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Abstract— This study investigates subsurface conditions to inform foundation design through geophysical surveying, specifically employing the Vertical Electrical Sounding (VES) method using a Schlumberger array with AB/2 spacing of 100 meters. Ten VES points were analyzed to determine subsurface composition, strength, and stability. Three to five separate layers, including topsoil, clayey sand, clay, and sandy layers, were identified in the interpreted geoelectric sections; the majority of the resistivity curves were categorized as HKA-type. Layer thicknesses ranged from 0.9 m to 45.9 m, and resistivity values ranged from 71.7 Ωm to 18,671.3 Ωm. More load-bearing capacity is shown by a higher resistivity in the sandy layer at traverse one, which qualifies it for heavy construction. The subsurface sequence in traverse two, on the other hand, has a clayey layer beneath the topsoil, indicating increased stability and suitability for constructions where minimal settlement is essential. The findings underscore the importance of integrating geophysical data with further geotechnical assessments to ensure optimal foundation planning.

Keywords— Vertical Electrical Sounding, Geophysical Survey, Geoelectric Section, Resistivity, Overburden Thickness,

I. INTRODUCTION

The foundation of a structure is the structural component that carries the load of the building to the ground, distributing it in such a manner as to prevent settlement or subsidence. It offers stability and support, ensuring that the building stays upright and safe [1]. The foundation is typically made of concrete, steel, or a combination of the two, and it is usually placed below ground level to secure the building, in which design and construction of the foundation are critical to the overall stability and longevity of the building structure [2]. However, the efficacy and lifespan of a foundation are significantly influenced by the properties of the geology of the subsurface.

First and foremost, understanding the rock and soil composition, strength, and stability is critical in establishing the best form of foundation for a construction project. Cohesion, bearing capacity, and settlement potential are all important soil attributes to consider while doing this study. Without a thorough rock study and analysis, there is a danger of selecting an insufficient foundation type, which might lead to costly structural concerns in the future [3]. In the realm of civil engineering and architecture, understanding the geological components underlying building foundations is paramount. These components play a critical role in determining the safety, durability, and cost-effectiveness of construction projects [4].

It should be noted that failure to check the subsurface soil can lead to building failure, which, according to [5], it is an unacceptable difference between expected and observed performance of building components, proving that proper soil investigation allows engineers to select appropriate foundation types, designs, and construction techniques tailored to the specific soil conditions encountered. Therefore, the applications of geophysical surveys in building foundation design, aim to enhance the efficiency, accuracy, and safety of construction practices [6].

Geophysical surveys utilize various techniques to probe the subsurface, each offering unique advantages depending on the geological context and project requirements. By examining various geological factors such as soil types, subsurface conditions, geological formations, and environmental considerations, we seek to provide a comprehensive understanding of the interplay between geology and structural integrity [7] .

Furthermore, incorporating geophysical surveys into foundation design lies in their ability to mitigate risks associated with inadequate site characterization. Surveying subsurface features, identifying potential hazards, and delineating rock stratigraphy, these surveys enable engineers to make informed decisions regarding foundation type, depth, and reinforcement [8].

Hence, in advancing the utilization of geophysical surveys in building construction, this research employs the Vertical Electrical Sounding (VES) method to characterize subsurface conditions beneath the proposed construction sites within Babcock University, Southwestern Nigeria.

II. DESCRIPTION AND GEOLOGY OF THE STUDY AREAS

The study area, Ilishan-Remo, is located in the sedimentary terrain of southwestern Nigeria. The study area is a town a few kilometers from the Shagamu highway and a few minutes’ drive to Ikene. The study area falls within 60 53’ 13.17012’’ N 60 53’ 24.82008’’ N and 30 43’ 3.10’’ E 60 43’ 14.76’’ E, and it can be accessed through several road networks: major and other minor roads and footpaths interconnecting the study area. It is situated within a combination of flat plains and gentle slopes. The study area lies within the Abeokuta sedimentary formation, which consists of grits, loose sand, sandstone, kaolinitic clay, and shale (figure 1). It was further characterized as usually having a basal conglomerate or a basal ferruginized sandstone [9]. The perimeter of the study area is indicated with the red polygon on the topographic map (figure 2).

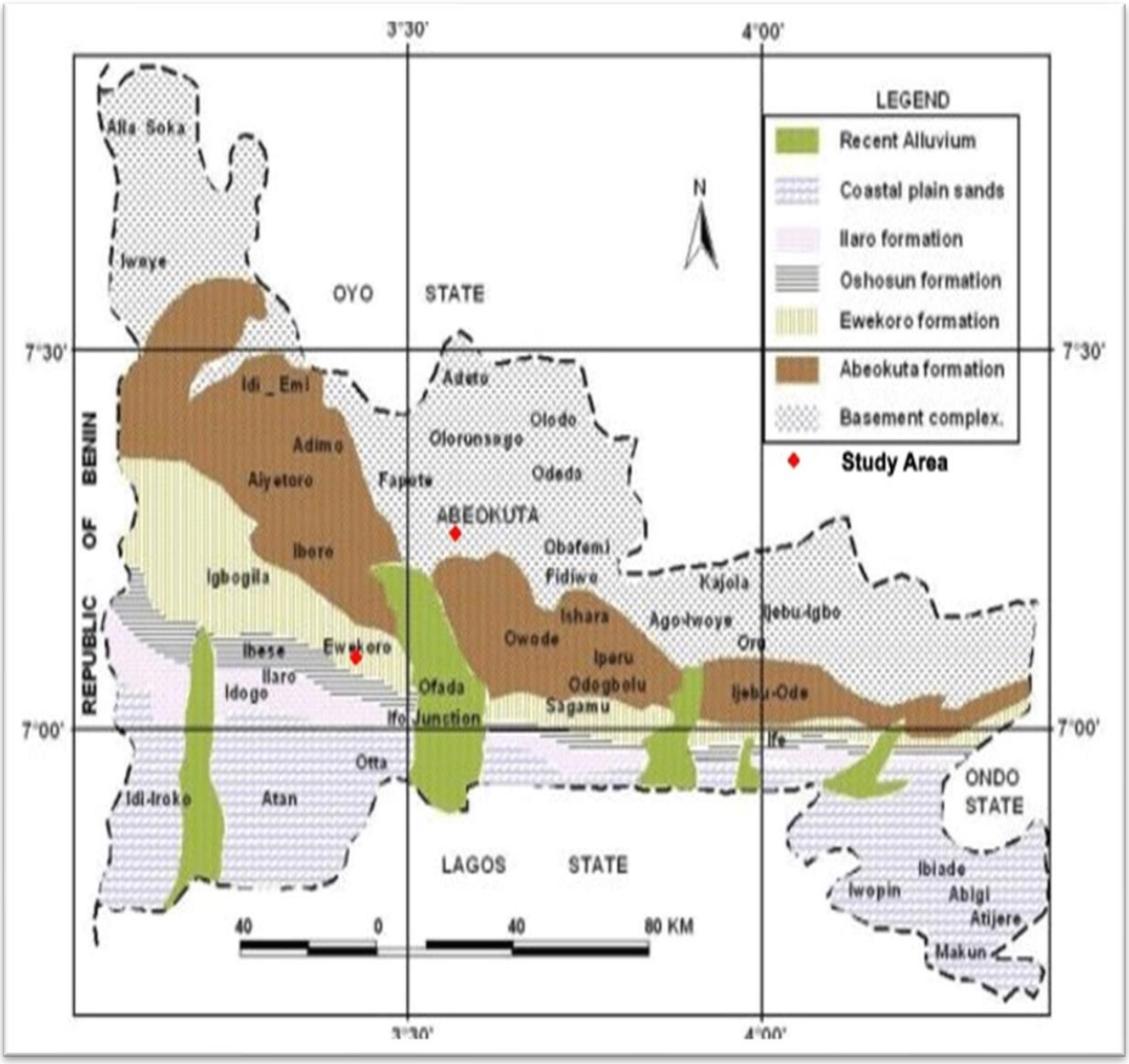

Figure 1: The geological map of Ogun State (Peters, 1982).

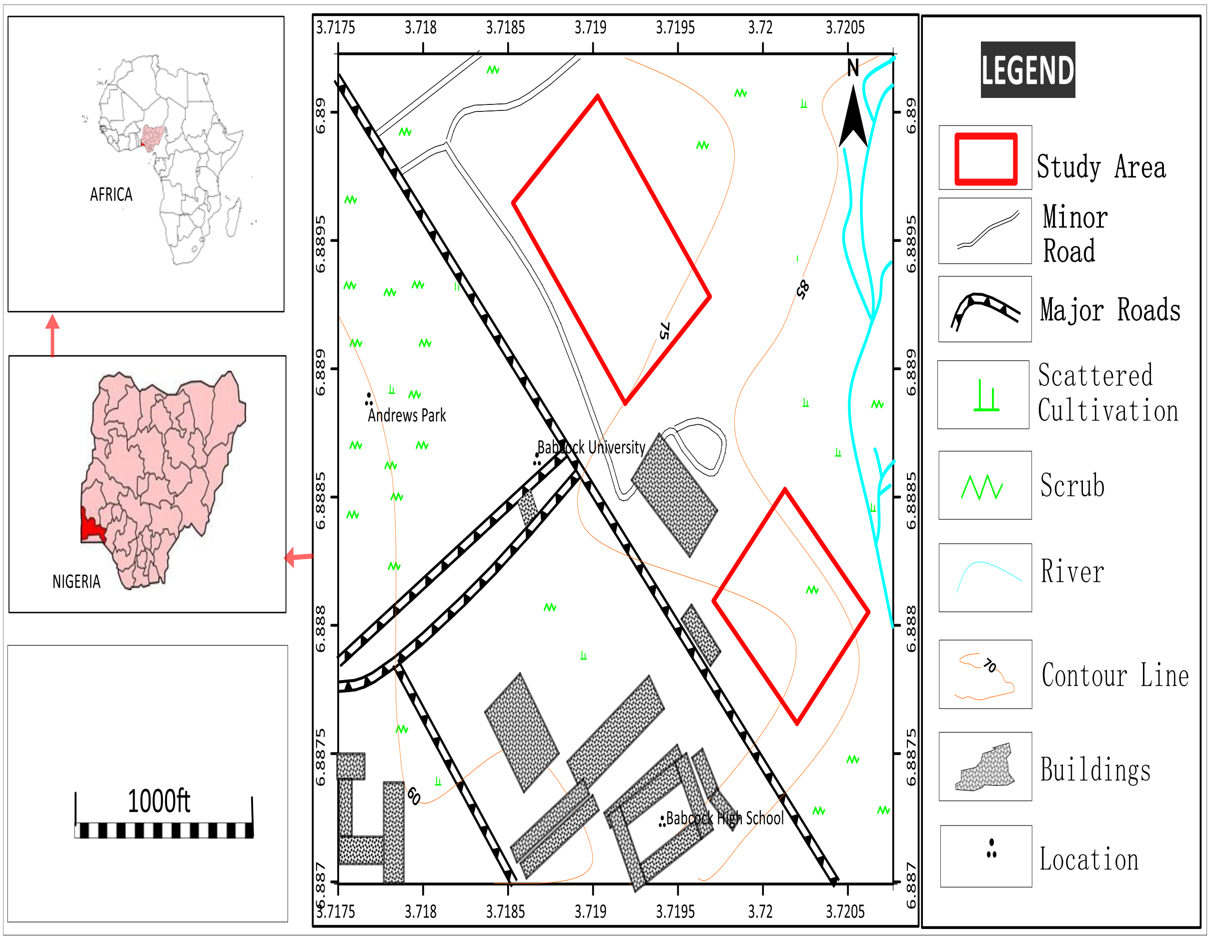

Figure 2: Topography Map of the study area

III. MATERIALS AND METHOD

The geophysical method adopted for this research is the electrical resistivity method using the Schlumberger electrode array in order to study the conditions such as resistivity, thickness, and depth to basement of the subsurface. The origin of electrical resistivity theory is Ohm's law, which states that the ratio of the potential difference, V, between two ends of a conductor in an electrical circuit to the current, I, flowing through it is a constant.

$$V = IR \tag{1}$$

Where R is a constant known as the resistance measured in ohms (Ω). If the conductor is a homogenous cylinder of length L and cross-sectional area A, the resistance will be proportional to the length and inversely proportional to the area.

$$R = \rho \frac{L}{A} \tag{2}$$

Where ρ is the resistivity measured in ohm-meter (Ωm).

The earth's material is predominantly made up of silicates, which are basically non-conductors. The presence of water in the pore space of the soil and in the rocks enhances the conductivity of the earth when an electrical current, I, is passed through it, thus making the rock a semiconductor.

If the electrical field generated by the current is E across the length when a potential difference, V, is applied, then the potential difference can be defined as

$$V = EL \tag{3}$$

$$E = j\rho \tag{4}$$

Where, E is the electric field strength with dimension of volt per meter. If the current electrode is taken to penetrate a small hemisphere of radius, r then the area of the hemisphere becomes $2\pi r^2$. Substituting for E and integrating equation 4 gives:

$$\Delta V = \int E.dr \tag{5}$$

$$\text{Or } \Delta V = I\rho.2\pi \tag{6}$$

$$\text{And } \rho = \frac{\Delta V}{2\pi rI} \tag{7}$$

Since the earth is not homogeneous, equation7 is used to define an apparent resistivity,

$$\rho_a = \frac{\Delta V.G}{I} \tag{8}$$

Where G is a geometric factor fixed for a given electrode configuration.

The apparent resistivity is a function of electrode configuration, electrode spacing, applied current, true earth resistivities, number of layers, layer thickness, potential gradient, and anisotropic earth properties. Ten (10) vertical electrical sounding (VES) data were carried out using the Schlumberger configuration. Electrical noise due to buried cables and other metallic conductors was avoided during the fieldwork. The field procedure involves the potential electrodes (M and N) remaining fixed, and the current electrodes (A and B) are expanded symmetrically about the center of the spread. The maximum half-current electrode (AB/2) separation used in this survey is 100 m. The depth of penetration is proportional to the separation between the electrodes, and varying the electrodes provides information about the stratification of the ground [10]. The VES data (figure 3) obtained were subjected to partial curve matching. The resistance value was processed using WINRESIST software to obtain the apparent resistivity values.

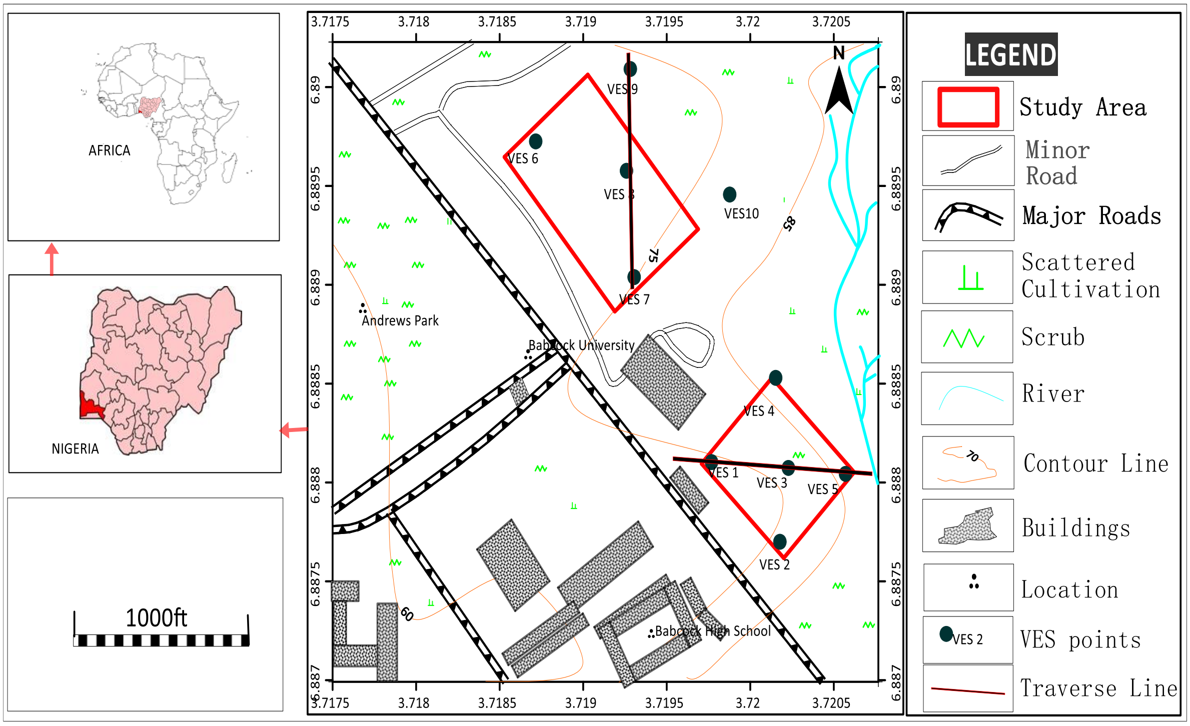

Figure 3: Basemap Indicating the VES points and traverse across the propose land

IV. RESULTS AND DISCUSSION

The result of the geophysical survey is presented in sounding curves and geoelectric sections. The summary of the result interpretation of the vertical electrical sounding obtained showed the different layers with their resistivities, depths, thicknesses, and curve types presented in the table. The inferred subsurface layers include a range of three to five geoelectric layers: topsoil, clayey sand, dry sand, and sandstone layer. The typical curve types obtained from the study areas include A and K for three-layer types; four-layer types are AH, AK, KQ, and HA; and for the five-layer curve types, we have KHA and AQK. The three-layer resistivity value ranges from 71.7 Ωm to 3448.1 Ωm; the four-layer ranges from 51.0 Ωm to 9082.9 Ωm; while the five-layer curve type ranges from 151.7 to 4093 Ωm.

Table 1: Interpretation of VES data of the study area.

No of VES	No of Layers	Resistivity Ohm meter (Ωm)	Thickness (m)	Depth (m)	Overburden thickness (m)	Curve type	Lithology Description	Competency Ratings
VES 1	1	166.6	1	1		AH	Topsoil	Moderately Competent
	2	536.5	7.2	8.2			Clayey Sand	Moderately Competent
	3	1973.7	16.9	25.1			Sandy	Competent
	4	18671.3			25.1		Sandy	Competent
VES 2	1	235.9	0.9	0.9		KHA	Topsoil	Moderately Competent
	2	299.5	3.4	4.4			Clayey Sand	Moderately Competent
	3	151.7	9.9	14.2			Clayey	Competent
	4	1219.7	26.5	40.7			Sandy	Competent
	5	2113			40.7		Sandy	Competent
VES 3	1	324.5	0.9	0.9		AK	Topsoil	Moderately Competent
	2	2382.8	3.8	4.6			Sandy	Competent
	3	4965.2	17.5	22.1			Sandy	Competent
	4	626.7			22.1		Clayey Sand	Moderately Competent
VES 4	1	478.1	0.6	0.6		AQK	Topsoil	Moderately Competent
	2	3673.8	5.4	6			Sandy	Competent
	3	4093	14	20			Sandy	Competent
	4	661	29.1	49			Clayey Sand	Moderately Competent
	5	378.8			49		Clayey Sand	Moderately Competent
VES 5	1	336	0.8	0.8		KQ	Topsoil	Moderately Competent
	2	10393.1	4.3	5			Sandy	Competent
	3	6044.5	16	21.1	21.1		Sandy	Competent
	4	1974.6					Sandy	Competent
VES 6	1	451.1	0.9	0.9		AK	Topsoil	Moderately Competent
	2	674.4	4.9	5.7			Clayey Sand	Moderately Competent
	3	4869.6	45.9	51.6	51.6		Sandy	Competent
	4	2575.6					Sandy	Competent
VES 7	1	213.4	1	1		A	Topsoil	Moderately Competent
	2	1817.5	13.6	14.6	14.6		Sandy	Competent
	3	3448.1					Sandy	Competent
VES 8	1	123.9	0.9	0.9		HA	Topsoil	Moderately Competent
	2	51	3.6	4.5			Clayey	Competent
	3	184.1	17.5	22	22		Clayey	Competent
	4	364.4					Clayey Sand	Moderately Competent
VES 9	1	121.9	1.1	1.1		AK	Topsoil	Moderately Competent
	2	872.4	5.6	6.7			Clayey Sand	Moderately Competent
	3	9082.9	35.3	42	42		Sandy	Competent
	4	7512.7					Sandy	Competent
VES 10	1	71.7	1.2	1.2		K	Topsoil	Moderately Competent
	2	2923.9	40.4	41.6	41.6		Sandy	Competent
	3	1896.4					Sandy	Competent

A. Geoelectric Section

The present geological or lithological layers in the subsurface can be well modeled and shown diagrammatically; this image is called a geoelectric section. The geoelectric section represents the depth and thickness of the underlying lithology and their respective resistivity values. As shown in Figure 4, the map indicates two traverse points that fall on a straight line. Geoelectric section is used to correlate lithologies, which was carried out along a profile, and to view the lithology across the subsurface.

Traverse one

This traverse is made up of three vertical electrical sounding points that fall on a straight line of points VES 1, VES 3, and VES 5 traversing from the W to E direction (figure 5). The moderately competent topsoil layer has a resistivity value range of 166.6 Ωm (at VES 1) to 336 Ωm (at VES 5). The second layer, indicating the competent sandy layer, shows resistivity values ranging from 1972.7 Ωm (at VES 1) to 10,393 Ωm (at VES 5). The third layer, indicating moderately competent clayey layer, shows resistivity values ranging from 536.5 Ωm (at VES 1, layer 2) to 626.7 Ωm (at VES 3, layer 4).

Traverse two

This traverse is made up of three vertical electrical sounding points that fall on a straight line of points VES 7, VES 8, and VES 9 traversing from the S to N direction (figure 6). The moderately competent topsoil layer has a resistivity value range of 121.9 Ωm (at VES 9) to 213.4 Ωm (at VES 7). The second layer, indicating the moderately competent clayey layer, shows resistivity values ranging from 51 Ωm (at VES 8) to 872.4 Ωm (at VES 9). The third layer, indicating competent Sandy Layer, shows resistivity values ranging from 1817.5 Ωm (at VES 7, layer 2) to 9082.9 Ωm (at VES 9, layer 3).

Traverse one runs from west to east, while traverse two runs from south to north. In traverse one, the sequence is topsoil, sandy, and then clayey layers. In traverse two, the sequence is topsoil, clayey, then sandy layers.

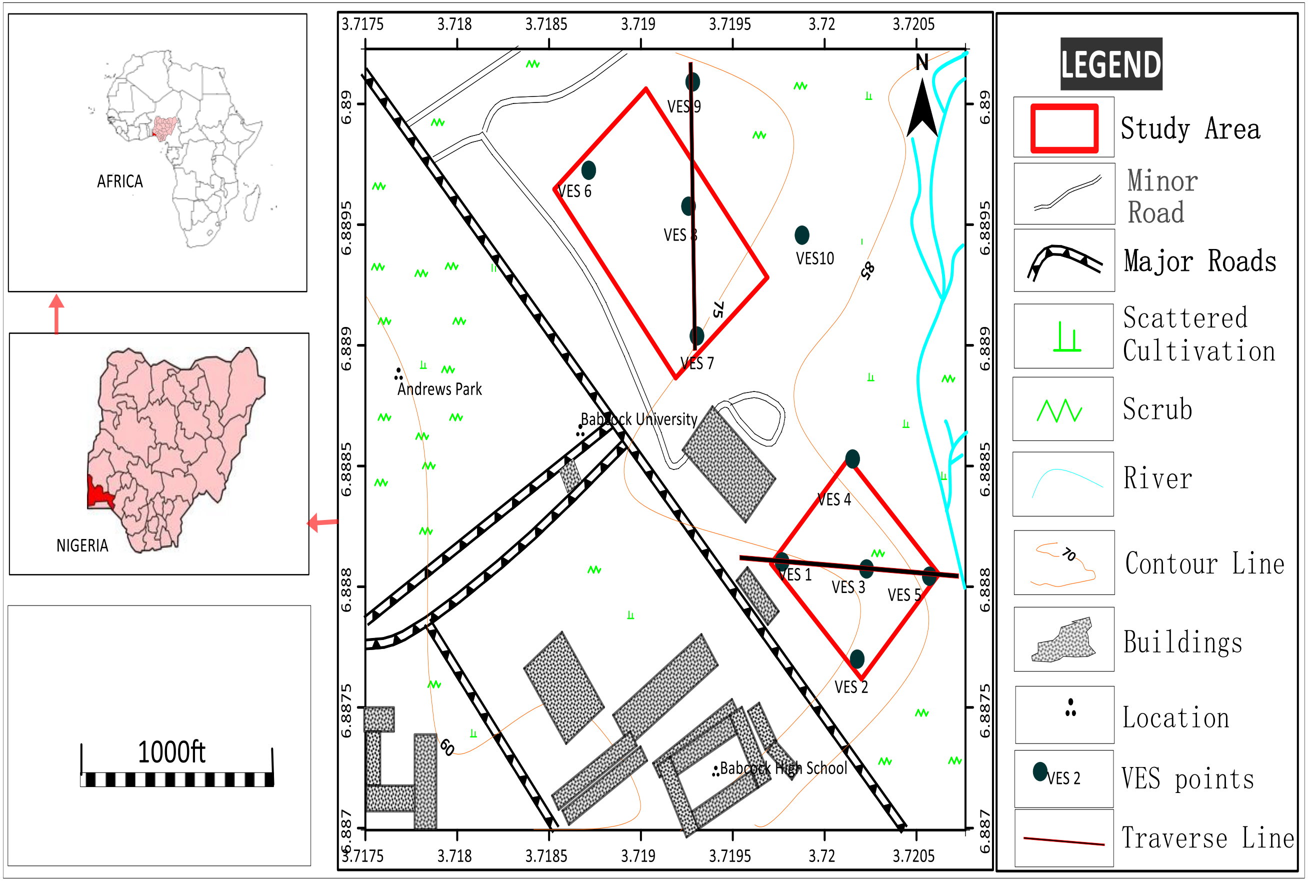

Figure 4: Map Showing VES points and the traverse of the study area

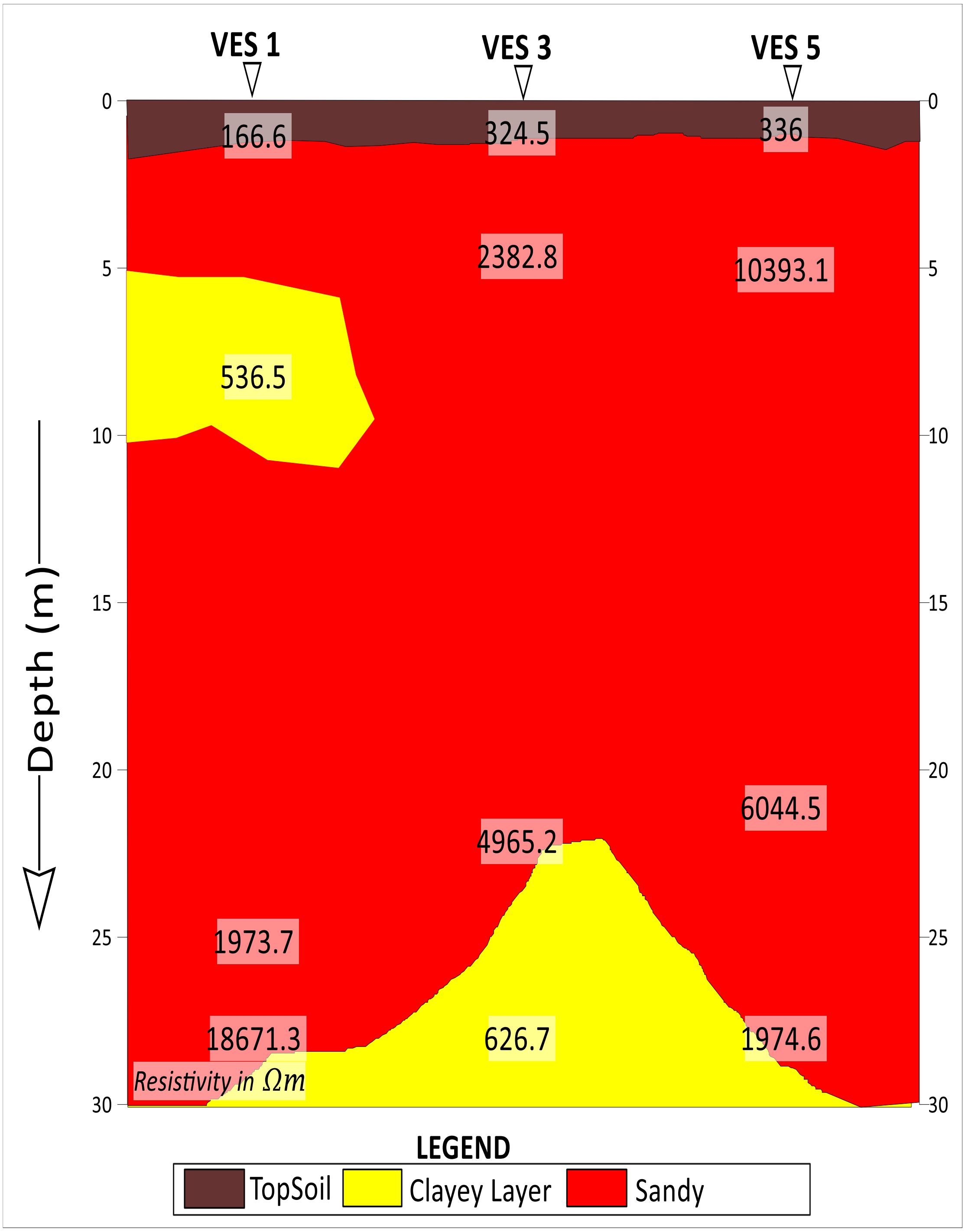

Figure 5: Geoelectric Section of Traverse 1

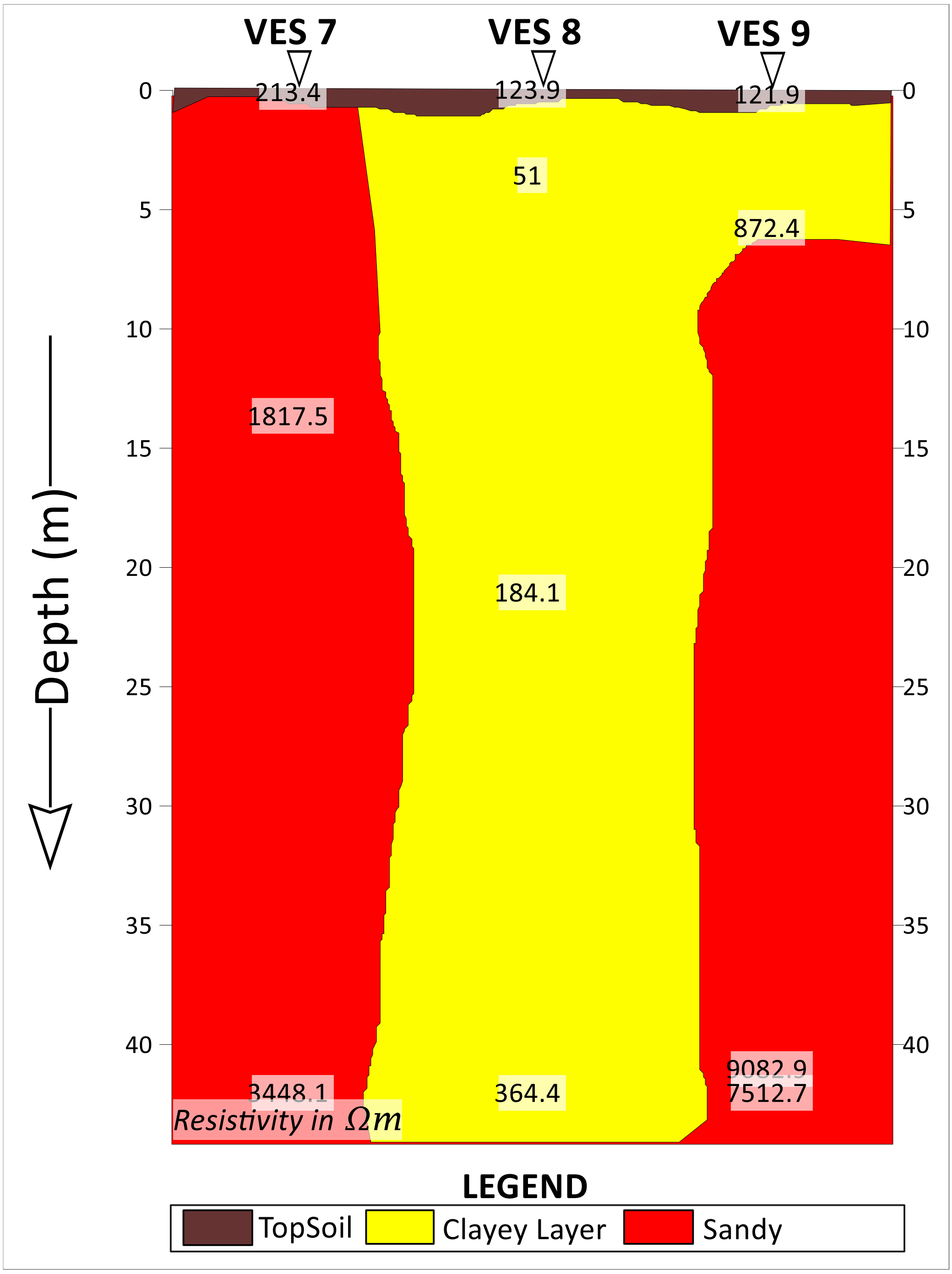

Figure 6: Geoelectric Section of Traverse 2

V. CONCLUSION

The application of the electrical resistivity method has been employed in delineating the various litho units at a proposed building site of Babcock University, southwestern Nigeria. Based on the ten (10) VES measurements taken, three to five layers were delineated from the study area, which comprise topsoil, clayey sand, and a sandy layer, with most of the curves being QKA-type. The results have shown that the resistivity values in traverse one generally tend to be higher than those in traverse two across all layers because of its high resistivity, especially in the sandy layer, indicating better load-bearing capacity, as reported by [11]. This might be preferable for foundation design if the project requires significant load-bearing capacity. Traverse two shows a sequence where the clayey layer lies beneath the topsoil, which provides better stability against settlement. This area is preferable for structures where minimizing settlement is crucial. More importantly, it is recommended that further geotechnical investigations should be carried out to make an informed decision.

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