International Journal of Science and Research Archive

eISSN: 2582-8185

Cross Ref DOI: 10.30574/ijsra

Journal homepage: https://ijsra.net/

(Research Article)

Check for updates

A geophysical site investigation in the basement complex of Akure southwestern Nigeria

Taofik O. Ewumi *

Department of Physics, Ekiti State University, Ado Ekiti, Nigeria.

International Journal of Science and Research Archive, 2025, 15(03), 029–038

Publication history: Received on 21 April 2025; revised on 27 May 2025; accepted on 30 May 2025

Article DOI: https://doi.org/10.30574/ijsra.2025.15.3.1670

Abstract

Geophysical investigation involving Schlumberger Resistivity Sounding has been carried out to provide information on the subsurface conditions in terms of the lithological characteristics, geologic structures and the groundwater vulnerability to surface infiltration. A total of thirty-six (36) Vertical Electrical Sounding (VES) stations were occupied within the study site. Four subsurface geologic layers were delineated within the study area; the topsoil (sand, silt and clay), the weathered layer (comprising of clay, clayey sand / sandy clay/ laterite), the weathered / fractured basement and the basement. Also, within the weathered layer is the clay protective layer overlying the weathered / fractured basement that serving as cover for the major aquifer unit. Groundwater development is feasible through the use of tube wells as such are protected from surface infiltration.

Keywords: Basement; Fracture; Geoelectric Section; Geoelectric Surveying; Lithology; Subsurface

1. Introduction

As an integral part of the site investigations at SASA Area, Akure, a geophysical site investigation involving geoelectric surveying was carried out with the objectives to determine from soil resistivity measurements the nature of the soil, identify existing subsurface geologic features and delineate the subsurface geological sequence. Such investigations are mandatory for regular site characterization studies.

Several researchers have demonstrated the efficacy of geolectric surveying in site investigation (Oyeyemi & Olofinnade, 2016; Bawallah et al., 2019; Falowo, 2020; Bouassida et al., 2022; Joseph et al., 2023). Vertical Electrical Sounding (VES) is a prolific non-invasive geophysical technique with impressive depth of investigation (Arekumo & Lawrence, 2019; Hasan et al., 2020; Ajayi et al., 2022). Improved resolutions are achieved with closely spaced VES stations (Adebo et al., 2021; Ajayi et al., 2022; Oyedele et al., 2022).

The site (Figure 1) is situated at Owode, in Akure North Local Government Area of Ondo State, Nigeria along the Akure Owo Road. It falls between latitude 60 40’N and 6041’N and longitude 5045’E and 5046’E. The area is underlain by the Precambrian Basement Complex rocks of Southwestern Nigeria. The identified lithological units include granite, gneiss, forming part of the migmatite gneiss complex. The granite rock mostly outcropped forming inselbergs at distances afar from the study area. The terrain is fairly rugged particularly along the north-eastern and western flanks of the area; the southern and central portions are characterized by low relief. The mean annual rainfall in the area ranges from 700 to 800 mm approximately. The evaporation in the area is high due to the humidity, relatively high sunshine hours and low precipitation. The area is rained by River Ala, River Ogijan and other tributaries (Adeyemi, 2015; Ogunrayi et al., 2016; Oyedele et al., 2020).

* Corresponding author: Taofik O. Ewumi.

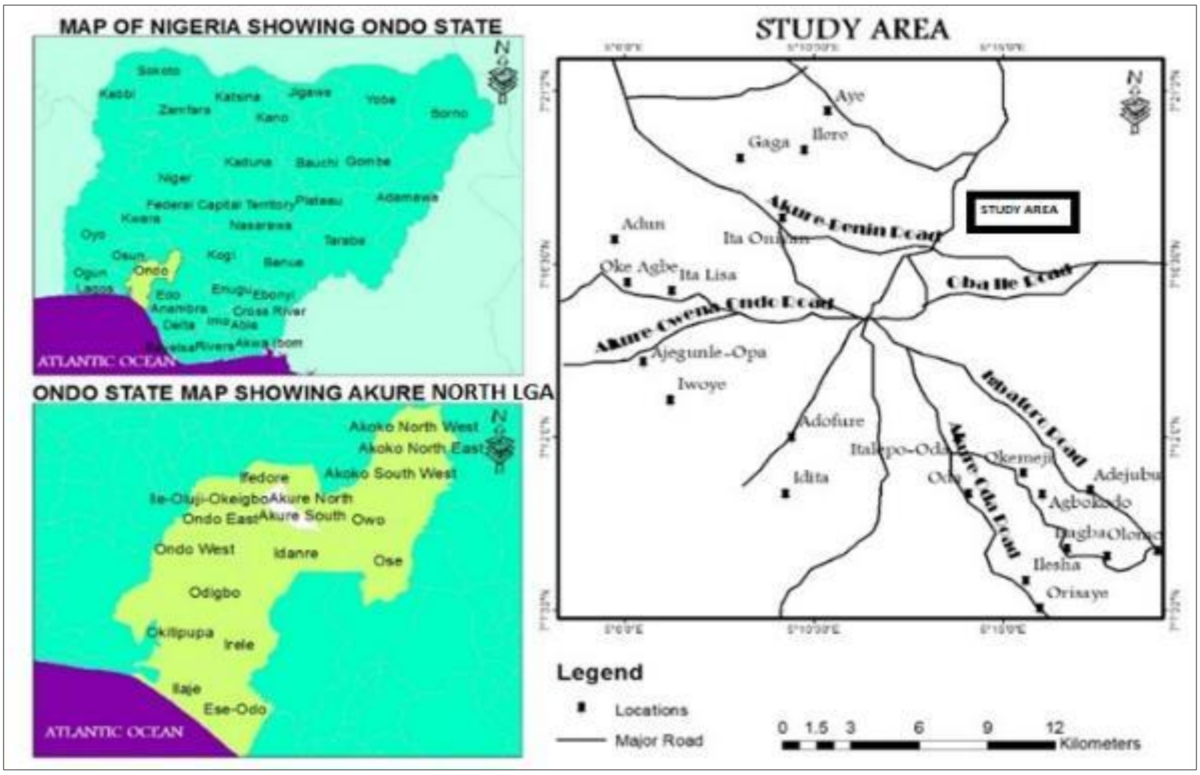


Figure 1 Map of the study area

2. Materials and methods

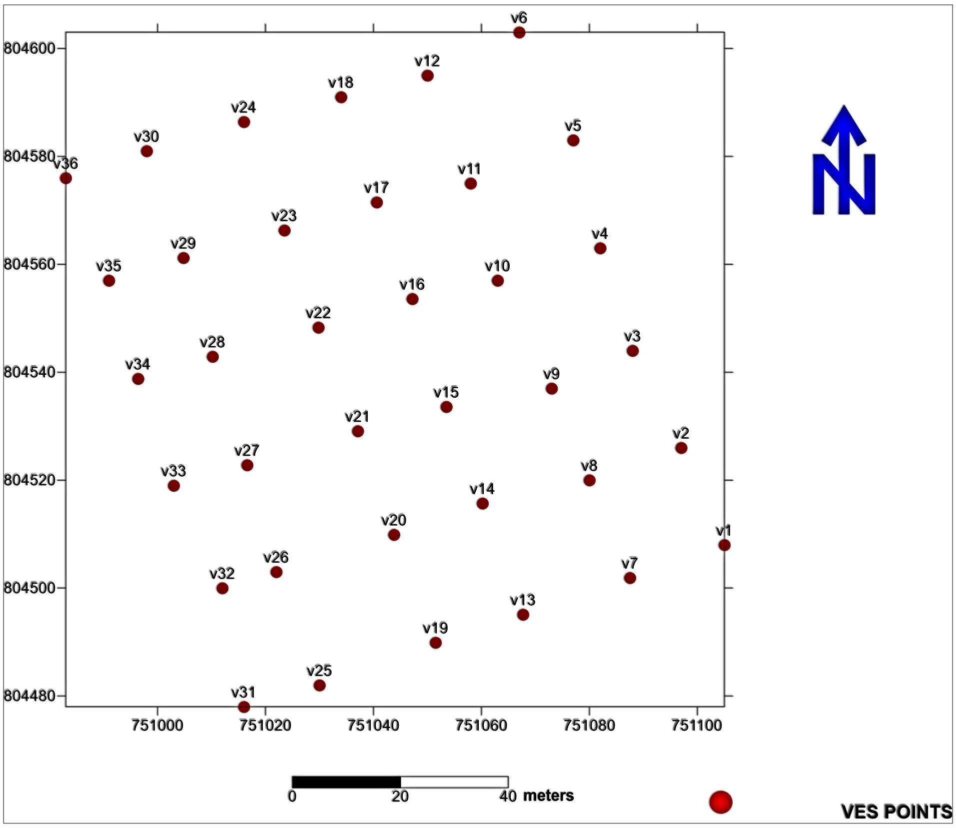


Figure 2 Location Map of the study area showing distribution of VES Points

A grid, at regular interval of 20 m was established/placed across the study area for site-specific identification of features and eventual follow-up. Six (6) traverses trending approximately North-South and East-West with lengths ranging from 100 m to 120 m were established in the grid. Thirty-six (36) Vertical Electrical Soundings (VES) were conducted at regular intervals of 20 m with six VES points per traverse to ensure high data density (Figure 2).

Measurements of ground resistance were made with Omega Resistivity Meter. Schlumberger array with the current electrode separations (AB/2) ranging from 1 to 100 m was adopted for the survey.

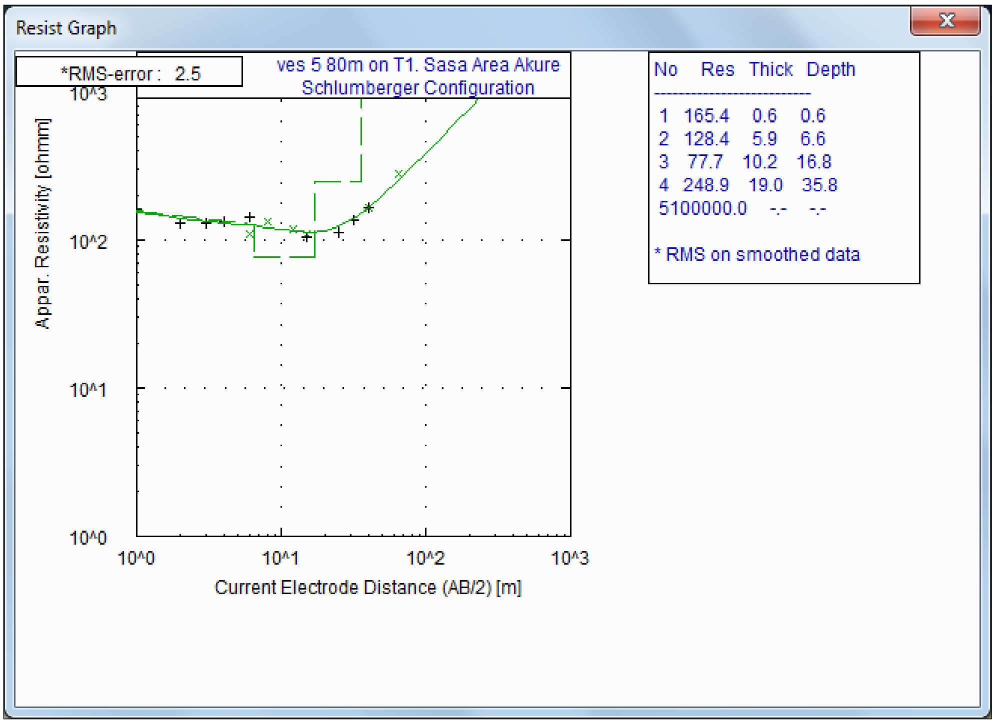
The location of each sounding station was recorded in Universal Traverse Mercator (UTM) coordinates with the aid of a GARMIN 12 channel personal navigator (GPS) unit. The soundings were performed parallel to the traverse lines. The VES data were plotted as depth sounding curves and interpreted qualitatively and quantitatively. The quantitative interpretation was done via partial curve matching and computer iteration technique (Vander-Velpen, 2004; Ademilua et al., 2015; Bawallah et al., 2019).

3. Results and discussion

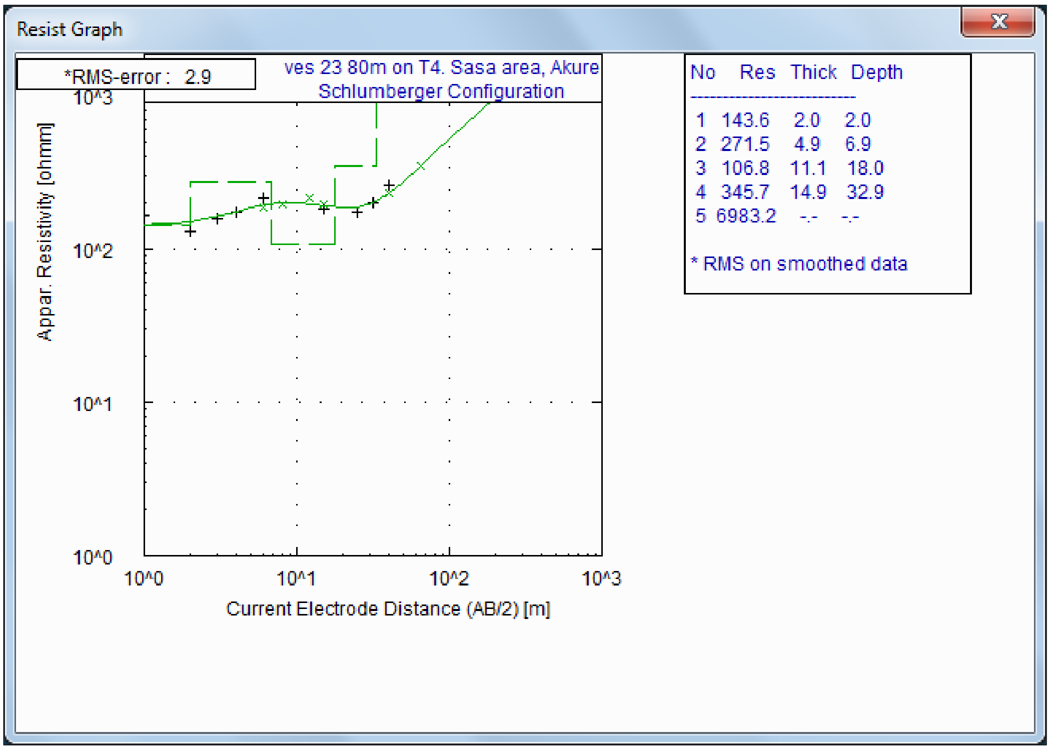
The VES data are presented as sounding curves and geoelectric sections. The typical depth sounding curves are presented in Figure 3. The sounding curves are essentially H, A, AA, KH, QHA, KHA, HKH, HKHA- types with maximum of six geoelectric layers. The layer parameters provide information on the layer resistivity and the layer thickness which informed the nature of the geologic layers and depth extent of each subsurface layer (Olayanju et al., 2017; Bawallah et al., 2019)

3.1. Bedrock Relief Map

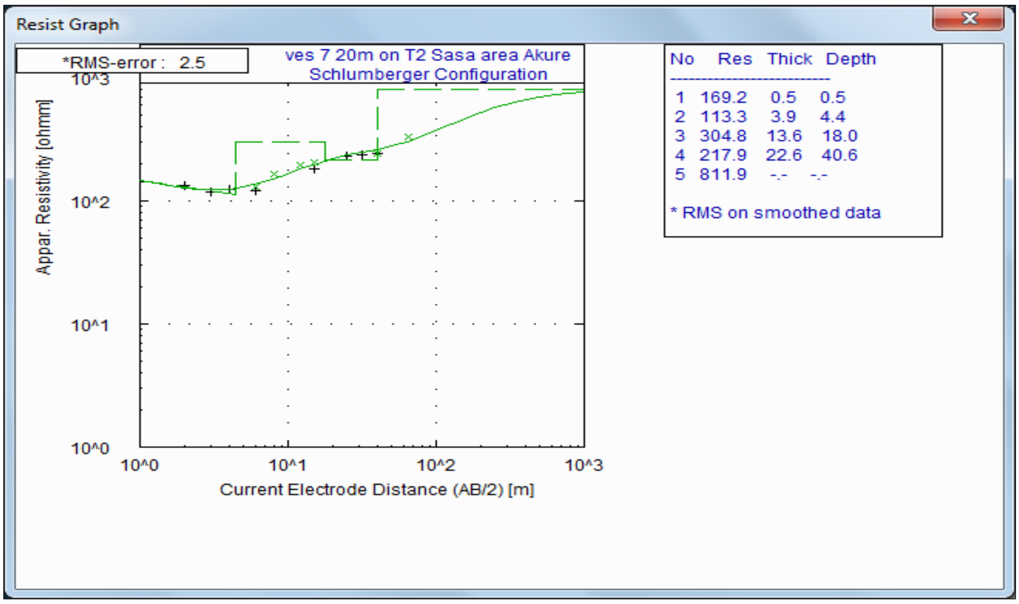
The bedrock relief map (Figure 4) is a contoured map of the bedrock elevations beneath all the VES stations. These elevations were obtained by subtracting the overburden thicknesses from the surface elevations at the VES stations. The overburden is assumed to include all materials above the presumably fresh basement. The basement relief of the study area shows the undulating nature of the basement surface which has given rise to depressions and ridges. Areas with values ranging from 316m - 328 m are classified as ridges while areas with values between 288m – 296 m is regarded as depression in the location. The northern and western portion of the grid is characterized by ridges while the southeastern part is characterized by depression. These observations could also suggest that groundwater flow in the area is likely to be in the NW-SE direction (Ademilua et al., 2015; Bawallah et al., 2019; Joseph et al., 2023)



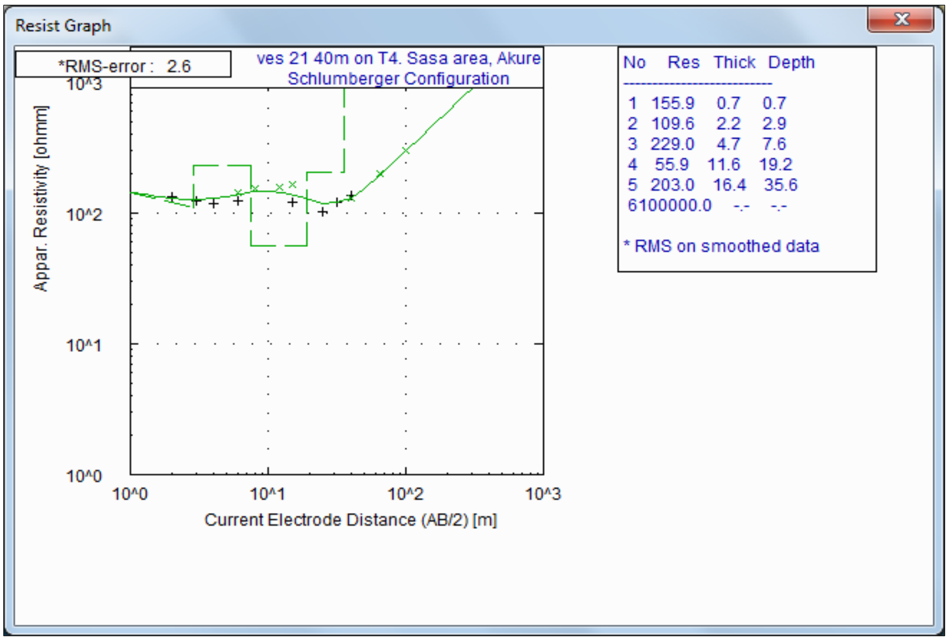
QHA-Type


Resist Graph
*RMS-error : 2.9
ves 23 80m on T4. Sasa area, Akure
Schlumberger Configuration
Appar. Resistivity [ohmm]
10^3
10^2
10^1
10^0
10^0
10^1
10^2
10^3
Current Electrode Distance (AB/2) [m]
No Res Thick Depth
1 143.6 2.0 2.0
2 271.5 4.9 6.9
3 106.8 11.1 18.0
4 345.7 14.9 32.9
5 6983.2 -.- -.-
* RMS on smoothed data

KHA


Resist Graph
*RMS-error : 2.5
ves 7 20m on T2 Sasa area Akure
Schlumberger Configuration
Appar. Resistivity [ohmm]
10^3
10^2
10^1
10^0
10^0
10^1
10^2
10^3
Current Electrode Distance (AB/2) [m]
No Res Thick Depth
1 169.2 0.5 0.5
2 113.3 3.9 4.4
3 304.8 13.6 18.0
4 217.9 22.6 40.6
5 811.9 -.- -.-
* RMS on smoothed data

HKH-Type



HKHA-Type

Figure 3 Typical sounding curves of the study area

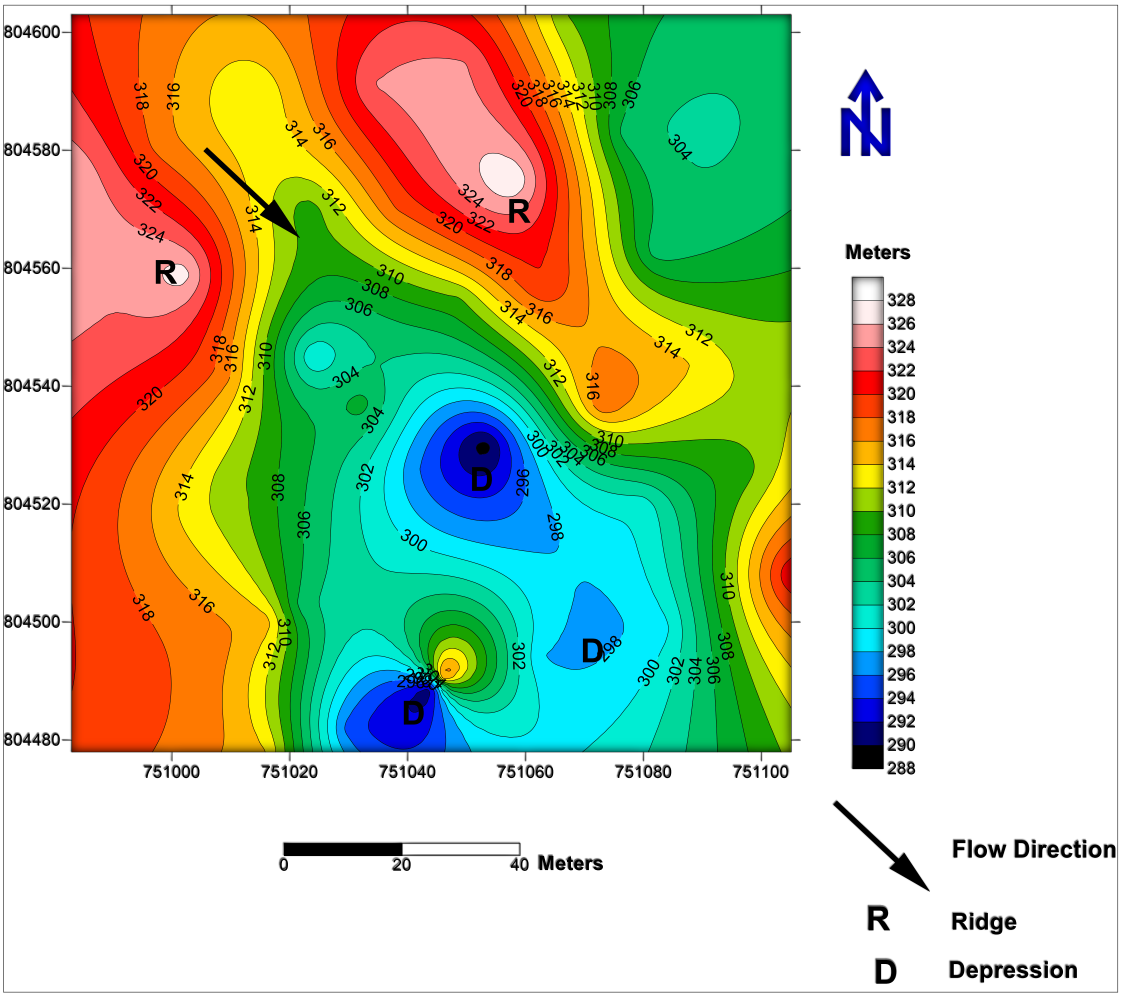


Figure 4 Bedrock Relief Distribution Map

3.2. Geo-Electric Sections

Six Geo-electric sections were produced across the area for vivid characterization of the subsurface.

3.2.1. Section A - A′

This section runs through VES 1, VES 2 VES 3, VES 4, VES 5 and VES 6 in the S-N direction (Figure 5). The profile revealed four subsurface layers; the top-soil, weathered layer, weathered basement layer and the presumed fresh basement. The topsoil resistivity values ranging from 39 to 244 Ωm indicate material composition of clay, sandy clay and clayey sand. The thickness of the topsoil is 0.5 – 1.1 m. The weathered layer (thickness: 2.3 - 12.5 m and resistivity: 105 - 150 Ωm) indicates lithological units of clayey sand / sandy clay. The weathered basement constitutes the main aquifer unit for groundwater development. The weathered basement characterized by resistivity values ranging from 46 to 374 Ωm is underlain by the fresh basement with resistivity value of 100000 Ωm.

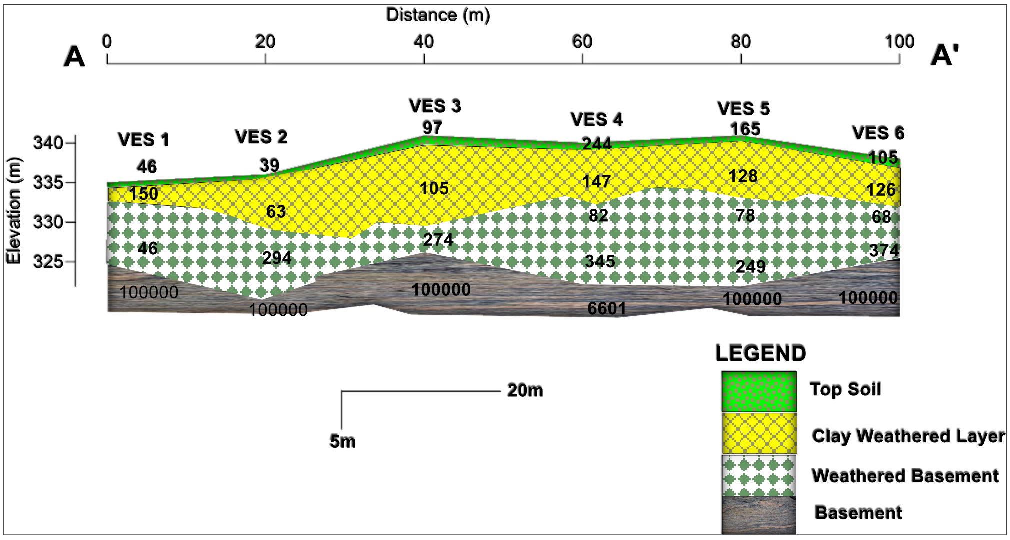


Figure 5 Geo-electric section along traverse 1

3.2.2. Section B - B′

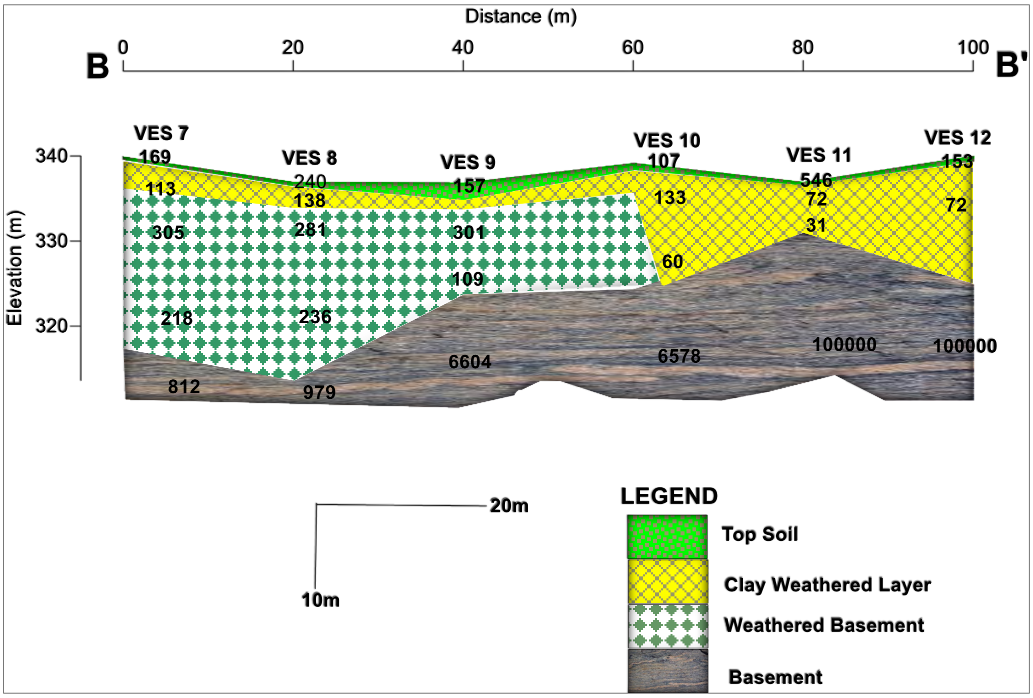


Figure 6 Geo-electric section along traverse 2

This section occupies a length of about 100m and runs through VES 7, VES 8, VES 9, VES 10, VES 11 and VES 12 in the S-N direction (Figure 6). The profile revealed four subsurface layers; the top-soil, weathered layer, weathered basement and the presumed fresh basement. The topsoil resistivity values, 107 to 546 Ωm, indicate varied compositions of clay, sandy clay / clayey sand and sand with thickness of 0.4 - 2.1 m. The weathered layer with thickness ranging from 3.3 - 15.0 m and resistivity values ranging from 72 to 301 Ωm indicates lithological units of clay, clayey sand and sandy clay. The weathered basement is found beneath VES 7, 8 and 9 with resistivity values of 109 - 305 Ωm. The basement resistivity of less than 1000 Ωm suggests fractured basement of relevance in groundwater development.

3.2.3. Section C - C′

Section C - C′ runs through VES 13, VES 14 VES 15, VES 16, VES 17 and VES 18 in the S-N direction (Figure 7). The profile revealed four subsurface layers; the top-soil, clay/sandy clay layer, weathered basement layer and the presumed fresh basement. The topsoil resistivity values varied from 119 to 195 ohm-m indicating sandy clay layer. The clay/sandy clay layer with thickness ranging from 6.3 - 23.8 m and resistivity values ranging from 49 to 314 Ωm indicates lithological units varying from clay to sand. The last layer is the fresh bedrock with resistivity values of 3700 - 100000 Ωm (Ademilua et al., 2015; Coker, 2015).

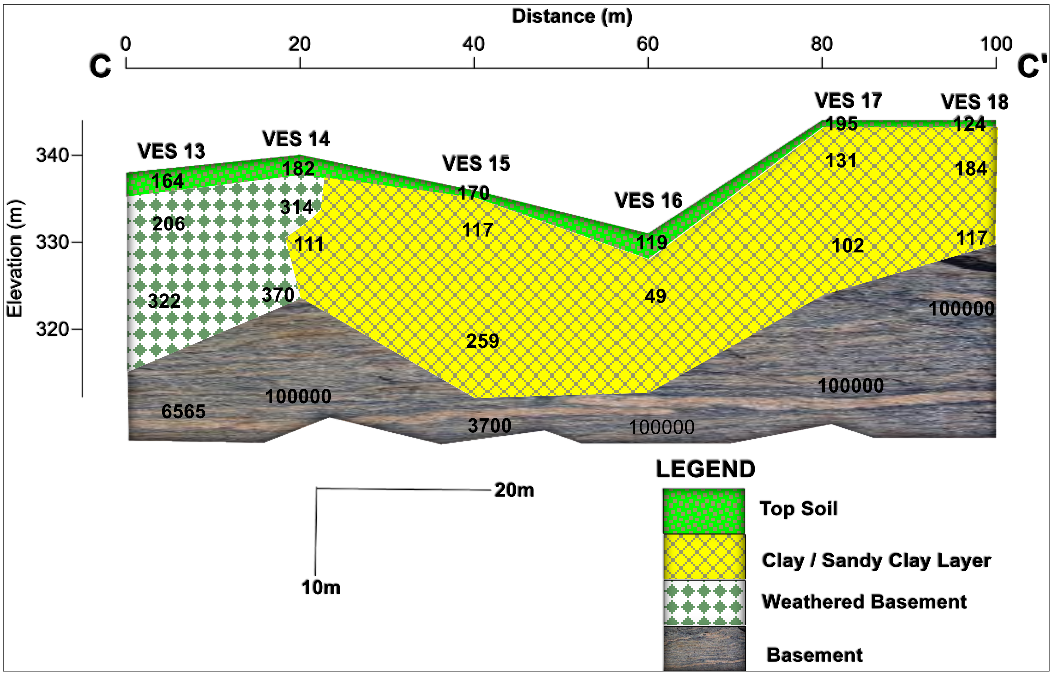


Figure 7 Geo-electric section along traverse 3

3.2.4. Section D - D′

This section occupies a length of about 100m running through VES 19, VES 20, VES 21, VES 22, VES 23 and VES 24 in the S-N direction (Figure 8). The profile revealed five subsurface layers; the top-soil, sand layer, clay/sandy clay layer, weathered basement layer and the presumed fresh basement. The topsoil resistivity values varying from 93 to 158 Ωm indicate a clay and sandy clay composition. The Clay/Sandy Clay layer with thickness ranging from 14.5m-16.3 m and resistivity value ranging from 56 to 160 Ωm indicate lithological units varying from clay to sandy clay. The weathered basement beneath VES 20 to 24 constitutes the aquifer units. The weathered basement resistivity values of 203 - 346 Ωm with thickness 14.5 m - 22.1 m. The fresh bedrock has resistivity values of 6983 - 100000 Ωm.

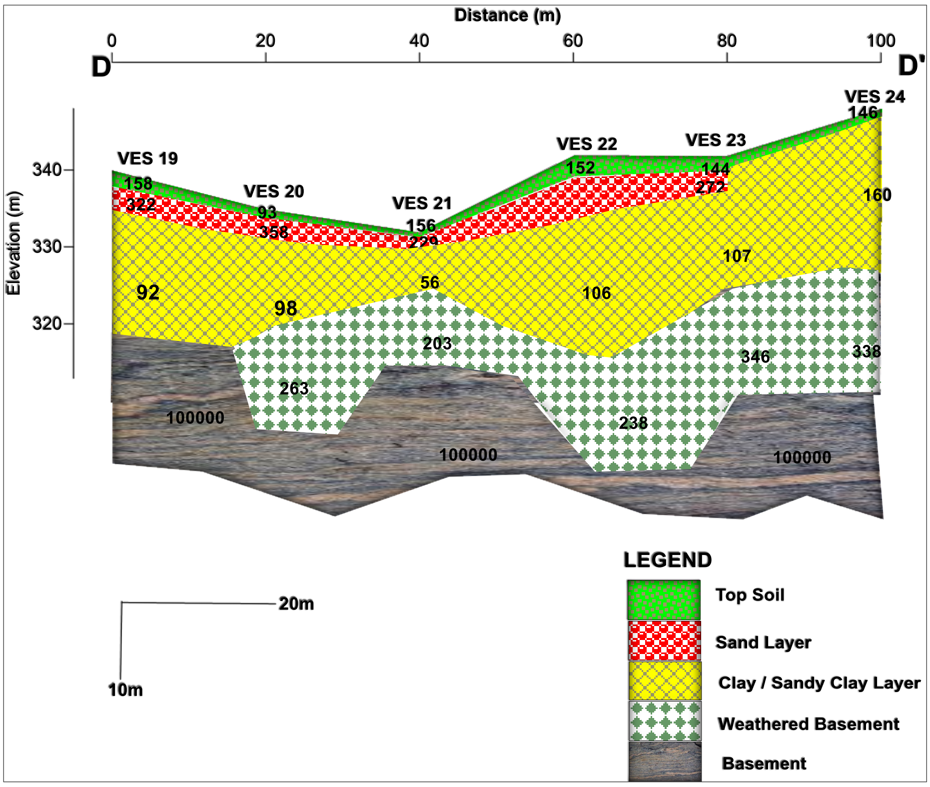


Figure 8 Geo-electric section along traverse 4

3.2.5. Section E - E′

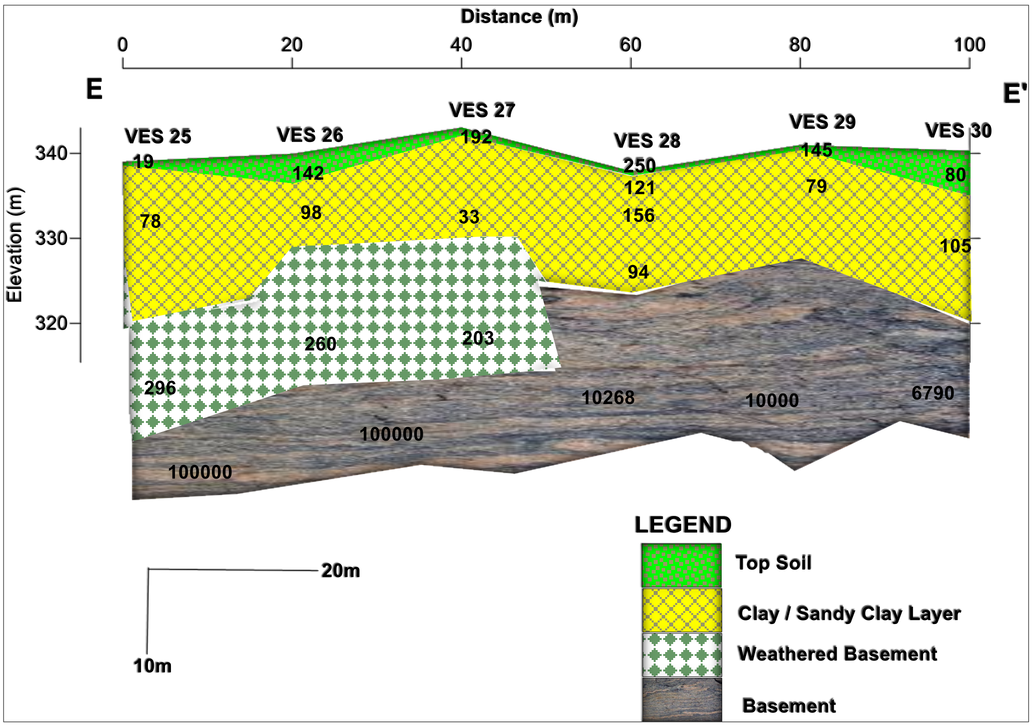


Figure 9 Geo-electric section along traverse 5

The section covers VES 25, VES 26 VES 27, VES 28, VES 29 and VES 30 in the S-N direction (Figure 9). The profile revealed four subsurface layers; the top-soil, clay/sandy clay layer, weathered basement layer and the presumed fresh basement. The topsoil resistivity values range from 19 to 250 Ωm indicating that the composition of the topsoil is clay, sandy clay and clayey sand. The clay/sandy clay layer has thickness ranging from 7 - 15 m and resistivity values ranging from 33 to 156 Ωm. The weathered basement which is beneath VES 25, 26 and 27 constitutes the aquifer unit (resistivity values: 203 to 296 Ωm; thickness of between 15.5 m and 19.6 m). The last layer is the fresh bedrock with resistivity values of 6790 - 100000 ohm-m.

3.2.6. Section F - F′

This section occupies a length of about 100m and runs through VES 31, VES 32 VES 33, VES 34, VES 35 and VES 36 in the S-N direction (Figure 10). The profile revealed four subsurface layers; the top-soil, clay/Sandy Clay layer, weathered basement layer and the presumed fresh basement. The topsoil resistivity values, 70 - 344 Ωm indicate that the composition of the topsoil is clay, sandy clay / clayey sand and Sand. The topsoil thickness ranges from 0.5 – 0.7 m. The Clay/Sandy Clay weathered layer has thickness ranging from 5.2 - 9.1 m with the resistivity values ranging from 102 to 170 Ωm. The weathered basement resistivity value ranges from 35 to 117 Ωm with thickness of 3 – 12 m. The fresh bedrock has resistivity values of 7907 - 100000 Ωm.

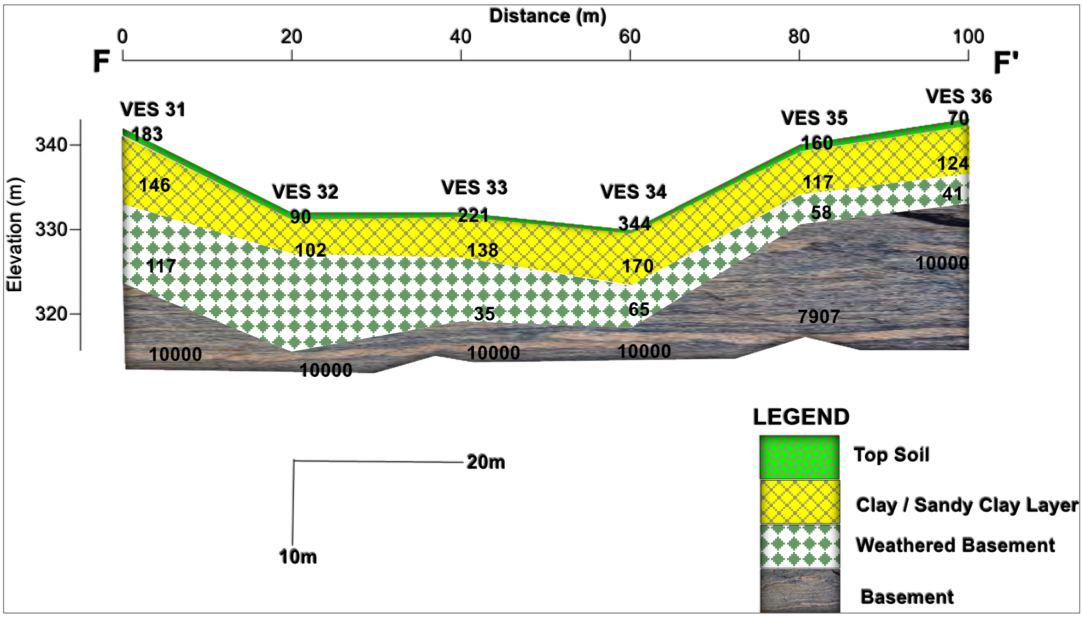


Figure 10 Geo-electric section along traverse 6

4. Conclusion

The geoelectric surveying revealed the nature of the soil, subsurface geologic features and the subsurface geological sequence. The topsoil consists of loose sand/sandy clay/clayey sand to clay materials. The weathered layer indicates lithological units of clayey sand / sandy clay. The weathered /fractured basement constitutes the main aquifer unit for groundwater development. The northern and western portion of the grid is characterized by ridges while the southeastern part is characterized by depression. The geoelectric sections provided vivid view of the subsurface lithological heterogeneities and geological structures including fractured zones, and favorable groundwater potential zones in the study area.

References

[1] Adebo, B. A., Makinde, O. E., & Ilugbo, S. O. (2021). Application of Electrical Resistivity Method to Site Characterisation for Construction Purposes at Institute of Agriculture Research and Training Moor Plantation Ibadan. Indonesian Journal of Earth Sciences, 1(2), 49-62. https://doi.org/10.52562/injoes.v1i2.248

[2] Ademilua, O. L., Eluwole, A. B., & Bawallah, M. (2015). Geophysical Investigations for Subsurface Integrity Assessment and Its Implications on Existing and Proposed Buildings Around the Southwestern Part of the Ekiti State University Campus, Ado-Ekiti, Southwest Nigeria. International Journal of Advancement in Engineering Technology, Management and Applied Science, 1(3), 1-10.

[3] Adeyemi VA (2015). The geological report of; Akure/Owo road, Igarra area, Igarra-Auchi road and Auchi Fuga-Agenebode area, 42p.

[4] Ajayi, C.A., Aderemi, S.A., Ilugbo, S.O., Adebo, B.A., and Adewumi, O.A. (2022). Geophysical Post-Foundation Studies of Minisrty of Justice Building, Ekiti-State Secretariat, Ado Ekiti, Ekiti-State, Nigeria. Geological Behaviour, 6 (2), Pp. 65-69.

[5] Arekumo, T., & Lawrence, O. O. (2019). Evaluation of Lateritic Soil from Field Resistivity Data at Okada, South-South, Nigeria. International Journal of Science and Research, 8(6), 2188 – 2192.

[6] Bawallah, M.A., Ayuks, M.A., Ilugbo, S.O., Ozegin, K.O., Oyedele, A.A., Aigbedion, I., Aina, A.O., Whetode, J.M., Ladipo, K.O. (2019). Geodynamics and its implications to environmental protection: A case study of Aule area, Akure, Ondo State, Southwestern, Nigeria. Applied Journal of Physical Science, 1 (3), Pp. 37-53.

[7] Bouassida, M., Manigniavy, S.A., Azaiez, D., Bouassida, Y. (2022): New approach for characterization and mitigation of the swelling phenomenon. Frontiers in Built Environment, 8, 836277, DOI:10.3389/fbuil.2022.836277.

[8] Coker, J. O. (2015). Integration of Geophysical and Geotechnical Methods to Site Characterization for Construction Work at the School of Management Area, Lagos State Polytechnic, Ikorodu, Lagos, Nigeria. International Journal of Energy Science & Engineering, 1(2), 40-48

[9] Falowo, O.O. (2020): Engineering site investigation and shallow foundation design in Ore Area of Ondo State, Nigeria. Materials and Geoenvironment, 67(1), pp. 21–33, DOI:10.2478/

[10] Hasan, M., Shang, Y., Jin, W. J. & Akhter, G. (2020). An engineering site investigation using non-invasive geophysical approach. Environmental Earth Sciences, 79, 265

[11] Joseph, T. A., Lukumon, A., Temitayo, O. J., Geraldine, C. A., & Taofik, A. (2023). Subsurface Integrity Assessments of a Proposed Plaza Building at Oniru Lekki, Lagos, South-western Nigeria, Using Geoelectrical and Geotechnical Methods of Investigations. Suan Sunandha Science and Technology Journal, 10(1), 74–91. https://doi.org/10.53848/ssstj.v10i1.425

[12] Ogunrayi OA, Akinseye FM, Goldberg V, Bernhofer C (2016). Descriptive analysis of rainfall and temperature trends over Akure, Nigeria. Journal of Geography and Regional Planning 9(11):195-202.

[13] Olayanju, G. M., Mogaji, K. A., Lim, H. S., & Ojo, T. S. (2017). Foundation integrity assessment using integrated geophysical and geotechnical techniques: Case study in crystalline basement complex, southwestern Nigeria. Journal of Geophysics and Engineering, 14(3), 675–690. https://doi.org/10.1088/1742-2140/aa64f7

[14] Oyedele, A. A., Bawallah, M. A., Ozegin K. O., Ilugbo S. O., Ajayi C. A and Aigbedion I. (2020). Probability functions of road failures in a typical basement complex region, South-western Nigeria: A case study of Akure - Oba Ile Airport Road, International Journal of Water Resources and Environmental Engineering, 12 (2): 10-21.

[15] Oyedele, A. A., Akinwamide, J. T., and Ogunyebi, S. N. (2022). Localized features in subsoil investigation and implications for foundation works: Case study from Ilora, Southwestern Nigeria. ITEGAM-JETIA Journal of Engineering and Technology for Industrial Applications, 8(35): 14-19. DOI://doi.org/10.5935/jetia.v8i35.81

[16] Oyeyemi, K. D., & Olofinnade, O. M. (2016). Geoelectrical-Geotechnical Studies for Near Surface Characterization, Case History: Lagos, SW Nigeria, Electronic Journal of Geotechnical Engineering, 21(10), 3735 – 3750.

[17] Vander-Velpen, B.P.A., 2004. WinRESIST Version 1.0 Resistivity Depth Sounding Interpretation Software. M. Sc Research Project, ITC, Delf Netherland.