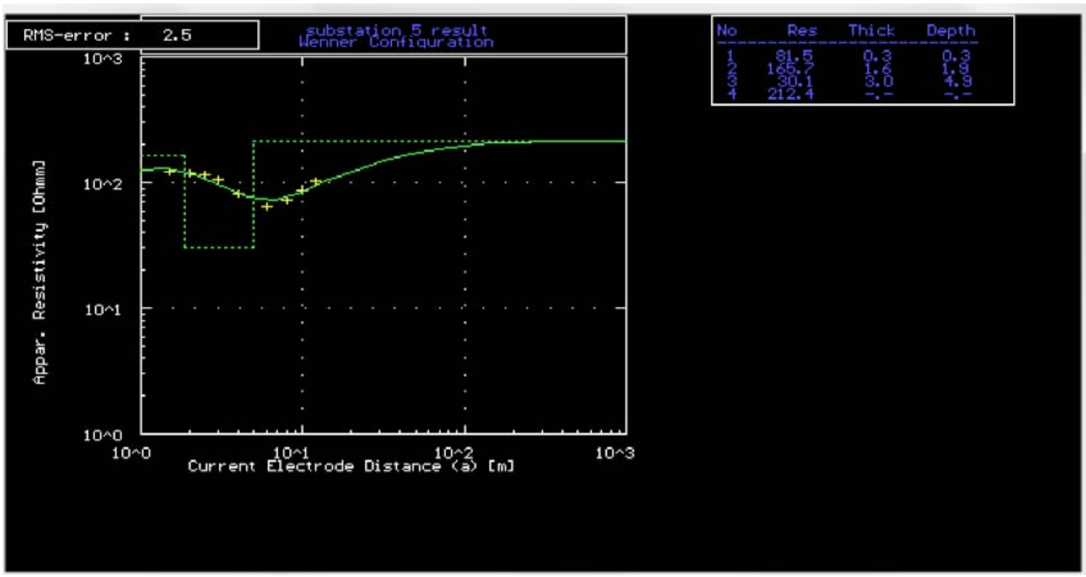

Figure 6: Graph of apparent resistivity (ρ_a)against electrode distance (m)

Table 6: Ogomudia Laboratory Area Resistivity Values (Sounding 1)

GPS CORDINATES(UTM): 73°56"01N : 80°76"28E: 388m				
REMARK : I = 0.5mA				
S/N	a (m)	K = 2πa	R (Ω)	ρ_a = K x R (Ω-m)
1	0.25	1.571	37.97	59.65
2	0.50	3.142	33.17	104.22
3	1.00	6.283	21.92	137.72
4	1.50	9.425	15.61	147.12
5	2.00	12.566	12.75	160.22
6	2.50	15.708	12.45	195.56
7	3.00	18.850	9.696	182.77
8	4.00	25.133	7.757	194.96
9	6.00	37.699	5.225	196.98
10	8.00	50.265	4.031	202.62
11	10.00	62.832	3.327	209.04
12	12.00	75.398	3.051	230.04

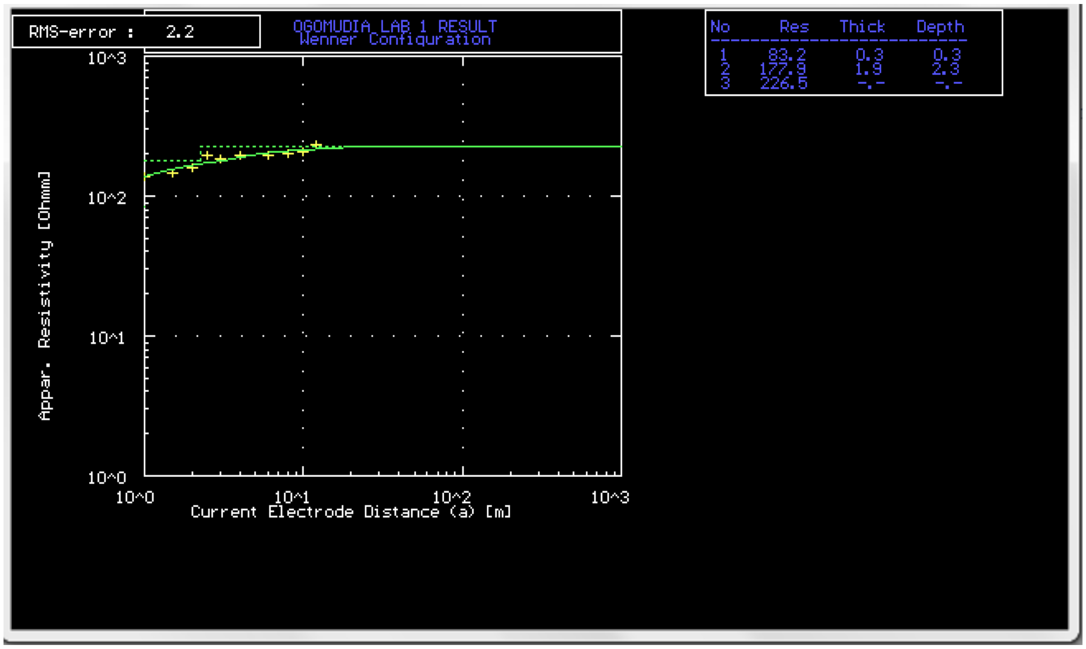

Figure 7: Graph of apparent resistivity (ρ_a) against electrode distance (m)

Table 7: Ogomudia Laboratory Area Resistivity Values (Sounding 2)

GPS CORDINATES(UTM): 73°56"05N : 80°76"08E: 388m				
REMARK : I = 0.5mA				
S/N	a (m)	K = 2πa	R (Ω)	ρ_a= K x R (Ω-m)
1	0.25	1.571	25.41	39.92
2	0.50	3.142	16.53	51.94
3	1.00	6.283	9.195	57.77
4	1.50	9.425	6.00	56.55
5	2.00	12.566	7.461	93.75
6	2.50	15.708	6.113	96.02
7	3.00	18.850	6.818	128.52
8	4.00	25.133	5.082	127.73
9	6.00	37.699	4.123	155.43
10	8.00	50.265	3.123	156.98
11	10.00	62.832	2.694	169.27
12	12.00	75.398	2.306	173.87

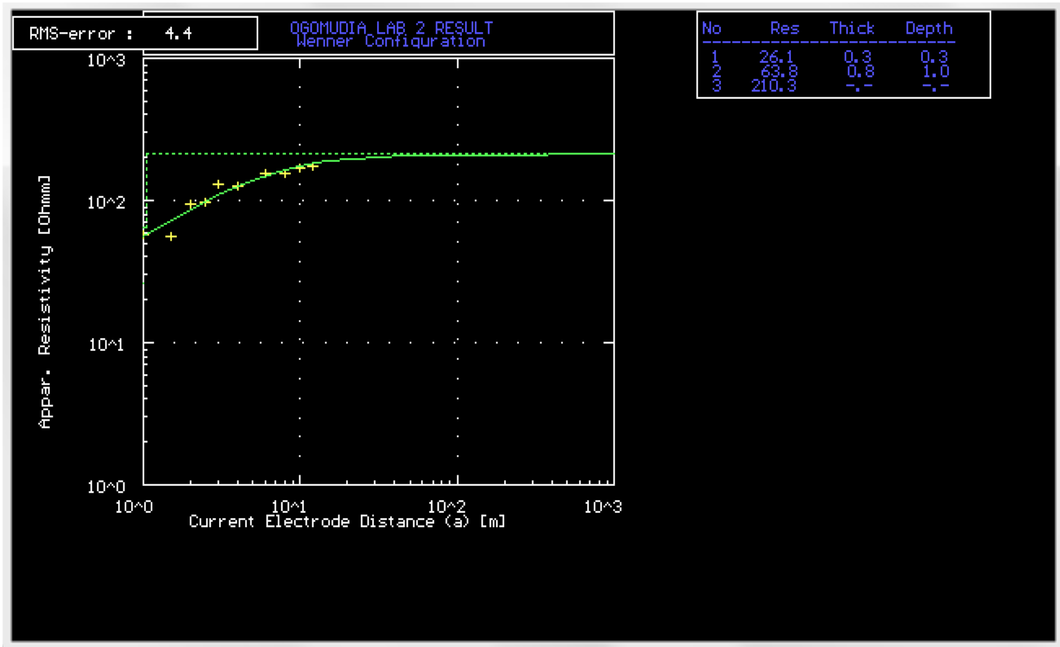

Figure 8: Graph of apparent resistivity (ρ_a) against electrode distance (m)

Table 8: Ogomudia Laboratory Area Resistivity Values (Sounding 3)

GPS LOCATION(UTM): 73°56"06N : 80°76"20E: 388m				
REMARK : I = 0.5mA				
S/N	a (m)	K = 2πa	R (Ω)	ρ_a = K x R (Ω-m)
1	0.25	1.571	63.48	99.72
2	0.50	3.142	59.30	186.32
3	1.00	6.283	21.74	136.60
4	1.50	9.425	15.20	143.26
5	2.00	12.566	12.86	161.60
6	2.50	15.708	11.32	177.81
7	3.00	18.850	11.32	213.38
8	4.00	25.133	7.992	200.86
9	6.00	37.699	6.011	226.61
10	8.00	50.265	4.756	239.06
11	10.00	62.832	3.521	221.23
12	12.00	75.398	2.970	223.93

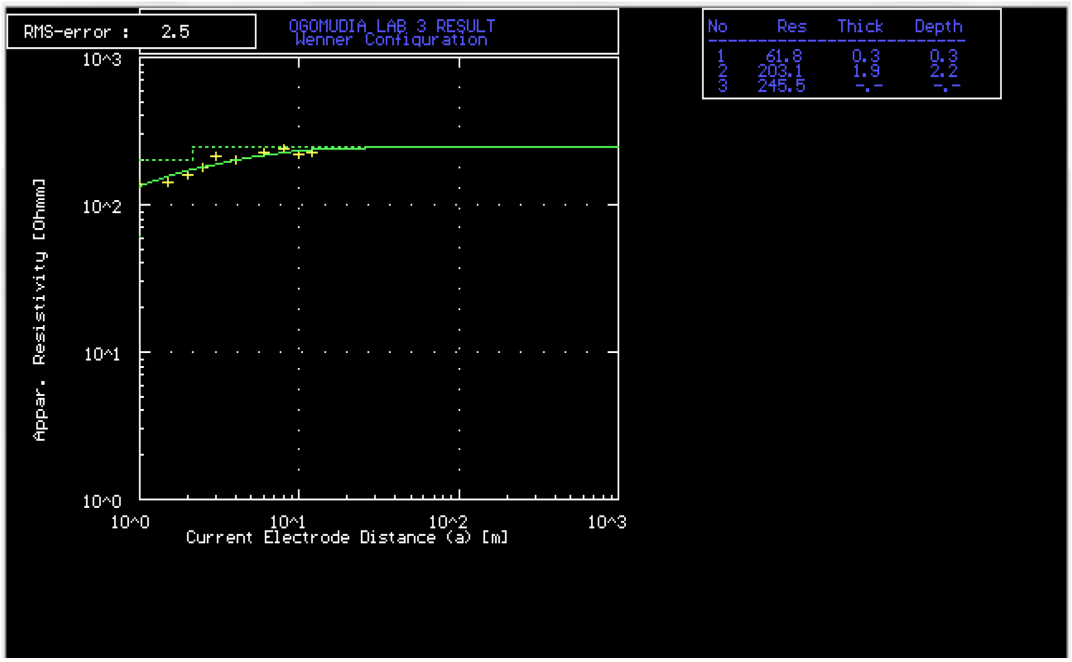

Figure 9: Graph of apparent resistivity (ρ_a) against electrode distance (m)

Table 9: Ogomudia Laboratory Area Resistivity Values (Sounding 4)

GPS LOCATION(UTM): 73°55”95N : 80°76"14E: 386m				
REMARK : I = 0.5mA				
S/N	a (m)	K = 2πa	R (Ω)	ρ_a= K x R (Ω-m)
1	0.25	1.571	29.29	46.01
2	0.50	3.142	23.27	73.11
3	1.00	6.283	18.67	117.30
4	1.50	9.425	15.31	144.30
5	2.00	12.566	13.16	165.37
6	2.50	15.708	11.53	181.50
7	3.00	18.850	10.00	188.50
8	4.00	25.133	8.257	207.52
9	6.00	37.699	6.052	228.15
10	8.00	50.265	4.327	217.50
11	10.00	62.832	3.419	214.82
12	12.00	75.398	3.051	230.04

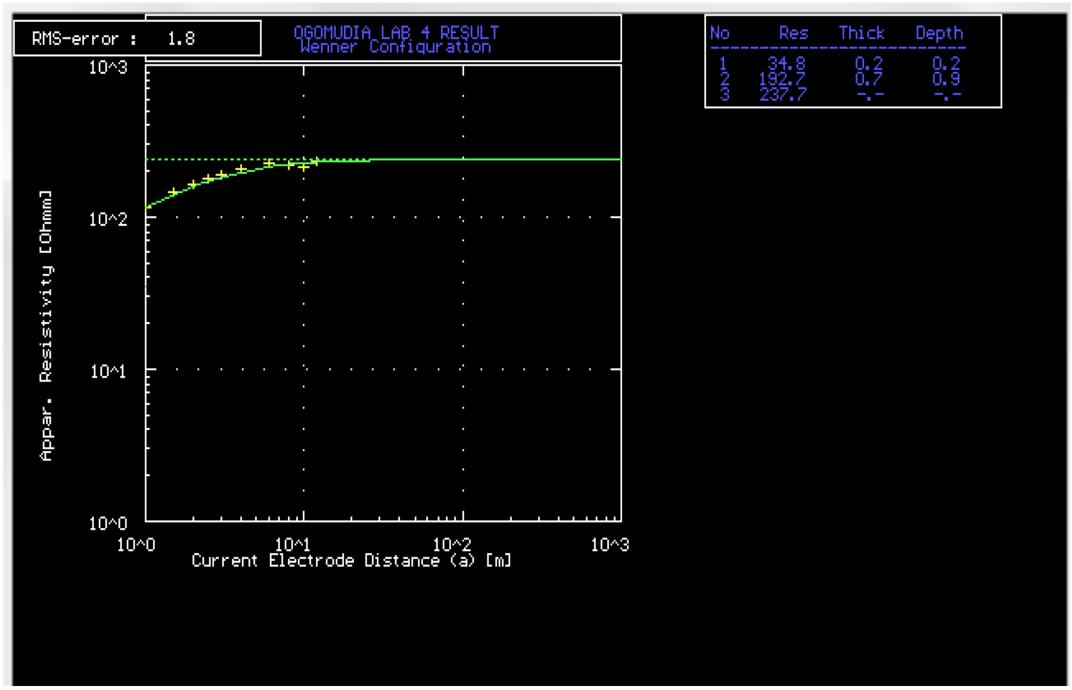

Figure 10: Graph of apparent resistivity (ρ_a) against electrode distance (m)

Table 10: Ogomudia Laboratory Area Resistivity Values (Sounding 5)

GPS LOCATION(UTM): 73°56"05N : 80°76"14E: 392m				
REMARK : I = 0.5mA				
S/N	a (m)	K = 2πa	R (Ω)	ρ_a= K x R (Ω-m)
1	0.25	1.571	37.97	59.65
2	0.50	3.142	26.12	82.07
3	1.00	6.283	17.55	110.28
4	1.50	9.425	12.75	180.12
5	2.00	12.566	10.41	130.83
6	2.50	15.708	8.858	139.16
7	3.00	18.850	8.154	153.72
8	4.00	25.133	7.011	180.25
9	6.00	37.699	5.358	202.02
10	8.00	50.265	3.990	200.59
11	10.00	62.832	3.235	206.52
12	12.00	75.398	2.816	212.35

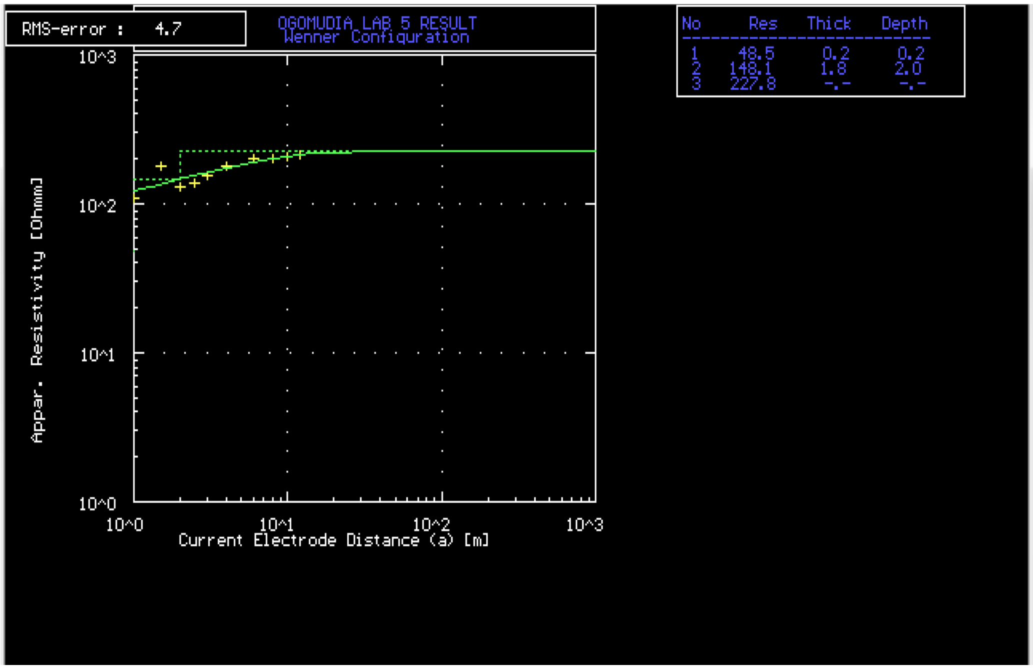

Figure 11: Graph of apparent resistivity (ρ_a) against electrode distance (m)

Table 11: University Library Area Resistivity Values (Sounding 1)

GPS LOCATION(UTM): 73°57"31N : 80°77"75E: 394m				
REMARK : I = 1mA				
S/N	a (m)	K = 2πa	R (Ω)	ρ_a = K x R (Ω-m)
1	0.25	1.571	98.29	154.4
2	0.50	3.142	62.35	195.9
3	1.00	6.283	36.02	226.35
4	1.50	9.425	32.66	335.19
5	2.00	12.566	26.94	338.6
6	2.50	15.708	18.88	296.6
7	3.00	18.850	16.12	303.89
8	4.00	25.133	13.98	359.43
9	6.00	37.699	13.26	499.96
10	8.00	50.265	13.57	682.19
11	10.00	62.832	12.75	801.21
12	12.00	75.398	11.22	846.08

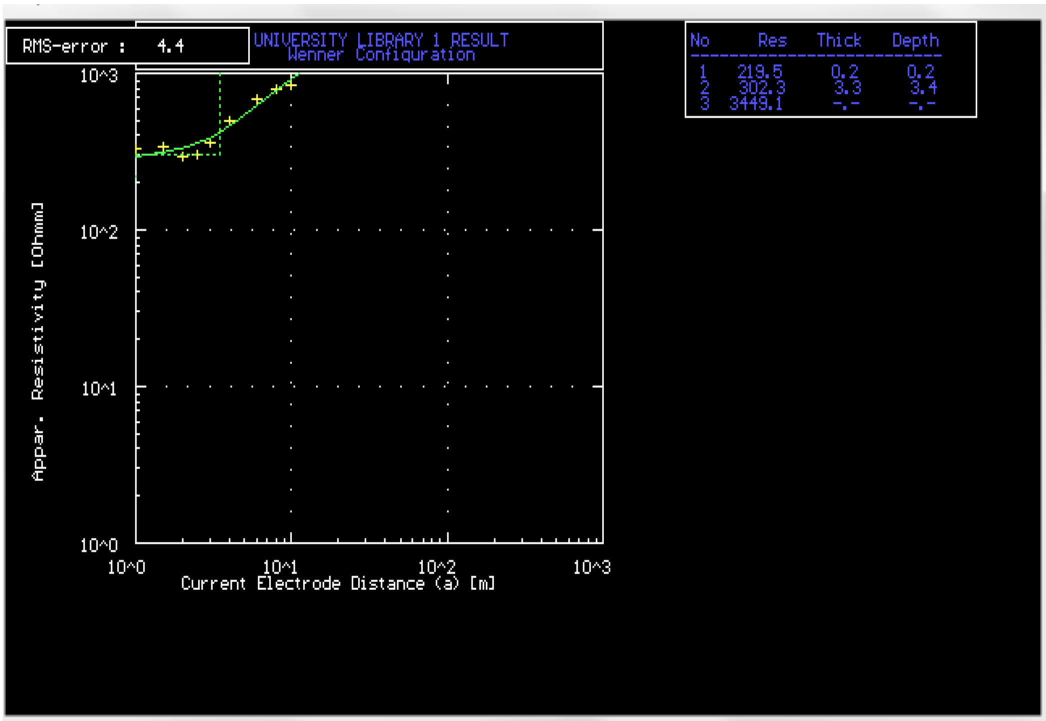

Figure 12: Graph of apparent resistivity (ρ_a)against electrode distance (m)

Table 12: University Library Area Resistivity Values (Sounding 2)

GPS LOCATION(UTM): 73°57”21N : 80°77"75E: 395m				
REMARK : I = 1mA				
S/N	a (m)	K = 2πa	R (Ω)	ρ_a= K x R (Ω-m)
1	0.25	1.571	75.02	117.86
2	0.50	3.142	32.56	102.30
3	1.00	6.283	31.33	196.85
4	1.50	9.425	19.39	182.75
5	2.00	12.566	18.37	230.84
6	2.50	15.708	17.55	275.68
7	3.00	18.850	17.35	327.05
8	4.00	25.133	18.06	453.88
9	6.00	37.699	15.51	584.71
10	8.00	50.265	13.36	671.54
11	10.00	62.832	11.83	743.30
12	12.00	75.398	11.12	838.43

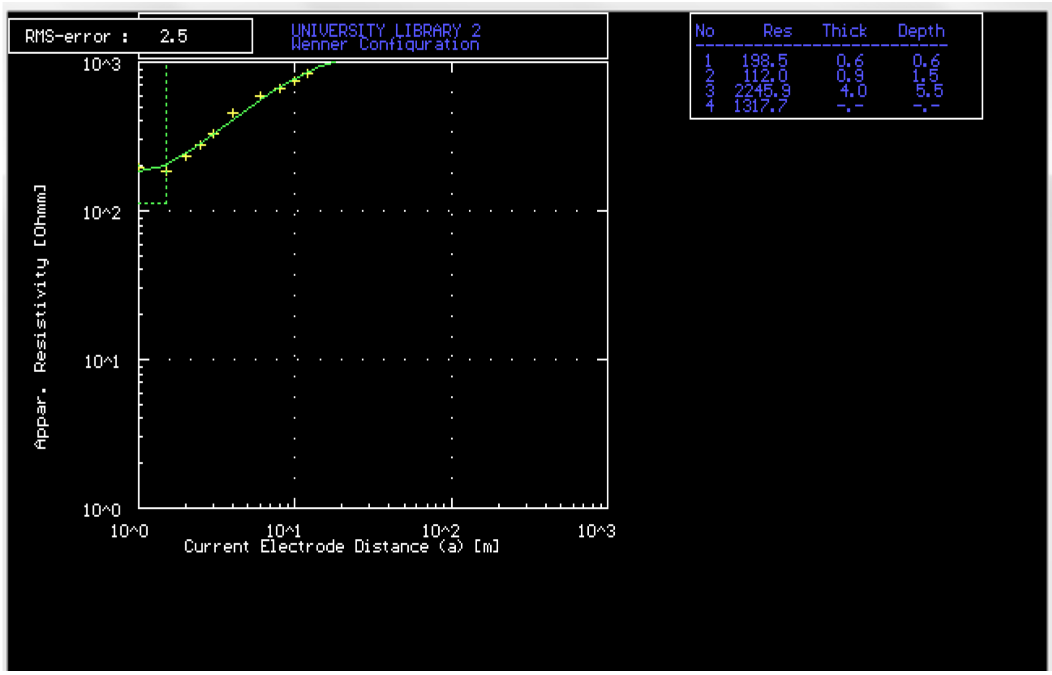

Figure 13: Graph of apparent resistivity (ρ_a)against electrode distance (m)

Table 13: University Library Area Resistivity Values (Sounding 3)

GPS LOCATION(UTM): 73°57”28N : 80°77"82E: 391m				
REMARK : I = 1Ma				
S/N	a (m)	K = 2πa	R (Ω)	ρ_a = K x R (Ω-m)
1	0.25	1.571	75.31	118.31
2	0.50	3.142	48.58	152.64
3	1.00	6.283	37.45	235.30
4	1.50	9.425	25.41	264.90
5	2.00	12.566	19.69	247.42
6	2.50	15.708	18.88	296.57
7	3.00	18.850	18.88	355.89
8	4.00	25.133	17.76	446.34
9	6.00	37.699	16.02	603.94
10	8.00	50.265	13.57	682.10
11	10.00	62.832	11.43	718.17
12	12.00	75.398	10.71	807.51

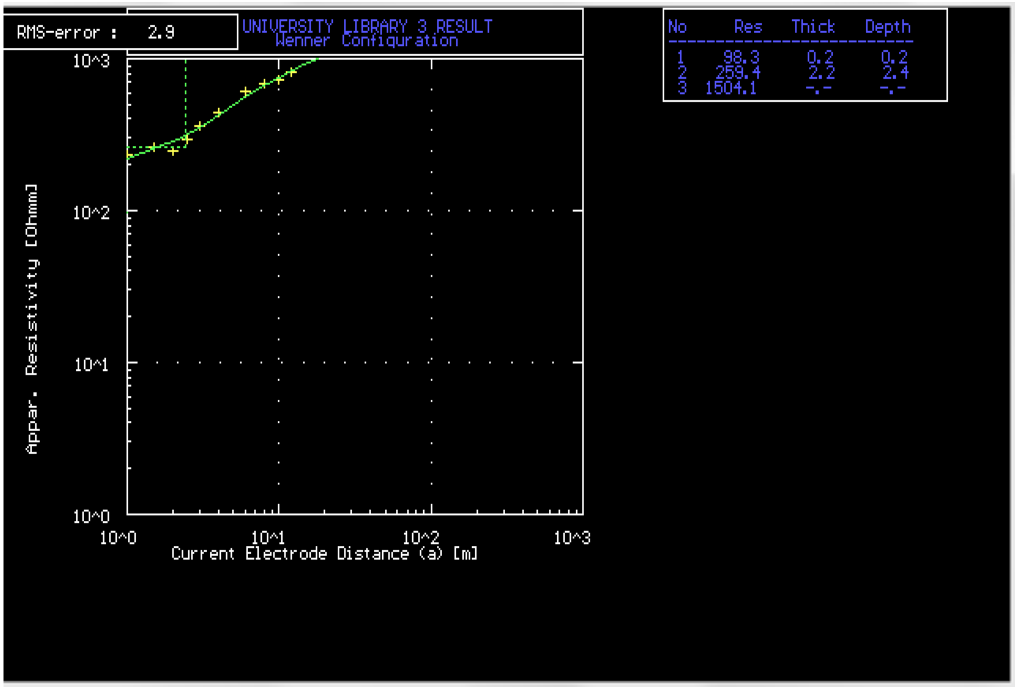

Figure 14: Graph of apparent resistivity (ρ_a)against electrode distance (m)

Table 14: University Library Area Resistivity Values (Sounding 4)

GPS LOCATION(UTM): 73°57”36N : 80°77"84E: 390m				
REMARK : I = 1mA				
S/N	a (m)	K = 2πa	R (Ω)	ρ_a = K x R (Ω-m)
1	0.25	1.571	52.36	82.26
2	0.50	3.142	35.21	110.63
3	1.00	6.283	24.59	154.50
4	1.50	9.425	17.96	169.27
5	2.00	12.566	15.10	189.75
6	2.50	15.708	16.02	251.64
7	3.00	18.850	11.43	215.64
8	4.00	25.133	8.706	218.80
9	6.00	37.699	6.124	230.87
10	8.00	50.265	3.725	187.24
11	10.00	62.832	1.969	123.72
12	12.00	75.398	1.459	110.01

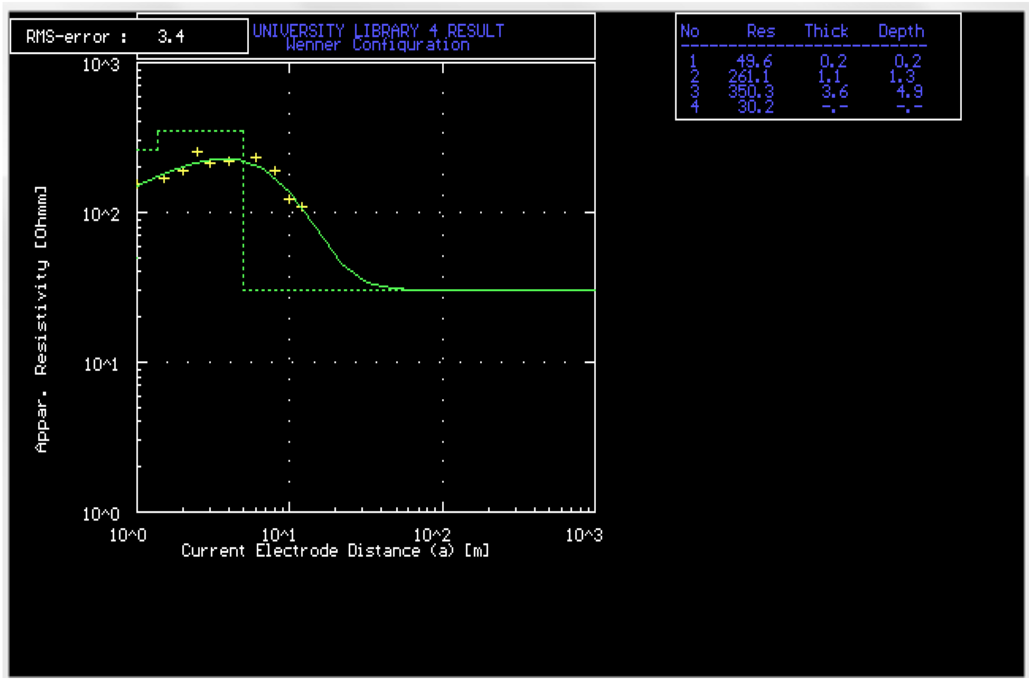

Figure 15: Graph of apparent resistivity (ρ_a)against electrode distance (m)

Table 15: University Library Area Resistivity Values (Sounding 5)

GPS LOCATION(UTM): 73°57"27N : 80°77"76E: 398m				
REMARK : I = 1Ma				
S/N	a (m)	K = 2πa	R (Ω)	ρ_a= K x R (Ω-m)
1	0.25	1.571	58.58	92.03
2	0.50	3.142	36.74	115.44
3	1.00	6.283	29.80	187.23
4	1.50	9.425	25.51	240.43
5	2.00	12.566	23.06	289.77
6	2.50	15.708	19.18	301.28
7	3.00	18.850	15.82	298.207
8	4.00	25.133	12.75	320.43
9	6.00	37.699	12.04	453.90
10	8.00	50.265	11.83	594.63
11	10.00	62.832	9.951	625.24
12	12.00	75.398	8.072	608.61

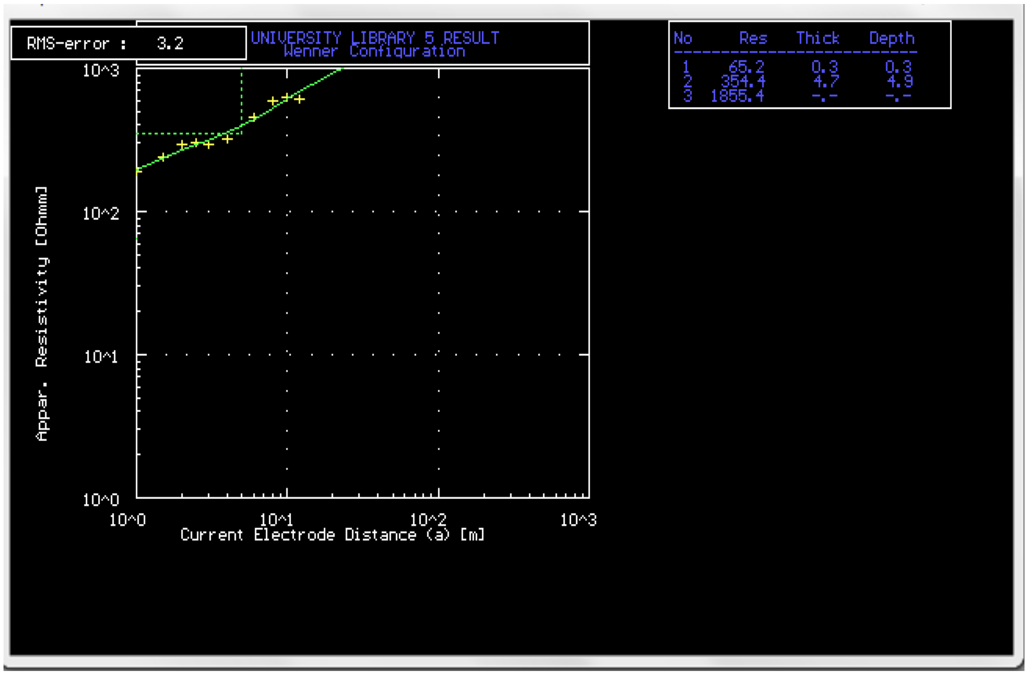

Figure 16: Graph of apparent resistivity (ρ_a) against electrode distance (m)

Table 16: Education Trust Fund (ETF) Area Resistivity Values (Sounding 1)

GPS LOCATION(UTM): 73°58"58N : 80°76"77E: 400m				
REMARK : I = 1mA				
S/N	a (m)	K = 2πa	R (Ω)	ρ_a= K x R (Ω-m)
1	0.25	1.571	161.2	253.25
2	0.50	3.142	71.44	224.46
3	1.00	6.283	27.45	172.47
4	1.50	9.425	19.100	180.02
5	2.00	12.566	11.43	143.63
6	2.50	15.708	10.30	161.79
7	3.00	18.850	9.339	176.04
8	4.00	25.133	8.471	212.90
9	6.00	37.699	6.430	242.41
10	8.00	50.265	4.868	244.69
11	10.00	62.832	3.970	249.44
12	12.00	75.398	3.347	252.36

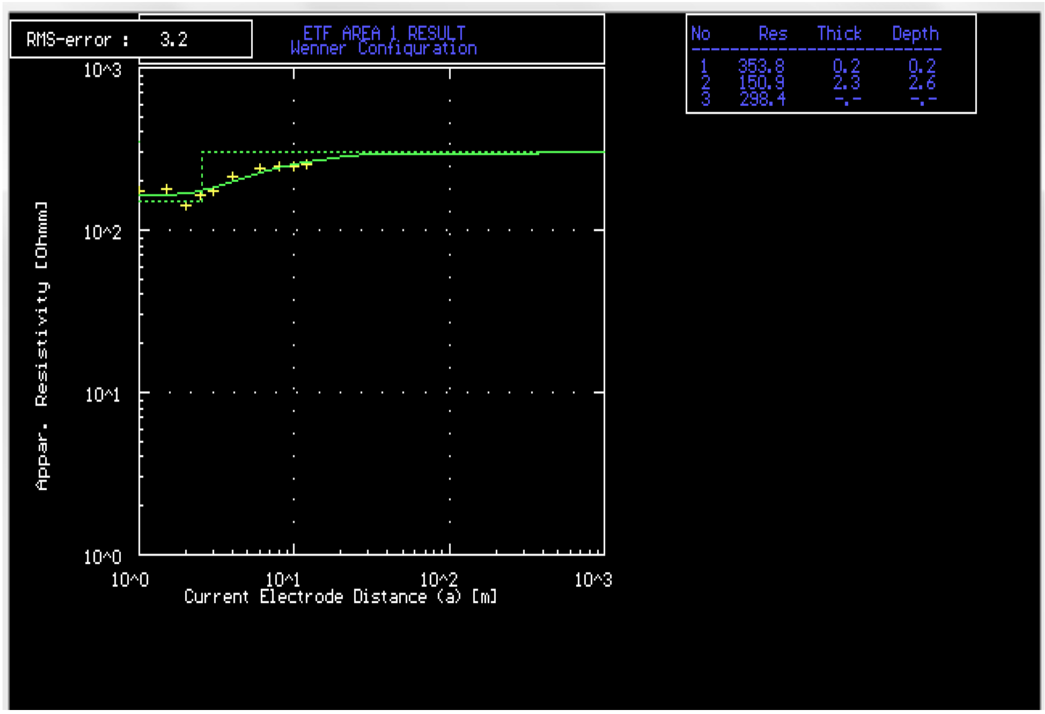

Figure 17: Graph of apparent resistivity (ρ_a) against electrode distance (m)

Table 17: Education Trust Fund (ETF) Area Resistivity Values (Sounding 2)

GPS LOCATION(UTM): 73°58"40N : 80°76"81E: 364m				
REMARK : I = 1mA				
S/N	a (m)	K = 2πa	R (Ω)	ρ_a= K x R (Ω-m)
1	0.25	1.571	191.8	301.32
2	0.50	3.142	36.54	114.81
3	1.00	6.283	34.80	218.65
4	1.50	9.425	20.82	196.23
5	2.00	12.566	14.59	183.34
6	2.50	15.708	11.73	184.26
7	3.00	18.850	10.41	196.23
8	4.00	25.133	8.910	223.94
9	6.00	37.699	7.053	265.89
10	8.00	50.265	5.103	256.50
11	10.00	62.832	4.123	259.06
12	12.00	75.398	3.899	293.98

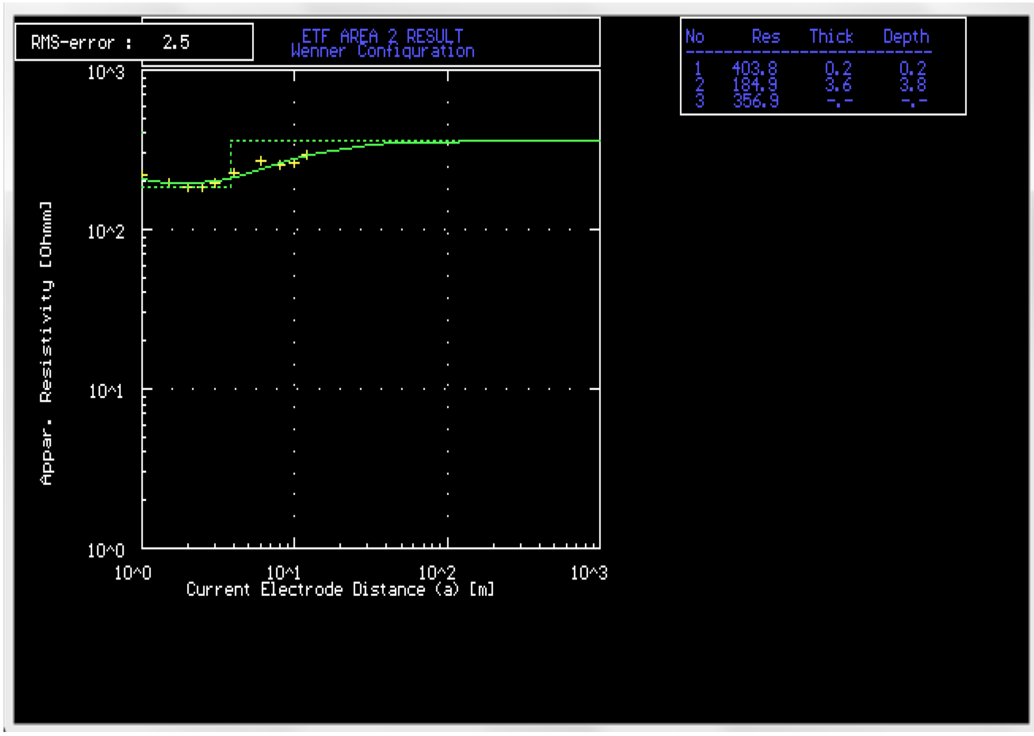

Figure 18: Graph of apparent resistivity (ρ_a) against electrode distance (m)

Table 18: Education Trust Fund (ETF) Area Resistivity Values (Sounding 3)

GPS LOCATION(UTM): 73°58"39N : 80°76"64E: 398m				
REMARK : I = 1mA				
S/N	a (m)	K = 2πa	R (Ω)	ρ_a= K x R (Ω-m)
1	0.25	1.571	89.82	141.11
2	0.50	3.142	40.21	126.33
3	1.00	6.283	19.59	123.08
4	1.50	9.425	10.08	95.00
5	2.00	12.566	8.451	106.20
6	2.50	15.708	8.297	130.33
7	3.00	18.850	6.470	121.96
8	4.00	25.133	6.235	156.70
9	6.00	37.699	5.756	216.10
10	8.00	50.265	4.439	223.13
11	10.00	62.832	3.704	232.73
12	12.00	75.398	3.827	288.55

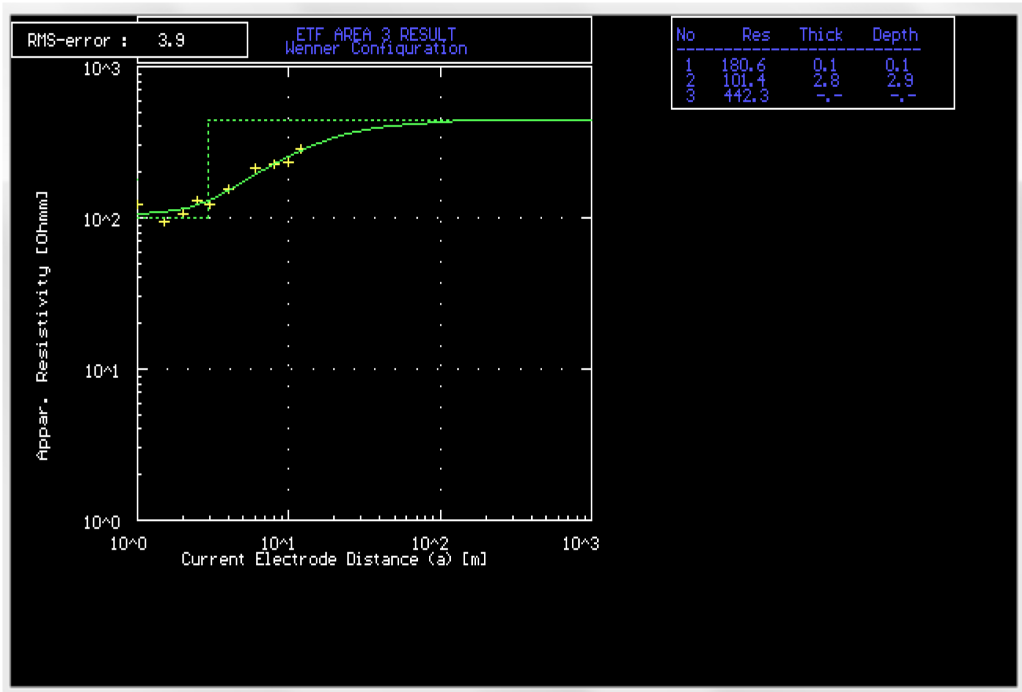

Figure 19: Graph of apparent resistivity (ρ_a) against electrode distance (m)

Table 19: Education Trust Fund (ETF) Area Resistivity Values (Sounding 4)

GPS LOCATION(UTM): 73°58”57N : 80°76"69E: 382m				
REMARK : I = 1mA				
S/N	a (m)	K = 2πa	R (Ω)	ρ_a = K x R (Ω-m)
1	0.25	1.571	133.7	210.04
2	0.50	3.142	58.78	184.69
3	1.00	6.283	25.61	160.91
4	1.50	9.425	14.39	135.63
5	2.00	12.566	9.736	122.34
6	2.50	15.708	11.22	176.24
7	3.00	18.850	7.011	132.16
8	4.00	25.133	5.929	149.01
9	6.00	37.699	5.378	202.75
10	8.00	50.265	4.919	247.25
11	10.00	62.832	4.061	255.16
12	12.00	75.398	3.347	252.36

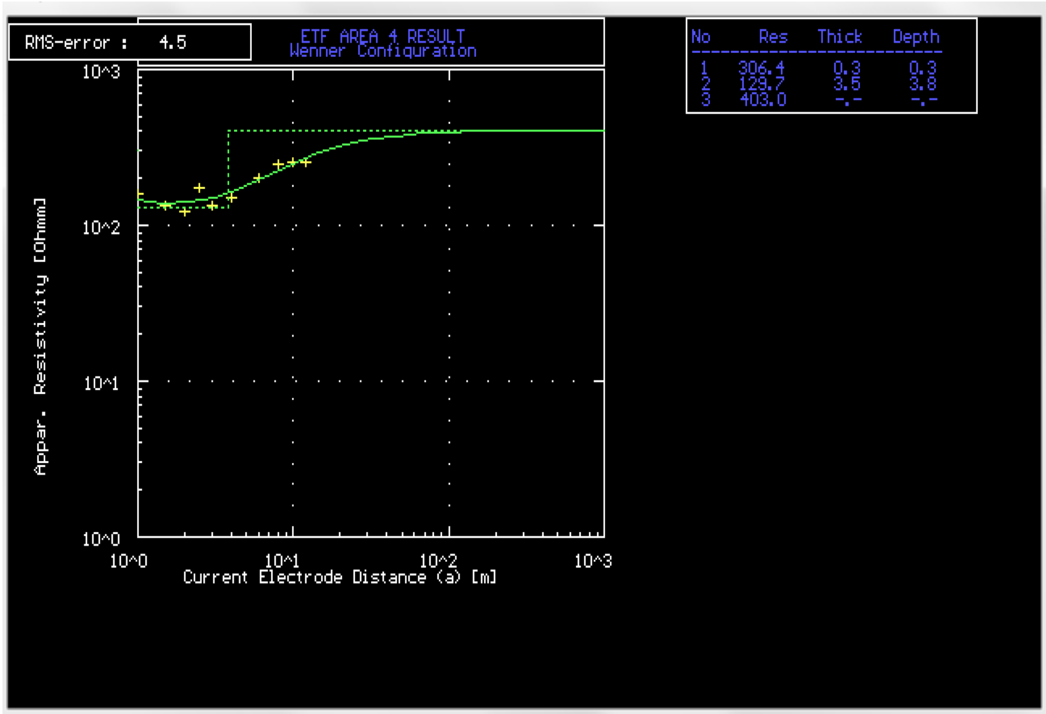

Figure 20: Graph of apparent resistivity (ρ_a)against electrode distance (m)

Table 20: Education Trust Fund (ETF) Area Resistivity Values (Sounding 5)

GPS LOCATION(UTM): 73°58"40N : 80°76"89E: 369m				
REMARK : I = 1mA				
S/N	a (m)	K = 2πa	R (Ω)	ρ_a = K x R (Ω-m)
1	0.25	1.571	87.06	136.77
2	0.50	3.142	48.27	151.66
3	1.00	6.283	20.20	126.92
4	1.50	9.425	14.28	134.59
5	2.00	12.566	11.32	142.25
6	2.50	15.708	10.13	159.12
7	3.00	18.850	8.573	161.60
8	4.00	25.133	7.246	182.11
9	6.00	37.699	3.755	141.56
10	8.00	50.265	5.868	294.96
11	10.00	62.832	4.490	282.12
12	12.00	75.398	3.174	239.31

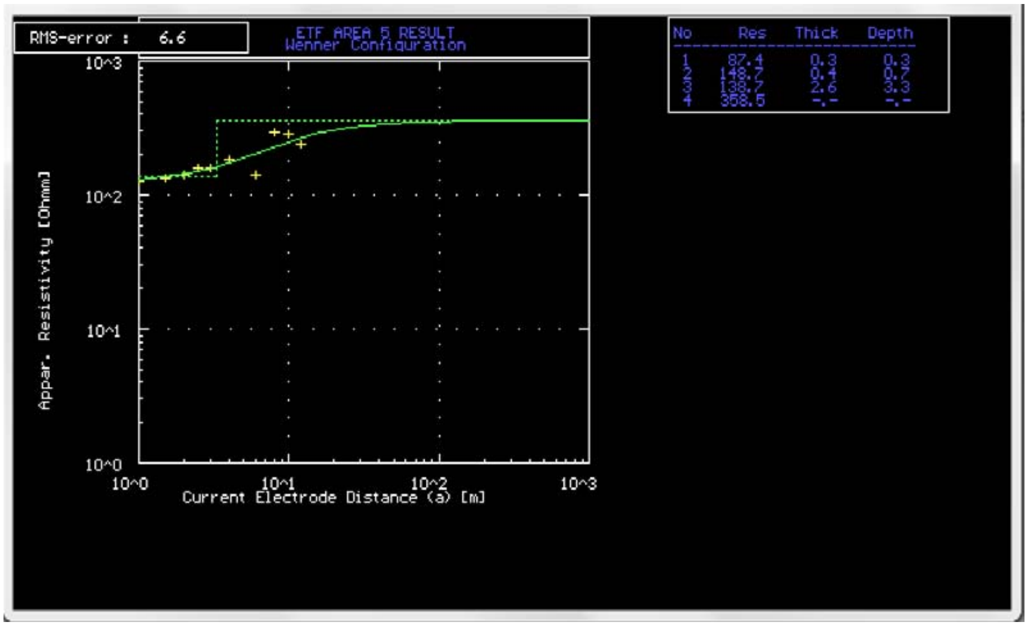

Figure 21: Graph of apparent resistivity (ρ_a) against electrode distance (m)

The resistivity sounding curves were interpreted quantitatively by partial curve matching. Partial curve matching method involves a segment matching of the sounding curves with theoretical Wenner layer. The interpretation was done by plotting apparent resistivity data in ohm metre obtained from the study area against the electrode spacing in metre on a transparent logarithm graph to obtain a curve of best fit, with the axis of the two graphs parallel to each other. The curve match on the transparent double logarithmic graph was then placed on bi-logarithm graph to obtain the value of apparent resistivity for the first layer (ρ)in ohm-meter and its corresponding layer thickness (h) in metre. Furthermore reflected apparent resistivity (ρ_r) values in ohm-meter with their corresponding reflected layer thickness (h_r) in metre and the depth ratio was obtained from the auxiliary curve. Hence equation (2) was used to calculate respective layer resistivity and their thickness.

$$\rho_n = \rho_n \frac{(1+kn)}{(1-kn)} \qquad (2)$$

33kv Substation Area

Sounding 1

$\rho_1 = 60\ \Omega\text{m} \qquad h_1 = 0.25\text{m}$

$\rho_{2r} = \rho_1 \frac{(1+k1)}{(1-k1)} \rho_{2r} = \rho_1 \frac{(1+k1)}{(1-k1)}$

$=60 \frac{(1+0.2)}{(1-0.2)}$

Sounding 2

$\rho_1 = 130\ \Omega\text{m} \qquad h_1 = 0.29m$

$= 130 \frac{(1+0.1)}{(1-0.1)} = 159\ \Omega\text{-m}$

=90 Ω-m h_2 =2mh_2 =0.8mρ_3=

$\rho_{2r}\frac{(1+k2)}{(1-k2)}$

ρ_{3r}= 85 $\frac{(1+(-0.1))}{(1+0.1)}$ =70 Ω-m =170$\frac{(1-0.3)}{(1+0.3)}$ = 92 Ω-m

h_3 =14mh_3 =4.1m

ρ_{4r}= 65 $\frac{(1+0.2)}{(1-0.2)}$ = 98 Ω-m ρ_{4r}= 95 $\frac{(1+0.1)}{(1-0.1)}$ = 116 Ω-m

60<90>70<98 - QA curve 130<159<92<116 - QA curve

Sounding 3 Sounding 4 Sounding 5

ρ_1 = 170 Ωm h_1 =0.25m ρ_1 = 280h_1 =0.55mρ_1 = 90h_1 =0.28m

=170$\frac{(1+0.1)}{(1-0.1)}$ =280$\frac{(1-0.4)}{(1+0.4)}$ =90$\frac{(1+0.3)}{(1-0.3)}$

=208 Ω-m = 120 Ω-m = 167 Ω-m

h_2 =1.7mh_2 =16mh_2 =2m

=220$\frac{(1-0.6)}{(1+0.6)}$ =95$\frac{(1+0.6)}{(1-0.6)}$ =198$\frac{(1-0.6)}{(1+0.6)}$

= 55 Ω-m =380Ω-m = 50Ω-m

h_3 =3.2m 280>120<380 -H curve h_3 =2.7m

=50$\frac{(1+0.5)}{(1-0.5)}$ =68$\frac{(1+0.2)}{(1-0.2)}$

= 150 Ω-m = 102Ω-m

170<208>55<150 - QA curve 90<167>50<102- QA Curve

The tests conducted in all the locations reveal that there is diverse soil condition for each soil. The vertical electrical sounding (VES) data are presented as depth sounding curve, which are obtained by plotting apparent resistivity values against electrode spacing on a log-log or bi-log graph. The depth sounding curves are classified based on layer resistivity combinations. The curve types obtained from twenty VES sounding were A, QA, H, AQ and HK types. A curve (three layers) is characterized by $\rho_1<\rho_2<\rho_3$. It is predominant as it constitutes 45% of the total number of the VES curve.The H –curve (three layers)is characterized by $\rho_1>\rho_2<\rho_3$ has an intermediate layer of low resistivity value that is recognized at these VES location. It occurred five times in the plot. QA curve (four layers) is characterized by $\rho_1<\rho_2>\rho_3<\rho_4$, occurred five times in the plot. HK curve (four layers) is characterized by $\rho_1>\rho_2<\rho_3<\rho_4$, occurred once in the plot while AQ curve (four layers) is characterized by $\rho_1<\rho_2<\rho_3>\rho_4$ occurred once in the plot.

The test results prove that the soil is made of various layers and that the resistivity reduces as the rod penetration increases as shown in Table 21. Hence to achieve low resistivity in an area, the rod should be driven into the ground to reach the water level.

VES NO	CURVE TYPE	LAYER NO	RESISTIVITY (Ω-m)	THICK NESS (m)	DEPTH (m)	SOIL TYPE
LIBRARY 1	A	1	219.5	0.2	0.2	Sandy clay
		2	302.3	3.3	3.4	Coarse sand
		3	3449.1			
2	HK	1	198.5	0.6	0.6	Sandy clay
		2	112.0	0.9	1.5	Top soil
		3	2245.9	4.0	5.5	
		4	1317.7			Lateritic sand
3	A	1	98.3	0.2	0.2	Top soil
		2	259.4	2.2	2.4	Weathered layer
		3	1504.1			Lateritic sand
4	AQ	1	49.6	0.2	0.2	Weathered basement
		2	261.1	1.1	1.3	Lateritic sand
		3	350.3	3.6	4.9	Weathered layer
		4	30.2			Partially weathered
5	A	1	65.2	0.3	0.3	Clay
		2	354.4	4.7	4.9	Weathered layer
		3	1855.4			Lateritic sand
LAB AREA 1	A	1	83.2	0.3	0.3	Partially weathered
		2	177.9	1.9	2.3	Top soil
		3	226.5			Fractured basement
2	A	1	26.1	0.3	0.3	Fractured basement
		2	63.8	0.8	1.0	Clay
		3	210.3			Sandy clay

3	A	1	61.8	0.3	0.3	Clay
		2	203.1	1.9	2.2	Sandy clay
		3	245.5			Lateritic sand
4	A	1	34.8	0.2	0.2	Weathered layer
		2	192.7	0.7	0.9	Weathered layer
		3	237.7			Fractured basement
5	A	1	48.5	0.2	0.2	Weathered basement
		2	148.1	1.8	2.0	Top soil
		3	227.8			Sandy clay

Table 21: Vertical Electrical Sounding (VES) Data and Soil type of Library and Ogomudia Laboratory Area.

Data less than 1.0 are considered negligible due to WINRESIST software could not accept data less than 1.0.

CONCLUSION

In this work,Wenner four pin method was used. The soil resistivity measurement was taken during peak period of rainfall (June to July). The locations were characterized with much moisture. Soil classification was achieved and areas with clay soil have good soil resistivity due to its compact nature. This was verified using WINRESIST software. From the graphs obtained, the type of soil determines the type of resistivity in the area. From the work, University Library and Ogomudia Laboratory areas composed mainly of clay and sandy clay respectively is the best area to install a substation or communication base station. This is because the area has low resistivity (high conductivity) value.

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