Nigerian Journal of Theoretical and Environmental Physics (NJTEP)
ISSN Print: 3026-9601
ISSN Online: 1597-9849
DOI: https://doi.org/10.62292/njtep.v3i2.2025.91
Volume 3(2), June 2025

Groundwater Exploration in Nifor Area of Edo State using Electrical Resistivity Method

***[1]Odigwe, Promise A., [2]Ezomo, Friday A. and [1]Matthew E. Jackson-Abara**

[1]Department of Physics, University of Delta, Agbor, Delta State, Nigeria
[2]Department of Physics, University of Benin, Benin City, Edo State, Nigeria

Corresponding author: Email: Promise.odigwe@unidel.edu.ng; odigwepromise@yahoo.com

ABSTRACT
Groundwater exploration was carried out in Nigerian Institute for Oil Palm Research (NIFOR) community in Ovia North-East Local Government Area of Edo State, Nigeria using electrical resistivity method. It lies between latitude of 6° 32′ 12.12″ N and longitude of 5° 37′ 23.52″ E. The geology of the study area is overlain by the Benin Formation. The study area is hilly and had little natural topographical variations. The topography is generally low, lying area with gentle slope. The vegetation is made up of trees, shrubs and grasses. Their main livelihood is farming and trading. The method employed in this study involves the measurement of apparent resistivity with depth and also for measurement underlying rocks structure such as sedimentary beds or depth of water table. The equipment employed for taking Vertical Electrical Sounding (VES) readings was Parsi (A.C) Earth Resistivity meter. The soundings were taken using Schlumberger array with maximum current electrode separation of 430m.A total of four locations were surveyed along Cattle Yard Road, Iyamu Street, and Church Street and to Feeding 31 Street (locations 1, 2, 3 and 4). The data acquired were interpreted using computer software IPI2WIN. It was discovered that all VES locations have six layers with apparent resistivity ranging from 0.675Ωm to 616291Ωm with depth ranging from 0.5m to 129m.The major lithologic units penetrated by the sounding curve were lateritic sand, clay and fine wet sand. The results from the survey areas were correlated with the existing borehole driller's log of NIFOR for proper interpretation. The results defined the existence of aquifer with low resistivity of 0.675Ωm immediately after 5th layer in the areas under investigation. The existence of a probabilistic aquifer layer propose the study area may be a potential location for groundwater exploration, and I therefore recommend that the results of this research work should be used by drillers before a borehole is sunk.

Keywords:
Groundwater,
Exploration,
Resistivity,
Vertical Electrical Sounding (VES),
Geoelectric,
Subsurface.

INTRODUCTION

Water is one of the most essential common natural resources for continuous existence. Groundwater has at all times been a fundamental complement in absence of surface water which has become insufficient reserve in most parts of Nigeria. In areas where surface water is accessible are frequently regular and prone to pollution by humans and animals' activities (Bello and Makinde, 2007). The main geophysical method used for olden rivers canalinvestigation is the electrical resistivity technique (Minasian, 1979). Resistivity values of earth materials cover a wide range. The variety of resistivity has been the essential reason why the technique can be used for different applications (Loke, M.H., 2001). Electrical resistivity technique has been appliedwidely in groundwater exploration in difficult basement topography (Barongo and Palacky, 1991; Abiola et al., 2009; Ilugbo et al., 2018c). Resistivity technique works by sending non-natural source of current into the earth using resistivity set up. The information received from electrical sounding on water bearing formation can easily verify the vertical disparity of the earth electrical properties which can be correlated to the geology of the region (Omada and Olurunfemi, 2012). Different boreholes have been drilled in the surveyed location, but all are arid wells. This study was carried out to verify the existence of groundwater using electrical resistivity technique (VES) at NIFOR area of Edo State to obtain information about subsurface formation of the area under investigation and to recommend the total drill depth based on potential aquifer unit discovered.

MATERIALS AND METHODS

The materials used for the project include: Parsi (A.C) earth resistivity meter, four stainless steel metallic electrodes, cables, hammer, measuring tapes and Global Positioning System (G.P.S).

Study Location

Nigerian Institute for Oil Palm Research (NIFOR), Figure1 in Ovian North-East LGA of Edo State has a latitude of 6° 32′ 12.12″ N and longitude of 5° 37′ 23.52″ E. The geology of NIFOR area can best be clarified using the stratigraphy of the Niger Delta Basin (Benin Formation). The major lithologic unit in Benin formation are lateritic sand, sandy, clay and fine wet sand. The study area is hilly and had little natural topographical variations. The topography is generally low-lying area with gentle slope. The type of soil available in the area is sandy. The vegetation is made up of trees, shrubs and grasses. Their main livelihood is farming and trading. The plane rocks inside NIFOR area are geologically distinguished by reasonably fresh deposits laid down throughout the tertiary and cretaceous periods (Reyment, 1965).

Figure 1: Map of NIFOR showing the study area (Source: Google Map, 2012)

Field Data Acquisition

The Parsi (A.C) Earth Resistivity meter was used to acquire field data. Total of four (4) vertical electrical soundings (VES) were taken in NIFOR, along Cattle yard road, Iyamu street, Church street and to Feeding 31 street under suitable weather condition using Schlumberger array with maximum current electrode separation of 430m.This spacing depends on the number of points per decade, which in this research work is n=4.

Data Processing

This work involves computer inversion; the sounding curves were produced using computer software IP2WIN to confirm the layer thicknesses and resistivity values. The field data imputed into the preliminary model of this software program automatically calculates the sounding curve that best fits the field data. This process was repeated until a satisfactory fit is obtained between the model and the field data. The apparent resistivity values obtained from the measurement was plotted against half the current electrode spacing. In practice, the basic principle underlying this method is to pass current into the ground by means of two electrodes called current electrodes and to measure the resulting potential difference on the earth's surface across two potential electrodes. Apparent resistivity measurements were taken at increasing current electrode distances so that the current introduced into the ground penetrates greater depths. In places where the ground was dry, small amount of water was applied to the ground for easy penetration of current electrode into the ground which will in turn ensure good contact with the ground.The current electrodes were expanded at six points per decade while the potential electrodes remained fixed. Precautions were taken during the course of electrode spacing.

The apparent resistivity was calculated using the relation:

$$\rho_a = K \times R \quad (1)$$

$$K = \frac{((AB/2)^2 - (MN/2)^2)\pi}{2(\frac{MN}{2})} \quad (2)$$

Where K = Constant, R = Resistance in Ohms as obtained from the Terrameter, AB = the current electrode spacing in meters, MN = the potential electrode spacing in meters

The following sounding curves were acquired from the inversion process for vertical electrical sounding location 1, 2, 3 and 4 as shown in Figures 2(a-d):

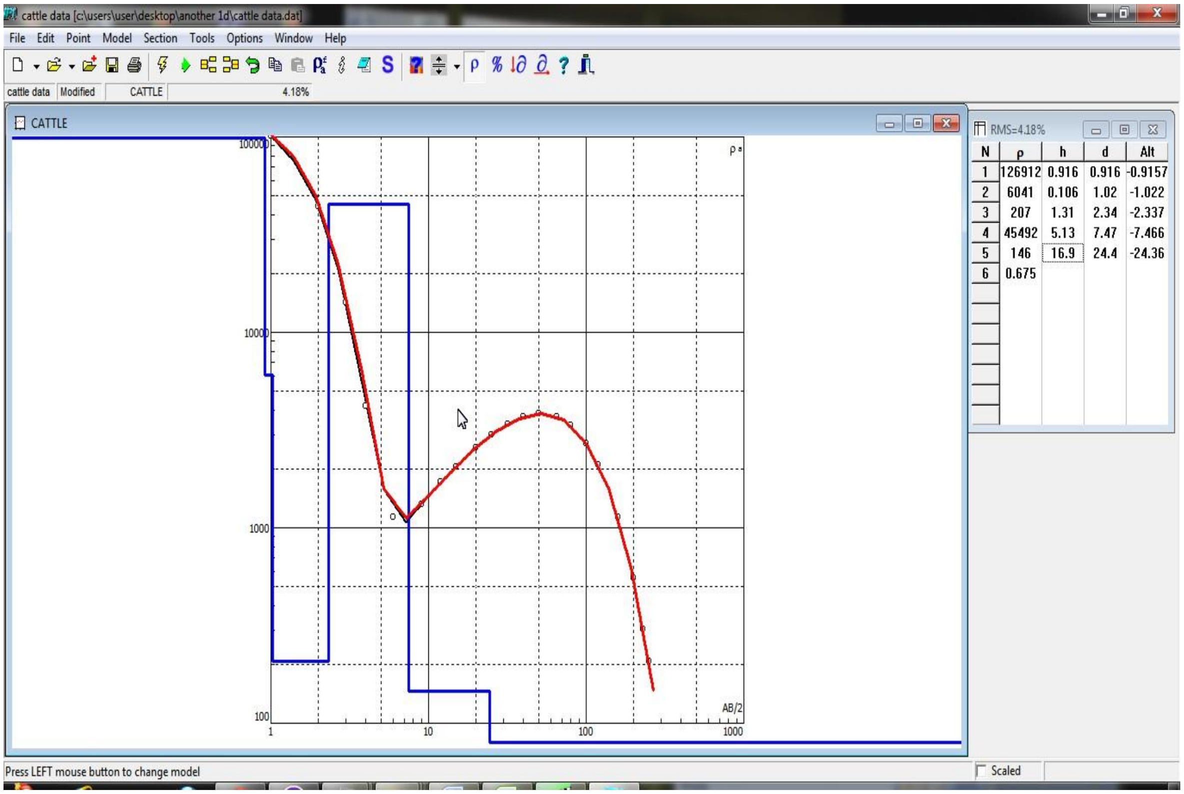

Figure 2a: VES Location 1 Sounding for Typical QHHK Curve Type

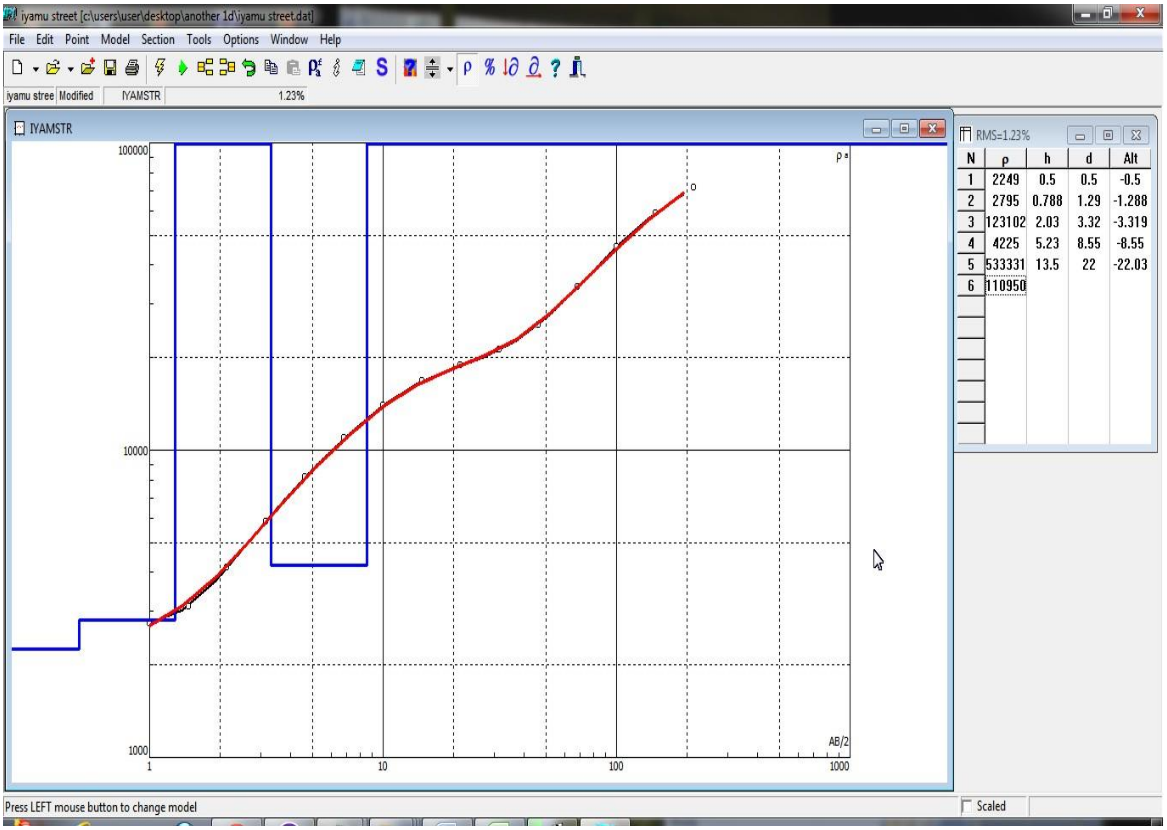

Figure 2b: VES Location 2 Sounding for Typical KHA Curve Type

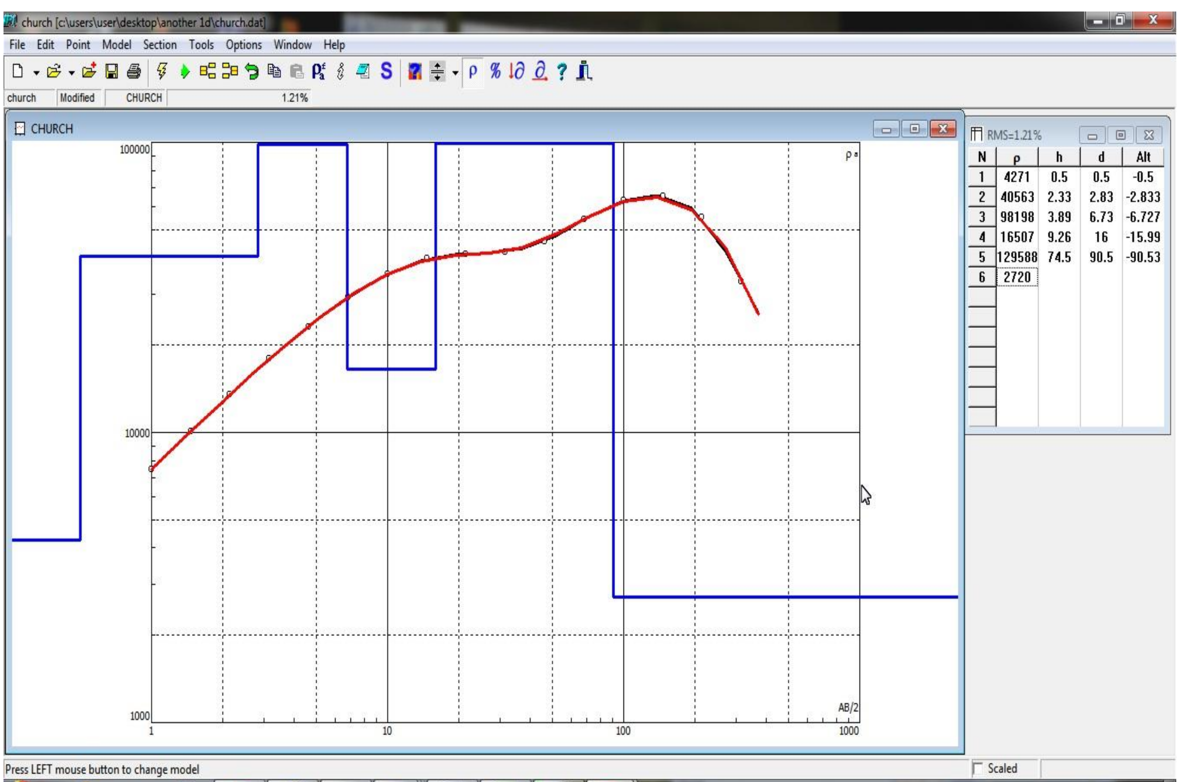

Figure 2c: VES Location 3 Sounding Curve for Typical AK Curve Type

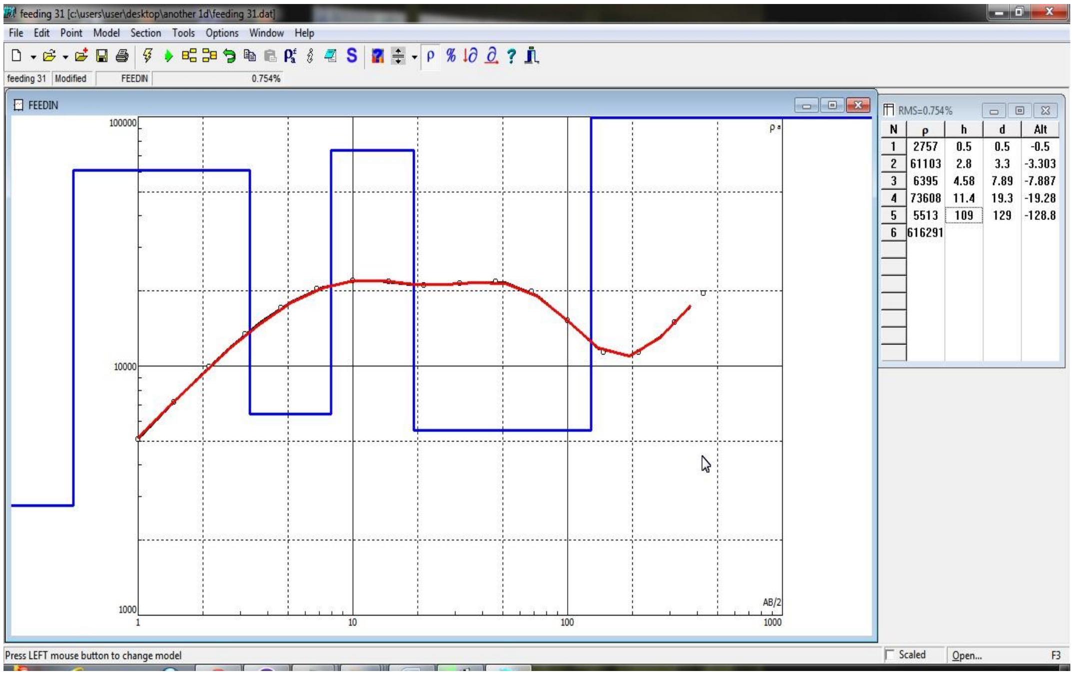

Figure 2d: VES Location 4 Sounding Curve for Typical HK Curve Type

Borehole / Drillers Log of NIFOR

The lithology is made up of laterite, different kinds of sand, gravel clay, etc.

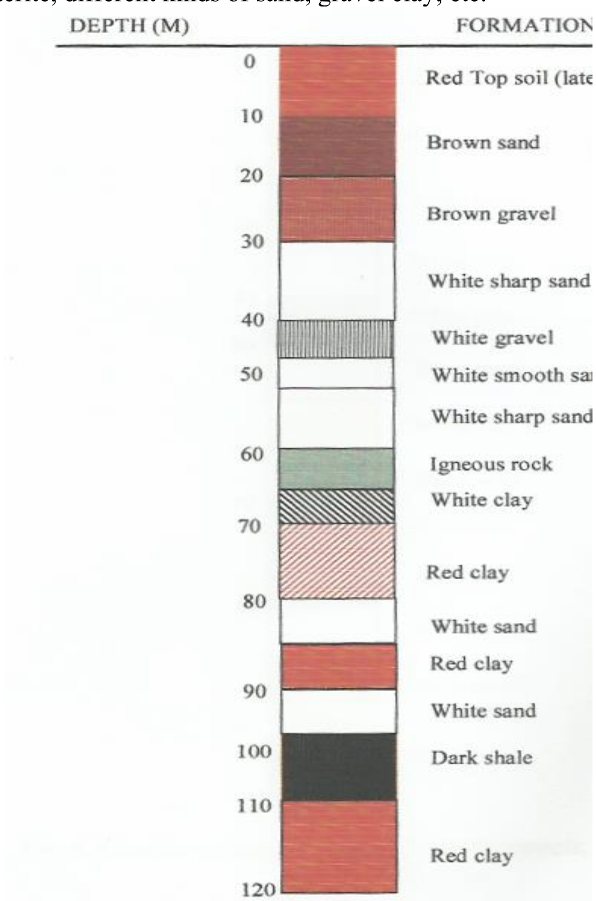

Figure 3: Edo State Urban Water Board (2012)

Table 1: Interpreted VES Results with Model Parameters, Lithology and Curve Type

VES	Layers	Resistivity (Ωm)	Thickness (m)	Depth (m)	Lithology	Curve Type
1	1	126912	0.916	0.916	Hard rock/dense Limestone	QHHK
	2	6041	0.106	1.02	Dry sand or Gravel/Laterite	
	3	207	1.31	2.34	Wet sand	
	4	45492	5.13	7.47	Hard rock/ dense Limestone	
	5	146	16.9	24.4	Laterite	
	6	0.675	NIL	NIL	Potential aquifer	
2	1	2249	0.5	0.5	Dry sand or Gravel/ Laterite	KHA
	2	2795	0.788	1.29	Dry sand or Gravel/Laterite	
	3	123102	2.03	3.32	Hard rock/ dense Limestone	
	4	4225	5.23	8.55	Dry sand or Gravel/Laterite	
	5	533331	13.5	22	Hard rock/ dense Limestone	
	6	110950	NIL	NIL	Hard rock/ dense Limestone	
3	1	42771	0.5	0.5	Hard rock/ dense Limestone	AK
	2	40563	2.33	2.83	Hard rock/ dense Limestone	
	3	98198	3.89	6.73	Hard rock/ dense Limestone	
	4	16507	9.26	16	Hard rock/ dense Limestone	
	5	129588	74.5	90.5	Hard rock/ dense Limestone	
	6	2720	NIL	NIL	Dry sand or Gravel/Laterite	
4	1	2757	0.5	0.5	Dry sand or Gravel/Laterite	HK
	2	61103	2.8	3.3	Hard rock/ dense Limestone	
	3	6395	4.58	7.89	Dry sand or Gravel/Laterite	
	4	73608	11.4	19.3	Hard rock/dense Limestone	
	5	5513	109	129	Dry sand or Gravel/Laterite	
	6	616291	NIL	NIL	Hard rock/ dense Limestone	

RESULTS AND DISCUSSION

The results of the interpreted vertical electrical sounding (VES) curves were presented as geoelectric section in Figures 2(a-d) and correlated with the existing borehole driller's log of NIFOR; six subsurface layers were identified beneath these sections. These layers include laterite, dry and wet sand, gravel, clay and hard rock/dense limestone. The geoelectric section covered a total length of 430m. It involved VES points 1, 2, 3, and 4.

In VES 1 the curve type is QHHK, the first layer of geoelectric section of Cattle yard road is at a depth of 0.916m of thickness 0.916m, the resistivity was found to be 126912Ωm. The lithogy of the formation is interpreted as hard rock or dense limestone, which corresponds to fractured or weathered basement rock. The second layer is at a depth of 1.02m and of thickness 0.106m, has resistivity value of 6041Ωm. The formation lithology is interpreted as dry sand, gravel or laterite, suggesting topsoil and weathered basement. The third layer is at a depth of 2.34m of thickness 1.31m, has resistivity value of 207Ωm. The formation lithology is interpreted as wet sand, suggesting topsoil or saturated overburden. The fourth layer is at a depth of 7.47m of thickness 5.13m, has resistivity value of 45492Ωm. The lithology of the formation is interpreted as hard rock or dense limestone, which corresponds to fractured or weathered basement rock. The fifth layer is at a depth of 24.4m of thickness 16.9m; the resistivity was found to be 146Ωm. The formation lithology is interpreted as laterite, suggesting topsoil and weathered basement. The sixth formation, which is undefined and has an undefined sand thickness, has a resistivity value of 0.675Ωm, suggesting prospective water formation (aquiferous zone).

In VES 2, the curve type is KHA. The first layer of geoelectric section of Iyamu Street is at a depth of 0.5m of thickness 0.5m, and has resistivity value of 2249Ωm. The lithology of the formation is interpreted as dry sand, gravel or laterite, suggesting topsoil and weathered basement. The second layer is at a depth of 1.29m of thickness 0.788m, and has resistivity value of 2795Ωm. The formation lithology is interpreted as dry sand, gravel or laterite, signifying top topsoil and weathered basement. The third layer is at a depth of 3.32m of thickness and has resistivity value of 123102Ωm. The lithology of the formation is interpreted as hard rock or dense limestone, which corresponds to fractured and weathered basement rock. The fourth layer is at a depth of 8.55m of thickness 5.23m, and has resistivity value of 4225Ωm. The lithology of the formation is interpreted as dry sand, gravel or laterite, suggesting topsoil and weathered basement. The fifth sand is at a depth of 13.5m of thickness 13.5m, and has resistivity value of 533331Ω. The formation lithology is interpreted as hard rock or dense limestone, which corresponds to fractured or weathered basement rock. The sixth layer which is undefined and has an undefined sand thickness has resistivity value of 110950Ωm. The lithilology of the formation is interpreted as hard rock or dense limestone, which corresponds to fractured or weathered basement rock.

In VES 3, the curve type is AK. The first layer of geoelectric section of Church Street is at a depth of 0.5m of thickness 0.5m, and has resistivity value of 4271Ωm. The lithology of the formation is interpreted as hard rock or dense limestone, which corresponds to fractured or weathered basement rock. The second layer is at a depth of 2.83m of thickness 2.33m, and has resistivity value of 40563Ωm. The formation lithology is also interpreted as hard rock or dense limestone, which corresponds to fractured or weathered basement rock. The third layer is at a depth of 6.73m of thickness 3.89m, and has resistivity value of 98198Ωm. The lithology of the formation is interpreted as hard rock or dense limestone, which corresponds to fractured or weathered basement rock. The fourth layer is at a depth of 16m of thickness 9.26m, has resistivity value of 16507Ωm. The formation lithology is interpreted as hard rock or dense limestone, which corresponds to fractured or weathered basement rock. The fifth layer is at a depth of 90.5m of thickness 74.5m, and has resistivity value of 129588Ω. The lithology of the formation is interpreted as hard rock or dense limestone, which corresponds to fractured or weathered basement rock. The sixth layer which is undefined and has an undefined sand thickness has resistivity value of 2720Ωm. The lithology of the formation is interpreted as dry sand, gravel or laterite, suggesting topsoil and weathered basement

In VES 4, the curve type is HK. The first layer of geoelectric section of Feeding 31 is at a depth of 0.5m of thickness 0.5m, has resistivity value of 2757Ωm. The formation lithology is interpreted as dry sand, gravel or laterite, suggesting topsoil and weathered basement. The second layer is at a depth of 3.3m of thickness 2.8m, has resistivity value of 61103Ωm. The lithology of the formation is interpreted as hard rock or dense limestone, which corresponds to fractured or weathered basement rock. The third layer is at a depth of 7.89m of thickness 4.58m, has resistivity value of 6395Ωm. The formation lithology is interpreted as dry sand, gravel or laterite, suggesting topsoil and weathered basement. The fourth layer is at a depth of 19.3m of thickness 11.4m, and has resistivity value of 73608Ωm. Lithology of the formation is interpreted as hard rock or dense limestone, which corresponds to fractured or weathered basement. The fifth sand is at a depth of 129m of thickness 109m, and has resistivity value of 5513Ωm. The formation lithology is interpreted as dry sand, gravel or laterite, suggesting topsoil and weathered basement. The sixth layer which is undefined and has an undefined sand thickness has resistivity value of 616291Ωm. The lithology of the formation is interpreted as hard rock or dense limestone, which corresponds to fractured or weathered basement rock.

In this study, VES1 indicates potential for groundwater exploration within weathered basement, as evidenced by a very low resistivity value. In contrast, VES 2, 3, and 4 exhibit high resistivity values, suggesting limited groundwater potential due to the presence of partially weathered basement rock with possible fractures or fresh basement rock.The report's findings align with those of previous studies conducted in the area. For instance, (Airen and Ekhoragbon, 2021) employed 2D electrical resistivity tomography in Ugbogiobo community revealing several subsurface layers with resistivity value ranging from 50Ωm to 30,000Ωm. Also, (Ehigiator, 2018), conducted a vertical electrical sounding (VES) in the study area, which corresponds to the present study. However, his investigation was limited to a single VES location, whereas this study covers four VES locations. Additionally, this research incorporates borehole log data from the study area, which serves as a control for interpreting the corresponding VES data.

Correspondingly, (Airen and Iyere, 2021) carried out a 3D resistivity imaging in Ovia North East, classifying resistivity formations indicative of clayey sand and sand with depths up to 66m. These broad studies provide a more comprehensive perceptive on the surface geology of the study area. Hydrogeologists, (Akinlabi and Oladunjoye, 2008), also conducted VES in the study area. The results of their analysis indicate a remarkable inhomogeneity in the geological composition. This conclusion aligns with our analysis as presented in Table 1.

CONCLUSION

From the results obtained, the four vertical electrical sounding stations were observed; VES 2, 3 and 4 have high resistivity values. So, there was no possibility of obtaining water as a result of partially weathered basement rock with possible fractures and fresh basement rock. However, VES 1 shows the possibility of water layer with low resistivity value of 0.675Ωm. In light of the findings, the following recommendations are proposed: the results of this research work should be used by drillers before a borehole is sunk, greater spreads should be taken to enable Geophysicists and Geologists to investigate more subsurface features and thus making the work to serve as a reference for what buried structures look like in NIFOR area of Edo State, more than one geophysical method should be used and integrated in order to provide better interpretations, proper care should be taken when rolling out cables from reels,it is also highly recommended that the batteries (power source) should be fully charged and additional batteries should be available during vertical electrical sounding.

REFERENCES

Abiola, O., Enikanselu, P.A., and Oladipo, M.I., 2009. Groundwater potential and aquifer protective capacity of overburden units in Ado-Ekiti, southwestern Nigeria. International Journal of Physical Sciences, 4(3), Pp. 120-132. Available at: http://www.academicjournals.org/IJPS

Airen, J.O., and Ekhoragbon, M.O. (2021). The use of electrical resisivity tomography to classify the Earth's surface in Ugbogiobo Community, Edo State, South-South Nigeria. Nigerian Journal of Technology, 40(3), 1-10. Available at: https: https://www.ajoi.info/index.php/njt/article/view/225141

Airen, O.J., and Iyere, P.S. (2021). Geophysical investigation using 3-dimensional grid-formation for surface lithology characterization: A case study of Ovia North East, Edo State, South-South, Nigeria. International Journal of Environment and Climate change, 11(1), 182-194. Available at: https://journalijecc.com/index.php/IJECC/article/view/385

Akinlabi, I. A., and Oladunjoye, M.A., (2008). Geophysical investigation of dam site in a sedimentary terrain. Research Journal of Applied Sciences, 3(7), 484-489. Available at:https://doi.org/10.36478/rjasci.2008.484.489 or https://www.makhillpublications.co/view-article/1815-932x/rjasci.2008.484.489

Barongo, J.O., and Palacky, G. J., (1991). Investigation of electrical properties of weathered layers in the Yala area, western Kenya, using resistivity soundings. Geophysics, 56 (1), Pp. 133-138doi:10.1190/1.1442949. Available at: https://doi.org/10.1190/1.1442949

Bello, A. and Makinde, V. (2007). Delineation of aquifer in the basement complex of South Nupe basin, Kwara State, Nigeria. Journal of American science; Vol.3 (2), Pp. 36- 44. Bawallah et al; 2021b; Ozegin et al; 2024b. Available at: https://www.jofamericanscience.org/journals/am-sci/0304/02_0300

Ehigiator M.O. (2018). Hydrogeophysical survey of groundwater development in Okha community (along Sapele Road), Ikpoba-Okha L.G.A., Edo State. Nigerian Journal of Technology, 37(3), 576-581. Available at: https://doi.org/10.4314/njt.v37i3.3

Ilugbo, S.O., Adebo, B.A., Olomo, K.O., Adebiyi, A.D., 2018c. Application of Gis and multi criteria decision analysis to geoelectric parameters for modeling of groundwater potential around Ilesha, Southwestern Nigeria. Eur J Acad Essays 5(5), Pp. 105-123. Available at: https://doi.org/10.31248/AJPS2020.28 or https://integrityresjournals.org/journals.org/journal/AJPS

Loke, M.H., (2001): Electrical imagine survey for environmental and engineering is studies: A practical guide to 2D and 3D surveys. Available at: https://www.geotomosoft.com/downloads.php or researchgate.net

Minasian, R.S. (1979). Prospecting for subsurface in the volcanic highland of Armenia by Geophysical methods. Geophysical Prospecting,Vol. 27, No. 4. Pp 808-814. Available at: https://doi.org/10.1111/j.1365-2478.1979.tb00999.x

Omada, J.I and Olurunfemi, O.O. (2012). An assessment of groundwater resource in BasementComplex terrain of Gwarinpa-Kafe area of Abuja metropolis central Nigeria. Advance in applied Science research. Vol. (3), Pp 393-398. Available at: https://www.primescholars.com/advances-in-applied-science-research/citation-index.html

Reyment, R.A. (1985): International Geological Programme No. 58 Published as Vol. 16 of the Journal of physics of the earth. Pergamon journals Ltd Pp 213. (Google Scholar)