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A Geoelectric Survey in Cocoa Research Institute of Nigeria (CRIN), Idi-Ayunre, Ibadan.

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Abstract

A geophysical investigation was carried out in Cocoa Research Institute of Nigeria (CRIN). The method employed in this study was the Vertical Electrical Sounding (VES) using the Schlumberger configuration. The soundings were carried out with half-spacing in the range 1- 100m. The VES points were geo-located using the Global Positioning System (G.P.S.). The co-ordinates of the VES locations lie within latitudes E003^0 51$^/$ 28.2$^{//}$ to E003^0 51$^/$ 48.7$^{//}$ and longitudes N 07^0 12$^/$ 22.9$^{//}$ to N07^0 12$^/$ 38.3$^{//}$. The elevations also range from 129 to 160 metres. The interpretation and analysis of the VES data show that there are suitable aquifers that can be tapped for boreholes.

***Keywords*:** Groundwater, electrical resistivity sounding, aquifer, water formation.

1.0 Introduction

Groundwater is water located beneath the ground surface in soil pore spaces and in the fractures of lithologic formations. A unit of rock or an unconsolidated deposit is called an aquifer when it can yield a usable quantity of water [1]. Nearly all the water in the ground comes from precipitation that has infiltrated into the earth. Observations have shown that a good deal of surplus rainfall runs-off over the surface of the ground while the other part of it infiltrates underground and becomes the groundwater responsible for the springs, lakes and wells [2]. Groundwater is often withdrawn for agricultural, municipal and industrial use by constructing and operating extraction wells. Groundwater is also widely used as a source for drinking supply and irrigation. Naturally, about 53% of all population relies on groundwater as a source of drinking water. Electrical resistivity method of geophysical exploration happens to be the most preferred method in groundwater exploration. The vertical electrical sounding (VES) is a geoelectrical method for measuring vertical alterations of electrical resistivity. The method has been recognized to be more suitable for hydrogeological survey of sedimentary basin [1, 3]. The reason for its wide use is because the instrument is simple; field logistics are easy and straight forward while the analysis of data is less tedious and economical. This is the reason why many researchers [4, 5] have all used this method for the determination of aquifer boundary. The area under investigation in this study is a fast growing community in terms of population and business activities. This has impacted on the growing demand for portable water. Suffice it to say that Idi- Ayunre has no public water supply and depends on personal efforts in getting water for domestic use. From my findings, no geophysical resistivity surveys in the determination of groundwater have been carried out in this community before now. This is why it is important to initiate a proper groundwater resource and exploration program. The realization of such a program requires data from geophysical survey which this study is out to address.

2.0 Geology of the study area

The dominant rock types in Ibadan area are quartzite of the meta-sedimentary series, migmatic complex comprising banded gneiss, augen gneiss and migmatite. These rocks are intruded by pegmatite, quartz veins, aplites and doleritic dykes. Quartz-schist outcrops occur as long ridges with relatively high elevation which made them to be seen conspicuously. 33Their strike line runs in the north-south direction between 340^0 and 350^0 with a consistent easterly dip **.**

Banded gneiss outcrop in the western and north-eastern part of Ibadan. They strike along the north direction with average dip angle of 47^0 W and 36^0 E. They are obliterated in some places by intrusive veins and dykes. Minor structures such as folds, shear zone, pinch and swell structures concordant and discordant quartz veins and quartz veins and quartzofeldpathic intrusions are present on the banded gneiss.

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The study area is underlain by banded and augen gneisses. While banded gneiss outcrops in every part except the north eastern part of the area, few outcrops of augen gneiss were visible at the centre of the study area. Foliation planes are well developed on the banded gneiss and strike is between 346^0 and 358^0 with average dip angles of 44^0 W and 49^0 E. Banded gneiss identified in the area, apart from having distinct foliation plane, also have coarse grain texture with occurrence of striation and lenticular arrangement of feldspar and quartz. The rocks have been subjected to weathering, which led to ridge of quartz vein in them. Exfoliation has left some of the outcrops as rounded rock mass of exfoliation dome. The most visible texture of the gneiss on the field is the network of quartzo-felspathic vein that dissect them.

3.0 Methodology

Vertical Electrical Soundings (VES) were carried out in the study area with an ABEMTERRAMETER SAS (Signal Averaging System) 3000B with booster SAS 2000 manufactured in Sweden was used for taking surface resistivity readings. The equipment is light and powerful for deep penetrations. The resistivity survey was completed with three sounding stations. The VES was conducted by using the schlumberger array (AB) ranging from 2 metres to 200 metres (AB/2 was 1 – 100m). The field data acquisition was generally carried out by moving two or four of the electrodes used between each measurement [6].

The VES of the three sounding stations were obtained by plotting the calculated apparent resistivity against electrode spacing. Computer programs for reducing geoelectrical sounding curves into thickness and resistivity of individual layer were applied. The field curves were interpreted by the method of curve matching. The field curve and the result of the curve matching were then subjected to computer assisted iterative interpretation. The end result of the field measurement is the computation of the apparent resistitivity, using the equation

$$\rho_a = \frac{KV}{I} = KR \qquad (1)$$

where

$$K = \frac{\frac{\Pi}{2}\left[\left(\frac{AB}{2}\right)^2 - \left(\frac{MN}{2}\right)^2\right]}{\left(\frac{MN}{2}\right)} \qquad (2)$$

and

ρ_a = Apparent Resistivity
K = Geometric factor
V = Volt; I = Current;
R = Resistance
AB = Current Electrodes Separation
MN = Potential Electrodes Separation.

4.0 Discussion and conclusion

The geoelectric section of VES 1 indicates three geoelectric layers and its apparent resistivity curve is the H-type, with $\rho_1 > \rho_2 < \rho_3$. The first layer has a resistivity value of 93.20 Ωm with a thickness of 0.50m indicating the top soil. The second layer has a resistivity value of 37.80 Ωm with a thickness of 6.50m and it shows the presence of clay. The third layer has a resistivity value of 4493.90 Ωm and it is composed of fresh basement complex.

The geoelectric section of VES 2 indicates four geoelectric layers and its apparent resistivity curve is the QH-type, with $\rho_1 > \rho_2 > \rho_3 < \rho_4$ .The first layer has a resistivity value of 123.50 Ωm with a thickness of 1.10m indicating the top soil. The second layer has a resistivity value of 40.50 Ωm with a thickness of 0.90m. It is suspected to be surface water. The third layer has a resistivity value of 31.80 Ωm with a thickness of 2.0m, and it is suspected to be clay. The fourth layer has a resistivity value of 351.80 Ωm with a thickness of 3.10m is made of sandy clay. The fifth layer of apparent resistivity 22639.80 Ωm is suspected to be a fractured basement.

The geoelectric section of VES 3 comprises of four geoelectric layers and its apparent resistivity curve is the HA-type, with $\rho_1 > \rho_2 < \rho_3 < \rho_4$. The first layer has a resistivity value of 294.30 Ωm with a thickness of 0.50m indicating the top soil. The second layer has a resistivity value of 67.70 Ωm with a thickness of 1.60m and it is composed of clay. The third layer has a resistivity value of 225.70 Ωm with a thickness of 7.80m and it is suspected to be a weathered basement. The fourth layer of apparent resistivity value 1003.10 Ωm is made up of fresh basement complex.

The geoelectric section of VES 4 indicates three geoelectric layers and its apparent resistivity curve is the H-type, with $\rho_1 > \rho_2 < \rho_3$. The first layer has a resistivity value of 552.50 Ωm with a thickness of 0.5m indicating the top soil. The second layer has a resistivity value 110.20 Ωm with a thickness of 6.0m, and it is suspected to be clay. The third layer with a resistivity value of 526.20 Ωm is made up of sand. The geoelectric layer 2 is the aquifer layer with a depth of 6.50m.

The geoelectric section of VES 5 indicates three geoelectric layers and its apparent resistivity curve is the H-type, with $\rho_1 > \rho_2 < \rho_3$. The first layer has a resistivity value of 195.50 Ωm with a thickness of 0.60m indicating the top soil. The second layer has a resistivity value of 52.60 Ωm with a thickness of 7.40m and it is suspected to be surface water. The third layer has a resistivity value of 1274.20 Ωm. It is made up of sand.

The geoelectric section of VES 6 indicates five geoelectric layers and its apparent resistivity curve is the HKH-type, with $\rho_1 > \rho_2 < \rho_3 > \rho_4 < \rho_5$. The first layer has a resistivity value of 284.70 Ωm with a thickness of 0.60m indicating the top soil. The second layer has a resistivity value of 114.0 Ωm with a thickness of 1.8m, and it is composed of sandy clay. The third layer has a resistivity value of 420.20 Ωm with a thickness of 4.80m and it's made of sand. The fourth layer has a resistivity value 128.70 Ωm with a thickness of 16.10m, and it is suspected to be a fractured basement. The fifth layer has a resistivity value of 509.20 Ωm. It is a fresh basement. The fourth layer with a depth of 22.80m is an aquifer.

The geoelectric section of VES 7 indicates three geoelectric layers and its apparent resistivity curves is the H-type, with $\rho_1 > \rho_2 < \rho_3$. The first layer has a resistivity value of 257.40 Ωm with a thickness of 1.40m is the top soil. The second layer with a resistivity value of 100.60 Ωm with a thickness of 25.90m shows the presence of sandy clay. The third layer has a resistivity value of 1994 Ωm and it is detected to be a fresh basement. The second layer with a depth of 27.20m is the aquifer.

The geoelectric section of VES 8 indicates three geoelectric layers and its apparent resistivity curve is the A-type, with $\rho_1 < \rho_2 < \rho_3$. The first layer with a resistivity value of 158 Ωm and a thickness of 0.60m is the top soil. The second layer with apparent resistivity of 212.60 Ωm with a thickness of 1.30m is made up of clayey sand. The third layer with an apparent resistivity of 245 Ωm is suspected to be made up of sand.

The geoelectric section of VES 9 indicates five geoelectric layers and its apparent resistivity curve is the KQH-type, with $\rho_1 < \rho_2 > \rho_3 > \rho_4 < \rho_5$. The first layer has a resistivity value of 509.90 Ωm with a thickness of 1.0m indicating the top soil. The second layer has a resistivity value of 591.50 Ωm with a thickness of 2.0m is made up of lateritic sand. The third layer has a resistivity value of 302.70 Ωm and it contains sand. The fourth layer has a resistivity value of 235.50 Ωm with a thickness of 19.90m and it is suspected to be a fractured basement. The fifth layer with a resistivity value of 509.20m is a fresh basement. The third layer with a depth of 9.0m is the aquifer.

The geoelectric section of VES 10 indicates five geoelectric layers and its apparent resistivity curve is the QQH- type, with $\rho_1 > \rho_2 > \rho_3 > \rho_4 < \rho_5$. The first layer has a resistivity value of 455.90 Ωm with a thickness of 0.70m is the top soil. The second layer has a resistivity value of 417 Ωm with a thickness of 1.10m and it is suspected to be lateritic sand. The third layer has a resistivity value of 106 Ωm with a thickness of 3.40m indicating sandy clay. The fourth layer has a resistivity value of 65 Ωm with a thickness of 8.60m is a fractured basement. The fifth layer with a thickness of 457 Ωm is a fresh basement. The third layer with a depth of 5.20m is the aquifer.

In conclusion, we found that electrical resistivity method has proved very important in the mapping of subsurface aquifer layers. This research work therefore serves as a working guide for a complete borehole driller in Idi-Ayunre where source of pure portable water is a major problem.

Figure 1: Topographical Map of Idi-Ayunre and its environs.

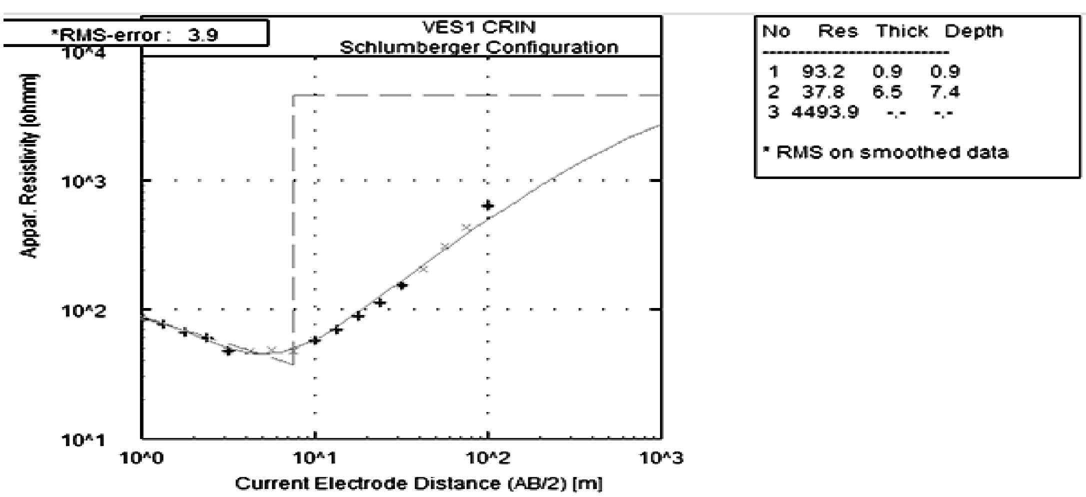

Figure 2: Field and theoretical Curve for VES No. 1

Table 1: Geoelectric layer parameter analysis of VES No. 1

Geoelectric layer	Resistivity (Ωm)	Thickness (m)	Depth (m)	Lithology
1	93.20	0.90	0.90	Top soil
2	37.80	6.50	7.40	Clay
3	-	-		Fresh basement

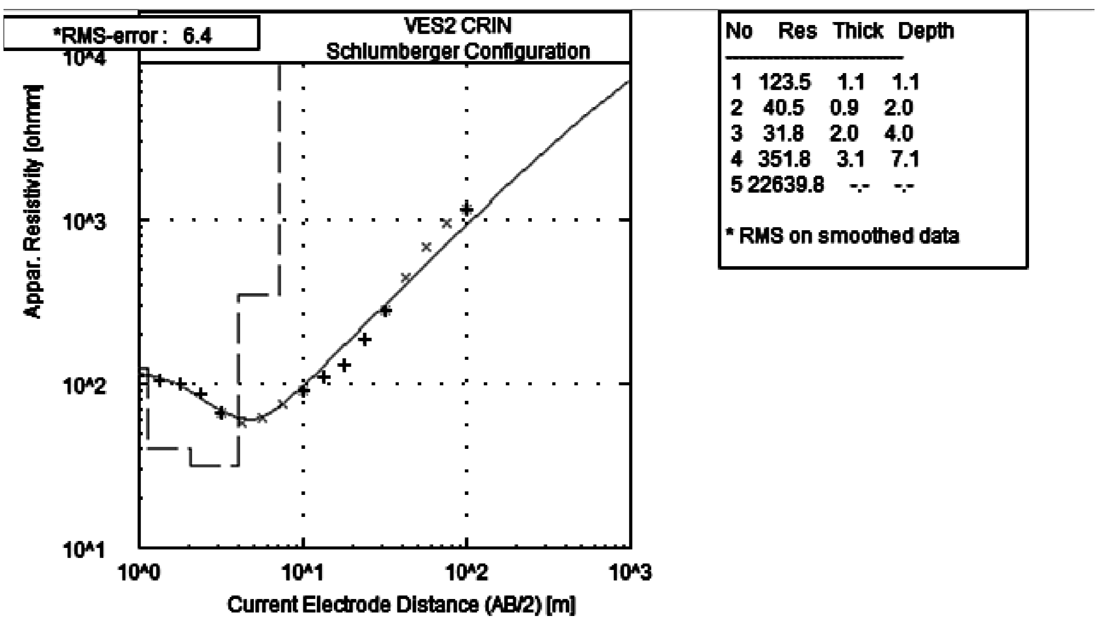

Figure 3: Field and theoretical Curve for VES No. 2

Table 2: Geoelectric layer parameter analysis of VES No. 2

Geoelectric layer	Resistivity (Ωm)	Thickness (m)	Depth (m)	Lithology
1	123.50	1.10	1.10	Top soil
2	40.50	0.90	2.00	Surface water
3	31.80	2.00	4.00	Clay
4	351.80	3.10	7.10	Sand clay
5	22639.80	-	-	Fractured basement

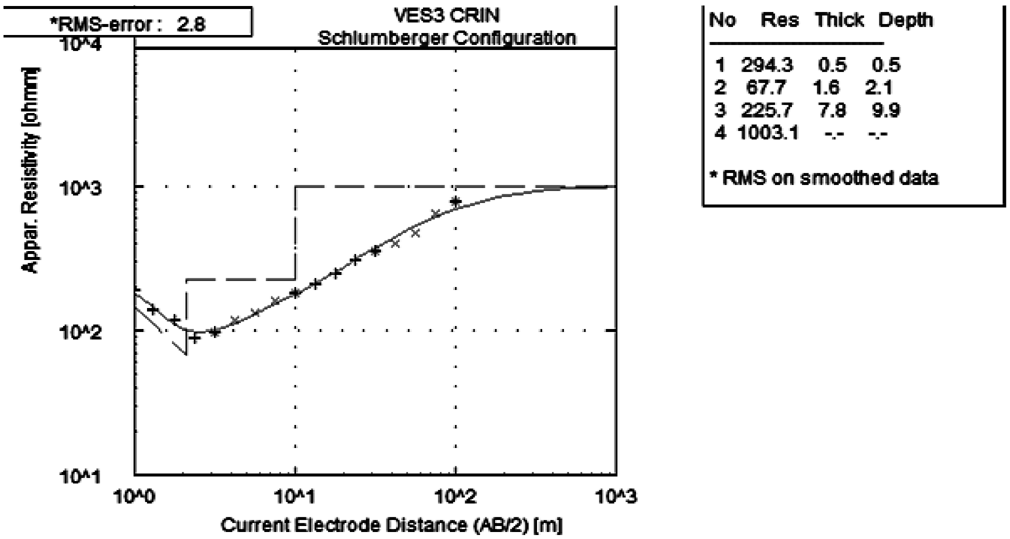

Figure 4: Field and Theoretical curves for VES 3

Table 3: Geoelectric layer parameter analysis of VES No. 3

Geoelectric layer	Resistivity (Ωm)	Thickness (m)	Depth (m)	Lithology
1	284.70	0.60	0.60	Top soil
2	114.00	1.30	1.90	Sandy Clay
3	420.20	4.80	6.70	sand
4	128.70	16.10	22.80	Fractured basement
5	509.20	-	-	Fresh basement

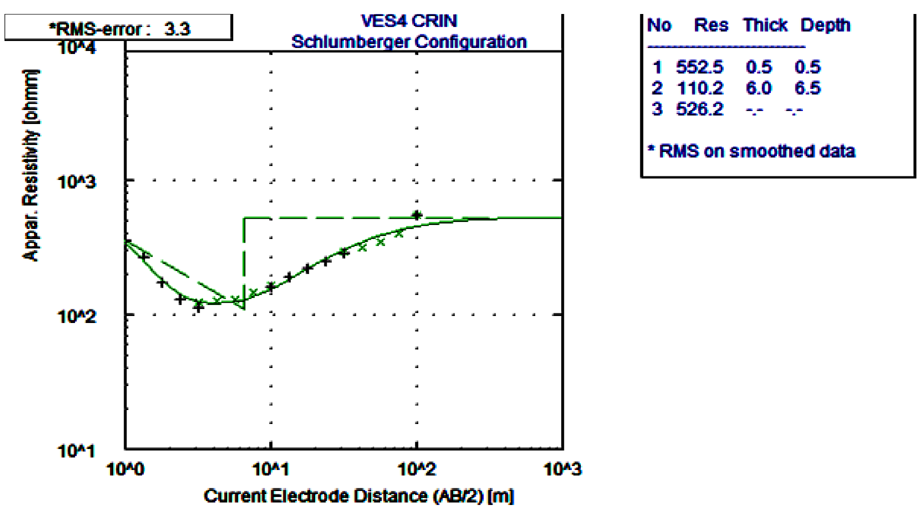

Figure 5: Field and Theoretical curves for VES 4

Table 4: Geoelectric layer parameter analysis of VES No. 4

Geoelectric layer	Resistivity (Ωm)	Thickness (m)	Depth (m)	Lithology
1	552.50	0.50	0.50	Top soil
2	110.20	6.00	6.50	Clay
3	526.20	-	-	Sand

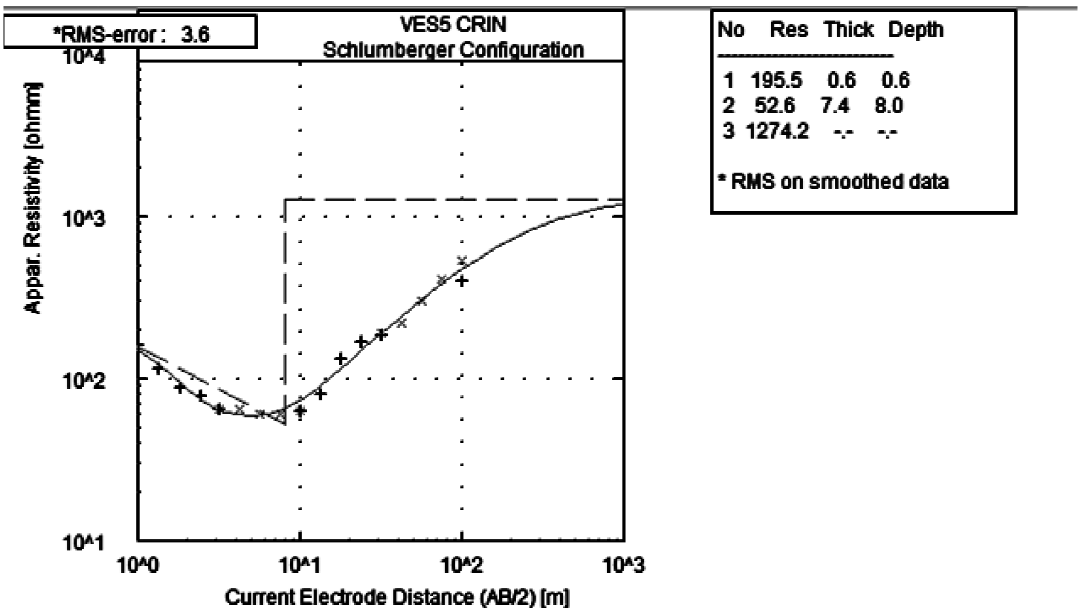

Figure 6: Field and theoretical curves for VES 5.

Table 5: Geoelectric layer parameter analysis of VES No. 5

Geoelectric layer	Resistivity (Ωm)	Thickness (m)	Depth (m)	Lithology
1	195.50	0.60	0.60	Top soil
2	52.60	7.40	8.00	Surface water
3	1274.20	-	-	Sand

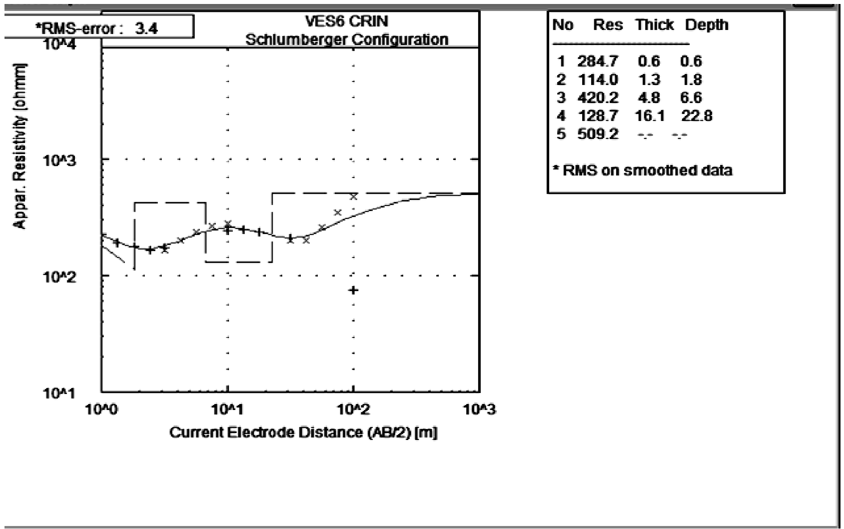

Figure 7: Field and theoretical curves for VES 6.

Table 6: Geoelectric layer parameter analysis of VES No. 6

Geoelectric layer	Resistivity (Ωm)	Thickness (m)	Depth (m)	Lithology
1	284.70	0.60	0.60	Top soil
2	114.00	1.30	1.90	Sandy Clay
3	420.20	4.80	6.70	sand
4	128.70	16.10	22.80	Fractured basement
5	509.20	-	-	Fresh basement

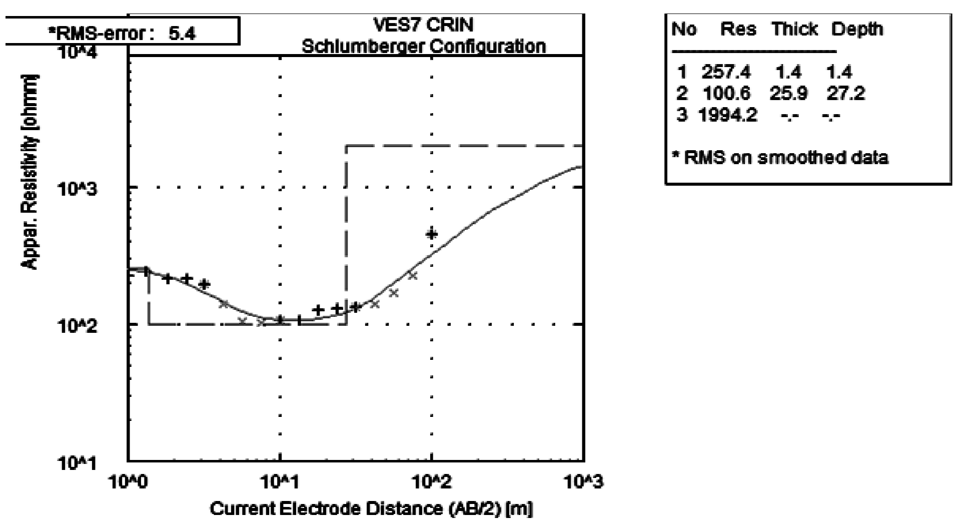

Figure 8: Field and theoretical curves for VES 7.

Table 7: Geoelectric layer parameter analysis of VES No.7

Geoelectric layer	Resistivity (Ωm)	Thickness (m)	Depth (m)	Lithology
1	257.40	1.40	1.40	Top soil
2	100.60	25.90	27.20	Sandy Clay
3	1994.00	-	-	Fresh Basement

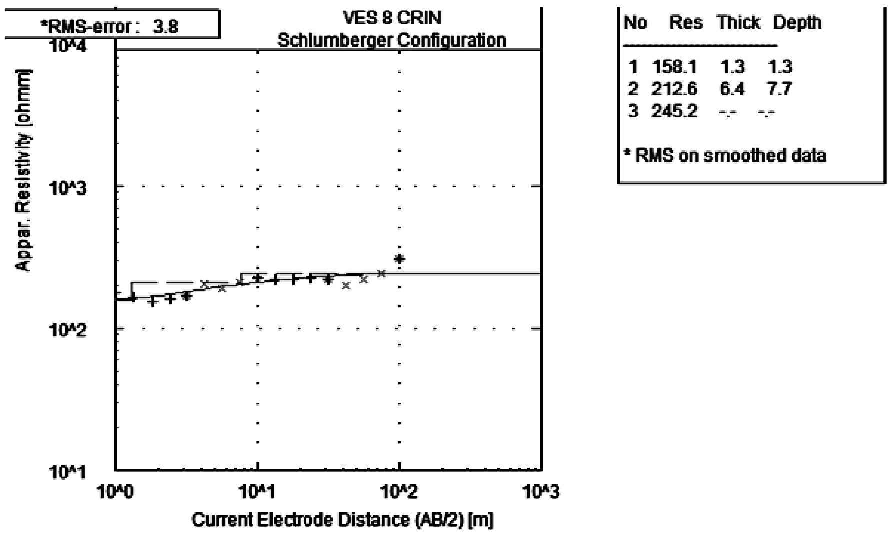

Figure 9: Field and theoretical curves for VES 8.

Table 8: Geoelectric layer parameter analysis of VES No. 8

Geoelectric layer	Resistivity (Ωm)	Thickness (m)	Depth (m)	Lithology
1	158.00	1.30	1.30	Top soil
2	212.60	6.40	7.70	Clayey Sand
3	245.20	-	-	sand

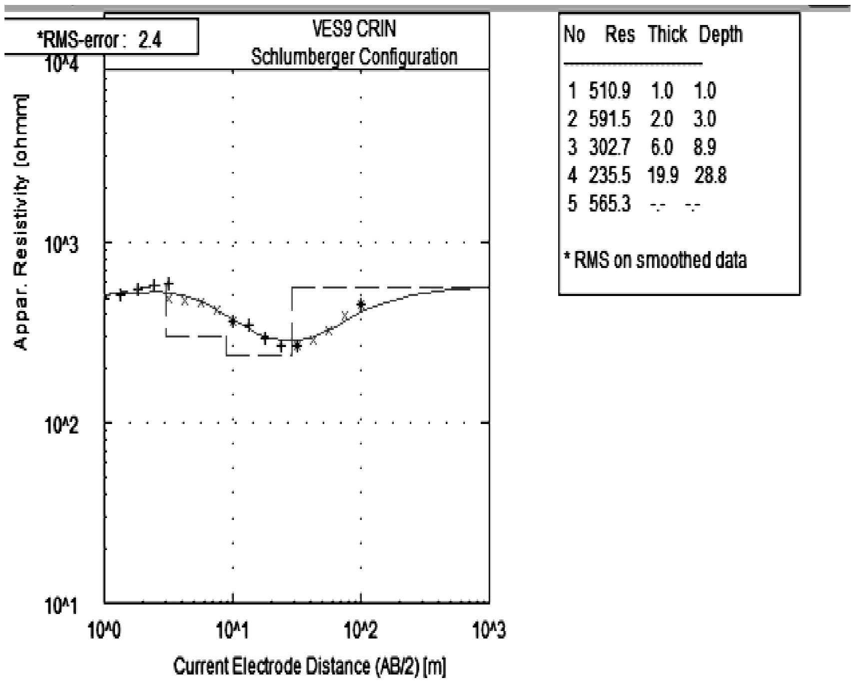

Figure 10: Field and theoretical curves for VES 9.

Table 9: Geoelectric layer parameter analysis of VES No. 9

Geoelectric layer	Resistivity (Ωm)	Thickness (m)	Depth (m)	Lithology
1	509.90	1.00	1.00	Top soil
2	591.50	2.00	3.00	Lateritic Sand
3	302.70	6.00	9.00	sand
4	235.50	19.90	28.90	Fractured basement
5	509.20	-	-	Fresh basement

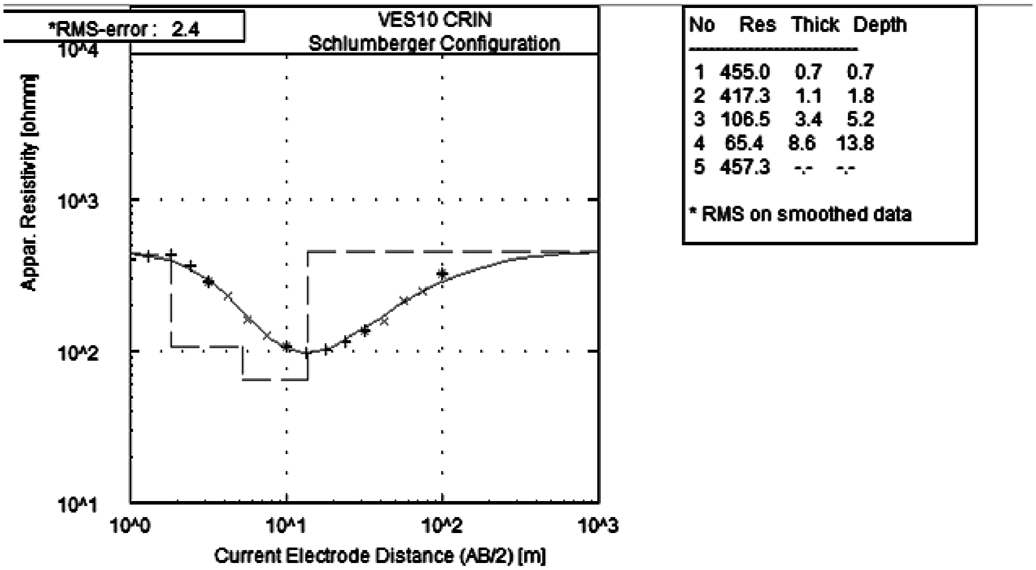

Figure 11: Field and theoretical curves for VES 10.

Table 10: Geoelectric layer parameter analysis of VES 10.

Geoelectric layer	Resistivity (Ωm)	Thickness (m)	Depth (m)	Lithology
1	455.90	0.70	0.70	Top soil
2	417.00	1.10	1.80	Lateritic sand
3	106.00	3.40	5.20	Sandy clay
4	65.00	8.60	13.80	Fractured basement
5	457.00	-	-	Fresh basement

Table 11: Summary of results

Geoelectric Layer	Curve Shape	Depth to Aquifer(m)	Latitude	Longitude	Elevation (m)
1.	H	Not penetrated	E003^{0} 51$^{/}$ 28.2$^{//}$	N07^{0} 12$^{/}$ 28.4$^{//}$	141
2.	QH	Not penetrated	E003^{0} 51$^{/}$ 28.2$^{//}$	N07^{0} 12$^{/}$ 28.1$^{//}$	137
3.	HA	Not penetrated	E003^{0} 51$^{/}$ 30.8$^{//}$	N07^{0} 12$^{/}$ 23.2$^{//}$	160
4.	H	6.50	E003^{0} 51$^{/}$ 37.2$^{//}$	N07^{0} 12$^{/}$ 29.7$^{//}$	153
5.	H	Not penetrated	E003^{0} 51$^{/}$ 38.9$^{//}$	N07^{0} 12$^{/}$ 29.11$^{//}$	144
6.	HKH	22.80	E003^{0} 51$^{/}$ 42.1$^{//}$	N07^{0} 12$^{/}$ 22.9$^{//}$	160
7.	H	27.20	E003^{0} 51$^{/}$ 48.4$^{//}$	N07^{0} 12$^{/}$ 22.9$^{//}$	142
8.	A	Not penetrated	E003^{0} 51$^{/}$ 48.5$^{//}$	N07^{0} 12$^{/}$ 27.5$^{//}$	145
9.	KQH	9.00	E003^{0} 51$^{/}$ 48.7$^{//}$	N07^{0} 12$^{/}$ 34$^{//}$	129
10.	QQH	5.20	E003^{0} 51$^{/}$ 44.1$^{//}$	N07^{0} 12$^{/}$ 38.3$^{//}$	129

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