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Research Article

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Employing DC Resistivity Method for Hydrogeological Analysis of Zuma II, a VES Approach

Dikedi PN[1]*, Sule AU[1] and Adetoyinbo AA[2]

Abstract

This research work employs the DC Resistivity method for Hydrogeological analysis in Veritas University, Zuma II, Bwari Area Council, Abuja, FCT, Nigeria. The work attempts to tackle the immense water shortage crisis within the University, this work also, attempts to provide access to stratigraphic information and to assist groundwater development for the region.

Schlumberger array and electrical sounding technique are adopted for subsurface delineation. Eleven resistivity profile graphs generated from tabled data are presented by employing the Winresist software and Microsoft excel.

The outcome of this investigation revealed four spots with good potentials for ground water; these points are located within the fifth and third layers on 9.28498°N, 7.41875°E (VES 1); 9.28515°N, 7.41789°E (VES 5); 9.28437°N, 7.41793°E (VES 8); 9.28394°N, 7.41792°E (VES10).

Furthermore, the outcome of this work revealed the lithology of the region investigated. Five distinct layers of varying thicknesses and depths were displayed: Top soil, Clay, Sandy clay, Fractured and Basement Rocks. From the collated readings, the derived average thicknesses of topsoil, sandy clay and clay are 0.8 m, 10.2 m and 7.06 m respectively.

Keywords

Winresist; Delineation; Schlumberger; Electrical sounding

Introduction

General introduction

Within Zuma II, and indeed the Federal Capital Territory (FCT), the occurrence of groundwater is a function of overburden thickness, the type, composition and texture of rock fragments. Aquifers do exist and are naturally recharged by rainfall. Additionally, they are artificially recharged by lower Usumanu and Jabi dams. It is worth noting that, some Villagers extract groundwater from the overburden through hand-dug wells. Most of the boreholes are located on the overburden aquifer-depths to bedrock to vary from 0 to about 73 m with an average depth of 30 m; groundwater flows downhill, arriving in valleys and river channels.

*Corresponding author: Dikedi PN, Department of Pure and Applied Physics, College of Natural and Applied Sciences, Veritas University, Abuja, FCT, Nigeria, Tel: +2349021374449; E-mail: wisdominstitute@rocketmail.com

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Quantity of water in the region's water table varies from place to place with the water level rising during the rainy season and falling during the dry season resulting in seasonal fluctuation in the actual volume of water in storage. The various aquifer parameters obtained from developed boreholes sited in adjacent areas show that the area has low to moderate water yielding properties, maximum being 18 m^3/hr. The yields of boreholes vary from one rock type to another. Garki, Maitama and Wuse have low water yields-these regions are dominated with migmatites and schists earth materials, areas dominated by granite and gneisses have higher water yields. Wherever the weathered basement is deep and underlain by highly fractured bedrock, borehole yields are generally high. Boreholes were drilled and completed into these deep fractured basement rocks located at the presidential villa and Nicon Noga Hilton Hotel, after an electrical sounding was conducted. These rocks had depths of 100 m each and yielded 40 m^3/hr and 21.6 m^3/hr respectively with drawdowns of 26.5 m and 46.5 m respectively after 120 minutes of pumping [1].

Zuma II is the area under investigation. Bwari, is the region harboring the area of investigation (Figure 1).

Past research work on hydrogeology

Past hydrogeological analysis have been conducted by Clark and Fritz, Weiß, White and White, Yoram, Reid and Dunne, Barnet et al., Goldscheider, Paniconi and Putti, Vogel, Molz and Boman [2-11]. It is well reported that the two major elements of a hydro-geological survey are water depth and position [12]. Zuma II is located within Bwari in FCT. The Zuma settlement is rich in Muscovites, biotites, gneisses and Migmatites. This settlement is surrounded by granitic mountains dotted all over. Figures 1-3 are geologic maps of the FCT m Bwari and Zuma II-The study area.

Past research work on DC resistivity

DC resistivity method was first used in early 1900 and has been in common use since 1970 in mineral and groundwater exploration. As established by Doehring et al. [13], the electrical resistivity method was employed in the geophysical investigation for groundwater in the area around Bauchi town around the Barkumbo valley, Gudum Hill area and Tabari Valley. It successfully revealed highly decayed/weathered basement material leading to the suggestion that a part of the Barkumbo valley is best suited for a borehole program [14]. There was yet another geo-electric investigation of ground water resources at Onibode area investigated by Oyedele et al. [15], near Abeokuta south western Nigeria; probable drilling zones of water supply for boreholes were identified beneath a layer of fractured basement rock around the area.

By employing the DC resistivity method, Dikedi [16] successfully delineated a survey location which demonstrated the potential for groundwater. Furthermore, Alkali and Shemang et al. [17,18] confirmed the DC resistivity method, a reputable method for ground water search with good success-the method has been in vogue. This method is least expensive-owing to these reasons the DC method has been selected as my choice method.

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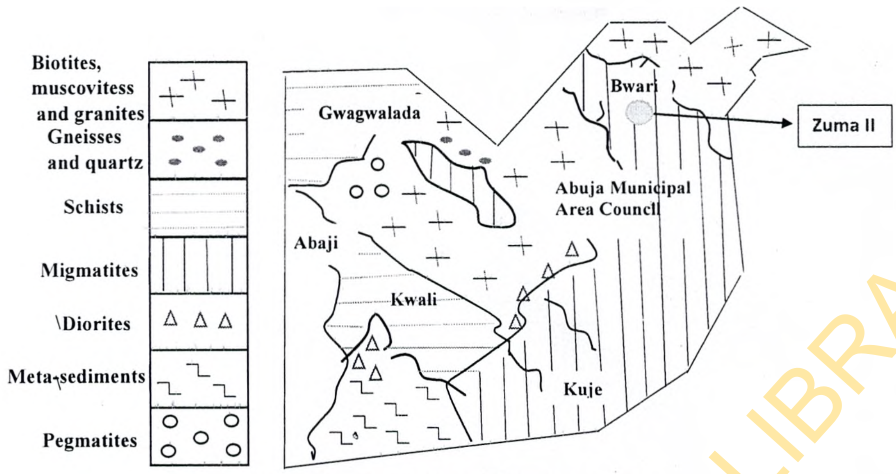

Figure 1: The Geologic Map of FCT and study area.

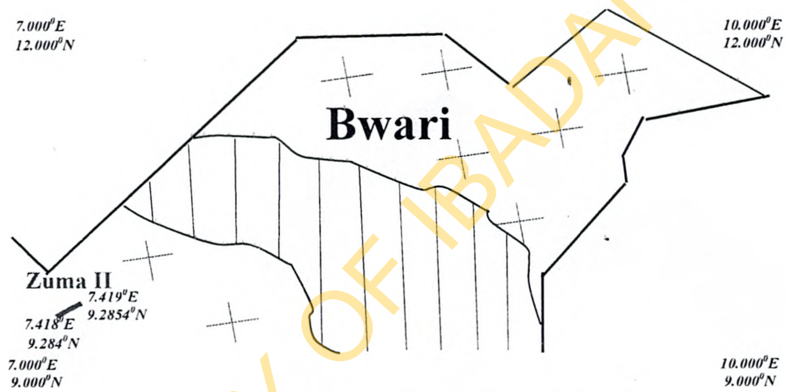

Figure 2: The Geologic Map of Bwari and Zuma II (Study area).

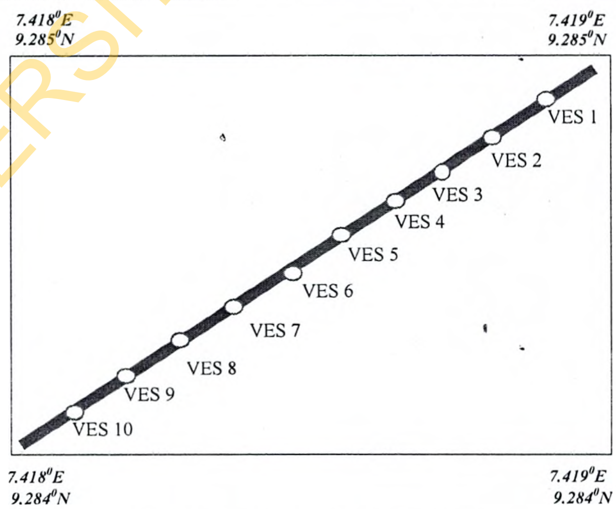

Figure 3: A schematic of location of study area.

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Methods

Research aims

The aim of this research is to delineate areas with good potential for groundwater, provide access to stratigraphic units/lithology information and hydro-geophysical data for future works.

Adopted array

Schlumberger Array was adopted in this research work. The Geometric factor (G-Factor) is presented as equation 1.

$$K = 2\Pi\left[\left(\frac{1}{AM}-\frac{1}{MB}\right)-\left(\frac{1}{AM}-\frac{1}{NB}\right)\right]^{-1} \quad (1)$$

This represents the general relation for the G-factor of any array thus, the G-factor is indeed unique to the array being used below is the derivation of the geometric factor of the Schlumberger array (Equation 2-8).

$$K = 2\Pi\left[\frac{1}{AM}-\frac{1}{MB}-\frac{1}{AN}+\frac{1}{NB}\right]^{-1} \quad (2)$$

$$K = 2\Pi\left[\frac{1}{\frac{l}{2}-\frac{a}{2}}-\frac{1}{\frac{l}{2}+\frac{a}{2}}-\frac{1}{\frac{l}{2}+\frac{a}{2}}+\frac{1}{\frac{l}{2}-\frac{a}{2}}\right]^{-1} \quad (3)$$

$$K = 2\Pi\left[\frac{\left(\frac{l}{2}+\frac{a}{2}\right)-\left(\frac{l}{2}-\frac{a}{2}\right)-\left(\frac{l}{2}-\frac{a}{2}\right)+\left(\frac{l}{2}+\frac{a}{2}\right)}{\left(\frac{l}{2}-\frac{a}{2}\right)\left(\frac{l}{2}+\frac{a}{2}\right)}\right]^{-1} \quad (4)$$

$$K = 2\Pi\left|\frac{2a}{\left(\frac{l}{2}\right)^2-\left(\frac{a}{2}\right)^2}\right| \quad (5)$$

$$K = 2\Pi\left|\frac{2a}{\left(\frac{l}{2}\right)^2-\left(\frac{a}{2}\right)^2}\right| \quad (6)$$

$$K = 2\Pi\left[\frac{2a}{\left(\frac{l}{2}\right)^2-\left(\frac{a}{2}\right)^2}\right]^{-1} \quad (7)$$

$$K = \frac{2\Pi}{2a}\left[\left(\frac{l}{2}\right)^2-\left(\frac{a}{2}\right)^2\right] \quad (8)$$

The Geometric factor of Schlumberger can therefore be presented as follows:

$$K = \frac{2\Pi}{2a}\left[\left(\frac{l}{2}\right)^2-\left(\frac{a}{2}\right)^2\right]$$

Field procedure

After an exhaustive view of the survey area to comprehend its topography, two potential electrodes, 0.5m apart were planted into the ground. Thereafter, two current electrodes were collinearly planted with the potential electrodes; current electrodes were separated, by distance of 2.50 m. Subsequent inter-electrode separations of 2.6 m, 3.6 m, 4.8 m, 6.4 m, 13 m, 15 m, 20 m, 26 m, 36 m, 48 m, 64 m, 84 m, 130 m, 150 m and 200 m were adopted for the two current electrodes. In the course of varying these current electrodes the inter-electrode separation of 0.5 m, 2 m, 5.0 m and 10 m were adopted for potential electrodes. It is important to note that the potential electrodes were moved less frequently compared to the current electrodes. These set of readings were tabulated under VES 1 caption. The next point along a straight profile was chosen 25m away from the initial point the above procedures were repeated and tabulated under the caption VES 2.

Further procedural repetitions were made and captioned VES 3, VES 4, VES 5, VES 6, VES 7, VES 8, VES 9 and VES 10 each consecutive VES points was separated by 25 m a distance of 225 m were covered along the profile in terms of separation between VES 1 and VES 10. At the end of these calculations, 10 tables of reading were created in all.

Employing the Winesist software and excel program, 11 graphs were plotted out of which 10 graphs were apparent resistivity profile graphs with apparent resistivity on the vertical axis and current separation on the horizontal axis. The 11th graph plotted described how depth to and arbitrary layer varied with current electrode separation (Figure 4).

Results

Tables 1-3 are tabled summaries of VES 5, 8 and 10 interpretations. They were selected from ten tables of VES interpretations because they harbored interpretations for good aquifer potentials (Table 4).

Discussions

Ten VES were conducted within the survey area (Figure 5). Outcome from results reveal that VES 1 interpretation displays five layers with three distinct probable lithology such as Topsoil, Sandy clay and Fractured Basement. Results further show that at a depth of 23.7 m, the fourth layer possesses fair aquifer potential. The fifth layer possesses good aquifer potential. VES 2 reveal four layers with probable lithology of top soil, Sandy clay and Fresh basement rock. Poor aquifer potential is spotted at the third and fourth layers at a minimum depth of 17.3 m. VES 3 results unravel the existence of four layers and probable lithology of Topsoil, Clay and Fresh basement rock with topsoil thickness of 0.8m located at a depth of 0.8m. Poor aquifer potential is observed at the third and fourth layers at a minimum depth of 14.3 m.

In VES 4, Topsoil, Sandy clay and Fractured Basement were revealed; fair aquifer potential is located in the third layer. Top soil, Sandy clay and fractured basement are three layers spotted from the revelation given VES 5 measurements; good aquifer potential is located in the third layer. VES 6 has three layers with Top soil, Sandy clay and Fresh basement rock as its constituents. Poor aquifer potential may be found in the third layer within the fresh basement rock constituents. VES 7 measurement reveals that the second and third layer at a minimum depth of 8.9m could be harbours for aquifers these layers are made of Sandy clay and fresh basement rock. VES 8 shows three layers with a probable lithology of Topsoil, Clay and Fractured Basement Rock. Aquifers could be located at a depth of 6.8m and a little beyond.

VES 9 also shows same thickness and depth of 0.7 m for Top soil; additionally, clay and Fresh basement are two other layers spotted. At a minimum depth of 4.0 m the second and third layers, demonstrates poor aquifer potentials. VES 10 result reveals a fractured basement layer as a good harbour-spotted within the third layer at a depth of 28.8 m. A fresh basement region within the fourth layer demonstrates

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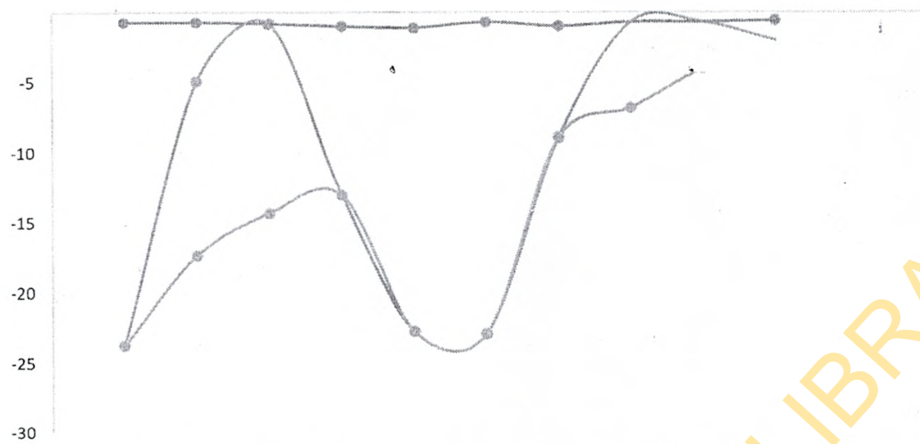

Figure 4: Map relating current electrode separation to depth to clay, sandy clay and fractured and basement rock.

Table 1: A tabled summary of VES 5 Interpretation.

Layer	Resistivity (ohm-m)	Thickness(m)	Depth (m)	Probable lithology	Hydrogeological Significance
1	117.6	1.1	1.1	Topsoil	-
2	144.2	21.7	22.7	Sandy-Clay	-
3	638.3	-	-	Fractured Basement	Good aquifer potential

Table 2: A tabled summary VES 8 Interpretation.

Layer	Resistivity (ohm-m)	Thickness (m)	Depth (m)	Probable lithology	Hydrogeological Significance
1	471.8	0.7	0.7	Topsoil	-
2	71.7	6.1	6.8	Clay	Poor aquifer potential
3	571.8	-	-	Fractured Basement	Good aquifer potential

Table 3: A tabled summary VES 10 Interpretation.

Layer	Resistivity (ohm-m)	Thickness (m)	Depth (m)	Probable lithology	Hydrogeological Significance
1	332.9	0.6	0.6	Topsoil	-
2	175.4	1.4	2.0	Sandy-Clay	-
3	503.7	26.9	28.8	Fractured basement	Good aquifer potential
4	3695.6	-	-	Fresh Basement	Poor aquifer potential

Table 4: Tabled summary of current electrode separation and depth to clay, sandy clay and fractured and basement rock.

Distance, *l* (m)	Depth to clay, d_c (m)	Depth to sandy clay, d_s (m)	Depth to fractured and basement rock, d_f (m)
25	-0.7	-23.7	-23.7
50	-0.7	-4.9	-17.3
75	-0.8	-0.8	-14.3
100	-1	-13	-13
125	-1.1	-22.7	-22.7
150	-0.7	-22.9	-22.9
175	-1	-8.9	-8.9
200	-0.7	-0.7	-6.8
225	-0.7	-0.7	-4
250	-0.6	-2	-2

poor aquifer potential. The Top soil and Sandy clay region are sited within the first and second layer.

Conclusions

The outcome of this investigation revealed four spots with good potentials for ground water; these points are located within the fifth and third layers on 9.28498°N, 7.41875°E (VES 1); 9.28515°N, 7.41789°E (VES 5); 9.28437°N, 7.41793°E (VES 8); 9.28394°N, 7.41792°E (VES10).

The third layer manifested fair aquifer potentials: while the second

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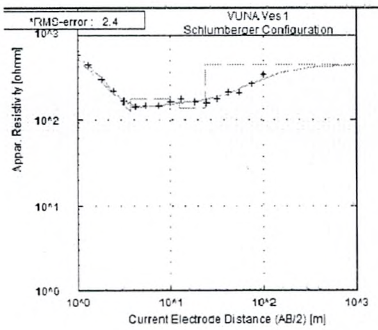
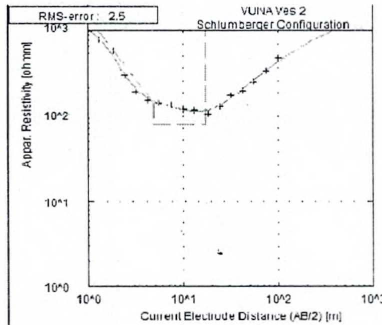
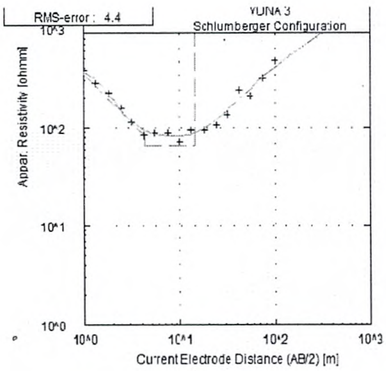


No	Res	Thick	Depth
1	710.0	0.7	0.7
2	123.8	3.0	3.7
3	169.1	8.7	12.4
4	136.6	11.2	23.7
5	422.9	-.-	-.-

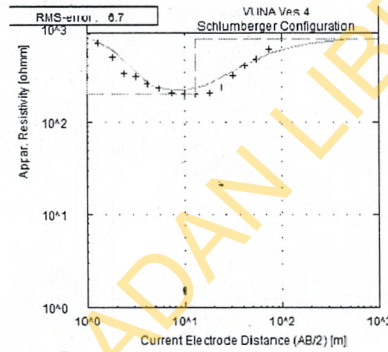
* RMS on smoothed data



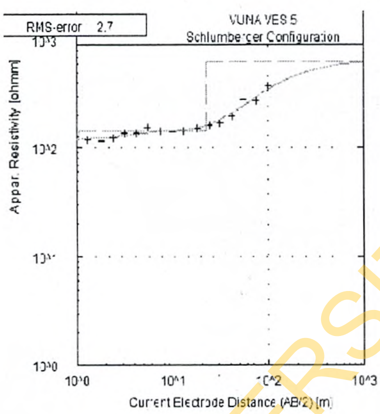
No	Res	Thick	Depth
1	1271.9	0.7	0.7
2	136.6	4.2	4.9
3	77.9	12.4	17.3
4	1423.5	.	.



No	Res	Thick	Depth
1	462.0	0.8	0.8
2	82.5	3.5	4.3
3	67.0	10.0	14.3
4	1723.3	-.-	-.-



No	Res	Thick	Depth
1	881.7	1.0	1.0
2	202.8	12.0	13.0
3	777.6	-.-	-.-



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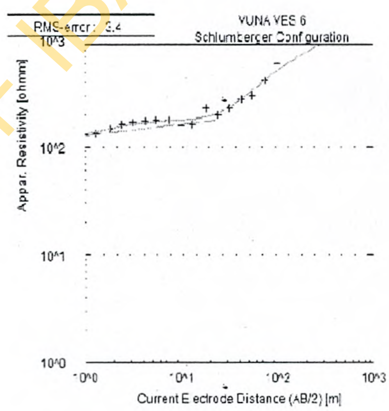
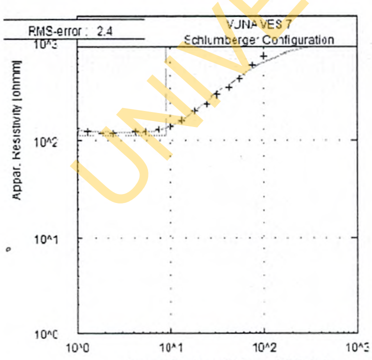
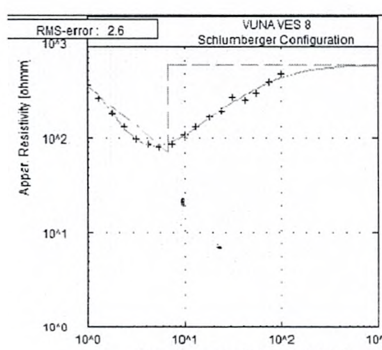
2	144.2	21.7	22.7
3	638.3	-.-	-.-



No	Res	Thick	Depth
1	124.3	0.7	0.7
2	178.4	22.2	22.9
3	1324.0	-.-	-.-



No	Res	Thick	Depth
1	128.5	1.0	1.0
2	113.6	7.9	8.9
3	1039.8	-.-	-.-



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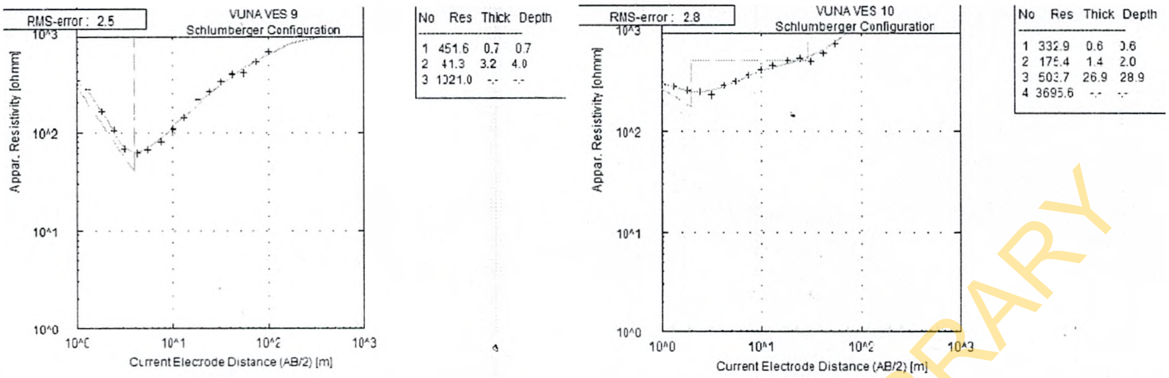

Figure 5: Apparent Resistivity-Current Electrode Separation maps for VES 1, VES 2, VES 3, VES 4, VES 5, VES 6, VES 7, VES 8, VES 9 and VES 10.

and third layers manifested poor aquifer potentials; these spots are located on 9.28434°N, 7.41834°N (VES 4); 9.28459°N, 7.41797°E (VES 7); 9.28551°N, 7.41809°E (VES 3); 9.28593°N, 7.41847°E (VES 2); 9.28486°N, 7.41777°E (VES 6); 9.28437°N, 7.41793°E (VES 8); 9.28403°N, 7.41784°E (VES 9).

Furthermore, the outcome of this work revealed the lithology of the region investigated. Five distinct layers of varying thicknesses and depths were displayed: Top soil, Clay, Sandy clay, Fractured and Basement Rocks. From the collated readings, the derived average thicknesses of topsoil, sandy clay and clay are 0.8m, 10.2m and 7.06m respectively.

It is strongly recommended that the points located on 9.28498°N, 7.41875°E (VES 1); 9.28515°N, 7.41789°E (VES 5); 9.28437°N, 7.41793°E (VES 8); 9.28394°N, 7.41792°E (VES10) be focused upon for water exploration. Additionally, the aquifer locations on the third layer are easier to assess when compared to those within the fifth layer because of the shallower depth.

Further recommendations, for future work should include the employment of Horizontal Electrical Sounding (HES) technique also called profiling technique-This infers that by employing both the HES and VES techniques, a truer picture of the sub surface may be captured. This combined technique will capture a lateral and horizontal variation in ground resistivity and reduce uncertainties related to interpretation (be it qualitative or quantitative). Outcome of work has fulfilled the aim.

Acknowledgements

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Author Affiliations

Top

[1]*Department of Pure and Applied Physics, College of Natural and Applied Sciences, Veritas University, Abuja, FCT, Nigeria*

[2]*Department of Physics, Faculty of Science, University of Ibadan, Ibadan, Oyo State, Nigeria*