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Research Article

SUB-SURFACE CHARACTERISTICS AND EVALUATION OF GROUNDWATER POTENTIAL ZONES OF IDI-AYUNRE SOUTHWEST, NIGERIA

[1]Adetoyinbo, Adedeji Adegoke, [2,*]Bello, Adekunle Kazeem and [1]Fredrick Fiyeboju Magi

[1]Department of Physics, University of Ibadan, Ibadan, Nigeria
[2]Department of Physical Sciences, Bells University of Technology, Ota, Nigeria

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Abstract

The groundwater potential areas in Idi-Ayunre, Ibadan, Oyo state was estimated using vertical electrical sounding and geographic information system, also the subsurface characteristics was described using the two methods. The survey was done using VES with twenty-one points to estimate the groundwater perspective. The results of the analysis are presented in the form of curves, tables, and maps. The analysis and interpretation of the VES results were processed using WINRESIT and $ARGIS$ 10.0. There is fracture zone at $7.8\ m$ depth in $VES10$with resistivity value of $21.2\ \Omega m$which indicate the existence of groundwater at that point. When considering the whole VES points on average, the analysis show that the groundwater prospective in this study area is low. The main aquifer units suited for groundwater exploration in this area as indicated in the results are the vertical electrical soundingsVES 1 and VES 16 respectively.

Keywords: Potential Groundwater, Main Aquifer Units, Groundwater Perspective, Vertical Electrical Soundings.

INTRODUCTION

Life depends on two natural elements. These elements are: water and Air. The later is gaseous and therefore, can be found anywhere there is vacuum. On the other hand water which makes up about 75% of earth's surface is found almost everywhere yet extremely sorted for. The existence of water on the earth's surface is limited due to its uneven distribution Wu *et al.,* (2011). There are various factors that controlled the presence and development of groundwater which includes porosity and permeability of the surface, underlying rock formations. Ishola*et al.,* (2013) reported that variation in groundwater potentials results from porosity and permeability. The capacity of permeability and porosity contained in the selithologies is determined by geological materials Akinwumiju and Olorunfemi, (2016). Electric current flow governed by dissolved ions movement in the soil solution was reported by Allred *et al.,* (2008). There is large difference between the fresh water and salt-water. Generally, the freshwater resistivity ranges between $10\ \Omega m$and $100\ \Omega m$while for salt-water it is less than $3\ \Omega m$. Adebowale *et al.*, (2014) studied groundwater exploration in south west, Nigeria using VLF and VES, their results compared favourably well with drilling information. Abebe, (2020) carried out groundwater potential mapping using geospatial techniques, the result shows that 89 % of springs were overlaying good groundwater potential zones while 58 % of deep well has similar trace, and 42 % of deep well overlays moderate zone. Bayewu*et al.,* (2017) carried out work on groundwater potential in south-west basement complex using VLF and VES methods, they used their result in delineated high fractured zones.Adeola and Oyebola, (2016) studied the mineralogy and geochemistry of the weathering profiles of basement rock in Idi-Ayunre and Akure districts,results showed that the lateritic profiles over banded gneiss, granite and porphyritic granite of the studied areas varied with thecomposition of the parent rocks. Adeyeye*et al.,* (2019) observed the translation of effluent rivers to influent riversas flow across the crystalline rock-sedimentary rock contact (CRSRC) to incorporate contact proximity thematic layer into GIS-based model. Okpoli and Ozomoge, (2020) applied VES and EM-3D to groundwater exploration in south western Niger, in their results, the VES were characterised by good aquifer resistivity on conductive zones and poor indication on non-conductive zones. Electrical Sounding survey were carried out by Venkateswaran*et al.,* (2014)using geophysical and GIS techniques in sarabanga sub basin, cauvery river, Nadu, India to delineate groundwater potential zones. Srivastava and Bhattacharya, (2006) applied GIS tools and remote sensing data to prepare and analyse digital layers of lithology, geological structure, drainage and topography to detect the most favorable sites for groundwater exploration in an arid basin in Jordan. Ogunseye*et al.,* (2022) carried out geochemical soil analysis for groundwater quality at Mokola, Ibadan, Nigeria, the results revealed that the mean concentrations of lead, cadmium, arsenic, nickel and chromium in the boreholes were above (WHO, 2017) contamination limit, except that of copper and zinc. In this work,GIS is integrated with VES todescribe geo-electric characteristics and assess groundwater potential zones of Idi Ayunre

Corresponding Author:** ***Bello, Adekunle Kazeem
Department of Physical Sciences, Bells University of Technology, Ota, Nigeria.

The study area

The geographical coordinates of the study area are longitude $7^{\circ}14^{'}N$ and latitude $3^{\circ}51^{'}E$. The major rock associations of study area make up part of the basement complex of Nigeria with an undulating topography. The entire western part of the study area is located and underlain by banded gneiss while the eastern part is predominantly made up of granite gneiss. The area is accessible by a major road, which is tarred.

Reflection coefficient

The reflection coefficient $r$for each of the Vertical Electrical Sounding (VES) point was done using the equation below:

$r = \begin{cases} \frac{\rho_n - \rho(n-1)}{\rho_n + \rho(n-1)} \end{cases}$

Where $\rho_n$is the layer resistivity of the nth layer and $\rho(n-1)$ is the layer resistivity overlying the nth layer.

MATERIALS AND METHODS

Geopulse Tigre Resistivity meter (Figures 2a and 2b)was used to acquire field data. The field work was accomplished in the month of August.The period coincided with a period of drastic reduction in the frequency of rainfall for few days in the study area. Electrical resistivity imaging using Schlumberger array was used. A total of 21 VES were carried out.

Field procedure

Four electrodes were placed similarly along a straight line. The potential electrodes $(P_1 and P_2)$ are place in between$(C_1 and C_2)$. In other to ensure good electrical contact with the earth, two-third of the length of the electrode was driven into the earth. The current electrode spacing $(AB/2)$was$110\ m$.The DC source powered the Terrameter and adjustments made on the instrument includes setting the number of circle to five, automatic reading of values in ohms and sending current of $5\ mA$ into the ground. The range of penetration depth was varied by outward displacement of current electrodes with fixed potential electrodes.The values of the resistance obtained in the field were multiplied with their respective Geometric factor (k) which gave the required apparent resistivity results. Partial curve matching was done by matching the plotted curves with a master curves. Through this process the apparent resistivity and the depths of the layers were also obtained respectively. This procedure was repeated for all 21 VES. Thereafter, the results obtained were introduced to the WinRESIST software as initial models for computation of the final model.

RESULTS AND DISCUSSION

The VES curves (Figures: 5 - 25, shown in the appendix) achieved from partial curve matching interpreted with computer using WINRESIST iteration software, data set analysis was done using geostatistical tool on $ArcGIS$ 10.0. The analysis root mean square error has an average value of 2.96 % as shown in Table 1. Figure 4 is the overburden thickness map of the study area, it ranged from$(1.1 - 44.4)\ m$, with average thickness of$8.7\ m$. The overburden within the south-western and south-eastern part of the study area has thickness of about $44.4\ m$and $34.4\ m$ respectively.Other parts of the study area have shallow overburden thickness, an indication that the basement is shallow.The resistivity values range between $12.8\ \Omega m$ to $1264.3\ \Omega m$ with a mean value of $153\ \Omega m$. The south-eastern part has the highest resistivity andprogressively decreases from the south-western parts to other area. The thin weathered basement's mean thickness is $7.7\ m$while thick weathered basement areas has thickness of $41.3m$, $33.5\ m$ and $16.4m$ respectively

Conclusion

There is unfavourable groundwater potential in the area that caused borehole failure. In small portion of the area, location of borehole did not favour groundwater. In general, the area has shallow overburden, except thesouth-western part that has thick overburden and good for groundwater abstraction. This low groundwater potential in the area result to shortage of water during dry season.

Declaration

There is no conflicts of interest among the authors

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There was no fund for the research

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APPENDIX

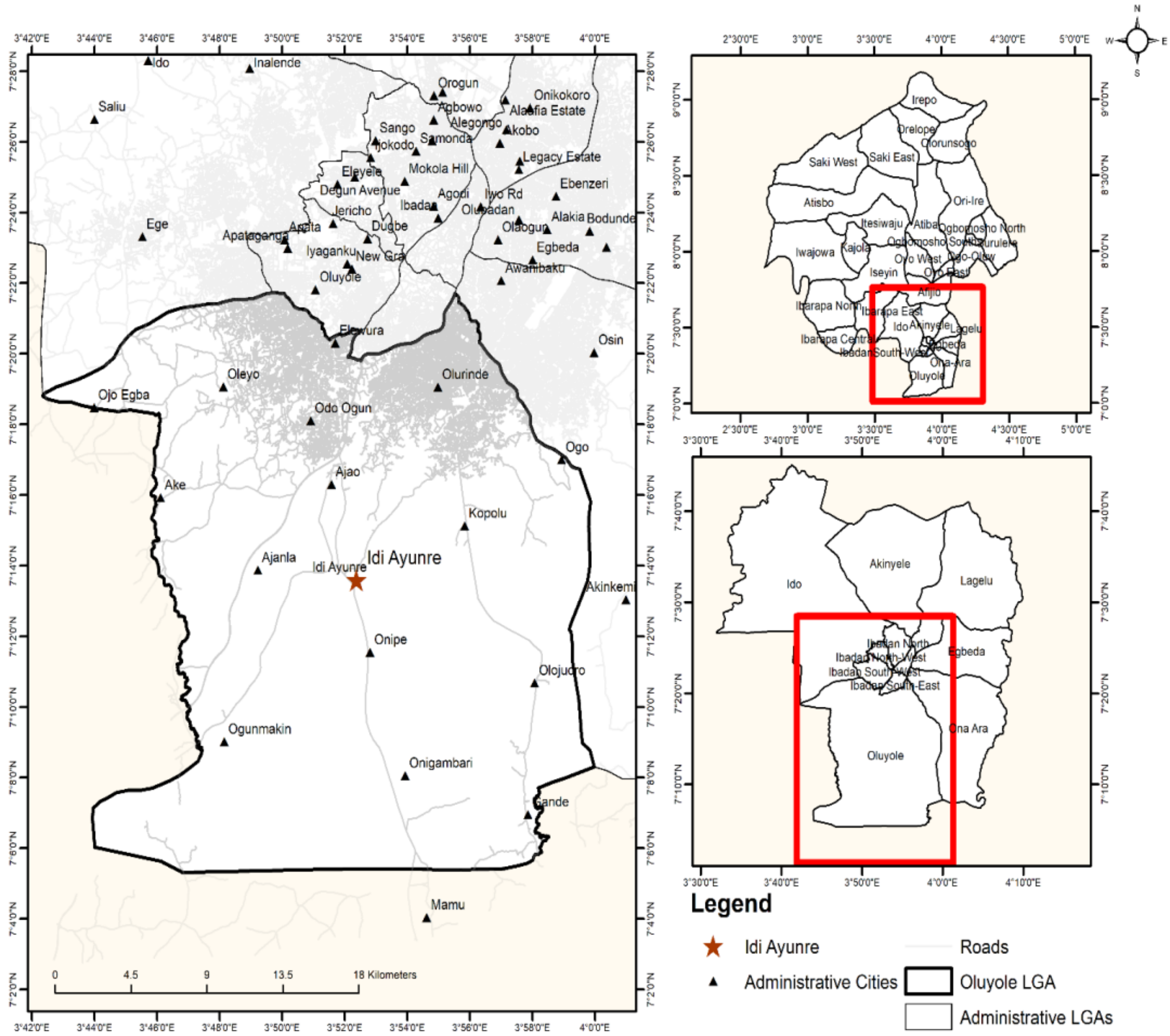


Figure 1. Map showing Idi-Ayunre and its environs

Figure 2aFigure 2B

Figures 2a and 2b. Pictures of data acquisition equipments

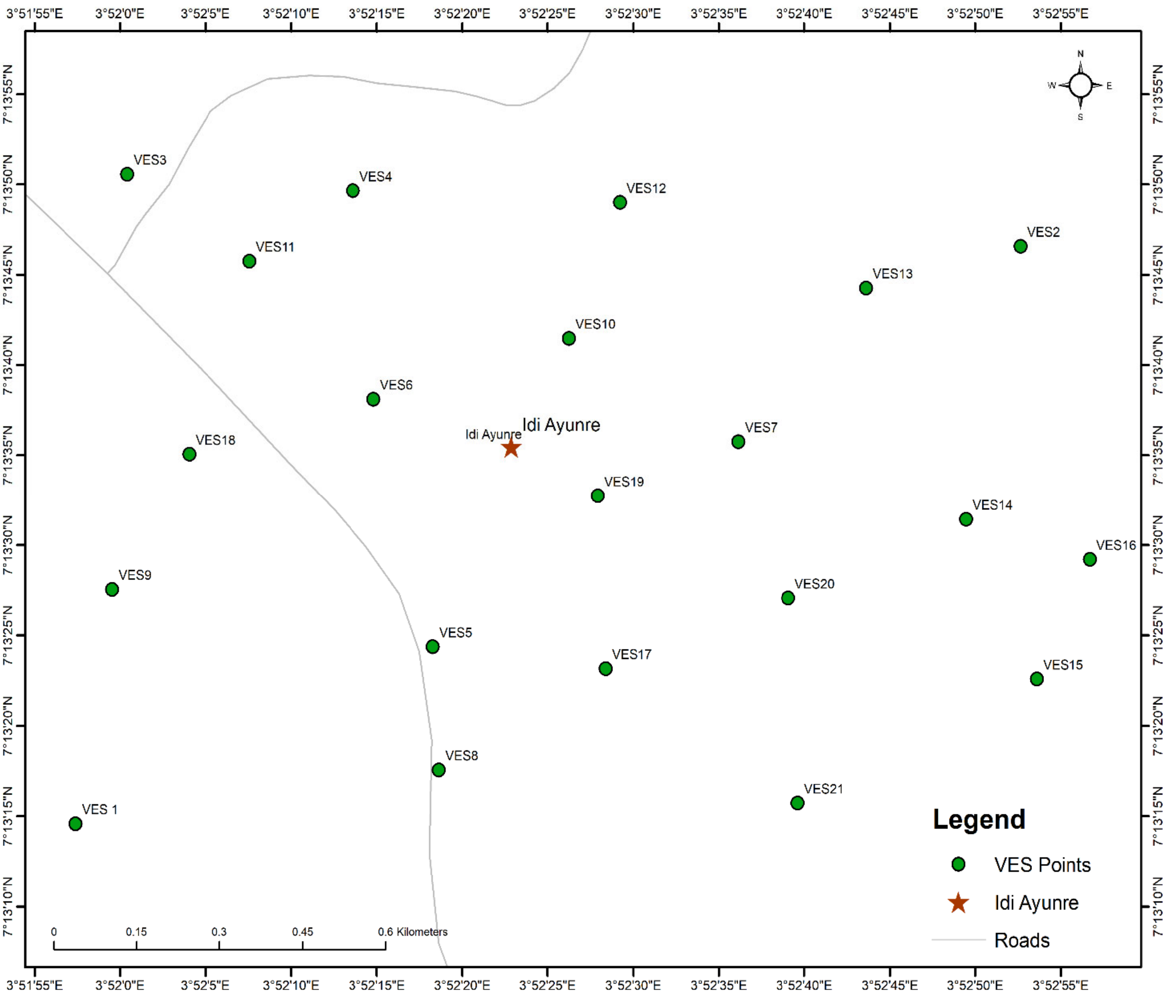


Figure 3. Shows a map of VES points

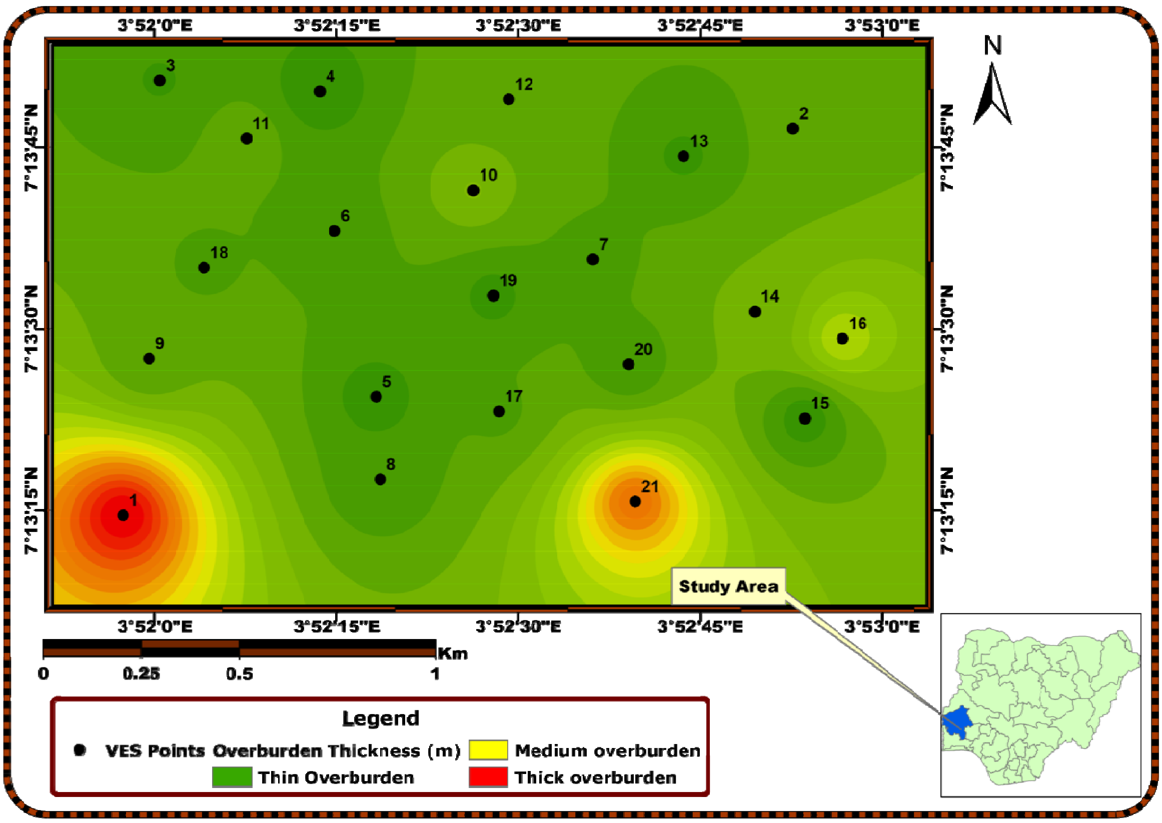


Figure 4. Overburden Thickness Map

Table 1. Summary of Interpreted VES curves

VES STATION	LAYER RESISTIVITY(Ωm)	THICKNESS(m)	DEPTH (m)	CURVE TYPE	R.M.S ERROR	LAYER DESCRIPTION
	753.6	1.4	1.4			Top Soil
1	413.1	43.1	44.4	H	2.5	Weathered Layer
	7218.6	------	-----			Bedrock
	271.8	1.0	1.0			Top Soil
2	105.4	5.4	6.3	H	2.3	Weathered Layer
	1262.6	-----	-----			Bedrock
	333.9	0.8	0.8			Top Soil
3	85.2	2.5	3.3	H	3.1	Weathered Layer
	1307.9	-----	-----			Bedrock
	480.6	0.6	0.6			Top Soil
4	106.3	1.1.	1.1	H	4.7	Weathered Layer
	1902.9	-----	------			Bedrock
	456.2	0.6	0.6		2.1	Top Soil
5	98.2	1.2	1.8	H		Weathered Layer
	1684.9	-----	-----			Bedrock
	309.8	2.7	2.7			Top Soil
6	68.5	1.6	4.4	H	2.4	Weathered Layer
	3218.0	-----	-------			Bedrock
	881.0	0.4	0.4			Top Soil
7	152.2	4.6	5.0	H	2.7	Weathered Layer
	1394.7	------	------			Bedrock
	485.9	0.6	0.6			Top Soil
8	101.1	2.9	3.5	H	1.9	Weathered Layer
	760.2	------	------			Bedrock
	516.1	0.7	0.7			Top Soil
9	196.9	5.3	6.0	H	5.6	Weathered Layer
	1526.2	-----	------			Bedrock

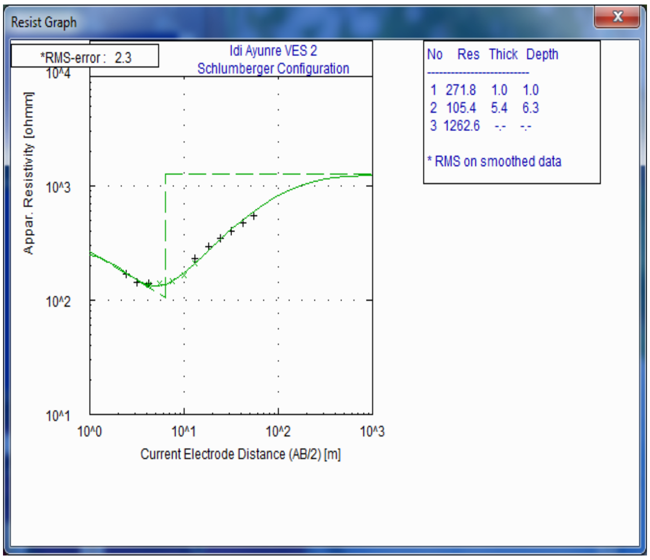
Table 2. Summary of Interpreted VES curves

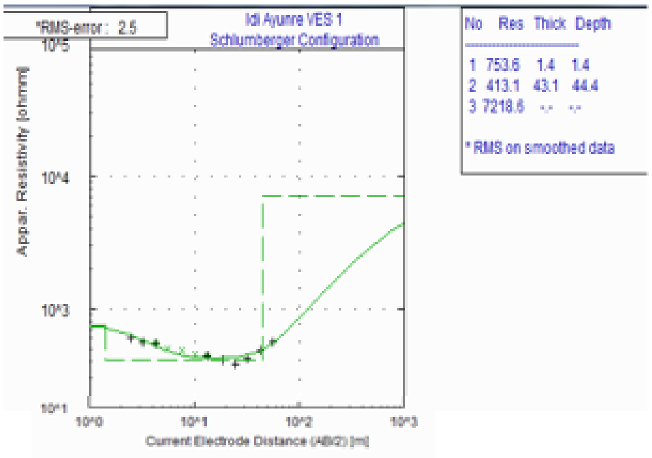
VES STATION	LAYER RESISTIVITY(Ωm)	THICKNESS(m)	DEPTH (m)	CURVE TYPE	R.M.S ERROR	LAYER DESCRIPTION
	69.1	3.0	3.0			Top Soil
10	21.2	7.8	10.9	H	3.4	Weathered Layer
	1191.7	----	-----			Bedrock
	133.7	1.0	1.0			Top Soil
11	13.6	6.2	7.2	H	2.5	Weathered Layer
	625.7	-----				Bedrock
	395.7	1.9	1.9			Top Soil
12	12.8	5.6	7.5	H	6.3	Weathered Layer
	155.9	-----	-----			Bedrock
	308.3	0.8	0.8			Top Soil
13	13.4	2.2	3.0	H	11.8	Weathered Layer
	6948.5	-----	-----			Bedrock
	202.5	1.0	1.0			Top Soil
14	30.9	7.9	8.9	H	2.5	Weathered Layer
	2464.8	-----	------			Bedrock
	45.7	1.3	1.3			Top Soil
15	16.9	0.8	2.1	H	2.5	Weathered Layer
	1694.4	-----	-----			Bedrock
	135.4	1.1	1.1		1.5	Top Soil
16	78.6	16.4	17.5	H		Weathered Layer
	169.7	-------	-----			Bedrock
	210.6	0.4	0.4			Top Soil
17	79.2	5.1	5.4	H	2.5	Weathered Layer
	1506.0	------	------			Bedrock
	200.1	0.4	0.4			Top Soil
18	84.5	5.2	5.5	H	1.9	Weathered Layer
	247.2	-------	------			Bedrock

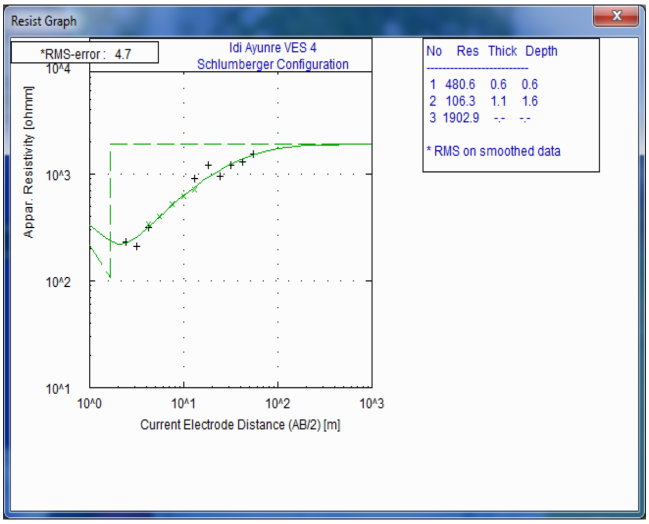
Table 3. Summary of Interpreted VES curves

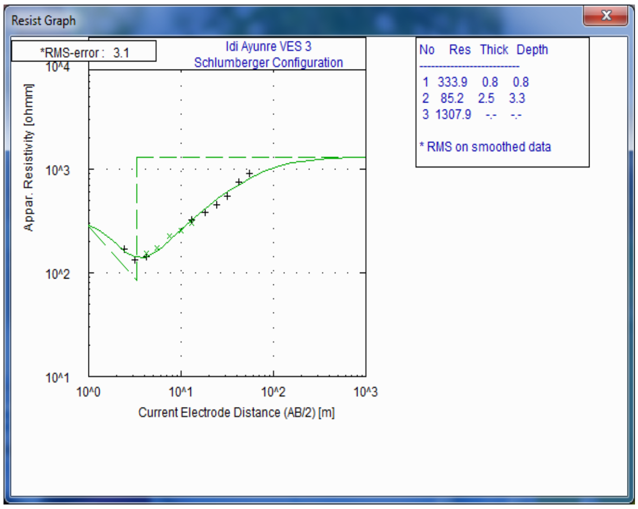
VES STATION	LAYER RESISTIVITY(Ωm)	THICKNESS(m)	DEPTH (m)	CURVE TYPE	R.M.S ERROR	LAYER DESCRIPTION
	155.5	0.4	0.4			Top Soil
19	29.6	2.2	2.5	H	3.9	Weathered Layer
	131.0	-----	----			Bedrock
	589.3	0.9	0.9			Top Soil
20	1264.3	2.6	3.4	K	3.3	Weathered Layer
	281.2	------	-----			Bedrock
	259.4	0.9	0.9			Top Soil
21	243.9	33.5	34.4	H	3.1	Weathered Layer
	4758.7	-----	------			Bedrock

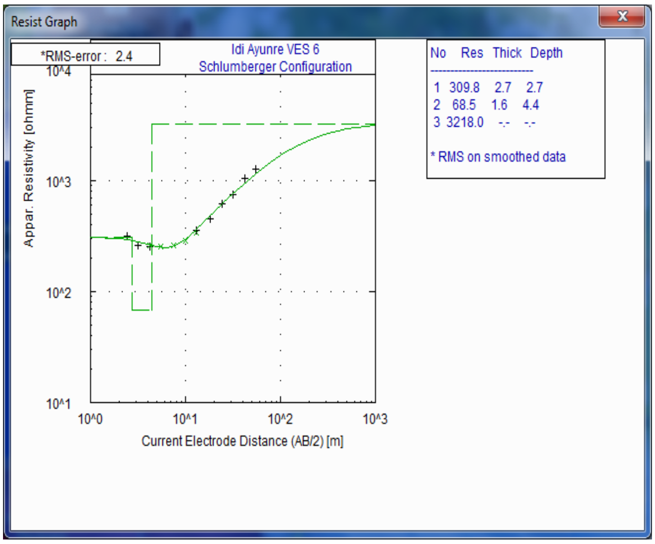
VES graphs for the area under study

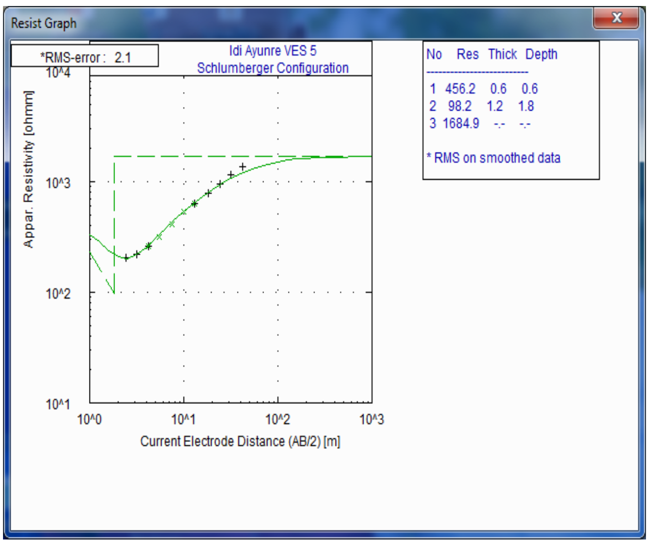


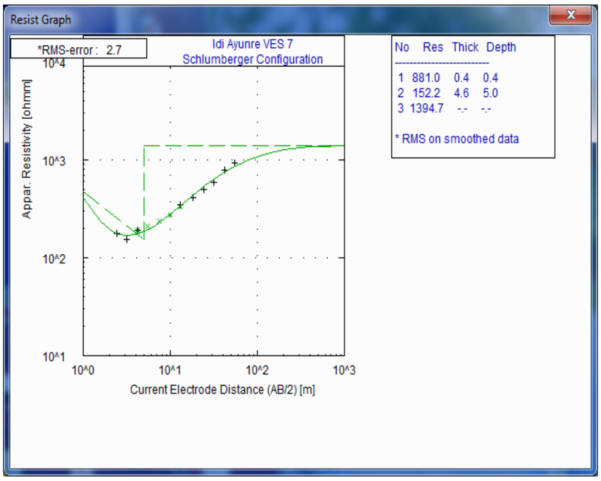








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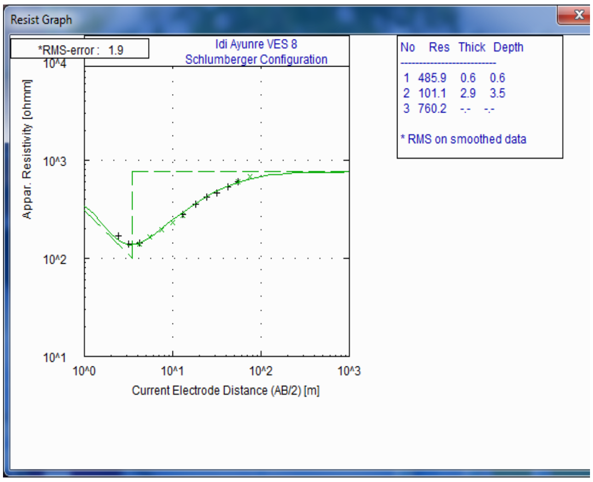
Idi Ayunre VES 7
Schlumberger Configuration
No Res Thick Depth
1 881.0 0.4 0.4
2 152.2 4.6 5.0
3 1394.7 -.- -.-
* RMS on smoothed data
Appar. Resistivity [ohmm]
Current Electrode Distance (AB/2) [m]


Resist Graph
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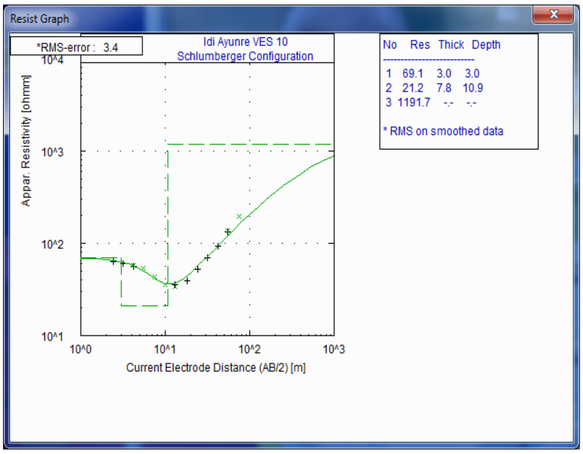
Idi Ayunre VES 8
Schlumberger Configuration
No Res Thick Depth
1 485.9 0.6 0.6
2 101.1 2.9 3.5
3 760.2 -.- -.-
* RMS on smoothed data
Appar. Resistivity [ohmm]
Current Electrode Distance (AB/2) [m]


Resist Graph
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Idi Ayunre VES 10
Schlumberger Configuration
No Res Thick Depth
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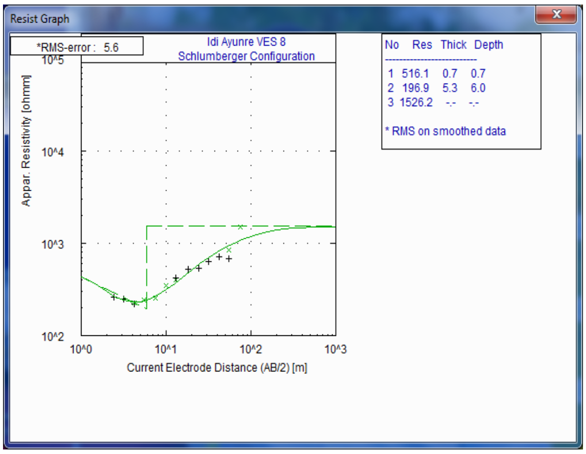
3 1191.7 -.- -.-
* RMS on smoothed data
Appar. Resistivity [ohmm]
Current Electrode Distance (AB/2) [m]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Idi Ayunre VES 8
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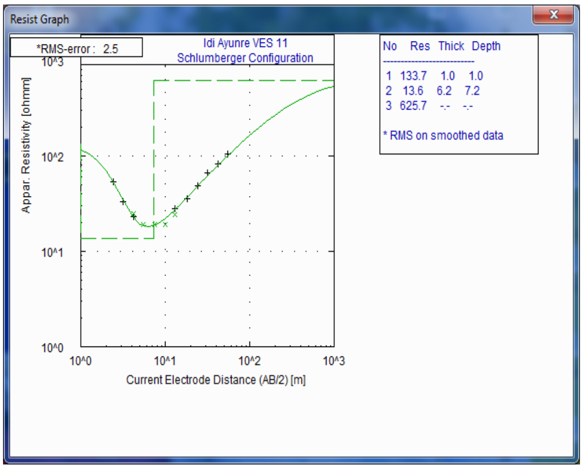
* RMS on smoothed data
Appar. Resistivity [ohmm]
Current Electrode Distance (AB/2) [m]


Resist Graph
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Schlumberger Configuration
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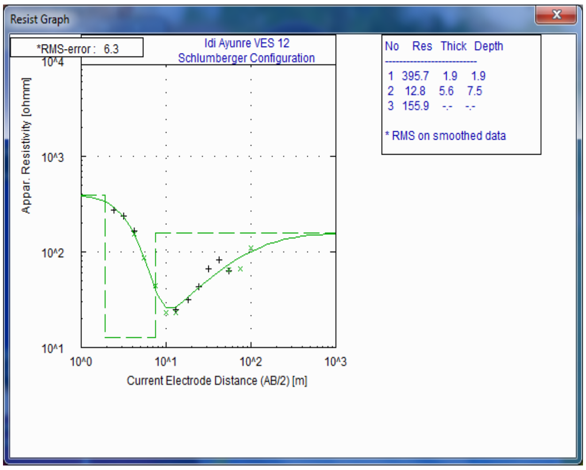
3 625.7 -.- -.-
* RMS on smoothed data
Appar. Resistivity [ohmm]
Current Electrode Distance (AB/2) [m]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Idi Ayunre VES 12
Schlumberger Configuration
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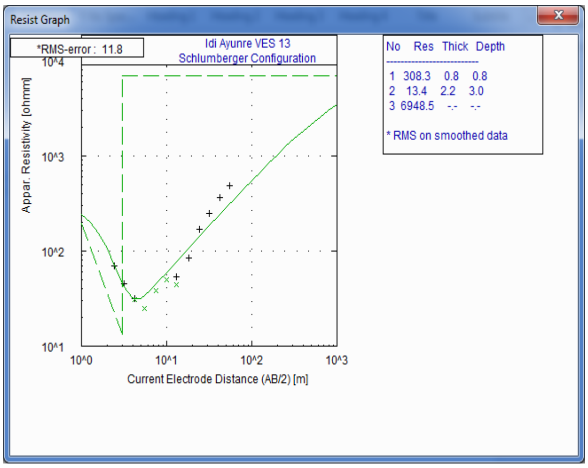
Appar. Resistivity [ohmm]
Current Electrode Distance (AB/2) [m]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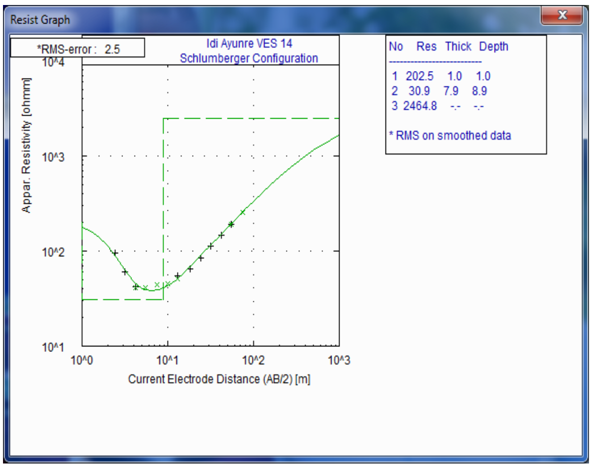
* RMS on smoothed data
Appar. Resistivity [ohmm]
Current Electrode Distance (AB/2) [m]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Idi Ayunre VES 14
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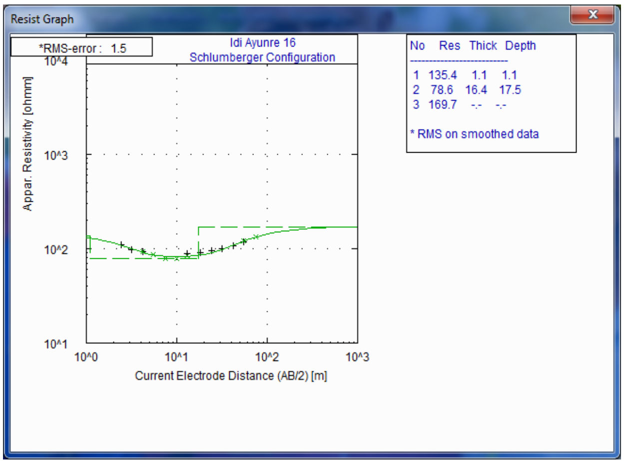
3 2464.8 -.- -.-
* RMS on smoothed data
Appar. Resistivity [ohmm]
Current Electrode Distance (AB/2) [m]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Idi Ayunre 16
Schlumberger Configuration
No Res Thick Depth
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2 78.6 16.4 17.5
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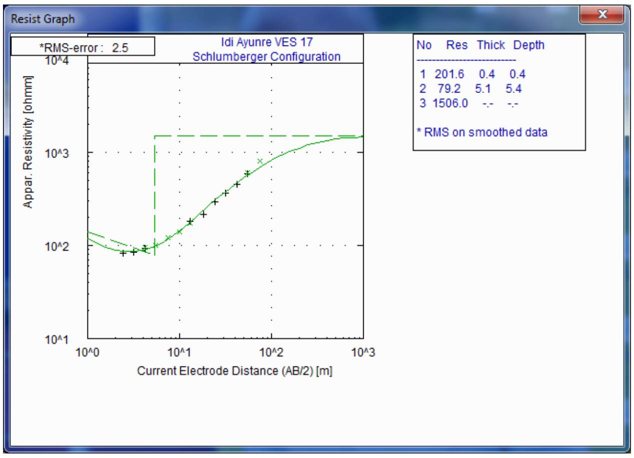
* RMS on smoothed data
Appar. Resistivity [ohmm]
Current Electrode Distance (AB/2) [m]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Idi Ayunre VES 17
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3 1506.0 -.- -.-
* RMS on smoothed data
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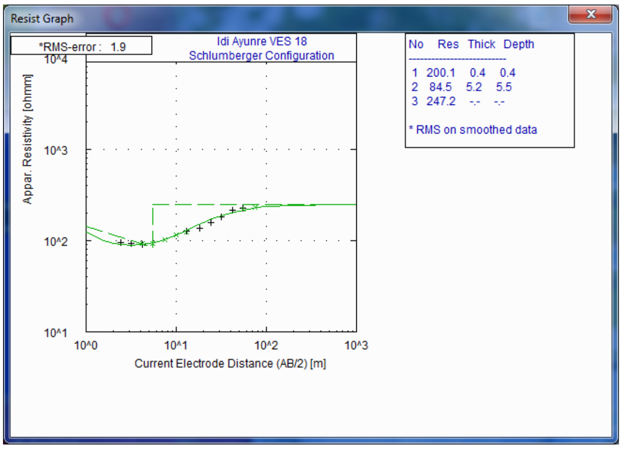
Current Electrode Distance (AB/2) [m]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* RMS on smoothed data
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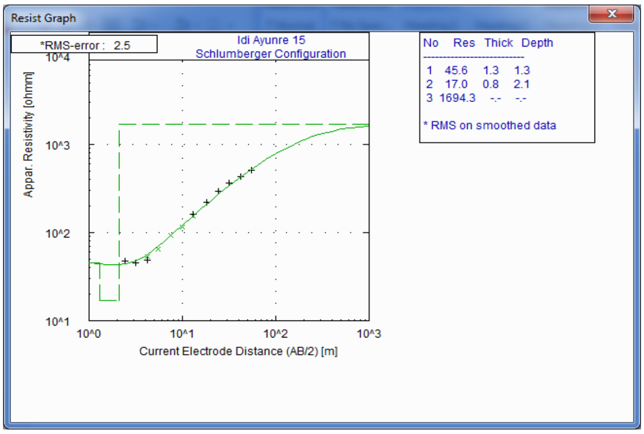
Current Electrode Distance (AB/2) [m]


Resist Graph
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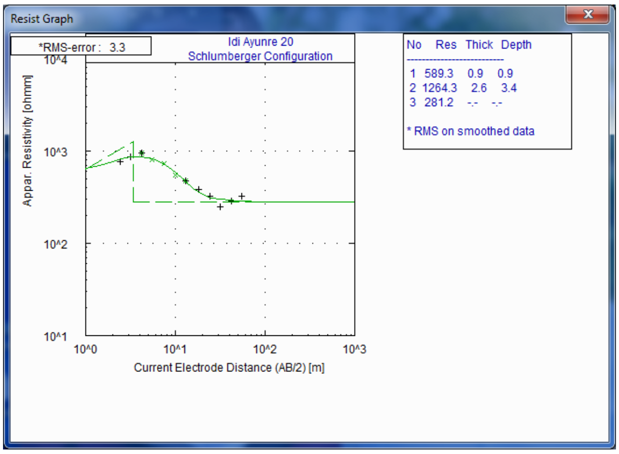
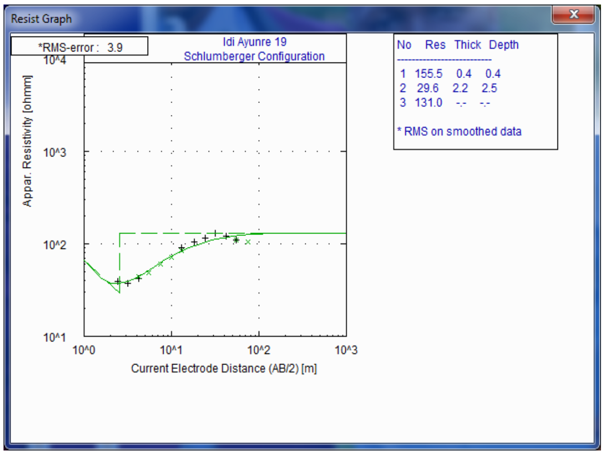
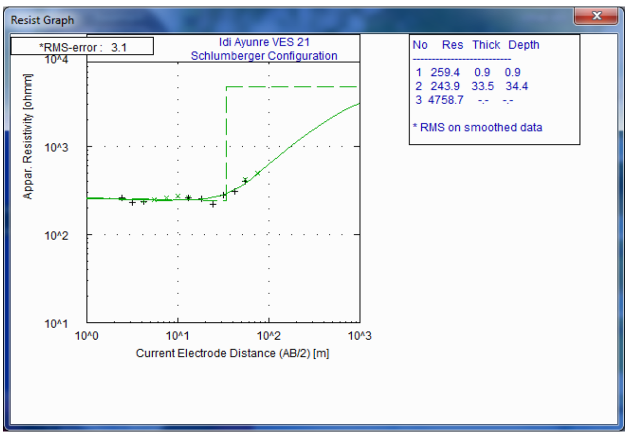
Idi Ayunre 15
Schlumberger Configuration
No Res Thick Depth
1 45.6 1.3 1.3
2 17.0 0.8 2.1
3 1694.3 -.- -.-
* RMS on smoothed data
Appar. Resistivity [ohmm]
Current Electrode Distance (AB/2) [m]


Resist Graph
*RMS-error : 3.3
Idi Ayunre 20
Schlumberger Configuration
No Res Thick Depth
1 589.3 0.9 0.9
2 1264.3 2.6 3.4
3 281.2 -.- -.-
* RMS on smoothed data
Appar. Resistivity [ohmm]
Current Electrode Distance (AB/2) [m]


Resist Graph
*RMS-error : 3.9
Idi Ayunre 19
Schlumberger Configuration
No Res Thick Depth
1 155.5 0.4 0.4
2 29.6 2.2 2.5
3 131.0 -.- -.-
* RMS on smoothed data
Appar. Resistivity [ohmm]
Current Electrode Distance (AB/2) [m]


Resist Graph
*RMS-error : 3.1
Idi Ayunre VES 21
Schlumberger Configuration
No Res Thick Depth
1 259.4 0.9 0.9
2 243.9 33.5 34.4
3 4758.7 -.- -.-
* RMS on smoothed data
Appar. Resistivity [ohmm]
Current Electrode Distance (AB/2) [m]

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