A SURVEY FOR GROUNDWATER AT A LOT AT THE DAN ZARIA ACADEMIC ESTATE, FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, CENTRAL NIGERIA

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Abstract

This study adopted a different approach from the conventional in order to do reconnaissance for a planned survey at the Dan Zaria Academic Estate, Federal University of Technology, Minna, Central Nigeria; the resistivity type of geoelectrical survey in the VES mode employing the Schlumberger array was employed for the reconnaissance and final stages of this investigation. The objective of this study was the search for possible location of aquifer at a defined lot at this estate. This "unconventional" approach was the acquisition of VES data at shallow depths (i.e. progressively down to 10m) over the area of study in order to determine the point of lowest resistivity instead of the approach to determine the lateral variation of resistivity at these shallow depths using the constant separation traversing (CST) method. The point of lowest resistivity thus identified was surveyed to a final depth of 100m. The authors based their interpretation for aquifer prospect at this point on the "Geoexplore Empirical Standardization for Minna Area." Based on this standardization, it is observed that the 30-40m depth interval at this point is the possible groundwater yield zone.

Keywords: Georeferenced; reconnaissance; resistivity; geoelectrical; outcrop

Introduction

Nearly everyone will agree that mankind, at this point in time more than ever before, is saddled with the critical responsibility of sustainably managing the earth's resources that are beginning to show signs of decline. Water is one such very important resource, and thus the search for underground water sources as supplements to the surface water sources to meet the demand of a burgeoning population is central to individual endeavours and government policies. In science, this search is encompassed in the earth sciences' disciplines of geology and applied geophysics. Geophysical prospecting for underground aquifers is often vexed by the problem of data resolution, although the availability of these data in the first place is a function of the availability of modern field surveying equipment which can be expensive indeed. Another constraint is the non-availability of a large spread of data over an area of study that would immensely help to reduce errors in interpretation.

Pre-drilling reconnaissance geophysical surveys for groundwater development are usually carried out by means of the CST mode of the resistivity method, but this study proposed to do the reconnaissance component of the survey using the VES mode of the resistivity method to an initial "probe" depth of 10m. By employing the VES mode of resistivity method for the reconnaissance phase, a greater data field would be created but at attendant high costs. Whilst the factor of cost should be of concern here, its impact has been spread thin for this survey because of the pooling of resources by the crew members involved in this survey. It is expected that the greater data field thus created would help minimize errors in pinpointing the possible location of aquifer within the surveyed lot. This comparatively greater data field would offset the apparent disadvantage of surveying a very limited land area; working within such a very restricted land area spurred the survey team members to adopt the VES method as a reconnaissance tool.

The area of survey is situated on a gentle slope of a seasonal stream bank, sloping gently southward. There is a clear absence of profusion of outcrops in the immediate vicinity of the area of survey, though a prominent porphyritic granite rock mass can be seen forming a truncated ring some distance to the southeast.

Problem Statement

The study group members were tasked to identify aquifer prospect within a 30m x 15m lot that severely limit the building of grid traverses that would have favoured the use of the CST method as a reconnaissance tool.

Objective of Project Work: The objective of this study was the search for the possible location of aquifer at a defined lot at the Dan Zaria Academic Estate.

Limitation of Project Work: From the outset it was recognized that the confining areal size of 30m x 15m that defines individual lots at the area of study would severely limit a desired spread of dataset that ought to be acquired in a typical survey of this nature.

The Geoelectric Survey

Project Location:- The lot surveyed is designated as a perfect rectangle of 30m x 15m dimension and identified by the following georeferenced signature of it's A, B, C, D points: $09^0$30'18.0", $006^0$27'33.5"; $09^0$30'18.5", $006^0$27'33.5"; $09^0$30'18.5", $006^0$27'32.6"; $09^0$30'18.0", $006^0$27'32.6".

The Method Employed: The geophysical work carried out here is based on electrical resistivity survey using the vertical electrical sounding (VES) technique (Kearey and Brooks, 1988; Parasnis, 1986). Generally, an electrical resistivity method involves the artificial introduction of current into the ground through point electrodes. Potentials are subsequently measured at other electrodes in the vicinity of the current flow. By this means, it is then possible to measure or determine an effective or apparent resistivity of the subsurface. Low resistivity in a given area is a likely indicator of the presence of groundwater (Ako and Olorunfemi, 1982; Bonde, 1997; Dangana, 2002; Gana, 1995; Okwueze and Ezeanyi, 1985; Okwueze et al, 1981; Olorunfemi and Fasuyi, 1993; Olorunfemi and Okhue, 1992; Shuaibu et al, 2004). The Schlumberger array or configuration was employed in the VES investigation of the area surveyed.

Data Collection: In order to define a grid pattern at 10m separation of traverse lines, the northernmost beacon of the property was designated longitudinal traverse 1 number 1 (LT1-1) at the following co-ordinate: $09^0$30'18.5"; $006^0$27'33.5". LT1-2 was exactly 10m to the south of LT1-1; LT2-1 was exactly 10m to the west of LT1-1; LT2-2 was exactly 10m to the south of LT2-1 and so on until the final point on the grid was LT4-2 at the following co-ordinate: $09^0$30'17.9"; $006^0$27'32.6". Thus 8 VES points were stipulated for the grid for the reconnaissance phase, and the survey was implemented on Saturday 9th March, 2013. The final phase of the survey was implemented on Monday 22nd March, 2013. The ABEM Terrameter SAS 4000 was employed for this survey.

Data Presentation

The ABEM Terrameter SAS 4000 measures the potential due to an appropriately selected (else the equipment automatically selects a default current value) current value and displays the computed value of resistance. The raw data recorded is the resistance (R) of the ground and the half-current electrode separation. This resistance multiplied by the geometrical configuration factor gives the apparent resistivity (ρ) of the ground. It follows therefore, that the value of the apparent resistivity obtained depends on electrode array and the distribution of the resistivity in the earth. The results for the reconnaissance phase of this survey are presented as Tables 1 to 8.

Table 1: Geoelectrical Data Record Sheet for LT1-1

TYPE OF SURVEY:... Resistivity....MODE:.... Vertical Electrical Sounding... ARRAY: .....Schlumberger.....

PLACE:...Dan Zaria.... WEATHER:...Sunny..... EQUIPMENT:.ABEM Terrameter SAS 4000

LOCATION: (i) N:.09^{0}30'18.5".....(ii) E:.006^{0}27'33.5".....ELEVATION:...219m.....

OPERATOR: G.O. JAMES.RECORDER: G.O. JAMES DATE:...9th March 2013..... TIME:...11:06a.m....

LONGITUDINAL TRAVERSE DESIGNATION:...LT1-1..... GPS UNIT:... Garmin GPSmap76.....

AB/2	MN/2	GEOM. FACTOR, K	RESISTANCE	STANDARD DEVIATION	CURRENT (I)	STACKS	RESISTIVITY
			-670.07mΩ	2.44%	10mA	4	-1.5815Ωm
1	.50	2.36					
			5.1774Ω	0.018%	10mA	2	61.093 Ωm
2	.50	11.8					
			823.19mΩ	0.017%	10mA	2	22.8847Ωm
3	.50	27.8					
			329.48mΩ	0.379%	10mA	2	25.6335Ωm
5	.50	77.8					
			279.68mΩ	2.24%	10mA	4	31.3242Ωm
6	.50	112					
			607.14mΩ	8.14%	10mA	4	33.3927Ωm
6	1.00	55					
			574.76mΩ	6.65%	10mA	4	56.9012Ωm
8	1.00	99					
			564.91mΩ	27.7%	2mA	4	88.1260Ωm
10	1.00	156					
			961.41mΩ	1.07%	5mA	4	56.6270Ωm
10	2.50	58.9					

Table 2: Geoelectrical Data Record Sheet for LT1-2

TYPE OF SURVEY:... Resistivity....MODE:.... Vertical Electrical Sounding... ARRAY: .....Schlumberger.....

PLACE:...Dan Zaria.... WEATHER:...Sunny..... EQUIPMENT:.ABEM Terrameter SAS 4000

LOCATION: (i) N:.09^{0}30'18.2".....(ii) E:.006^{0}27'33.5".....ELEVATION:...222m.....

OPERATOR: G.O. JAMES.RECORDER: G.O. JAMES ...DATE:...9th March 2013..... TIME:...11:21a.m....

LONGITUDINAL TRAVERSE DESIGNATION:...LT1-2..... GPS UNIT:... Garmin GPSmap76.....

AB/2	MN/2	GEOM. FACTOR, K	RESISTANCE	STANDARD DEVIATION	CURRENT (I)	STACKS	RESISTIVITY
			126.79Ω	0.031%	10mA	2	299.2244Ωm
1	.50	2.36					
			7.2900Ω	0.053%	10mA	2	86.0220Ωm
2	.50	11.8					
			1.6569Ω	0.345%	5mA	2	46.0618Ωm
3	.50	27.8					

			779.65mΩ	2.47%	10mA	4	60.6568Ωm
5	.50	77.8					
			576.27mΩ	0.942%	10mA	2	64.5422Ωm
6	.50	112					
			951.31mΩ	0.221%	10mA	2	52.3221Ωm
6	1.00	55					
			632.28mΩ	0.231%	10mA	2	62.5957Ωm
8	1.00	99					
			451.55mΩ	2.42%	10mA	4	70.4418Ωm
10	1.00	156					
			1.3024Ω	0.397%	10mA	2	76.7114Ωm
10	2.50	58.9					

Table 3: Geoelectrical Data Record Sheet for LT2-1

TYPE OF SURVEY:... Resistivity....MODE:.... Vertical Electrical Sounding... ARRAY: .....Schlumberger.....

PLACE:...Dan Zaria.... WEATHER:...Sunny..... EQUIPMENT:.ABEM Terrameter SAS 4000

LOCATION: (i) N:.$09^0$30'18.5".....(ii) E:.$006^0$27'33.2".....ELEVATION:...222m.....

OPERATOR: G.O. JAMES.RECORDER: G.O. JAMES DATE:...9th March 2013..... TIME:...12:36p.m....

LONGITUDINAL TRAVERSE DESIGNATION:...LT2-1..... GPS UNIT:... Garmin GPSmap76.....

AB/2	MN/2	GEOM. FACTOR, K	RESISTANCE	STANDARD DEVIATION	CURRENT (I)	STACKS	RESISTIVITY
			98.813Ω	0.00%	10mA	2	233.1987Ωm
1	.50	2.36					
			7.2609Ω	0.034%	10mA	2	85.6786Ωm
2	.50	11.8					
			1.5055Ω	0.028%	10mA	2	41.8529Ωm
3	.50	27.8					
			497.39mΩ	0.108%	2mA	2	38.6969Ωm
5	.50	77.8					
			309.39mΩ	0.819%	10mA	2	34.6517Ωm
6	.50	112					
			1.1497Ω	0.744%	10mA	2	63.2335Ωm
6	1.00	55					
			2.344Ω	1.60%	2mA	4	232.056Ωm
8	1.00	99					
			3.056Ω	0.943%	2mA	2	476.736Ωm
10	1.00	156					
			1.3420Ω	0.439%	2mA	2	79.0438Ωm
10	2.50	58.9					

Table 4: Geoelectrical Data Record Sheet for LT2-2

TYPE OF SURVEY:... Resistivity....MODE:.... Vertical Electrical Sounding... ARRAY: .....Schlumberger.....

PLACE:...Dan Zaria.... WEATHER:...Sunny..... EQUIPMENT:.ABEM Terrameter SAS 4000

LOCATION: (i) N:.09^{0}30'18.2".....(ii) E:.006^{0}27'33.2".....ELEVATION:...221m.....

OPERATOR: G.O. JAMES.RECORDER: G.O. JAMES DATE:...9th March 2013..... TIME:...12:45p.m....

LONGITUDINAL TRAVERSE DESIGNATION:...LT2-2..... GPS UNIT:... Garmin GPSmap76.....

AB/2	MN/2	GEOM. FACTOR, K	RESISTANCE	STANDARD DEVIATION	CURRENT (I)	STACKS	RESISTIVITY
1	.50	2.36	39.995Ω	0.011%	10mA	2	94.3882Ωm
2	.50	11.8	-3.943Ω	0.217%	10mA	2	-46.5321Ωm
3	.50	27.8	-6.7169Ω	0.000%	10mA	2	-186.7298Ωm
5	.50	77.8	-7.7849Ω	0.018%	10mA	2	-605.6652Ωm
6	.50	112	-8.1631Ω	0.00%	10mA	2	-914.2672Ωm
6	1.00	55	-1.0363Ω	0.196%	10mA	2	-56.9965Ωm
8	1.00	99	-1.4544Ω	0.061%	10mA	2	-143.9856Ωm
10	1.00	156	-1.9730Ω	4.88%	2mA	4	-307.788Ωm
10	2.50	58.9	405.38mΩ	3.01%	2mA	4	23.8769Ωm

Table 5: Geoelectrical Data Record Sheet for LT3-1

TYPE OF SURVEY:... Resistivity....MODE:.... Vertical Electrical Sounding... ARRAY: .....Schlumberger.....

PLACE:...Dan Zaria.... WEATHER:...Sunny..... EQUIPMENT:.ABEM Terrameter SAS 4000

LOCATION: (i) N:.09^{0}30'18.5".....(ii) E:.006^{0}27'32.9".....ELEVATION:...222m.....

OPERATOR: G.O. JAMES.RECORDER: G.O. JAMES DATE:...9th March 2013..... TIME:...1:00p.m....

LONGITUDINAL TRAVERSE DESIGNATION:...LT3-1..... GPS UNIT:... Garmin GPSmap76.....

AB/2	MN/2	GEOM. FACTOR, K	RESISTANCE	STANDARD DEVIATION	CURRENT (I)	STACKS	RESISTIVITY
1	.50	2.36	118.26Ω	0.002%	5mA	2	279.0936Ωm
2	.50	11.8	2.3596Ω	2.215%	10mA	2	27.8433Ωm
3	.50	27.8	1.0056Ω	0.188%	10mA	2	27.9557Ωm
5	.50	77.8	39.377mΩ	228%	2mA	4	3.0635Ωm
			424.82mΩ	0.428%	10mA	2	47.5798Ωm

6	.50	112	735.07mΩ	0.53%	10mA	2	40.4288Ωm
6	1.00	55	496.26mΩ	48.5%	2mA	4	49.1297Ωm
8	1.00	99	328.03mΩ	32.7%	10mA	4	51.1711Ωm
10	1.00	156	970.32mΩ	1.62%	10mA	4	57.1518Ωm
10	2.50	58.9					

Table 6: Geoelectrical Data Record Sheet for LT3-2

TYPE OF SURVEY:... Resistivity....MODE:.... Vertical Electrical Sounding... ARRAY: .....Schlumberger.....

PLACE:...Dan Zaria.... WEATHER:...Sunny..... EQUIPMENT:.ABEM Terrameter SAS 4000

LOCATION: (i) N:.09^{0}30'18.2".....(ii) E:. 006^{0}27'32.9".....ELEVATION:...221m.....

OPERATOR: G.O. JAMES.RECORDER: G.O. JAMES DATE:...9th March 2013..... TIME:...1:15p.m....

LONGITUDINAL TRAVERSE DESIGNATION:...LT3-2..... GPS UNIT:... Garmin GPSmap76.....

AB/2	MN/2	GEOM. FACTOR, K	RESISTANCE	STANDARD DEVIATION	CURRENT (I)	STACKS	RESISTIVITY
1	.50	2.36	32.33Ω	0.75%	10mA	2	76.2988Ωm
2	.50	11.8	2.3116Ω	0.87%	10mA	4	27.2769Ωm
3	.50	27.8	1.0155Ω	5.52%	10mA	2	25.2309Ωm
5	.50	77.8	523.69mΩ	0.72%	10mA	4	40.7431Ωm
6	.50	112	335.67mΩ	35.60%	10mA	4	37.595Ωm
6	1.00	55	819.70mΩ	0.00%	10mA	4	45.0835Ωm
8	1.00	99	518.97mΩ	1.19%	10mA	2	51.378Ωm
10	1.00	156	732.77mΩ	2.43%	10mA	4	114.3121Ωm
10	2.50	58.9	1.4022Ω	0.69%	2mA	2	82.5896Ωm

Table 7: Geoelectrical Data Record Sheet for LT4-1

TYPE OF SURVEY:... Resistivity....MODE:.... Vertical Electrical Sounding... ARRAY: .....Schlumberger.....

PLACE:...Dan Zaria.... WEATHER:...Sunny..... EQUIPMENT:.ABEM Terrameter SAS 4000

LOCATION: (i) N:.09^{0}30'18.5".....(ii) E:.006^{0}27'32.6".....ELEVATION:...222m.....

OPERATOR: G.O. JAMES.RECORDER: G.O. JAMES DATE:...9th March 2013..... TIME:...1:30p.m....

LONGITUDINAL TRAVERSE DESIGNATION:...LT4-1..... GPS UNIT:... Garmin GPSmap76.....

AB/2	MN/2	GEOM. FACTOR,	RESISTANCE	STANDARD DEVIATION	CURRENT (I)	STACKS	RESISTIVITY

		K					
			57.307Ω	0.070%	10mA	2	135.2445Ωm
1	.50	2.36					
			3.6325Ω	0.211%	10mA	2	42.8635Ωm
2	.50	11.8					
			1.4946Ω	1.46%	5mA	4	41.5499Ωm
3	.50	27.8					
			664.11mΩ	1.10%	2mA	4	51.6678Ωm
5	.50	77.8					
			490.47mΩ	0.138%	10mA	2	54.9326Ωm
6	.50	112					
			1.1446Ω	9.91%	10mA	4	62.9530Ωm
6	1.00	55					
			746.20mΩ	0.096%	10mA	2	73.8738Ωm
8	1.00	99					
			582.58mΩ	0.478%	10mA	2	90.8825Ωm
10	1.00	156					
			1.3506Ω	0.106%	10mA	2	79.5503Ωm
10	2.50	58.9					

Table 8: Geoelectrical Data Record Sheet for LT4-2

TYPE OF SURVEY:... Resistivity....MODE:.... Vertical Electrical Sounding... ARRAY: .....Schlumberger.....

PLACE:...Dan Zaria.... WEATHER:...Sunny..... EQUIPMENT:.ABEM Terrameter SAS 4000

LOCATION: (i) N:..09^{0}30'18.2".....(ii) E:. 006^{0}27'32.6".....ELEVATION:...219m.....

OPERATOR: G.O. JAMES.RECORDER: G.O. JAMES DATE:...9th March 2013..... TIME:...1:45p.m....

LONGITUDINAL TRAVERSE DESIGNATION:...LT4-2..... GPS UNIT:... Garmin GPSmap76.....

AB/2	MN/2	GEOM. FACTOR, K	RESISTANCE	STANDARD DEVIATION	CURRENT (I)	STACKS	RESISTIVITY
			32.327Ω	0.004%	10mA	2	76.2912Ωm
1	.50	2.36					
			2.7192Ω	0.38%	10mA	2	32.0866Ωm
2	.50	11.8					
			1.2664Ω	0.003%	10mA	2	35.2059Ωm
3	.50	27.8					
			669.67mΩ	0.107%	10mA	2	52.1003Ωm
5	.50	77.8					
			414.42mΩ	0.0179%	10mA	2	46.415Ωm
6	.50	112					
			802.87mΩ	0.28%	10mA	2	44.1578Ωm
6	1.00	55					
			808.40mΩ	0.515%	5mA	2	80.0316Ωm
8	1.00	99					
			515.02mΩ	0.63%	10mA	2	80.3431Ωm
10	1.00	156					
			1.1109Ω	0.450%	10mA	2	65.432Ωm
10	2.50	58.9					

Data Analysis

Reconnaissance VES Survey: The objective of this initial phase was to identify the VES point having the lowest resistivity at the 10m depth mark from amongst the eight VES stations of Tables 1-8. At a value of 23.8769Ωm, VES point LT2-2 was selected for the "deep-probe" stage down to a depth of 100m; the result of this final "deep-probe" survey is shown as Table 9.

Table 9: Deep-Probe Geoelectrical Data Record Sheet for LT2-2

TYPE OF SURVEY:... Resistivity....MODE:.... Vertical Electrical Sounding... ARRAY: .....Schlumberger.....

PLACE:...Dan Zaria.... WEATHER:...Mild..... EQUIPMENT:.ABEM Terrameter SAS 4000

LOCATION: (i) N:.$09^0$30'18.2".....(ii) E:.$006^0$27'33.2".....ELEVATION:...221m.....

OPERATOR: G.O. JAMES.RECORDER: G.O. JAMES DATE:...22th March 2013..... TIME:...9:45a.m....

LONGITUDINAL TRAVERSE DESIGNATION:...LT2-2..... GPS UNIT:... Garmin GPSmap76.....

AB/2	MN/2	GEOM. FACTOR, K	RESISTANCE	STANDARD DEVIATION	CURRENT (I)	STACKS	RESISTIVITY
			54.641Ω	0.031%	10mA	2	128.9527Ωm
1	.50	2.36					
			3.5944Ω	0.159%	10mA	2	42.4139Ωm
2	.50	11.8					
			1.3958Ω	0.204%	10mA	2	38.8032Ωm
3	.50	27.8					
			638.41mΩ	0.670%	10mA	2	49.6683Ωm
5	.50	77.8					
			467.96mΩ	0.000%	5mA	2	52.4115Ωm
6	.50	112					
			1.8113Ω	0.315%	5mA	2	99.6215Ωm
6	1.00	55					
			1.1296Ω	1.98%	2mA	4	111.8304Ωm
8	1.00	99					
			827.00mΩ	0.000%	10mA	2	129.012Ωm
10	1.00	156					
			1.1044Ω	0.129%	10mA	2	65.0492Ωm
10	2.50	58.9					
			654.24mΩ	0.071%	10mA	2	89.6309Ωm
15	2.50	137					
			480.33mΩ	0.007%	10mA	2	117.6809Ωm
20	2.50	245					
			348.82mΩ	0.092%	10mA	2	196.0368Ωm
30	2.50	562					
			247.65mΩ	0.101%	10mA	2	247.8977Ωm
40	2.50	1001					
			730.18mΩ	0.781%	10mA	2	235.8481Ωm
40	7.50	323					
			815.91mΩ	0.175%	10mA	2	417.7459Ωm
50	7.50	512					
			554.70mΩ	9.28%	10mA	4	411.5874Ωm
60	7.50	742					
			535.54mΩ	5.65%	10mA	4	543.0376Ωm
70	7.50	1014					
			330.00mΩ	7.41%	10mA	4	438.57Ωm
80	7.50	1329					

			682.44mΩ	6.544%	10mA	2	441.5386Ωm
80	15.00	647					
			604.42mΩ	0.797%	10mA	2	498.6465Ωm
90	15.00	825					
100	15.00	1024	557.85mΩ	0.806%	10mA	2	571.2384Ωm

Final VES Survey: The field curve for Table 9 was obtained by plotting the apparent resistivity against half-current electrode spacing by means of the WinResist® plot, see Fig.1.

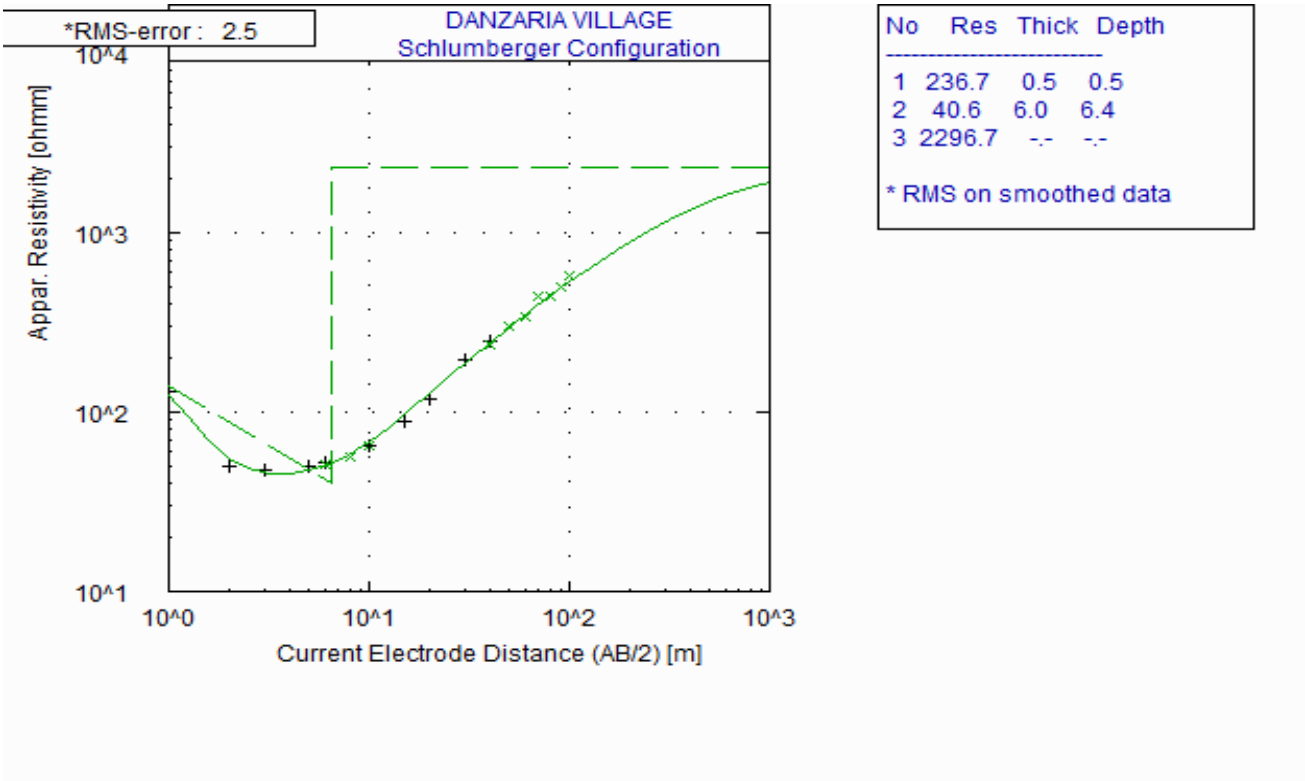

Fig.1: WinResist® plot for Table 9

Discussion and Conclusion

The Continuous Variation of Resistivity with Depth: A continuous variation of resistivity with depth curve is easily derived from multilayer step-function curve by drawing a curve that passes through the logarithmic midpoint of each vertical and horizontal line on the multilayer step function model. In view of the fact that the layer depths are logarithmically closely-shaped, the derived continuous variation of resistivity with depth model is equivalent to the original model; see Fig.1.

Vertical Electrical Depth Sounding Result: The derived continuous variation of resistivity with depth model indicates that a three-layer sequence was identified for VES LT2-2. The authors have based their interpretation for aquifer prospect at VES LT2-2 on an informal and fairly successful empirical rule to determine the likely presence of groundwater in the Minna basement complex geological province; the authors have taken much liberty here to call this empirical rule "Geoexplore Empirical Standardization for Minna Area." Based on this standardization, which states that ohmic resistance values of less than or equal to 0.3Ω at the 20m depth or greater (or, in resistivity terms, between 200Ωm and 300Ωm at the 20m depth and less than 200Ωm at depths greater than 20m) is indicative of possible groundwater prospect, it is observed that the 30-40m depth interval for LT2-2 fits the mark very well at optimum field current input with very minimum standard deviation. Thus, the authors conclude that the "10m

window" between the 30m depth mark and the 40m depth mark is the possible groundwater yield zone for LT2-2.

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