

Original Research Article

**APPLICATION OF ELECTRICAL RESISTIVITY METHOD IN SITE
CHARACTERIZATION ALONG ADO – AFAO ROAD, SOUTHWESTERN
NIGERIA.**

Abstract

A geophysical study was carried out at a proposed location for the construction of a structure along Ado-Afao road, Southwestern Nigeria. The aim of the study is to evaluate the electrical properties of the soil for Founding of Engineering structures. The geophysical investigation involved the Vertical Electrical Sounding (VES) technique using the Schlumberger configuration with a total of twenty one (21) VES within the investigated area. The electrode separation varies from 1 to 100 m. The geoelectric sections identified three to five geoelectric/geologic subsurface layers along the traverses. The topsoil comprising of clay, clayey sand and sandy clay with the resistivity values ranges from 28 to 800 Ω -m with its thickness varies from 0.4 to 1.9 m. The lateritic layer has a resistivity values range from 200 to 800 Ω -m and thickness ranges from 1 to 7.5 m while the weathered layer comprising of clay, clayey sand and sandy clay with resistivity varies from 30 to 220 Ω -m and its thickness varies from 1.2 to 54 m. The fractured basement with resistivity value of 763 Ω m and thickness value of 8m while the fresh basement has a resistivity value ranging from 365 to 2964 Ω m with depth to basement ranging from 8 to 58 m. The resistivity values of the topsoil are indicative of clay, sandy clay and clayey sand. This layer may not be of any special interest since topsoil is normally excavated. Hence, foundation of the proposed structures cannot be found on this layer. Based on the investigation, the competence of the subsurface of the study area can be generally classified as incompetent. There is a presence of lateral inhomogeneity of the subsurface layers and geologic features such as fractures and faults. The construction in the area should be founded on the lateritic layer or fresh basement layer coupled with pile foundation to ensure the stability of the building. The choice of foundation material, clay content and topography elevation should be put into consideration.

Keywords; Geoelectric section, Overburden Thickness, Isoresistivity Maps, Isopach Maps

Introduction

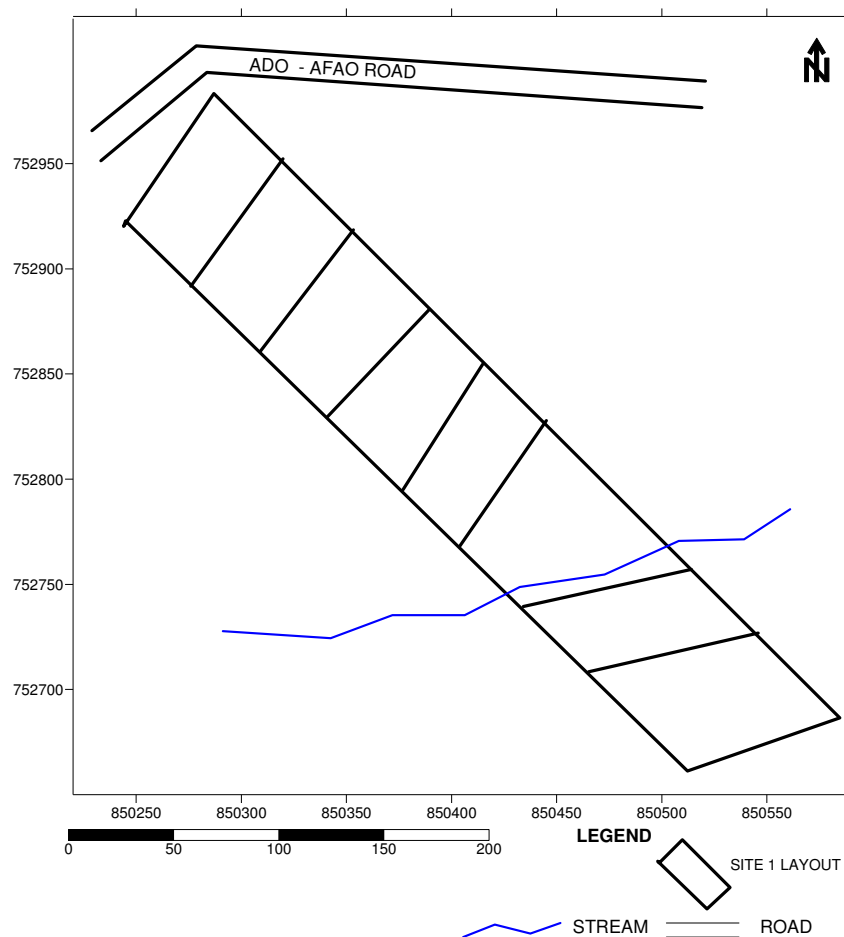
The Earth is complex in nature and very inhomogeneous in fracture distribution. The complexity of the earth materials is more pronounced in the basement complex regions while in the sedimentary terrain the soil properties may be fairly uniform over long distance. While

35 some areas are underlain by shallow bedrock or materials of higher load bearing capacity,
36 others may have significant superficial soil cover [2]. The near surface bedrock is a very good
37 foundation support material as the load bearing is infinity high. In areas of thick overburden
38 cover, the materials could have variety of engineering properties. While some may be very
39 weak especially where the clay content is high others may be of high load bearing capacity
40 especially if the aggregates are *gravelly*. The rate of failed structures in Nigeria has increased
41 in recent times [8]. These structural failures are in most cases associated with the problem of
42 poor quality of building materials, old age of buildings and improper foundation. In recent
43 times, the land expanses in Akure have been opened to rapid development [7]. Despite this
44 rapid growth and development, the impact of subsurface geologic structures in the area on the
45 durability and easy maintenance of the erected structures have been seldom discussed.
46 Vertical and near vertical cracks or discontinuities have been noticed in the walls of both old
47 and recent buildings [3]. This assertion can be attributed to the minimal attention paid
48 towards the use of geophysics in foundation studies. In Engineering Geophysics and site
49 investigation, structural information and physical properties of a site are sought [10]. This is
50 so because the durability and safety of the engineering structural setting depend on the
51 competence of the material, nature of the subsurface lithology and the mechanical properties
52 of the overburden materials [1]. Foundations are affected not only by design errors but also
53 by foundation inadequacies such as sitting them on incompetent earth layers. This research is
54 therefore targeted at revealing the use of electrical resistivity approaches as a reliable means
55 of undertaking studies of construction sites as related to the Geologic nature of the
56 environment thereby saving a lot of time and cost. Also, with the art of these methods, the
57 basic problems of structures that have emerged problematic can be investigated and
58 remediation actions can be taken.

59 **Description of the Study Area**

60 The studied area is located within Ekitit State along Ado-Afao road (Figure 1). It is situated
61 between the UTM coordinates of Eastings 850250 - 850550 m and Northings 752700 -
62 752950 m. The study area is in the southwestern central portion of Ado-Ekiti along Afao
63 Road. The accessibility of the study area is mainly by road and footpaths. The study area is
64 located within the sub-equatorial climatic belt of the tropical rain-forest with evergreen and
65 broad-leaved trees with luxuriant growth layer arrangement. The area is characterized by
66 uniformly high temperature and heavy well distributed rainfall throughout the year. The
67 average annual temperature ranges between 24⁰C and 27⁰C, while the rainfall is mostly

68 conventional, peaks twice in July and September and varies between 1500mm and 2000mm
69 per annum.

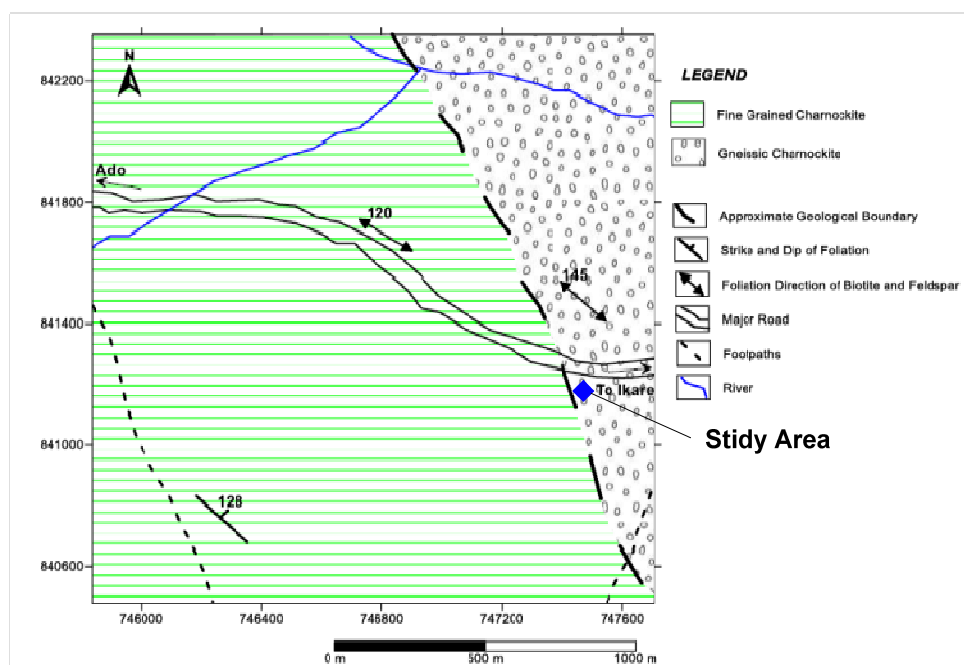


70
71 Figure 1. Base Map of the Study Area

72 Local Geological Setting

73 The geology of Ado-Ekiti belongs to the basement complex (igneous rock) rock of South
74 Western Nigeria. Major lithological rock units are basically crystalline basement rocks
75 (Figure 2). These include coarse grained charnockite, fine grained granite, medium grained-
76 granite and porphyritic biotite-hornblende granite with superficial deposit of clay and
77 quartzite. Association of the fine-grained charnockite and the porphyritic biotite-hornblende
78 granite suggest a common age [9]. A group of granites called younger granites, which are
79 made up of Granites, Granite porphyry, Syenites, Gabbro, Rhyolite and others are regarded as
80 Jurassic in age. A similar trace of these types of rock are found around Ado-Ekiti, Afao,
81 Ikole, Ikere, Aramoko, all in Ekiti state and are referred to as charnockite series. The granite
82 of Ado-Ekiti are referred to as older granites. These granites were emplaced during the
83 orogenic cycle that followed early sedimentation. Three phases in older granites are

84 recognized and distinguished: basic and intermediate plutonic rocks, fine grained granite and
85 syntectonic granites. The older granites which are associated with pegmatites is of common
86 occurrence and being resistant, smoothly domed inselbergs.

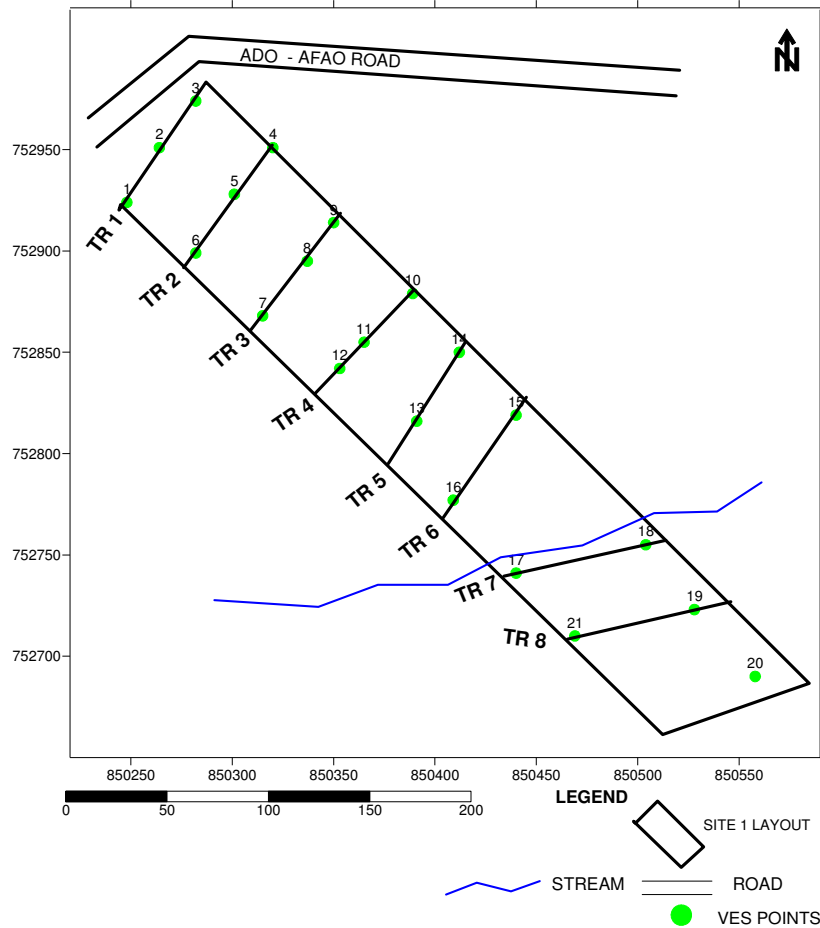


87
88 Figure 2. Geological Map of the Southwestern Part of Ado-Ekiti Showing the Study Area
89 (after Fadipe and Adeduro, 1990)

90 Methodology

91 Eight (8) traverses of about 1 to 60 m were established in an approximate E-W direction
92 (Figure 3). The electrical resistivity method utilized the **vertical electrical sounding** (VES)
93 techniques with the vertical variation in apparent resistivity of the subsurface beneath the
94 eight established traverses. The VES involved the use of Schlumberger array. Twenty one
95 (21) sounding stations were occupied along the eight established traverses and the current
96 electrode spacing ($AB/2$) was varied from 1 to 100 m. The Schlumberger depth sounding was
97 used to investigate the change **of** resistivity with depth [6], [4]. The measured unit is the
98 apparent resistivity, ρ_a , which is the product of a geometrical factor, K , and the quotient of
99 the measured potential, ΔU , and the source current, I . The apparent resistivity is plotted
100 versus $AB/2$ in meters on bilogarithmic paper resulting in a vertical electrical sounding
101 (VES) curve. The VES curve showed the change of resistivity with depth, since the effective
102 penetration increases with increasing electrode spacing. The interpretation of the VES curve
103 is both qualitative and quantitative. The qualitative interpretation involved visual inspection
104 of the sounding curves while the quantitative interpretation utilized partial curve matching

105 technique using 2-layer master curve which was later refined by a computer iteration
 106 technique Resist version [11] that is based upon an algorithm of [5]. The quantitatively
 107 interpreted sounding curves gave interpreted results as geoelectric parameters (that is, layer
 108 resistivity and layer thickness).



109
 110 Figure 3. Data Acquisition Map of the Study Area

111 Results and Discussion

112 The results of the study were presented as Sounding curves, geo-electric sections and maps

114 Characteristic of the VES curves

115 Curves types identified ranges from H, KH, HA and KHK varying between three to five geo-
 116 electric layers. The HKH curve type predominating. Typical curve types in the area are as
 117 shown in Figure 4(a-d)

118

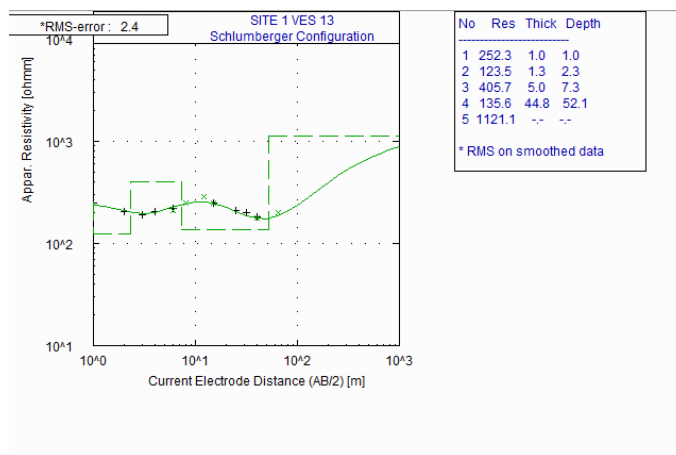


Figure 4a. Typical 'HKH' Sounding Curve

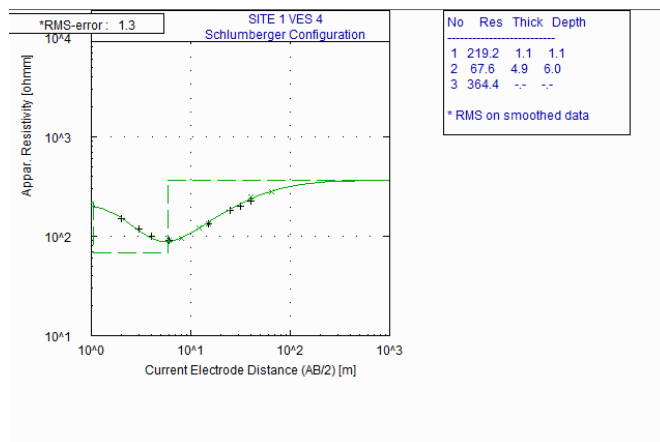


Figure 4b. Typical 'H' Sounding Curve

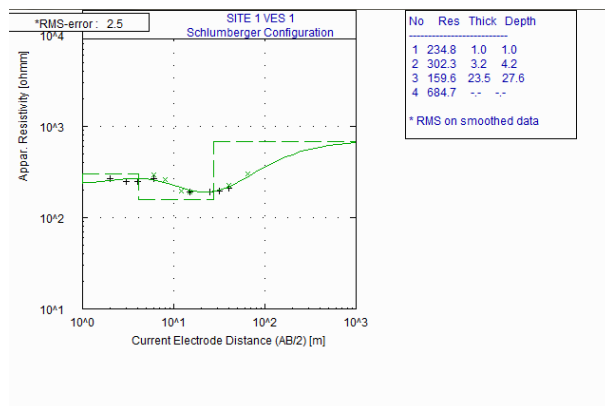


Figure 4c. Typical 'KH' Sounding Curve

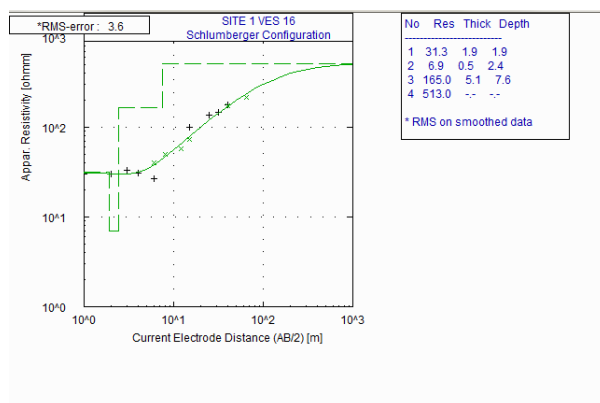


Figure 4d. Typical 'HA' Sounding Curve

Geoelectric and Lithological characteristic along the eight (8) Traverses

The geoelectric sections were represented by the 2-D view of the geo-electric parameters (depth and resistivity) derived from the inversion of the electrical resistivity sounding data. The geoelectric section along Traverse 1 to 8 (Figure 5a to 5h) attempted to correlate. The geoelectric sections along traverse one to eight identified three to five geoelectric/geologic subsurface layers along this traverses. From the geo-electric section, the top soil, lateritic layer, weathered layer, fractured basement and fresh basement were determined. The topsoil comprising of clay, clayey sand and sandy clay with the resistivity values ranges from 28 to 800 Ω -m with its thickness varies from 0.4 to 1.9 m. The lateritic layer has a resistivity values range from 200 to 800 Ω -m and thickness ranges from 1 to 7.5 m while the weathered layer comprising of clay, clayey sand and sandy clay with resistivity varies from 30 to 220 Ω -m and its thickness varies from 1.2 to 54 m. The fractured basement with resistivity value of 763 Ω m and thickness value of 8m while the fresh basement has a resistivity value ranging from 365 to 2964 Ω m with depth to basement ranging from 8 to 58 m. The resistivity values of the topsoil are indicative of clay, sandy clay and clayey sand. This layer may not be of any special interest since topsoil is normally excavated. Hence, foundation of the proposed structures cannot be found on this layer.

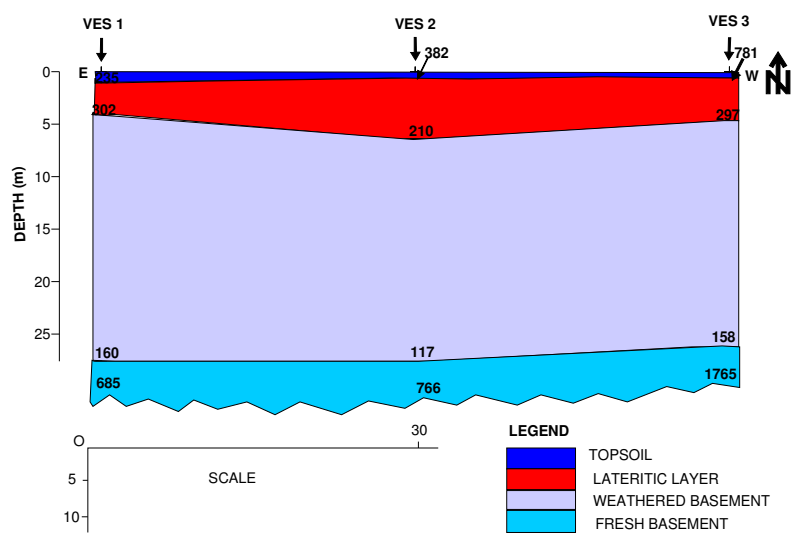


Figure 5a. Geoelectric Section along Traverse 1

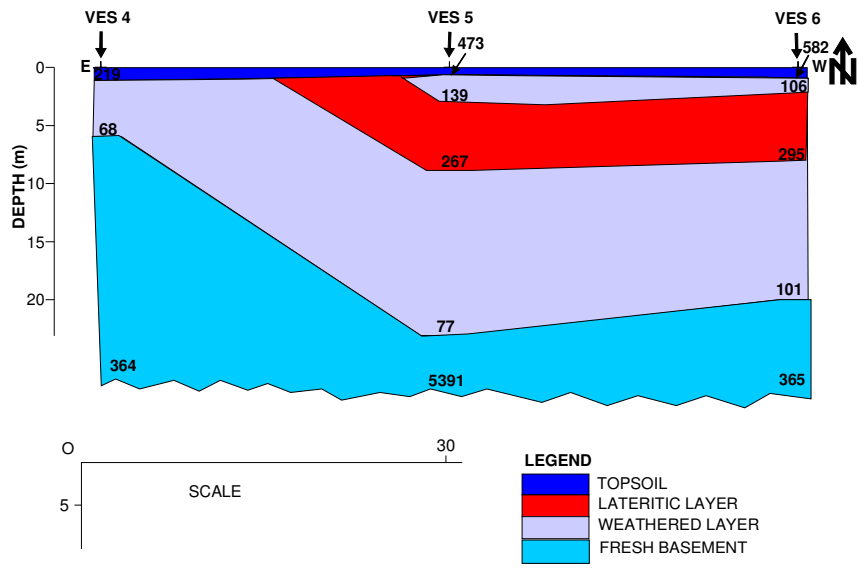


Figure 5b. Geoelectric Section along Traverse 2

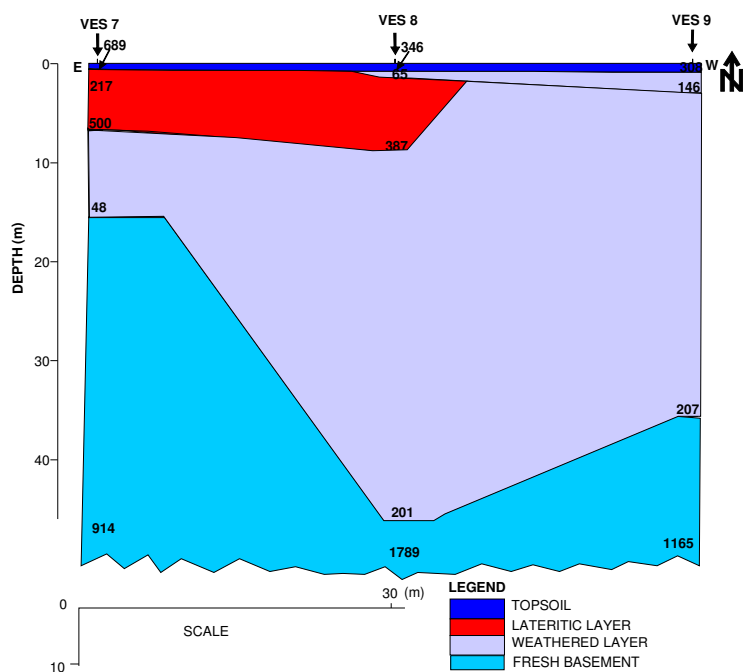


Figure 5c. Goelectric Section along Traverse 3

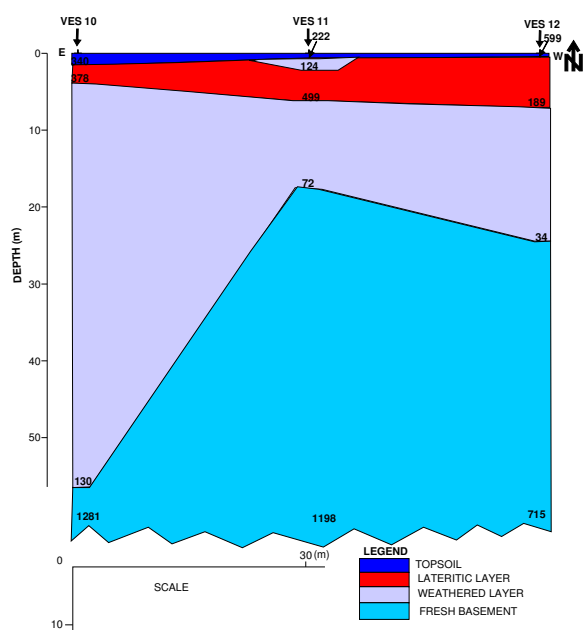
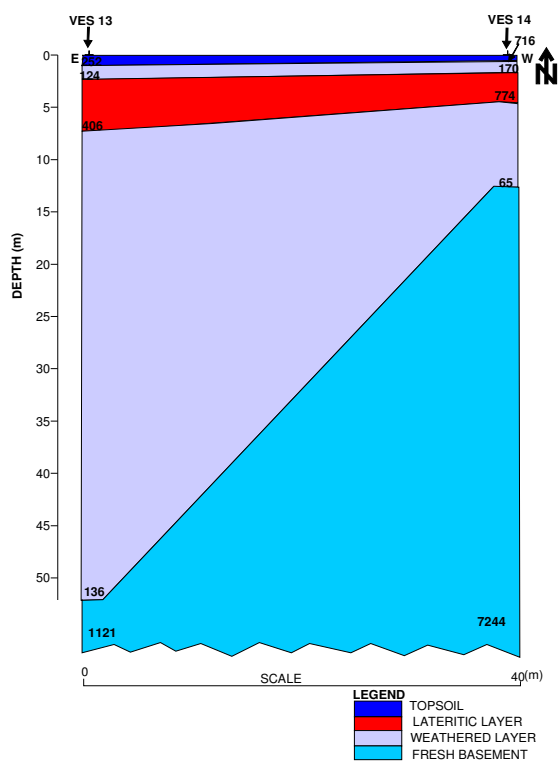
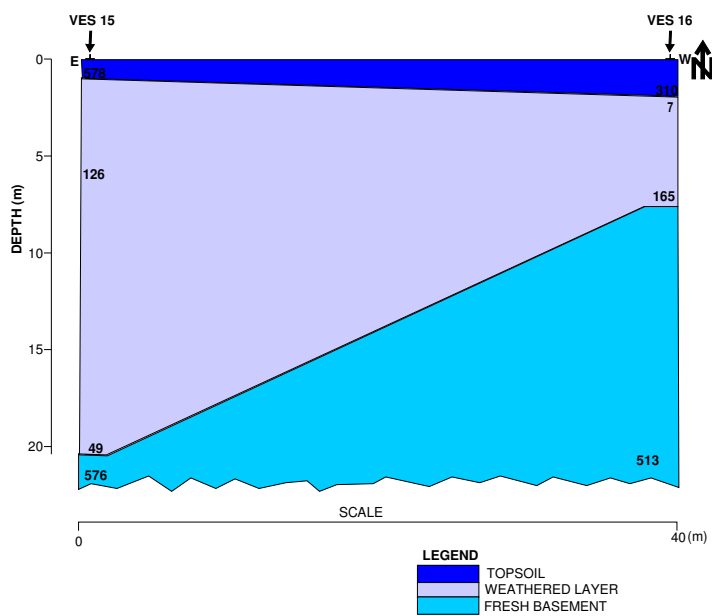


Figure 5d. Goelectric Section along Traverse 4



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157 Figure 5e. Goelectric Section along Traverse 5



158

159 Figure 5f. Goelectric Section along Traverse 6

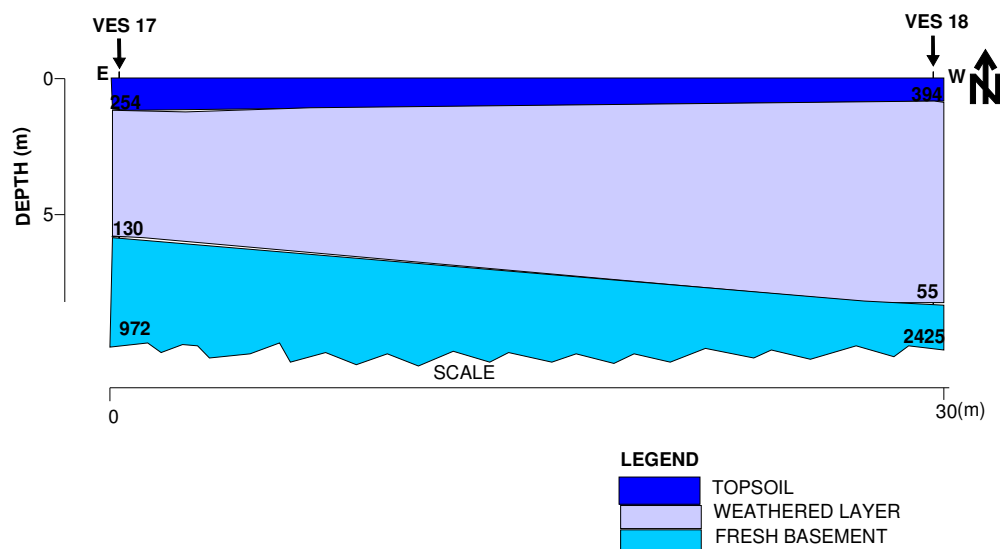


Figure 5g. Geoelectric Section along Traverse 7

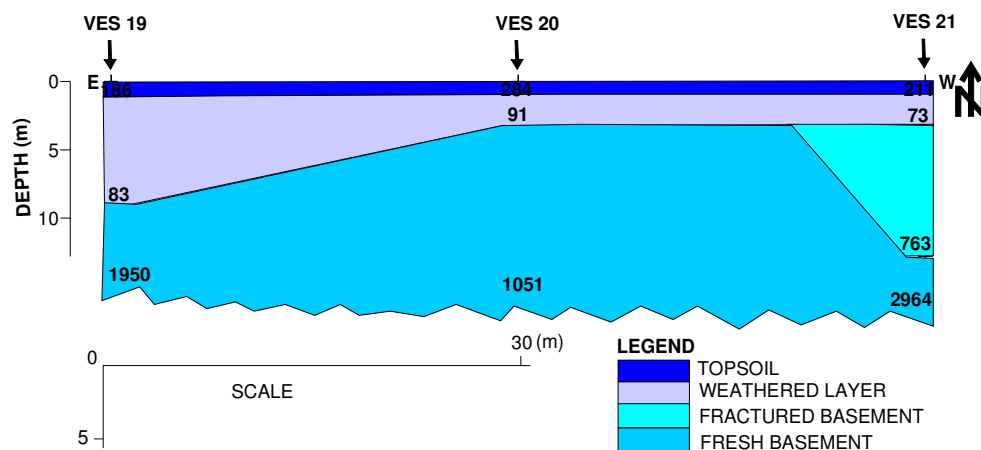


Figure 5h. Geoelectric Section along Traverse 8

Geoelectric Maps

Isoresistivity and isopach map of the topsoil

Figures 6 and 7 show the isoresistivity and Isopach map of the topsoil. The topsoil consists of clay, clayey sand, sandy clay and sand. The northwestern part of the area has the highest resistivity value from 600 to 800 Ωm . The northern, northeastern, western, southeastern and north western areas shows relatively moderate resistivity values from 350 to 550 Ωm . the northeastern, southwestern and southeastern displays low resistivity values ranging from 150 to 350 Ωm while small closure at the southwestern part illustrates very low ($<100 \Omega\text{m}$)

indicating that, the parts have larger clay content than the rest of the area. Figure 7 shows the Isopach map of the topsoil. The thickness of the topsoil ranges from 0.4 – 1.9 m and towards the south eastern, southwestern and northeastern parts of the area we have a small closure of highest thickness up to 1.9 m. The thickness of the topsoil may not be of any special interest since topsoil is normally excavated. Hence, foundation of the proposed structures cannot be found on this layer.

Isoresistivity and isopach map of the lateritic layer

Figures 8 and 9 display the Isoresistivity and Isopach map of the lateritic layer. The lateritic layer has a values ranging from 200 to 800 Ωm (Figure 8). The thickness ranges from 1 to 7.5 m (Figure 9), as shown on the Isoresistivity map. The highest resistivity values were identified towards the northeastern flank of the study area (up to 800 Ωm) and the lowest resistivity values were identified at the northeastern, southern, southeastern and southwestern flank. The Isopach map shows the largest thickness at the northeastern flank of the study area with a thickness up to 7.5 m. The second layer can be considered as a possible candidate for the erection of the proposed structure as a result of its appreciable thickness (up to 7.5 m in northeastern parts).

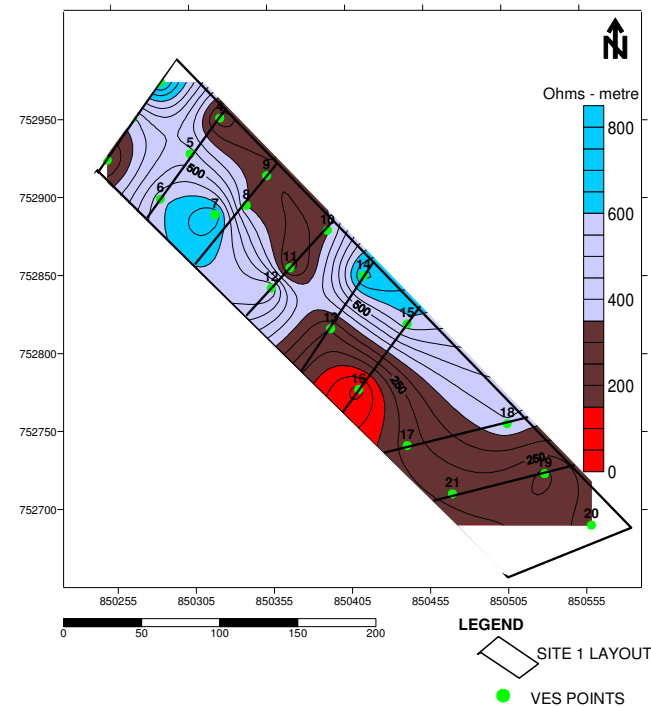
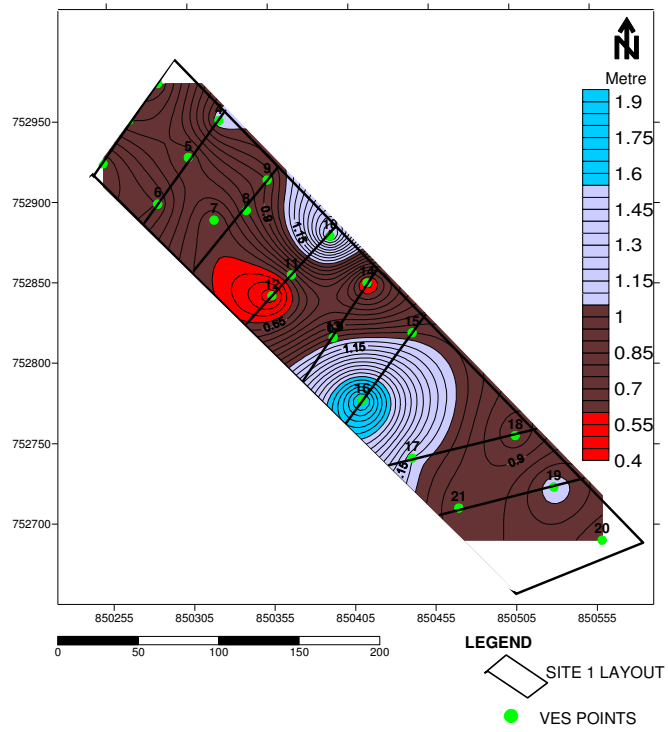
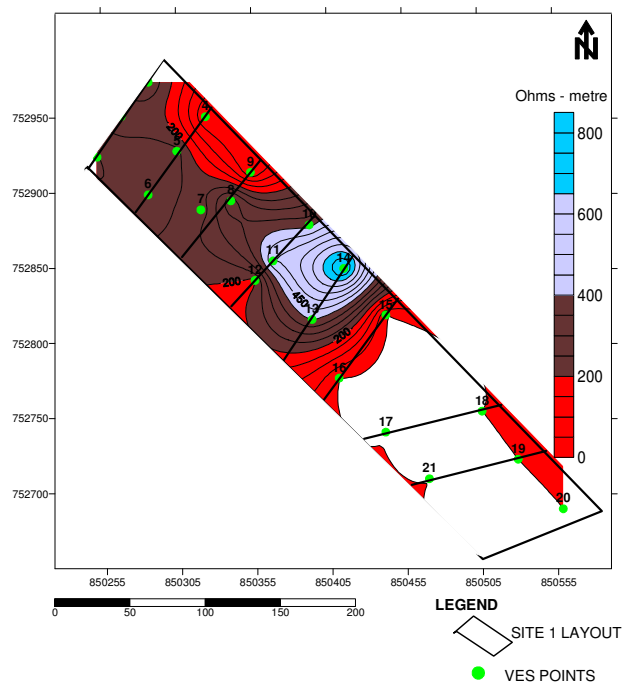


Figure 6. Isoresistivity map of the topsoil



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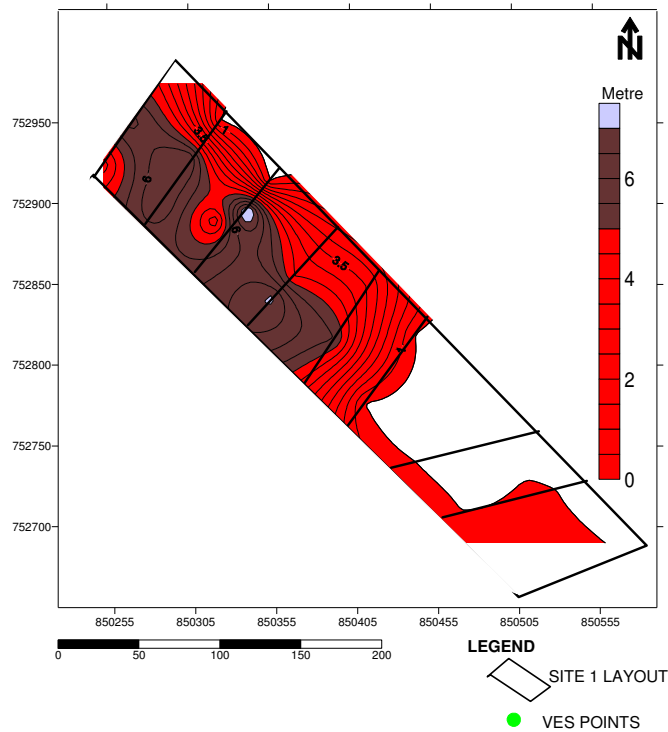
192 Figure 7. Isopach Map of the Topsoil



193

194 Figure 8. Isoresistivity map of the lateritic layer

195



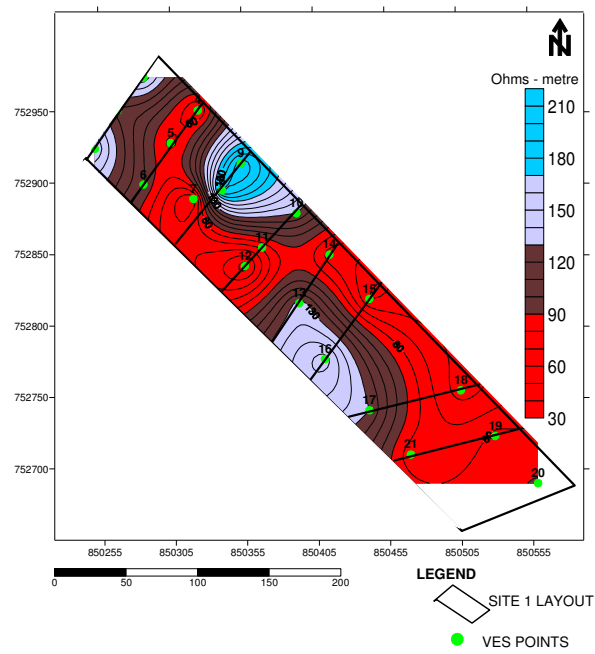
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197 Figure 9. Isopach map of the lateritic layer

198 Isoresistivity and isopach map of the weathered layer

199 Figures 10 and 11 display the isoresistivity and Isopach map of weathered layer. The
 200 weathered layer consists of clay, clayey sand, sandy clay and sand. The northeastern part of
 201 the area has the highest resistivity values ranging from 170 to 220 Ωm . The northeastern and
 202 southwestern areas shows relatively moderate resistivity values from 130 to 170 Ωm . the
 203 north, southeastern and northwestern displays low resistivity values ranging from 90 to 130
 204 Ωm while the northwestern, southeastern, southwestern and central part illustrates very low
 205 ($<90 \Omega\text{m}$) indicating that, the parts have larger clay content than the rest of the area. Figure
 206 11 shows the Isopach map of the weathered layer. The thickness of the weathered layer
 207 ranges from 0.4 – 54 m and towards the southeastern, southwestern, southern and small
 208 closure at northeastern and northwestern parts of the area has a low thickness ($<10 \text{ m}$). The
 209 highest thickness was observed at the northeastern part of the study area ($>40 \text{ m}$).

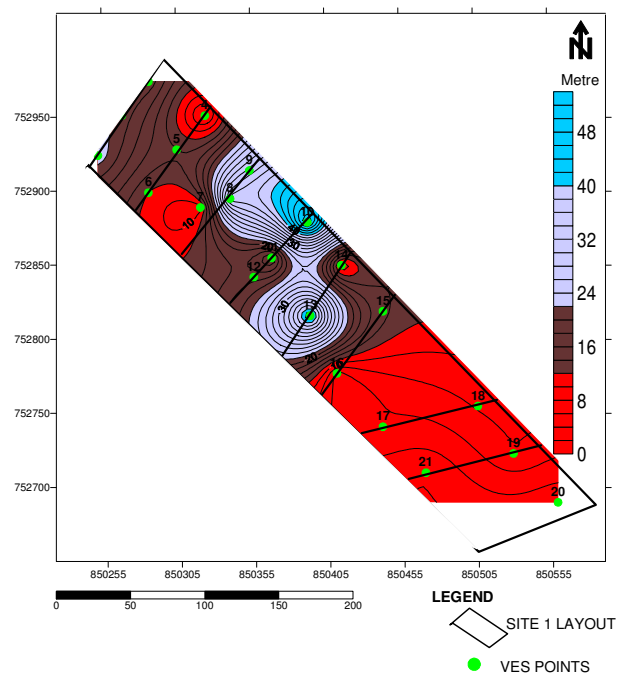
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212 Figure 10. Isoresistivity map of the weathered layer

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214

215 Figure 11. Isopach map of the weathered layer

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217

218

219 **Overburden Thickness Map**

220 Figure 12 displays the overburden thickness map which shows the variation in overburden of
221 the study area, from the topsoil down to the fresh bedrock. The overburden thickness varies
222 from 2 to 58 m. the overburden thickness is very thin between 2 to 18 m at the northeastern,
223 southeastern, southwestern and southern end. The northeastern, northwestern, southwestern
224 and southeastern has a low thickness with values ranging between 18 to 30 m , while it is
225 moderately thick between 30 to 46 m in the rest of the area, expect for small closure at the
226 northeastern end where the highest overburden thickness ranges between 46 to 58 m were
227 recorded.

228 **Bedrock Relief Map**

229 Figure 13 illustrates the bedrock relief map of the study area. A boundary between two or
230 more rock types can be inferred from the bedrock relief map. the southwestern, southeastern,
231 northwestern and the northeastern part , has a bedrock relief whose resistivity value ranges
232 between 500 to 1500 Ωm , with another rock type has bedrock resistivity between 1500 to
233 3000 Ωm was observed at the northeastern, southern and southeastern end of the study area.
234 As a way to establish the possibility of the existence of a linear structurally control feature
235 was noticed. The rest of the map is characterized mostly by another rock type, whose bedrock
236 resistivity is between 3000 to 5500 Ωm at the southeastern and northwestern part while a
237 small closure at the southeastern end with resistivity values ranging between 5500 to 7500
238 Ωm .

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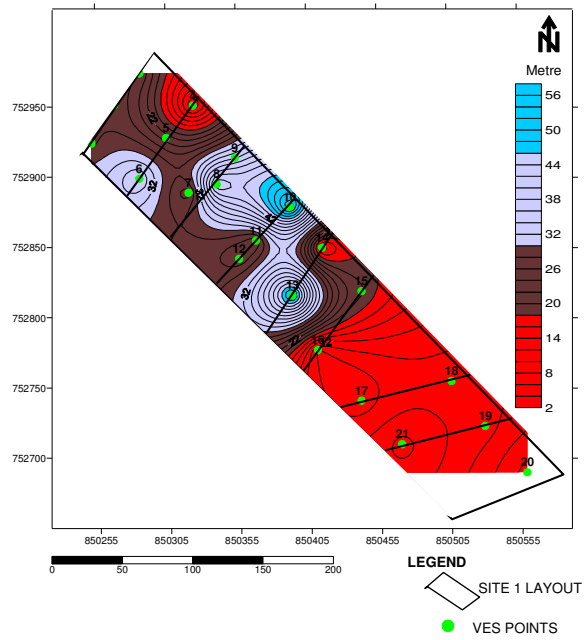


Figure 12. Overburden Thickness Map of the Study Area

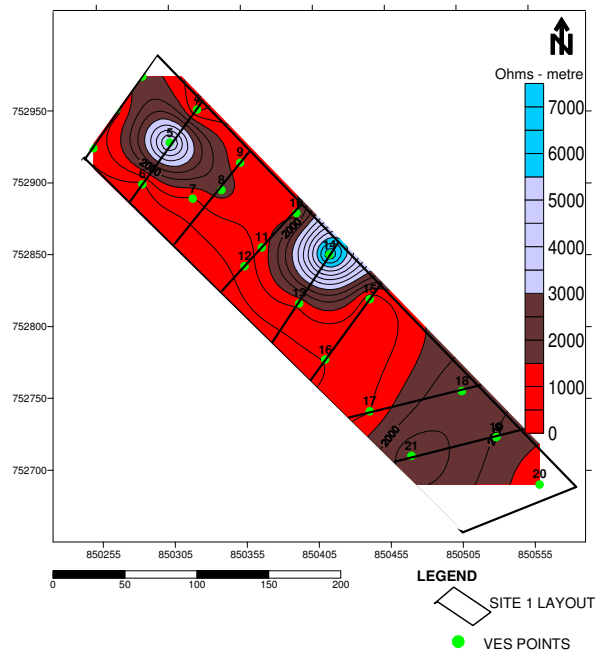


Figure 13. Bedrock Relief Map of the Study Area

3D Surface Elevation Map

Figure 14, shows the 3D view of surface elevation. The 3D view illustrate that the topography elevation is generally sloppy and must be put into consideration during the erection of the structures.

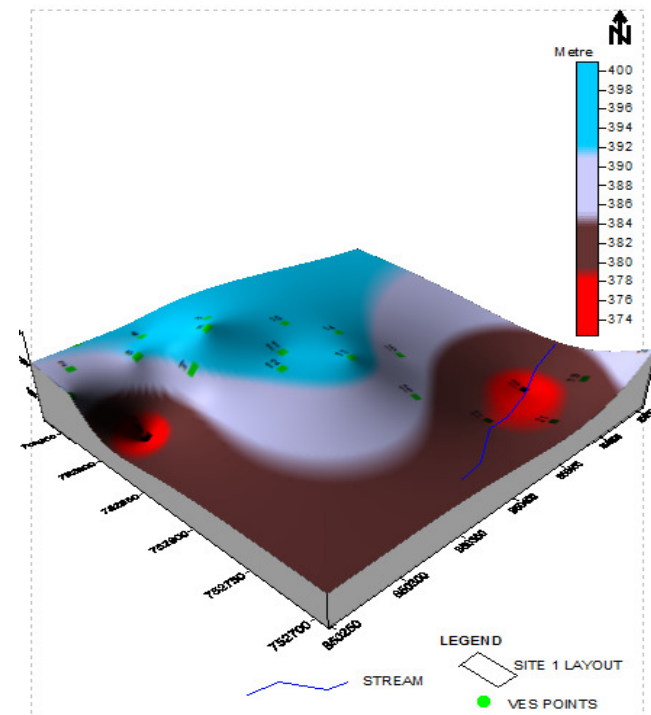


Figure 14. 3D Surface Elevation Map of the Study Area

Conclusion

The study has shown the relevance of geophysical site study for foundation design consideration. Geophysics therefore remains a very vital tool which can be applied in civil engineering work. The geoelectric sections along traverse one to eight identified three to five geoelectric/geologic subsurface layers along this traverses. From the geo-electric section, the top soil, lateritic layer, weathered layer, fractured basement and fresh basement were determined. The topsoil comprising of clay, clayey sand and sandy clay with the resistivity values ranges from 28 to 800 Ω -m with its thickness varies from 0.4 to 1.9 m. The lateritic layer has a resistivity values range from 200 to 800 Ω -m and thickness ranges from 1 to 7.5 m while the weathered layer comprising of clay, clayey sand and sandy clay with resistivity varies from 30 to 220 Ω -m and its thickness varies from 1.2 to 54 m. The fractured basement with resistivity value of 763 Ω m and thickness value of 8m while the fresh basement has a resistivity value ranging from 365 to 2964 Ω m with depth to basement ranging from 8 to 58 m. The resistivity values

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