Geophysical investigations for groundwater exploration in a crystalline basement, southwest Nigeria

Awomeso Awonusi[1], Orebiyi Olabisi[1] and Oyedokun Olabamiji[2].

[1]Department of Water Resources Management and Agrometeorology, University of Agriculture, P.M.B 2240 Abeokuta, Nigeria, [2]Department of Geology, The polytechnic Ibadan, Nigeria. nuelnice@yahoo.com

Abstract: As part of a borehole sitting programme for rural water supply in a crystalline basement terrain 17offset Werner electrical sounding of ground conductivity profiling with a resistivity meter SAT200 Resist 1.0 version software equipment (Terameter) were made in Osun State, Southwest Nigeria.. The Resistivity meter SAT200 Resistivity 1.0 version software provided a rapid reconnaissance tool in identifying high conductivity anomalies thought to be due to deep weathering and/or bedrock fissuring. Geophysical resistivity techniques are based on the response of the earth to the flow of electrical current passed through the ground and the potential difference between them. Resistivity measurements are associated with varying depths relative to the distance between the current and potential electrode in the survey, and can be interpreted quanlitatively and quantitatively in terms of a lithology and/or geohydrologic model of the subsurface. [New York Science Journal. 2008;1(4):19-35]. (ISSN: 1554-0200).

Key words: crystalline; basement; resistivity; sounding; aquifer; investigation; survey; groundwater; exploration; Nigeria

1 Introduction

Water is an essential resource for human development. It is used for various purposes which includes domestic; irrigation, industrial, power generation and recreation. The development of groundwater resources for potable use has increased substantially over the last two decades in developing countries as a result of rapid expansion of cities and subsequent population explosion. Ground water resource lends itself to flexible development and the capital cost of groundwater development when compared to surface water is modest. However, crystalline basement complex rocks typical of the study area in this research are relatively impermeable and have no storage capacity. Consequently, the ground water recourse in such terrains, which are spread in Africa, is limited. Nonetheless large numbers of water wells have been successfully developed in this area. To ensure maximum and perennial yields it is essential that a borehole be located where it can penetrate the greatest possible thickness of both the regolith and the fracture zone, before hitting the fresh bed rock. A ground geophysical survey is often carried out to locate the ground water aquifer accurately. The most commonly used geophysical techniques for groundwater exploration is electrical resistivity. The aim of electrical resistivity is the identification of high conductivity anomalies, normally thought to be due to deep weathering. Such anomalies are often further investigated by sounding in order to provide a more quantitative information on the geo-electrical profile through the weathered zone as an aid in sitting borehole. This paper present the result of an integrated geophysical survey involving resistivity sounding (both the Werner & schlumberger array) carried out in a basement area of Nigeria. The survey was aimed at locating sites suitable for drilling of abstraction well.

2 Materials and Methods

2.1 Study Area.

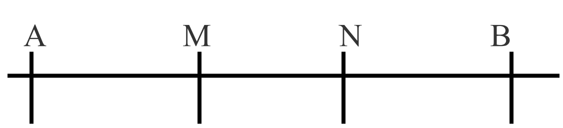
The study area lies within Latitude 7^0 $9^{'}$ N and 7^0 48'N; Longitude 4^0 12'E and 4028'E in Osun State in the Southwestern part of Nigeria. The climate is subequatorial with two peak of rainfall, first peak is in July and the second is in September. The two peaks are marked by heavy rainfalls; the mean annual rainfall is about 1,300mm with relative humidity of about 70%. As the humidity is subequatorial, the temperature is a times severe with an average annual temperature of about 20^0C.

2.2 Geology and Geomorphology

The area lies within the Nigeria Precambrian basement complex. The geology survey map suggests that the basement complex in this area comprises migmatised gneisses and granite. There are occurrences of schist and quartzite, occasionally amphybolite, gabro, diorites; the dominant in the surveyed area is gneisses (Jones and Hockey, 1964; Rahaman 1965). No outcrop of this rock could be seen within the villages. Geomorphologically, the rivers and stream in the study area flow over a slightly undulating valley the drainage could be said to be dendritic in pattern, because the stream within the area is topographically controlled and the homogeneous nature of the underlying rock and their resistance also relate to the drainage.

2.3 Field Measurements

The geo-electric investigation consisted of a combination of V.E.S & L.E.P. The geological structure such as fault, joint, fracture and other water bearing structure in the basement complex occurs either concordantly or discordantly within the host rock. A discordant fracture is localized within the locality that is why electrical profiling and V.E.S method favour the detection of these anomalies. Schlumberger and Werner array configuration were used for V.E.S & L.E.P respectively. The electrical resistivity method are based on the response of the earth to the flow of electrical current, in these method, an electrical current is passed through the ground and two potential electrode allow the recording of the resultant potential difference between them, giving a way to measure the electrical impedance; the arrangement is illustrated below.



Where A & B are the current electrode, M & N are the potential electrode. The space is equidistance and this differentiates it with V.E.S.

AB & MN obey ohm's law.

$\Delta V = IR$………………………………….. (1)

ΔV =Potential difference between any two points measured in volts

I = Current flowing

R = Resistance

is ϱ; the resistance R is expressed thus.

$R \propto L/A$ ………………………………….. (2)

$R = \varrho L/A$ ………………………………… (3)

Substituting R in equation (3) in (1).

$\Delta V = I/R$

$R= \Delta V\backslash I$

:. R in equation (3)

$\Delta V/I = \varrho L/A$ …………………………… (4)

.: $\varrho = \underline{VA}$ ………………………………. (5)

Measurement of voltage and current for different electrode geometry are then used to infer the sub-surfaces distribution of conductivity. Data acquired are presented in the form of resistant plotted against electrode spacing. The curve resulting from the data upon interpretation give thickness and resistivity of various layers.

Instrument used includes the topographical map to locate the villages, while the geological map was used in knowing the geology and structure of the area. Hand held high precision GPS receiver was used in determining the geographical co-ordinate of the V.E.S points. A resistivity survey system SAT terameter model SAT200, cables, electrodes and tape for linear measurement were used. Cutlass was used in cutting lines for the spread of the cable. Hammer was used in driving down the electrode into the earth surface.

Eighteen (18) vertical electrical sounding (V.E.S) locations were occupied, utilizing the Schlumberger electrode configuration. Electrode spacing (AB/2) was varied from 1.0m to

150.0m.Werner array was used for lateral profiling in other to locate the best possible point for sinking a productive hole.

The VES curves were qualitatively interpreted from curve matching and computer iteration technique using computer programme. The curve matching involved segment-by-segment matching of the field curves with 2 layer model curves and their corresponding auxiliary curves.

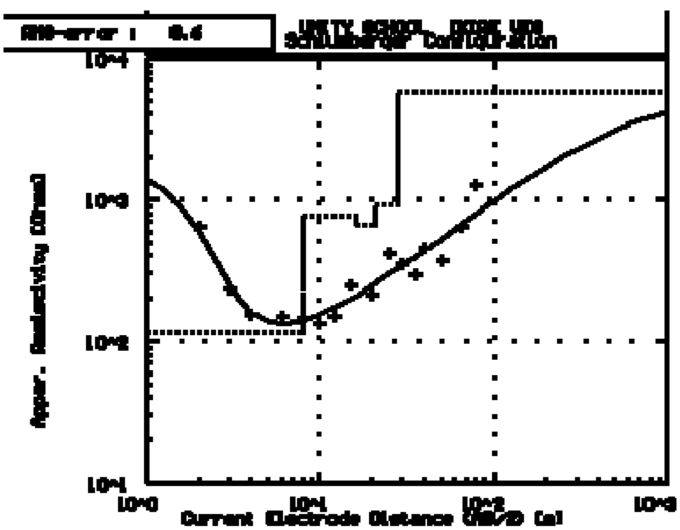
3 Result and Data Interpretation.

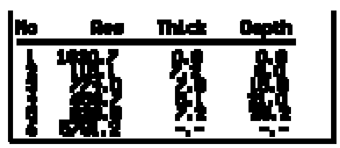
The result of the lateral resistivity profiling obtained were used for direct and immediate on the spot localization of sounding point and are therefore of relevance to evaluation and interpretation in this way. The curves obtained are shown in figures 2-19.

A total 18 VES position were occupied, depth-sounding curves were prepared for each sounding point. Qualitative interpretation was carried out for each sounding curve using curve-matching techniques. These provided approximate layer parameters, which were optimized using computer iterative techniques for qualitative interpretations.

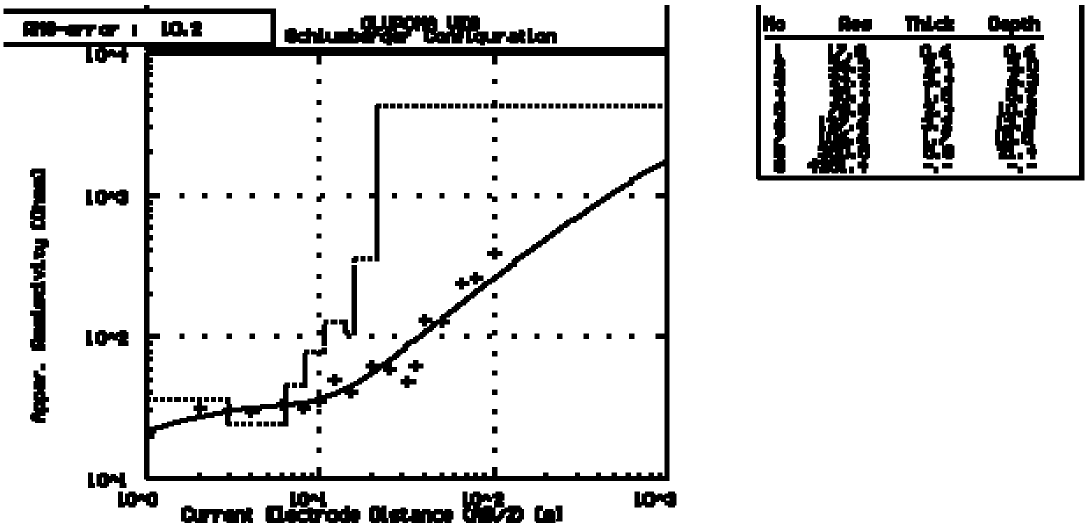
From the investigation of VES result, the curves are characterized as follows;

Unity School Ikire= HKHA,

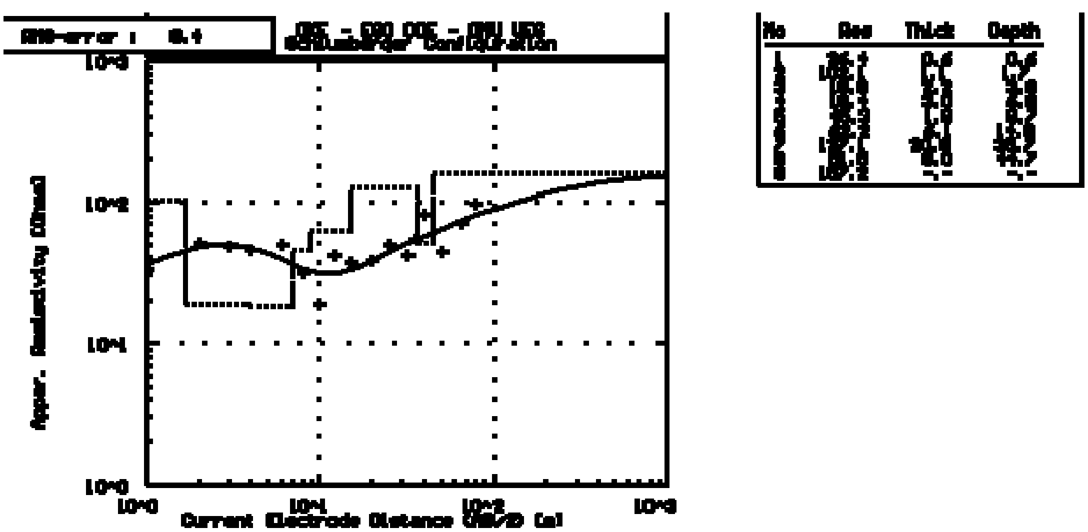




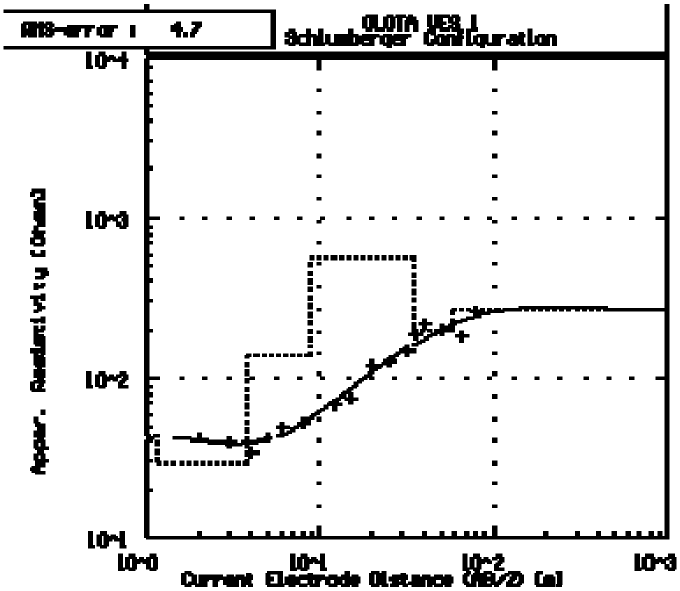
Olupona VES =AAA



Oke-Eso, Ode-Omu= KQHAAKH

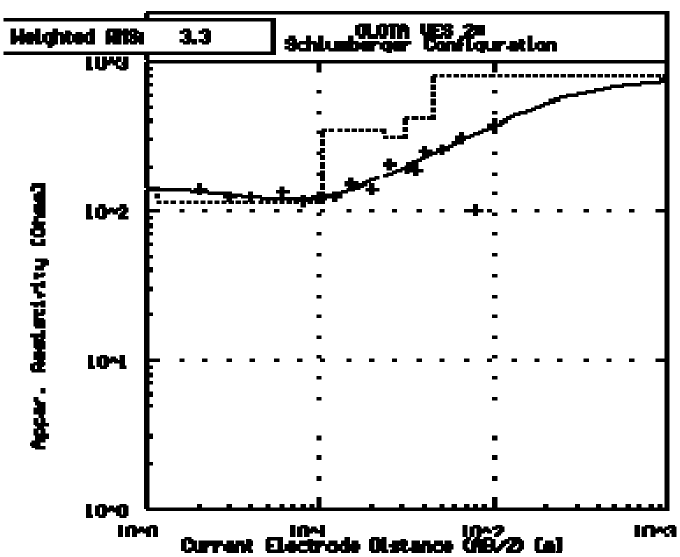


Olota VES1=HAKH



No	Res	Thick	Depth
1	44.2	1.2	1.2
2	28.1	2.7	3.9
3	[illegible]	6.0	[illegible]
4	[illegible]	[illegible]	[illegible]
5	[illegible]	24.7	[illegible]
6	272.3	-.-	-.-

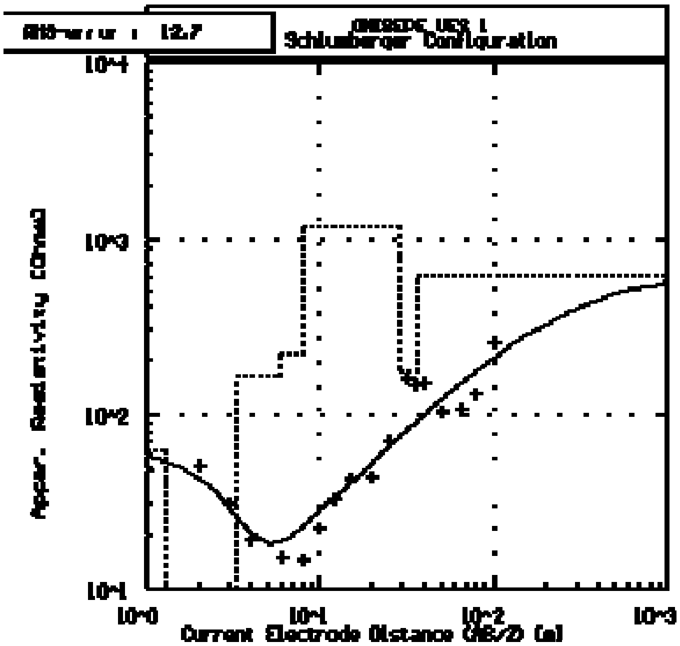
Olota VES 2= HKAA



No	Res	Thick	Depth
1	[illegible]	1.3	1.3
2	[illegible]	9.3	10.6
3	[illegible]	[illegible]	[illegible]
4	[illegible]	[illegible]	[illegible]
5	[illegible]	12.6	44.2
6	782.3	-.-	-.-

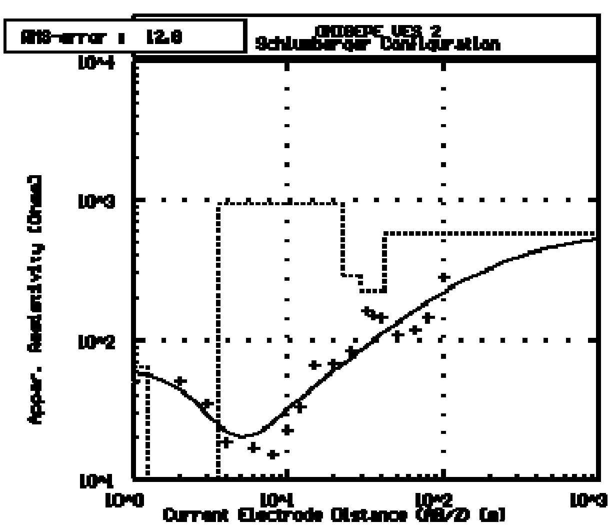
Ogun ward oju court=QHAA

Onibepe VES 1=HAA



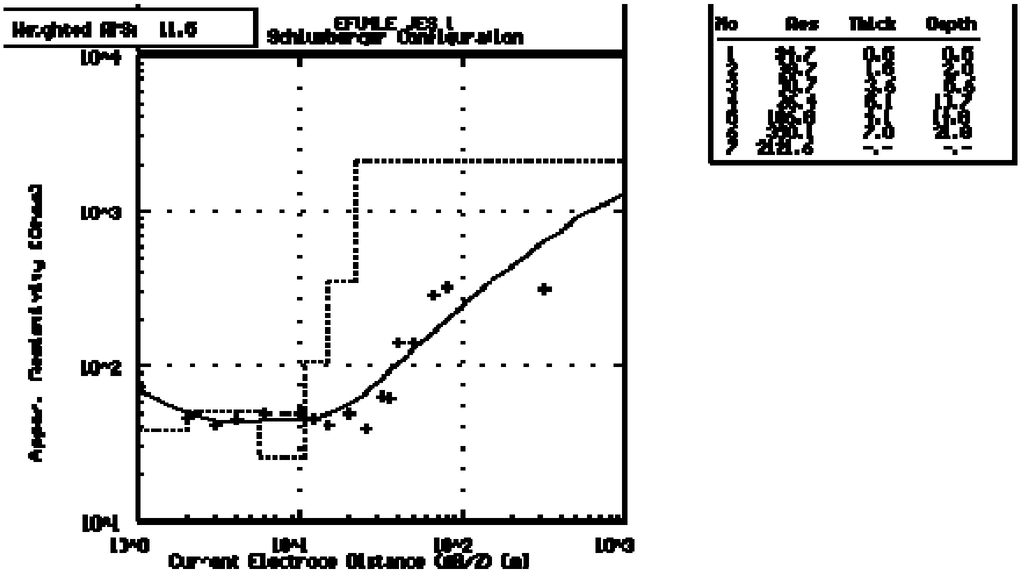
No	Res	Thick	Depth
1	62.0	1.3	1.3
2	6.1	2.0	3.3
3	161.9	2.6	5.9
4	220.0	2.2	8.1
5	1207.2	20.9	28.0
6	173.7	7.1	36.1
7	611.1	-.-	-.-

Onibepe VES2=HAAKH

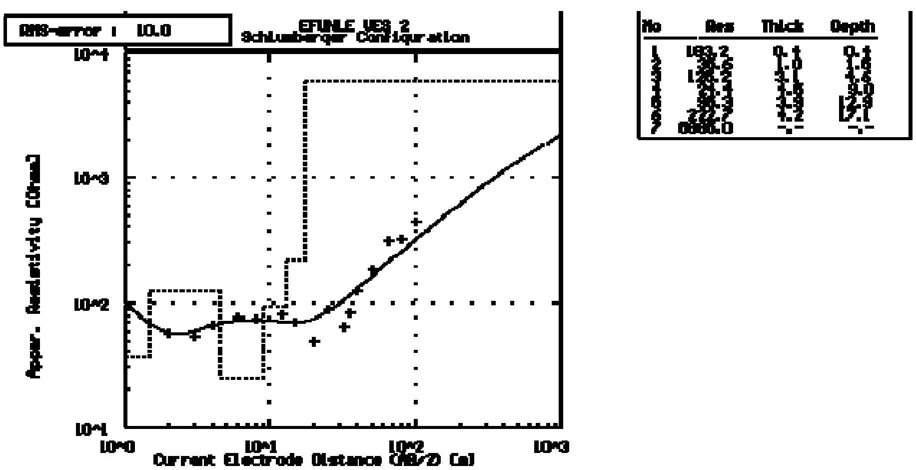


No	Res	Thick	Depth
1	61.6	1.2	1.2
2	8.0	2.3	3.5
3	[illegible]	[illegible]	[illegible]
4	[illegible]	[illegible]	[illegible]
5	[illegible]	12.6	41.6
6	[illegible]	-.-	-.-

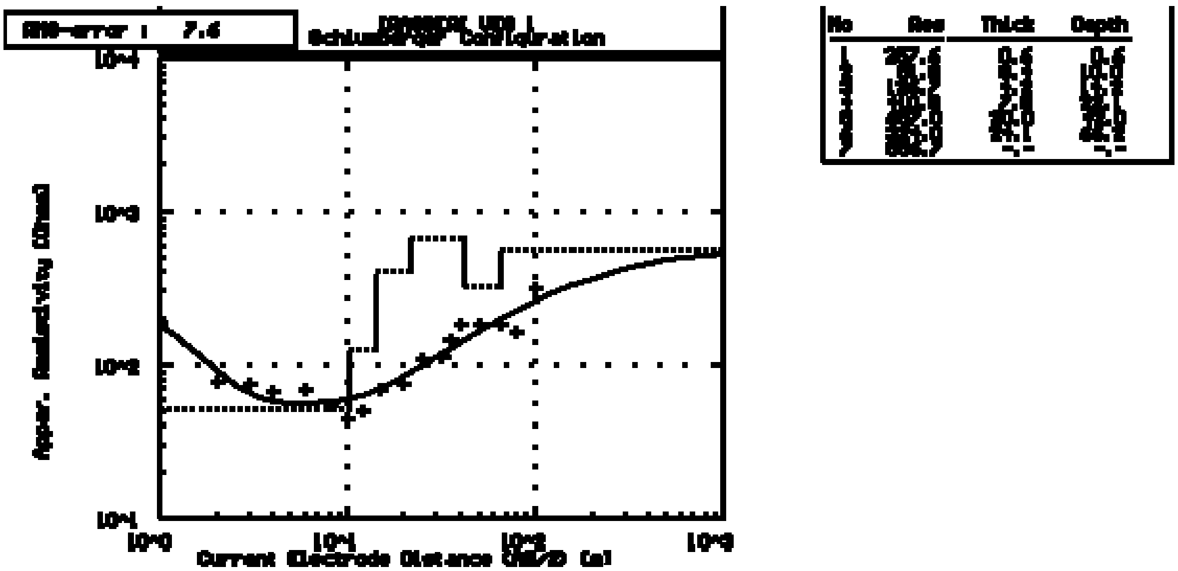
Efunle VES1=HKHAA



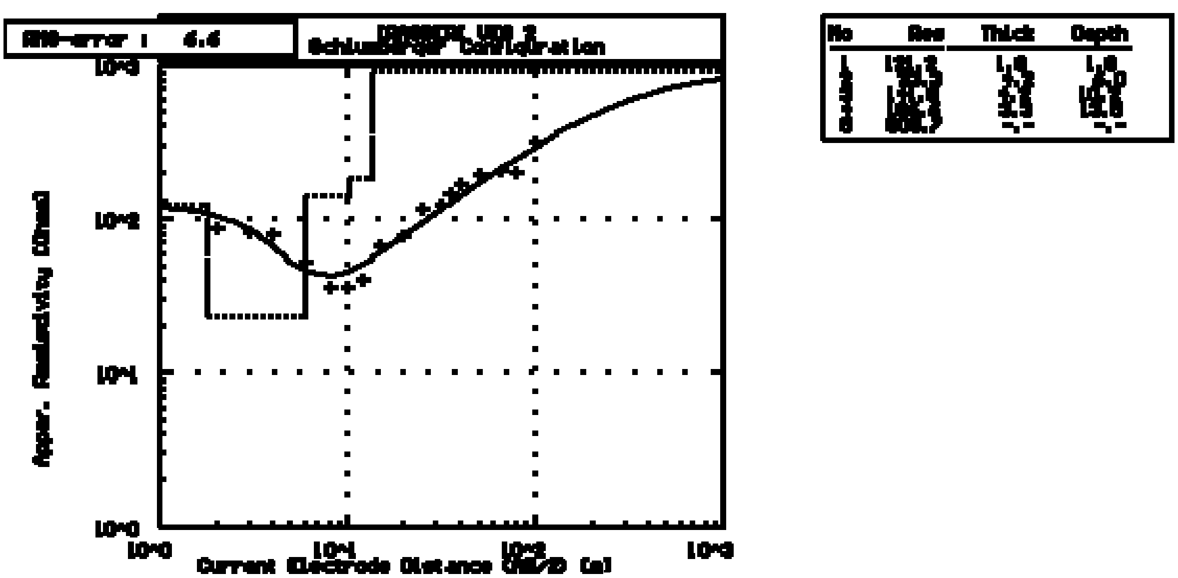
Efunle VES2=HKHAA



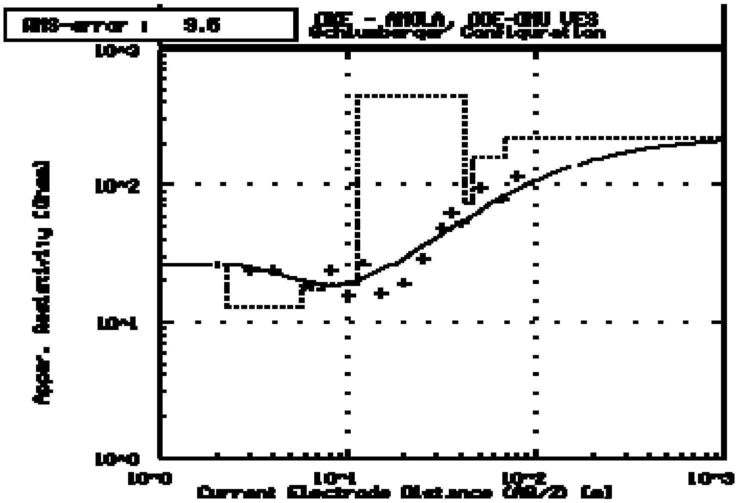
Iragberi VES 1



Iragberi VES2=HAAA

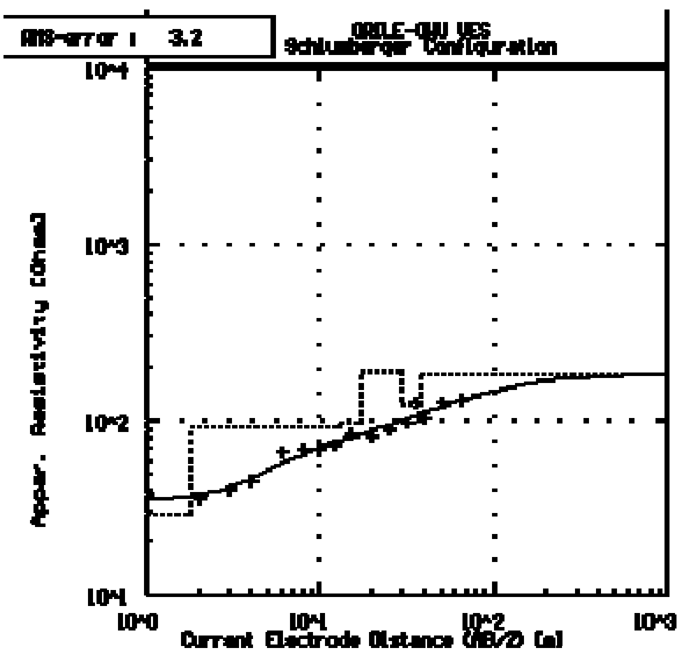


Oke-Amola, Ode-omu=HAAKHA



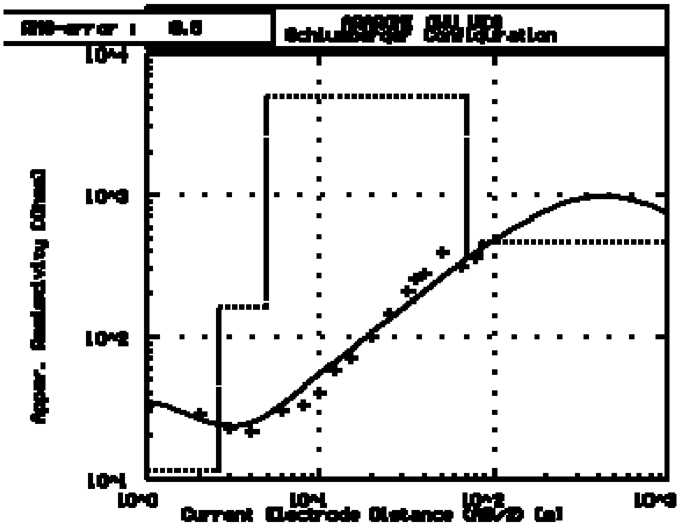
No	Res	Thick	Depth
1	22.2	2.3	2.3
2	13.6	4.3	6.6
3	14.6	1.9	8.3
4	15.1	3.7	11.0
5	498.1	30.9	42.0
6	27.9	7.3	48.1
7	103.2	21.8	68.0
8	217.4	-.-	-.-

Orile Owu



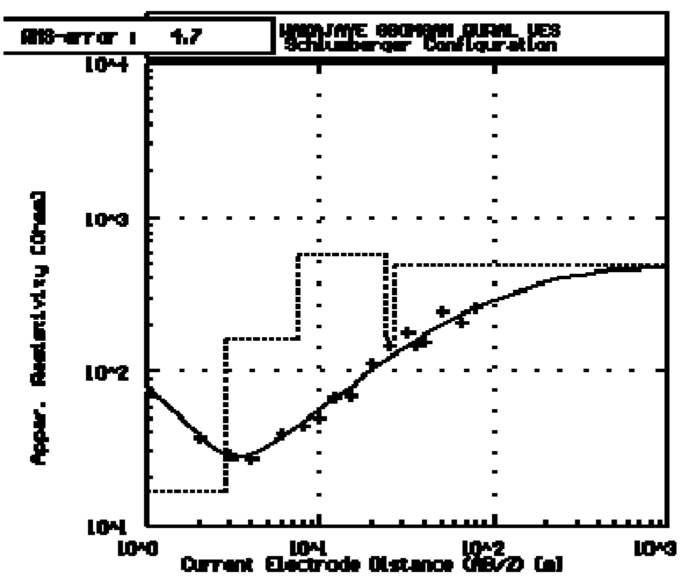
No	Res	Thick	Depth
1	36.8	0.9	0.9
2	33.1	0.9	1.8
3	32.1	11.0	12.7
4	36.7	4.4	17.1
5	187.9	12.1	29.8
6	121.2	7.7	37.4
7	184.9	-.-	-.-

Araromi Owu



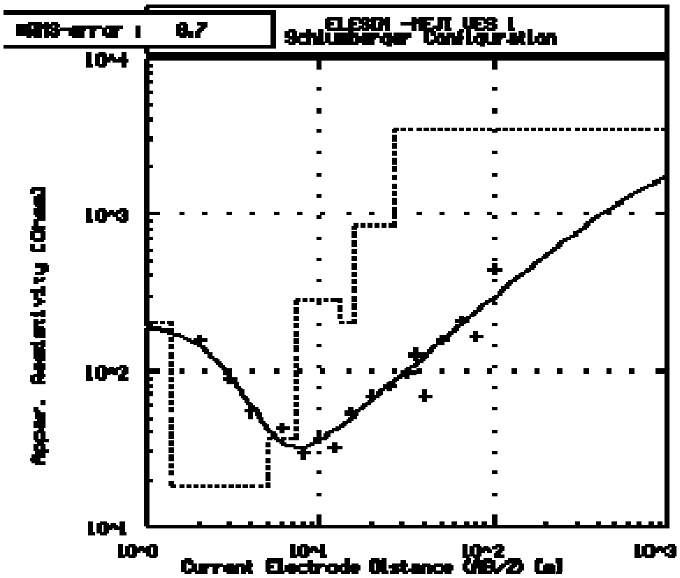
No	Res	Thick	Depth
1	[illegible]	[illegible]	[illegible]
2	[illegible]	[illegible]	[illegible]
3	[illegible]	[illegible]	[illegible]
4	[illegible]	[illegible]	[illegible]
5	[illegible]	[illegible]	[illegible]
6	[illegible]	-.-	-.-

Wakajaye Gbongan Rural VES



No	Res	Thick	Depth
1	107.8	0.7	0.7
2	[illegible]	[illegible]	[illegible]
3	[illegible]	[illegible]	[illegible]
4	[illegible]	[illegible]	[illegible]
5	[illegible]	[illegible]	[illegible]
6	[illegible]	-.-	-.-

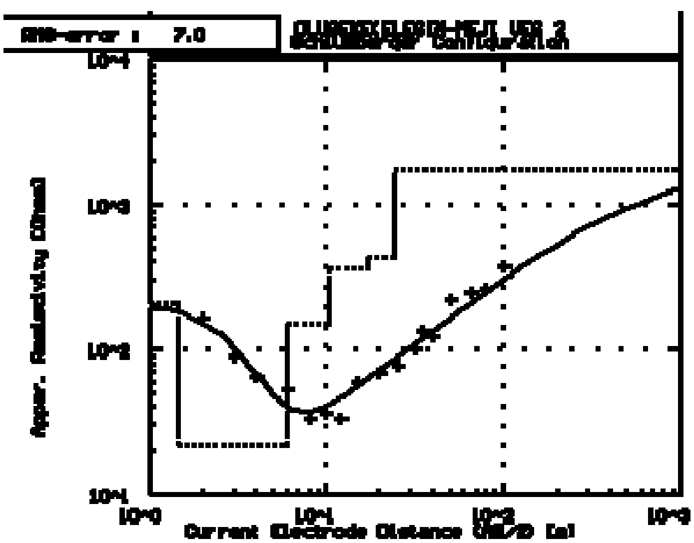
Elesin-meji VES 1=HAKHA



No	Res	Thick	Depth
1	200.4	1.4	1.4
2	18.2	3.6	5.0
3	35.8	2.3	7.3
4	281.6	5.6	12.9
5	200.9	2.9	15.7
6	880.6	11.3	27.0
7	3407.1	-.-	-.-

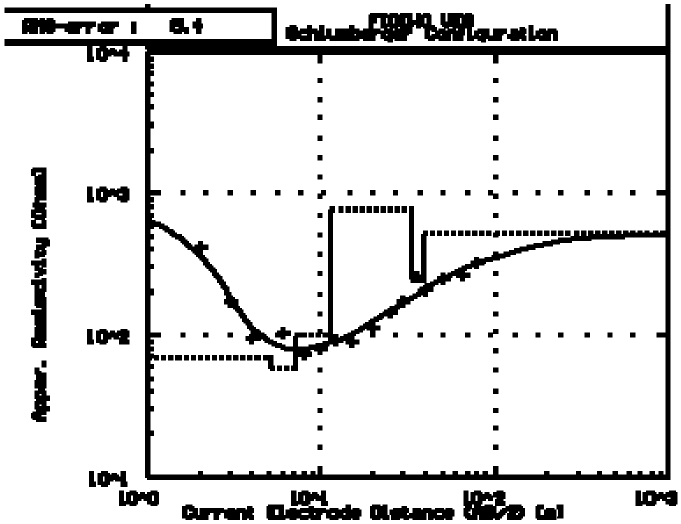
* RMS on smoothed data

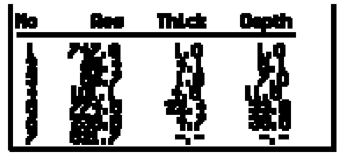
Oluseke(Elesin-mejiVES2)=HAAA



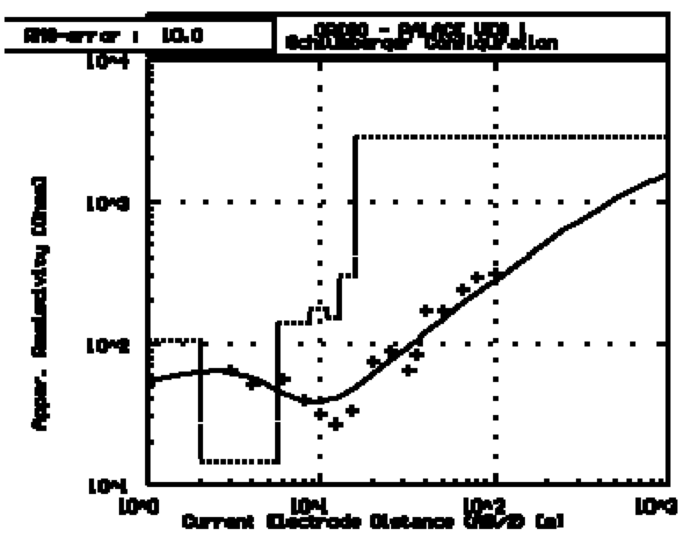
No	Res	Thick	Depth
1	207.2	1.4	1.4
2	[illegible]	[illegible]	[illegible]
3	[illegible]	[illegible]	[illegible]
4	[illegible]	[illegible]	[illegible]
5	[illegible]	[illegible]	[illegible]
6	[illegible]	-.-	-.-

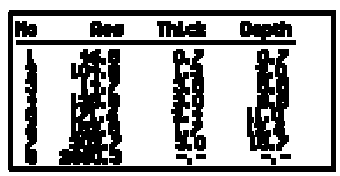
Fidiwo VES



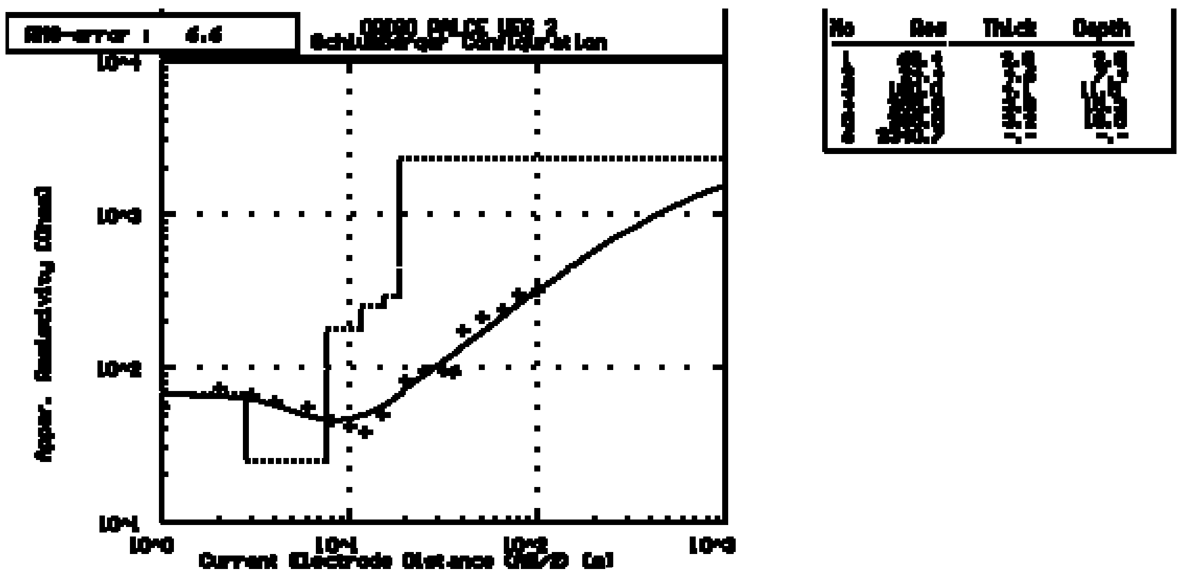


Origo Palace VES 1





Origo Palace VES 2



3.1 Interpretation

For unity school, drilling should reach 28.2m depth.

Olupona,based on the curve(AAA) the yield may not be reliable.

Oke-Eso-omu, drilling must reached the depth of 44.7m

Wakajaye Gbongba, drill depth should be up to 30- 35m.

Orile-owu, drilling should be up to 40m for good yield

Onibepe, drilling should be up to 40m, the point may not be reliable but averagely good

Efunle VES2, drilling to depth of 15m.

Olota VES2, drilling should be 30m or more and the presence of an experienced Hydrogeologist during drilling is very important in order to determine when to terminate drill depth.

Balogun ward, Oju Court Gbongan, drilling should be 15m or more to create a reservoir, the hole should be screen properly to allow good yield.

Elesin meji VES1, drilling should be 27m or more.

Elesin meji VES 2, based on the curve it is not advisable to drill.

Iragberi VES 2 is not advisable to drill.

Oke-Amola, Ode Omu, drilling should not extend beyond 68m; further drilling could render the hole abortive.

4 Conclusion

For every drilling in the study area, a rotary and down the hole hammer (DTHH) should be adopted, the weathered basement zone should be properly screen cased, the boreholes should be drilled down to the fresh bed rock and a hydrogeologist should be present throughout the duration of drilling.

Author for Correspondence- Orebiyi Olabisi, University of Agriculture, P.M.B. 2240, Abeokuta 110001 Nigeria. E-mail:nuelnice@yahoo.com.

References

COORAY P.G., (1974) Some Aspects of the Precambrian of Nigeria; A Review; Jour. Min. Geol. Vol. 8 No 1 & 2.

COORAY P.G., (1975) The Charnockitic Rocks of Nigeria; in Studies in Precambrian P 50-73.

COORAY P.G., (1977); Classification of the charnokitic rocks of Nigeria: In Jour. Min. Geol. Vol. 14 No 2 1977.

DOBRIN M.B. (1976) Introduction to Geophysical prospecting (3rd edition): McGraw Hills Books Coy. New York pp. 630.

Jones, H.A. & Hockey, R.D. (1964) The geology of southwestern Nigeria, Lagos, Geol. Surv. Nigeria Bull.,31-87.

Rahaman, M.A. (1975) Review of the basement geology of South-Western Nigeria. In: Geology of Nigeria (ed. by Kogbe, C.A.), 538 Rock View Limited, Nigeria.

ZOH DY, A.A.R, EATS N.G.P & MABEY, D.R., Application of surface Geophysics to Ground Water Investigations in Techniques of Water Resources Investigation of the United State Geological Survey, United States Government Printing Office, Washington.

Appendices

ST No.	AB/2 (m)	ρa (Ohm-m)						
		Efunle VES 1	Efunle VES2	Fidiwo VES	Elesinmeji Ves 1	Elesinmeji VES 2	Olota VES	Olota VES2
1.	1.00	74.14	99.29	606.11	182.15	192.30	41.76	134.81
2	2.0	46.81	58.07	414.75	154.50	164.50	43.37	137.22
3	3.0	42.04	54.33	174.72	89.50	90.30	39.04	120.93
4	4.0	44.93	67.15	95.17	54.10	64.10	33.82	121.26
5	6.0	48.98	77.87	104.25	42.70	52.70	42.70	135.65
6	8.0	50.24	75..36	73.27	29.30	33.30	50.39	117.22
7	10.0	50.24		78.50	37.60	35.70	53.38	119.32
8	12.0	45.21	81.38	90.42	31.65	33.30	67.81	122.06
9	15.0	42.42	70.89	90.13	53.01	59.00	74.22	148.44
10	20.0	50.24	50.24	113.04	69.08	68.20	119.52	138.16
11	25.0	39.27	88.36	147.26	78.54	76.60	127.63	206.17
12	30.0	64.34	64.33	176.43	96.51	100.50	144.72	193.02
13	35.0	62.80	83.73	257.48	125.60	135.80	188.39	188.04
14	40.0	140.74	127.88	208.61	67.86	123.15	218.24	253.84
15	50.0	140.06	186.75	249.00	155.62	221.10	202.31	264.56
16	65.0	288.87	315.13	262.61	210.08	245.30	183.83	315.15
17	80.0	325.00	367.15	321.00	294.07	262.60	260.00	162.50
18	100.0	314.16	493.87		421.04	376.40		376.99

ST No.	B/2(m)	ρa (Ohm-m)						
		Onibepe VES 1	Onibepe VES2	Iragberi VES 1	Iragberi Ves 2	Origo Palace VES 2	Origo palace VES 2	Oke Amola VES
1.	1.00	48.89	51.20	192.37	130.52	50.92	55.60	26.74
2	2.0	50.96	50.70	77.97	85.30	63.49	72.50	26.19
3	3.0	30.58	34.60	74.53	80.40	63.69	65.70	23.48
4	4.0	18.84	18.60	67.15	78.20	51.69	60.30	23.19
5	6.0	15.07	16.70	67.82	52.30	56.52	56.60	18.54
6	8.0	14.65	15.20	54.43	35.70	39.77	45.80	23.02
7	10.0	21.98	22.23	43.96	35.60	31.14	42.30	15.70
8	12.0	31.65	32.70	49.73	40.30	27.13	38.50	27.13
9	15.0	42.41	67.40	68.92	66.30	33.00	50.00	15.91
10	20.0	43.96	68.20	75.36	77.30	75.36	80.60	18.84
11	25.0	70.36	83.40	107.99	115.50	88.36	95.20	29.44
12	30.0	160.85	162.70	112.60	122.30	64.39	94.50	48.28
13	35.0	146.53	150.50	146.53	148.20	83.73	90.60	62.80
14	40.0	150.79	147.50	185.98	167.60	168.39	171.90	52.78
15	50.0	103.74	110.30	186.75	195.30	171.18	211.90	93.38
16	65.0	105.05	120.50	183.83	206.70	236.35	236.50	78.78
17	80.0	130.00	145.60	162.50	198.70	295.25	298.40	116.67
18	100.0		276.40	314.16	320.60	314.16	317.5	

ST No.	AB/2 (m)	ρa (Ohm-m)						
		Oke Eso Odeomu VES	Onibepe VES2	Orile Owu VES	Unity School VES	Wakajaye (Gbongan VES	Araromi Owu VES 2	Balogun Ward Gbongan VES
1.	1.00	33.09	19.86	37.93	1310.36	77.55	33.16	79.81
2	2.0	51.78	31.17	35.69	653.76	37.21	28.87	83.19
3	3.0	48.59	30.50	40.13	233.42	28.67	22.93	53.24
4	4.0	44.93	28.99	45.41	155.08	27.05	21.26	45.41
5	6.0	48.98	32.66	66.57	151.98	38.94	30.14	50.24
6	8.0	31.40	31.40	69.08	146.53	43.96	33.49	46.05
7	10.0	18.84	34.54	69.08	135.02	50.24	40.82	43.96
8	12.0	41.44	49.73	72.33	149.19	67.81	58.27	54.25
9	15.0	37.11	40.65	83.06	249.17	70.68	70.69	47.96
10	20.0	37.68	62.80	81.64	213.52	113.04	100.48	50.24
11	25.0	49.06	58.88	88.31	412.34	147.19	147.19	49.05
12	30.0	41.82	48.26	96.33	352.56	176.94	209.11	96.51
13	35.0	54.22	62.80	125.60	296.40	146.53	252.00	128.67
14	40.0	82.44	130.80	103.01	449.89	155.80	278.96	140.74
15	50.0	43.58	124.45	124.50	373.50	249.00	389.06	311.25
16	65.0	70.09	236.35	131.31	652.79	210.12	315.13	393.92
17	80.0	97.50	260.00		1244.76	260.00	357.00	487.50
18	100.0		376.99					