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Assessment of Groundwater Potential of the University of Ibadan Central Mosque, Southwestern, Nigeria

Taofik Olubunmi Ewumi[1]*; Taofik Titus Ogunseye[2]; Adekunle Kazeem Bello[3]; Godwin Babatunde Egbeyale[4]; Kehinde Hussein Adeleke[5]

[1]Department of Physics, Ekiti State University, Ado-Ekiti, Nigeria.
[2,5]Department of Physics, University of Ibadan, Ibadan, Nigeria
[3]Department of Physical Sciences, Bells University of Technology, Ota,
[4]Department of Physics and Material Sciences, Kwara State University, Malete, Nigeria

Corresponding Author: Taofik Olubunmi Ewumi

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Abstract: Electrical resistivity surveying using Wenner and Schlumberger electrode array was carried out for the assessment of groundwater potential at the Central Mosque, University of Ibadan. Nigeria. Three Constant Spacing Traverses (CST) and ten Vertical Electrical Sounding (VES) stations were conducted at the study area. The geoelectrical imaging from this study revealed that the lithologies consist of lateritic topsoil, sandy clay/clayey sand/clay/weathered rock and the bedrock (fractured and fresh). The fractured and weathered basement with relatively lower resistivity is inferred to be the aquiferous zone and could bear productive water for groundwater supply. The results revealed the study area to be a region of relatively high groundwater potential. It was inferred that VES 1, 2, and 8 are regions associated with high groundwater yield.

Keywords: *Geoelectrical, Lithologies, Lateritic, Fractured, Aquiferous Zone.*

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I. INTRODUCTION

Water is an indispensable natural resource in which life depends on (Oladejo et al., 2015; Anomohanran et al., 2017). Water can be obtained from rain, rivers and streams, and as groundwater (Anomohanran et al., 2017). Shortage of surface water has been predicted over the next decades, especially in sub–Saharan African countries due to exhaustion of existing supplies, increase in consumption and contamination (Oladejo et al., 2015). This has made groundwater a proven substitute for human use (Adagunodo, 2017a). Numerous elements, including climate, geology, hydrology, terrain, ecology, vegetation, and soil distribution, influence the presence and flow of groundwater. It was observed in the study location that there exists occasional water shortage during prayer sessions especially on days of Jumat. The water shortage leads to several issues during prayer sessions and for general cleaning. This research was aimed at investigating potential areas for drilling borehole to provide an additional water source to the Central Mosque. The provision of water within the mosque environment is of paramount importance. It plays a crucial part in the fundamental tasks needed for prayer in addition to being essential for maintaining cleanliness and general hygiene. Significant quantity of water could be extracted from the aquifers through boreholes. In particular, boreholes that are drilled into weathered or fractured basement, but which penetrate maximum possible thickness of the regolith have been found to provide maximum yield (Acworth, 1987; Olayinka, 1992). Various surface geophysical techniques are used in groundwater exploration, such as the electrical resistivity method, seismic refractive method, magnetic method, radioactivity method, gravity method, and electromagnetic method. These techniques can map bedrock architecture and topography, as well as overburden thickness, aquiferous zones, and bedrock architecture and topography (Adagunodo and Sunmonu, 2013; Adagunodo et al., 2018. The groundwater potential areas in Idi-Ayunre, Ibadan, Oyo state was estimated using vertical electrical sounding and geographic information system Adetoyinbo et al., (2023). This study focuses on the exploration stage of groundwater evaluation, development, and management, which includes drilling, exploration,

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development, and well completion. The aim of this study is to conduct a geoelectrical investigation of the groundwater potential within the vicinity of the Central Mosque of University of Ibadan.

II. MATERIALS AND METHODS

A. Geology of the Study Area

The study area is located between latitude $7.446^{\circ}N$ and longitude $3.899^{\circ}E$ as shown in figures 1 and 2. The area lies within the Precambrian Basement Complex terrain of southwestern Nigeria. The climate of the study area is tropical wet and dry, with the wet season from mid- March to October and dry period from November to March. The annual rainfall and the maximum temperature in Ibadan are approximately 1230 mm and 32 ℃, respectively (Aladejana et al., 2018). The geology of Ibadan is that of the Precambrian basement complex which is an integral of the reformed basement rocks of West Africa (Adagunodo et al. 2018a, 2018b, 2019a). The predominant rocks of the basement complex are mainly metamorphic and crystalline rocks (Adagunodo et al., 2013). In Ibadan, some intrusive rocks such as granites and porphyries are found within the metamorphic rocks (Ganiyu et al., 2018). The rocks within Ibadan and its environs are: amphibolites, undifferentiated gneiss complex, migmatite and banded gneiss, granite gneiss, pegmatite and quartz vein as well as quartzite quart schist (Okunlola et al., 2009). Migmatite and banded gneiss are the major rocks in Ibadan. These major rocks are originated from a highly altered metamorphic rock that is banded or mixed with granitic rocks.

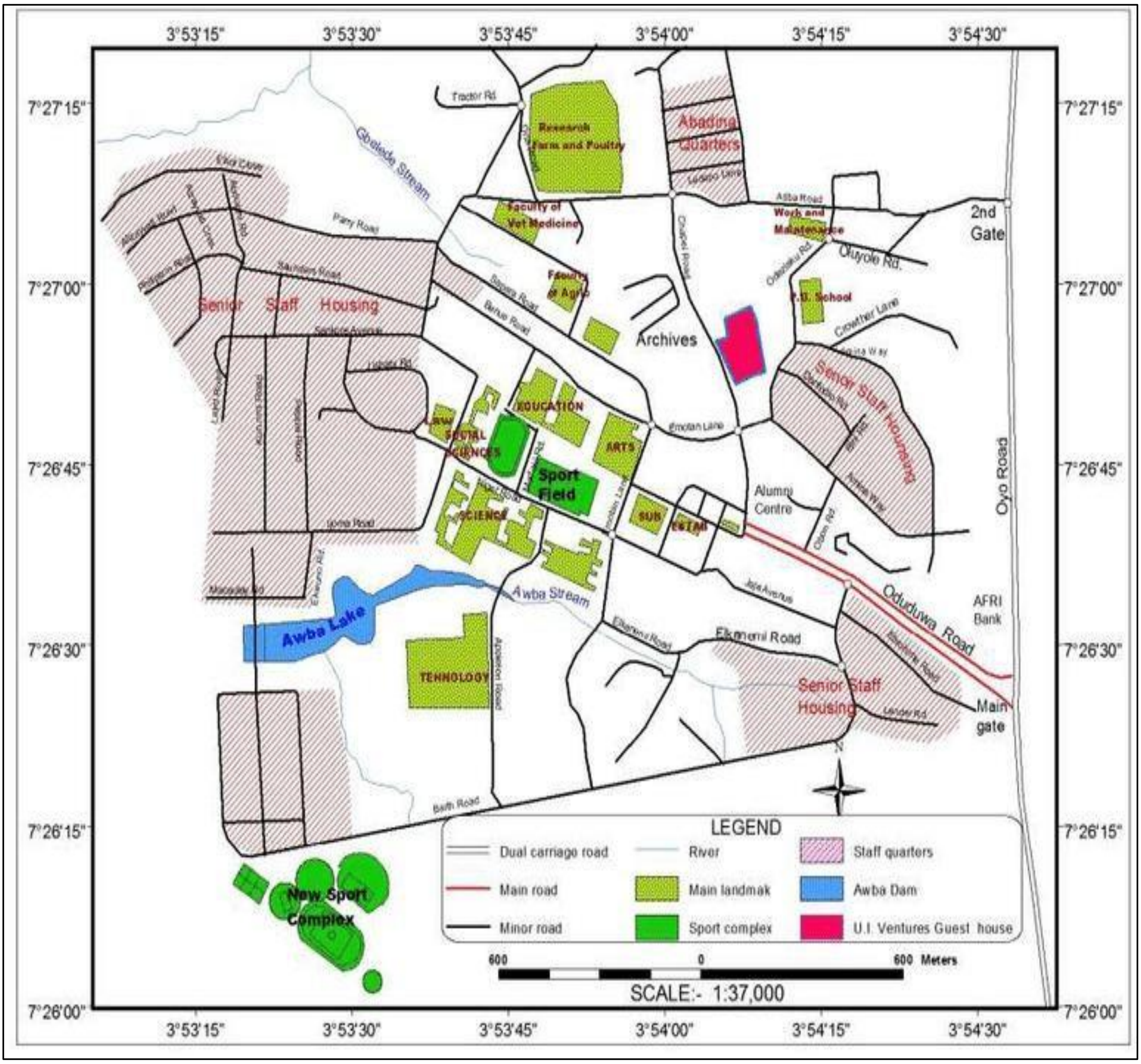

Fig 1: Map of University of Ibadan (Adetola et al., 2016)

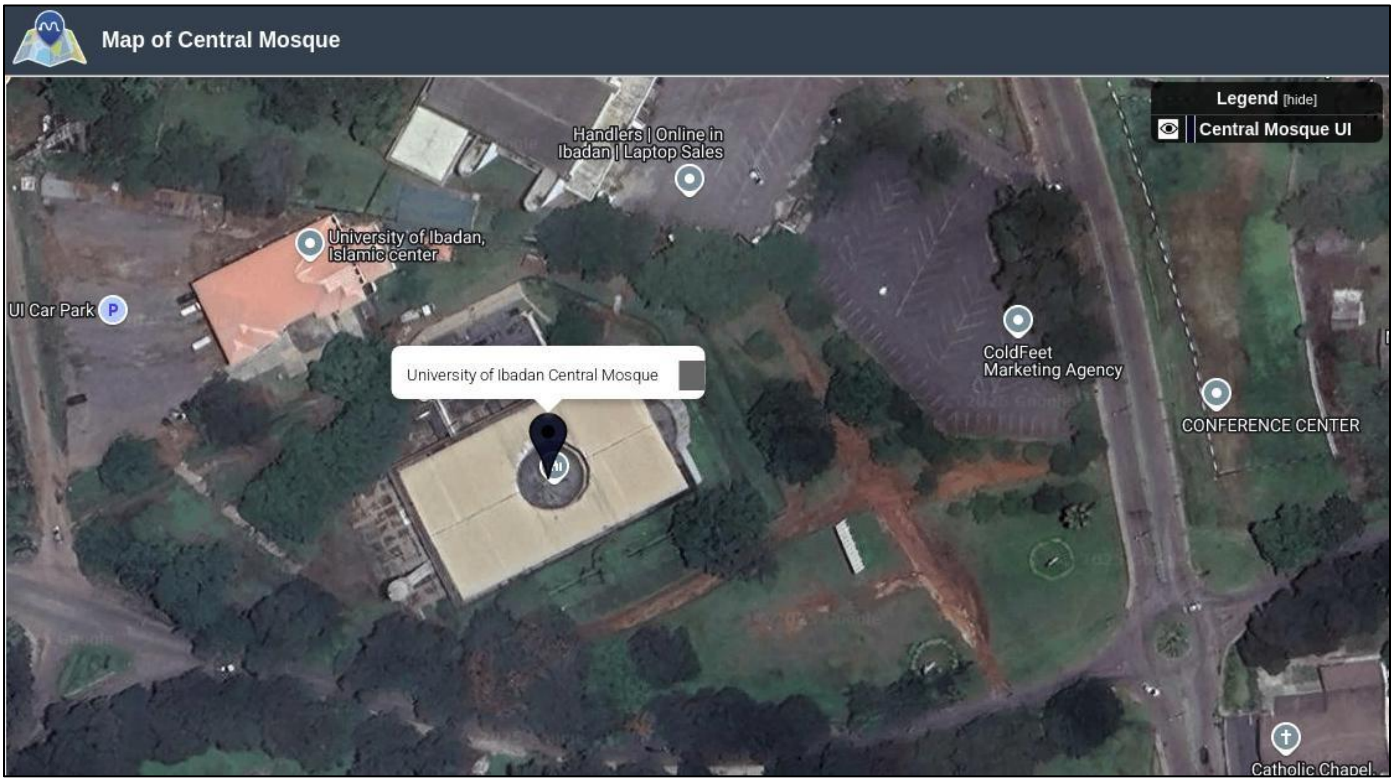

Fig 2: Map of the Study Area

B. Geophysical Investigation

A geoelectrical resistivity survey was carried out on the field using Vertical Electrical Soundings (VES) and Constant Separation Traversing (CST) with the aid of Campus Omega Resistivity Meter, figure 3.

Fig 3: Picture of Campus Omega Resistivity Meter

C. Apparent Resistivity

An electric current is injected into the ground through two electrodes, and the voltage difference is measured between two other electrodes. Apparent resistivity is calculated based on the relationship between the measured resistance and the geometry of the electrode configuration. The apparent resistivity is thus obtained from the general formula;

$$\rho a = KR \quad (1)$$

Where:

ρa = Apparent resistivity ($\Omega \cdot m$)
K = Geometric factor (depends on electrode configuration)
R = Measured Resistance (Ω)

D. CST Procedure

Three profiles of 130m, 150m and 130m respectively with a 10m electrode spacing. were investigated using Constant Separation Traversing configured using Wenner

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array. The current electrodes (C1 and C2) were placed at a set distance apart symmetrically on either side of an established central point. The potential electrodes (P1 and P2) are placed after the current electrodes, close to the center and aligned along the same straight line. The electrodes are connected to the resistivity meter and a controlled current (I) is injected into the ground using the current electrodes. The resulting potential difference (V) was measured between the potential electrodes, using the resistivity meter, and the geometric factor (K) and the apparent resistivity (ρa) were calculated using equations: 1 and 3 respectively. The spacing of the current electrodes (C1, C2) is increased consistently by 10m, that is 10m, 20m, 30m, 40m, 50m, for subsequent readings while keeping the central point fixed.

E. VES Procedure

A total of ten (10) Vertical Electrical Sounding (VES) was carried out using Schlumberger configuration, with the current electrode spacing (AB/2) having a maximum spread of 55m and potential electrode ranging from 0.25 - 2.5m. The location and distance of the VES points were obtained using the Global Positioning System (GPS). A central reference point is assigned for each VES point and the current electrodes (C1 and C2) were placed symmetrically around the center for the Schlumberger configuration. Uniform increase in distance is ensured between potential electrodes (P1, P2). The current electrodes (C1, C2) were firmly placed in the ground at the starting distance, while P1 and P2 potential electrodes are closer to the center for the initial measurement while keeping all the electrodes aligned. Water was used to increase conductivity in dry and rocky terrain and steer clear of recognized interference sources such as high-tension power lines, cables, and underground pipes. A controlled current (I) is injected into the ground via the current electrodes (C1, C2) and the resulting voltage difference (V) between the potential electrodes (P1, P2) is measured using the resistivity meter and the geometric factor (K) and the apparent resistivity (ρa) were calculated using equations: 1 and 2 respectively. The spacing of the current electrodes (AB/2) is gradually increased to expand the depth of investigation. The readings are taken consistently at each increment, typically doubling or increasing geometrically depending on the underlying subsurface type. If resistivity values are inconsistent, Reposition the electrodes or strengthen the grounding if the resistivity values are inconsistent.

III. RESULTS AND DISCUSSION

The results acquired from the geophysical survey through VES of the 10 stations are presented in Table 1. Partial curve matching was performed on the VES field data to obtain the initial values of each layer's apparent resistivity and thickness. Analysis and iteration of the acquired VES data was done using WinResist software. The generated curve-types distribution chart is displayed in Figures: 4 – 13.

Table 1: Geoelectric Parameter of UI Mosque

YES/NO	Layers	Resistivity (Ωm)	Thickness	Depth (m)	Curve Type	Lithology
1		262.5	1.0	1.0		Lateritic topsoil
1	2	113.2	3.0	4.0	Q	Clayey-Sandy weathered layer Fractured Bedrock
3		46.4	…	…		
1		629.6	0.8	0.8		Lateritic topsoil
2	2	231.0	3.5	4.3	QH	Sandy-clay weathered layer Fractured basement
3		36.6	11.6	15.9		
4		404.6	…	…		Fresh basement
1		432.2	1.1	1.1		Lateritic top soil
3	2	149.0	4.4	5.4	HK	Sandy weathered layer
3		440.6	10.0	15.4		Weathered basement
4		125.5	…	…		Fractured basement
1		460.0	1.0	1.0		Lateritic top soil
4	2	115.0	10.5	11.5	H	Clayey-sandy weathered layer Fractured basement
3		240.0	…	…		
1		220.0	1.0	1.0		Lateritic top soil
5	2	94.3	21.0	22.0	H	Sandy weathered layer
3		364.0	…	…		Weathered/fractured basement
1		257.3	1.0	1.0		Lateritic top soil
6	2	90.9	9.0	10.0		Clayey weathered layer
	3	269.9	…	…		Fractured basement
7	1	416.8	1.1	1.1		Lateritic top soil
	2	80.5	10.6	11.6	H	Clayey-sandy layer
	3	320.1	…	…		Fractured basement
8	1	349.7	1.0	1.0		Lateritic top soil

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	2	122.2	6.6	7.6	Q	Sandy weathered layer
	3	27.7	…	…		Fractured rock
9	1	279.6	1.1	1.1		Lateritic top soil
	2	60.0	18.8	20.0	H	Clayey-sandy weathered basement Fresh basement rock
	3	588.4	…	…		
10	1	364.1	0.9	0.9		Lateritic top soil
	2	50.0	10.8	11.7	H	Clayey weathered layer Weathered/fractured Basement
	3	449.3	…	…		

IV. COMPUTER- GENERATED VES CURVES

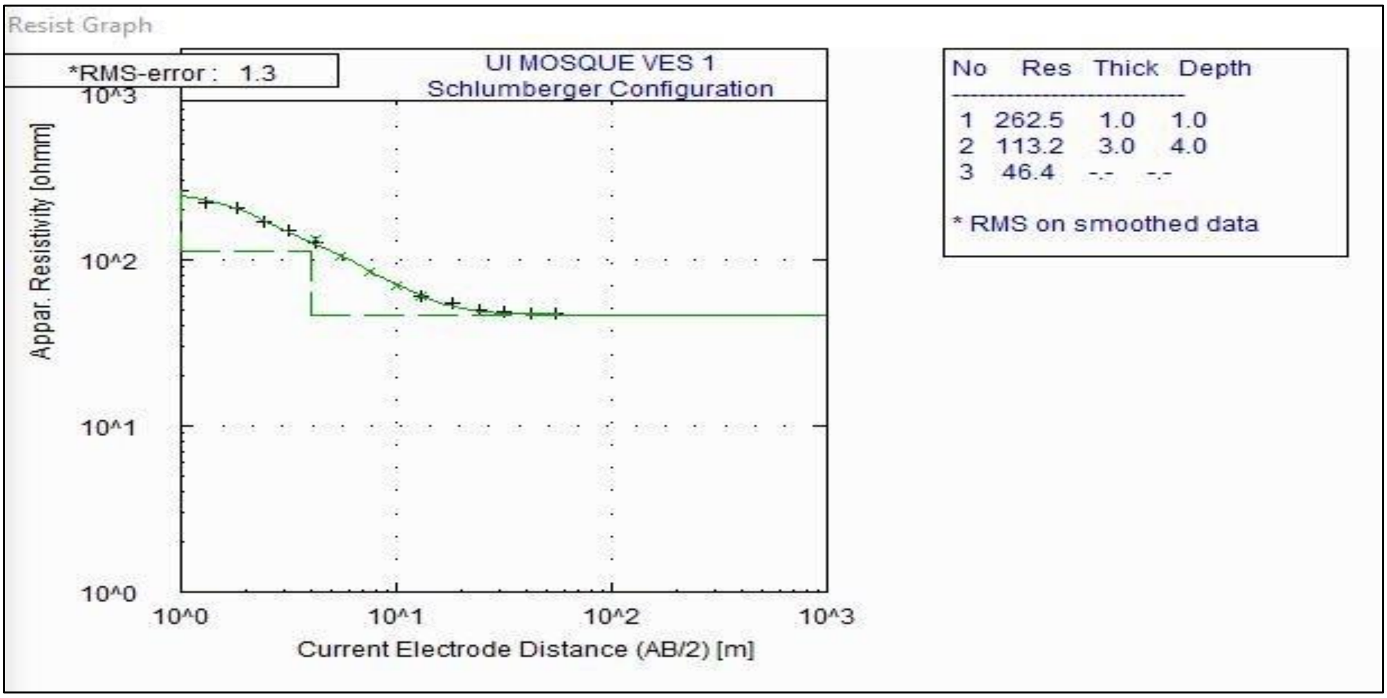

Fig 4: VES Curve 1 (UI Mosque)

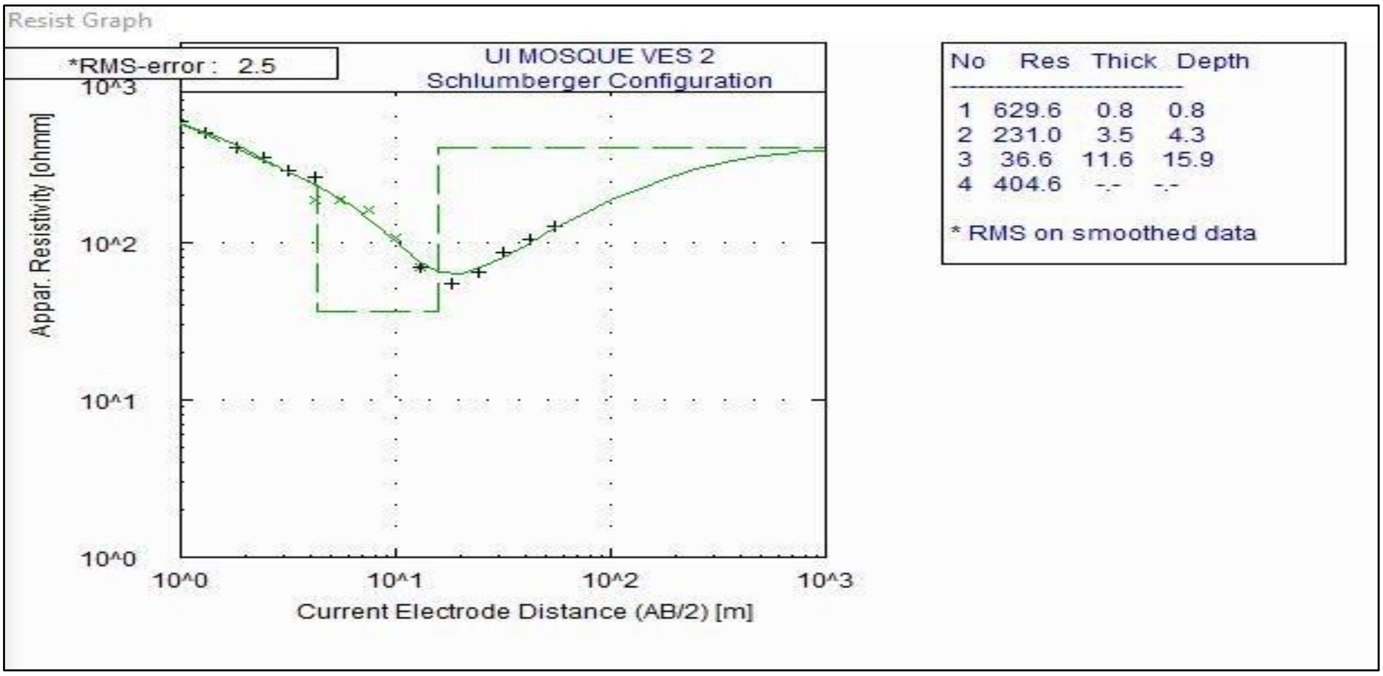

Fig 5: VES Curve 2 (UI Mosque)

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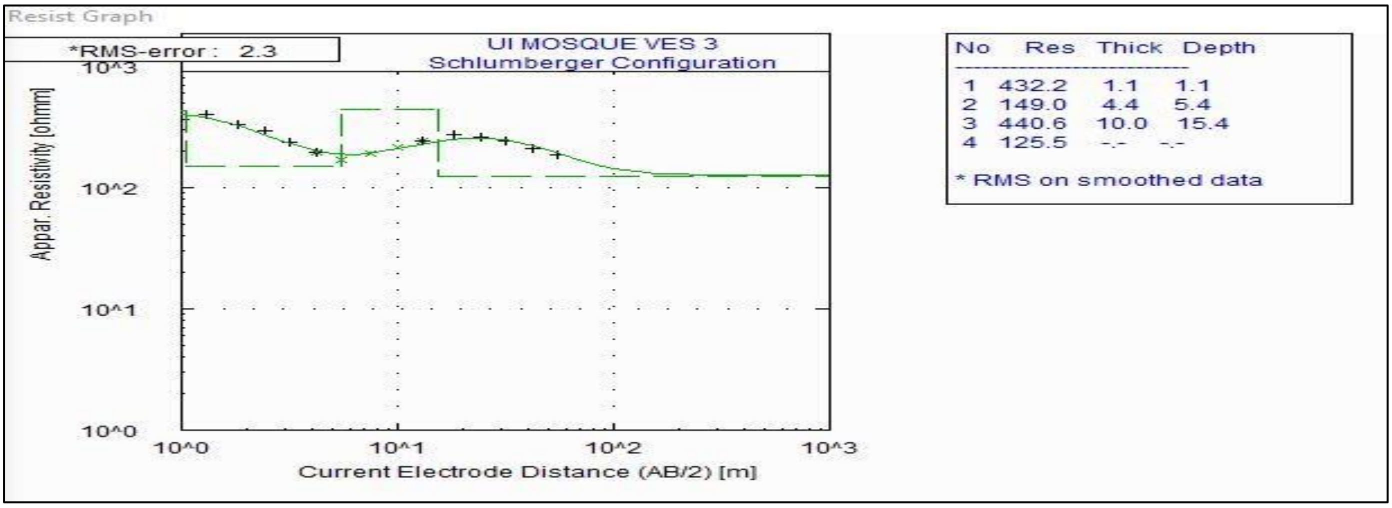

Fig 6: VES Curve 3 (UI Mosque)

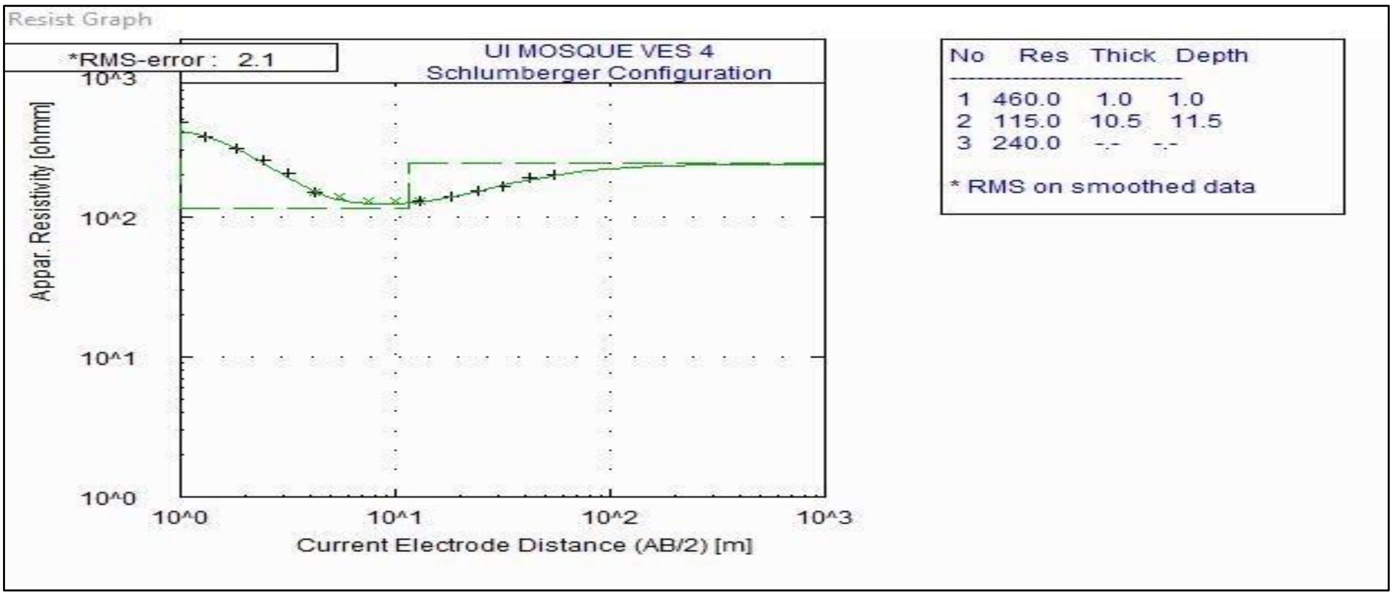

Fig 7: VES Curve 4 (UI Mosque)

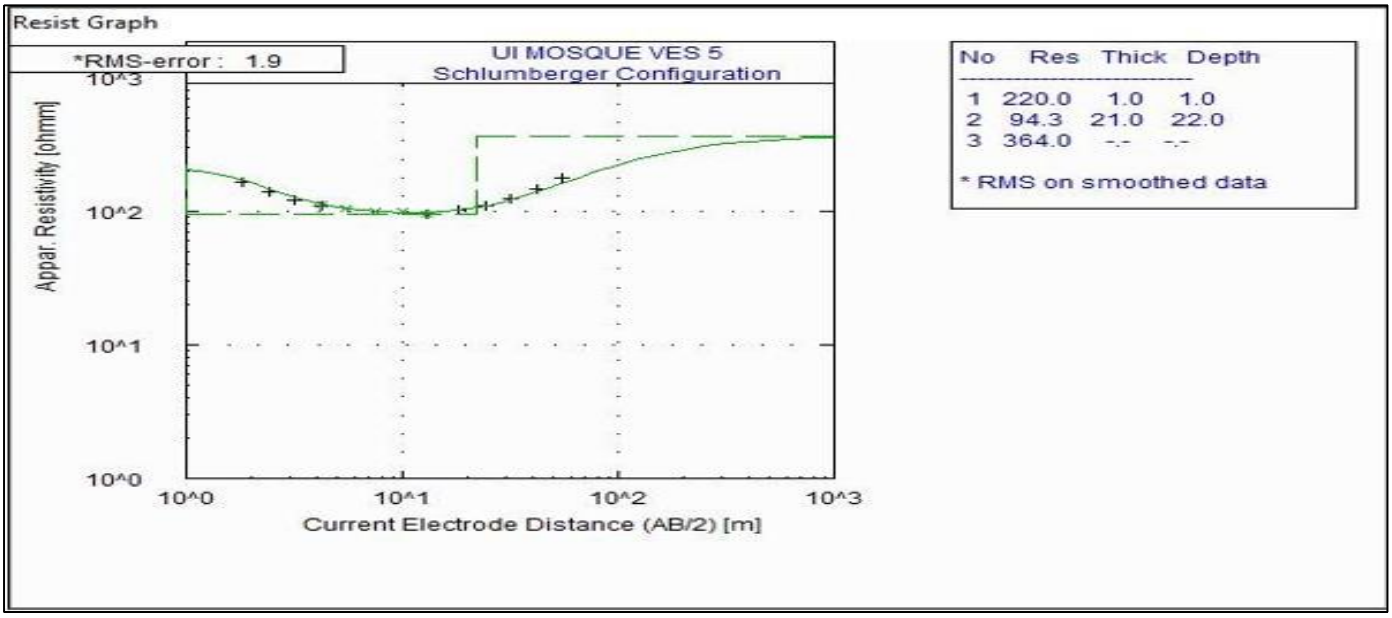

Fig 8: VES Curve 5 (UI Mosque)

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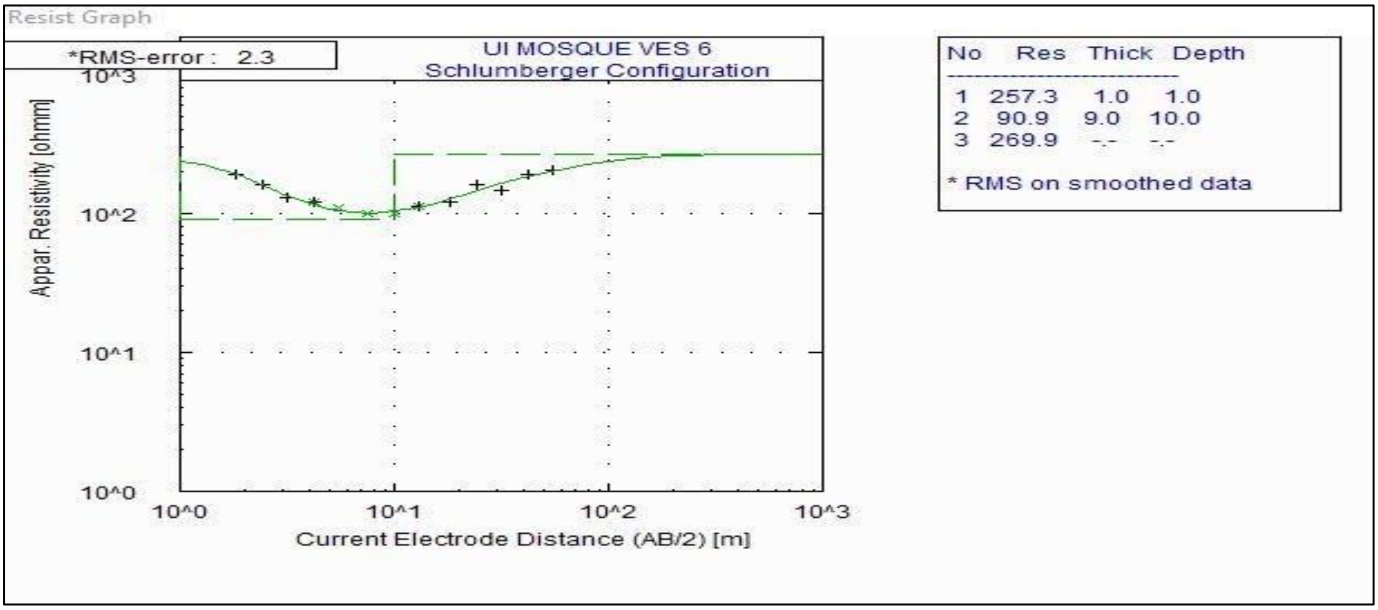

Fig 9: VES Curve 6 (UI Mosque)

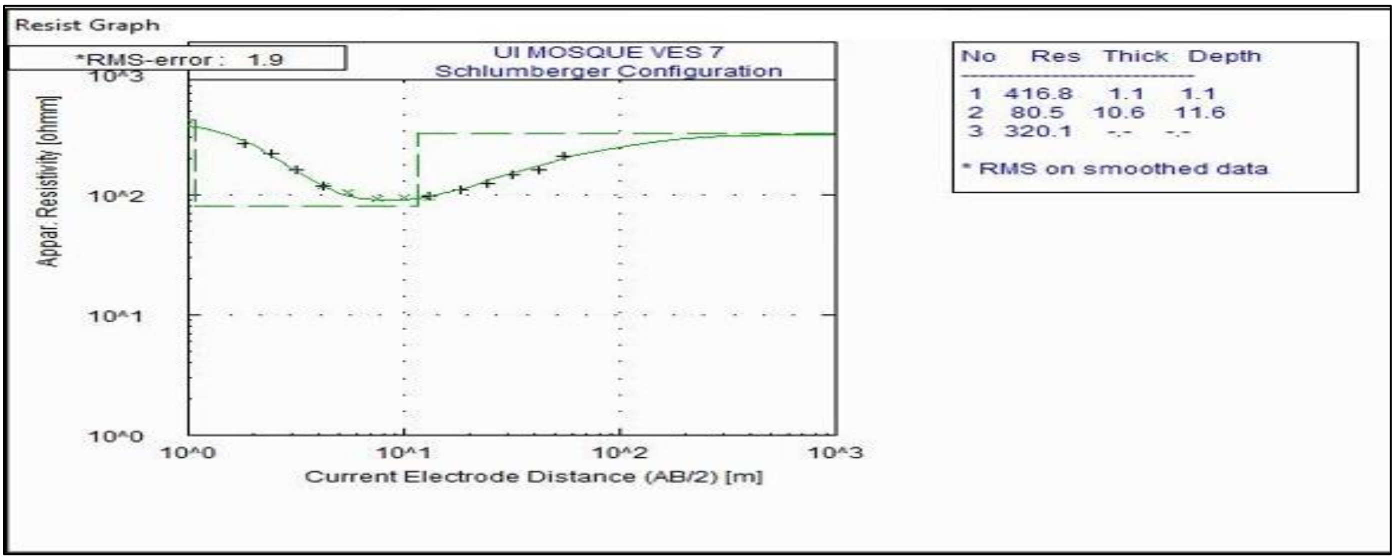

Fig 10: VES Curve 7 (UI Mosque)

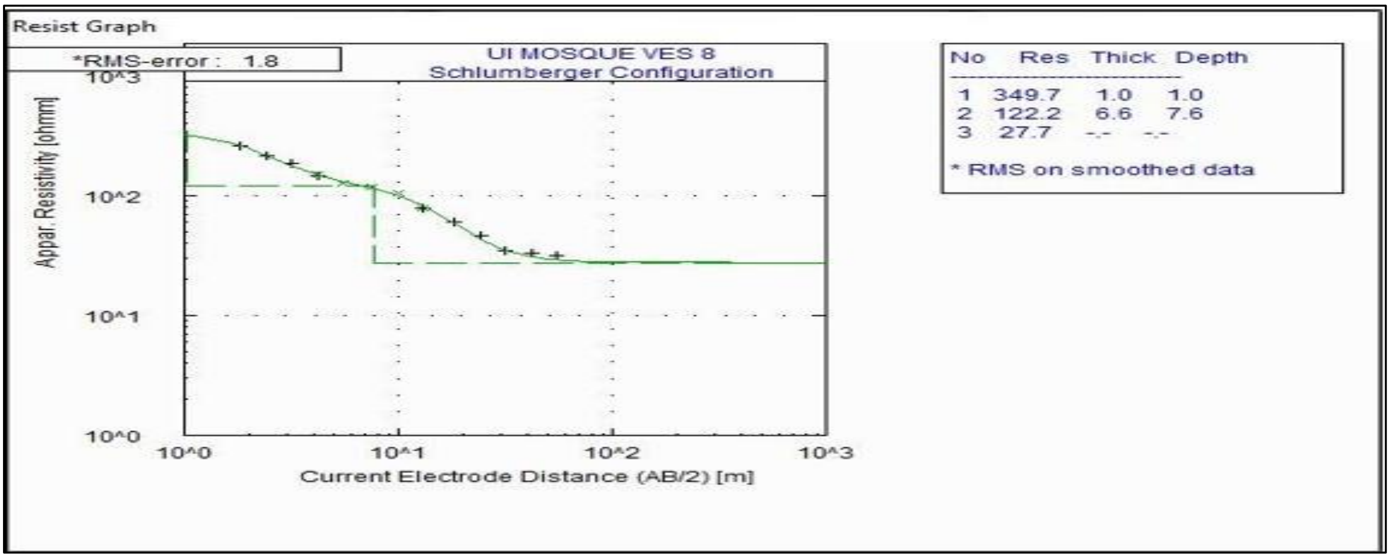

Fig 11: VES Curve 8 (UI Mosque)

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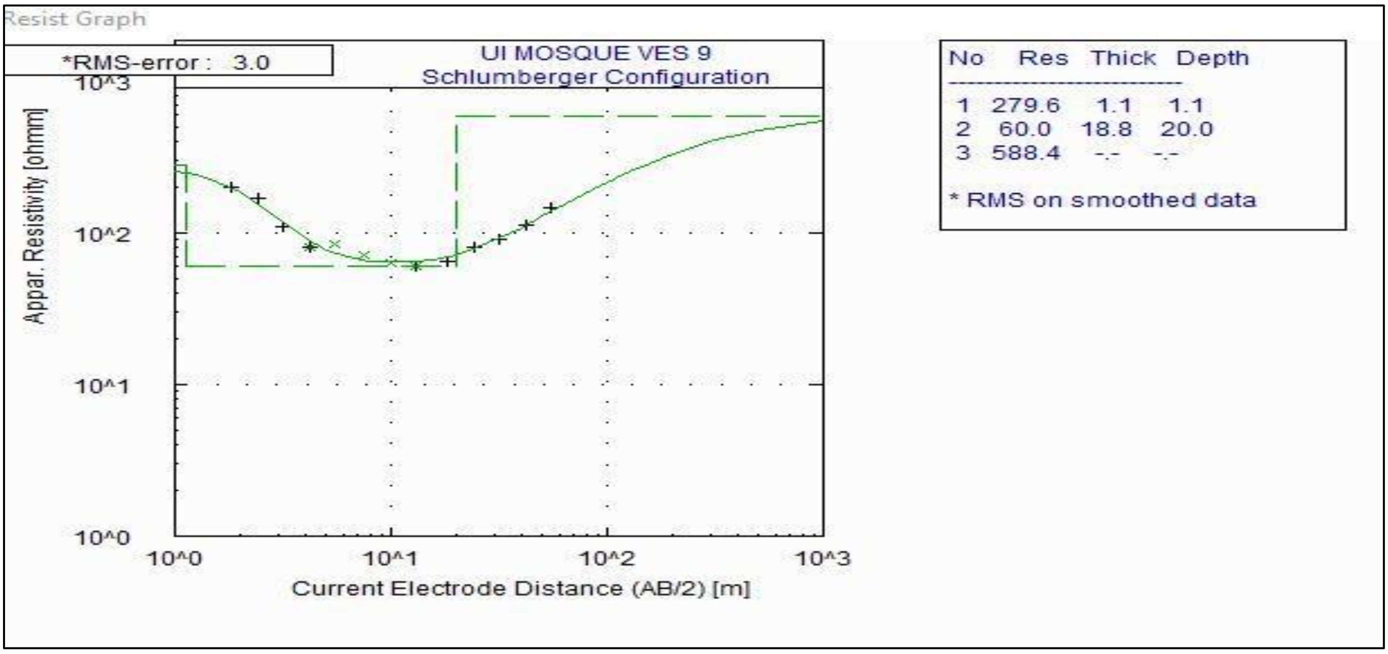

Fig 12: VES Curve 9 (UI Mosque)

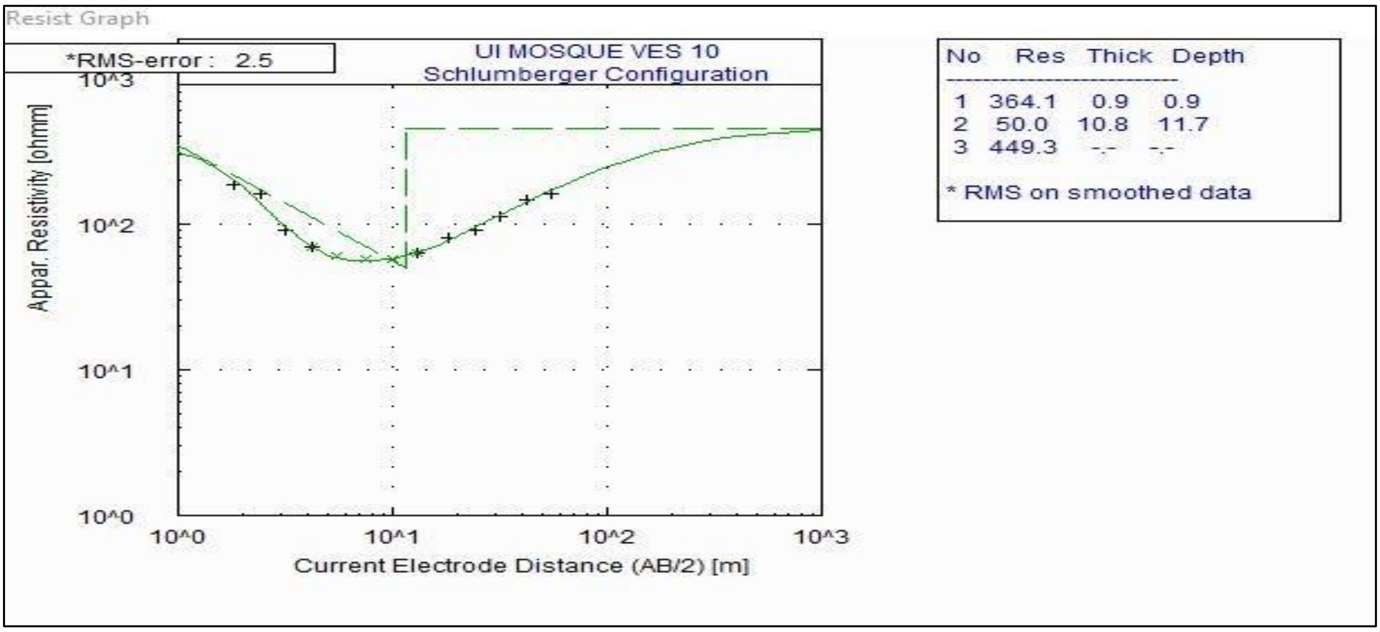

Fig 13: VES Curve 10 (UI Mosque)

V. DISCUSSION

It can be inferred that VES 1 and VES 8 (Curve Type Q) suggests good groundwater potential. The first layer, a lateritic topsoil with a relatively high resistivity is not a good indicator of high groundwater potential as it is relatively resistant to water. VES 2 (Curve Type QH) stands out as an area with good groundwater potential. Similarly, VES 4, 5, 6 and VES 7 (Curve Type H) show moderate to low potential for groundwater. The shallowest layer consists of lateritic topsoil of relatively high resistivity and beneath it, there is a clayey weathered layer at averagely 10 meters that is relatively thick and of low resistivity, indicating that it is likely to hold water, which contributes positively to groundwater potential. On the other hand, VES 3 (Curve Type HK) indicate a low groundwater potential area. The first layer has a high resistivity which suggests a dry or clay formation and the second layer, a sandy weathered layer, extends from 1.1 meters to 5.4 meters depth, which is relatively thick but still does not suggest significant groundwater storage due to the relatively higher resistivity. The third layer, the weathered basement, has a resistivity of 440.6 Ωm and extends to a depth of 15.4 meters. This high resistivity indicates that the weathered basement is not saturated with groundwater and the deeper fractured basement also has a resistivity of 125.5 Ωm, which is still relatively high. Therefore, this profile suggests low groundwater potential, particularly near the surface and in the weathered zone. (Curve Type H) and VES 9 (Curve Type H) shows similar characteristics suggesting low groundwater potential. While they both possess a mid-layer with relatively low resistivity, it is still not a good indicator of groundwater

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as the first and last layer have much higher resistivity readings.

VI. CONCLUSION

The results of the VES analysis suggest weathered layer and fractured bedrock constitute the aquifer units in the study area. The CST readings of the study area suggest predominantly regions of good groundwater potentials along the three traverses. The overburden thickness varied from 4.0 to 15.9 m. The evaluation of aquifers vulnerability to contaminants through geoelectric parameters showed a poor to medium protective capacity from contamination.

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