Scientia Africana, Vol. 23 (No. 4), October, 2024. Pp 133-140
© Faculty of Science, University of Port Harcourt, Printed in Nigeria *ISSN 1118 – 1931*

LITHOLOGICAL CHARACTERIZATION OF THE SUBSURFACE LAYERS AT 'NASS' FIELD, CHOBA, RIVERS STATE

Oghonyon, R., and Njoku, D.K.
Department of Geology, University of Port Harcourt, PMB 5323, Rivers State-Nigeria.
Corresponding Authors Mail: rorome.oghonyon@uniport.edu.ng ;danielnjoku113@gmail.com

Received: 05-09-2024
Accepted: 05-10-2024

https://dx.doi.org/10.4314/sa.v23i4.12

Journal Homepage: http://www.scientia-african.uniportjournal.info
Publisher: Faculty of Science, University of Port Harcourt.

ABSTRACT

The study on lithological characterization of subsurface layers at'NASS' field, Choba, Rivers State has been evaluated. However, the study deployed the use of electrical resistivity survey (Schlumberger Array Configuration method) in investigating the subsurface lithological layers. This method is efficient for characterizing the layers in terms of understanding the variations in lithology, the resistivity properties and changes with depth, andthe depth to portable water Formation as depth increases. The acquired field data was used to produce a resistivity curve for subsurface interpretation. The study investigated five stratigraphic layers and four thicknesses. In this way, the first layer has resistivity values of 84.7Ωm (at a depth of 1.6m); layer two has 689.2Ωm (at 2.7m); layer three has 8,593Ωm (at 14.1m); layer four has 3273Ωm (at 46.8m) and layer five has 791.1Ωm (at a depth greater than 46.8m) respectively. The aquifer formation is at a depth of 46.8m for the extraction of potable water in the area. The results above were used to produce a geoelectric section based on the resistivity properties of the different layers. The section produced revealed lithological layers that are characterized by good geological properties for groundwater exploration.

INTRODUCTION

The development of resistivity surveying techniques has been very rapid in the last three decades. The advent of automated data acquisition systems, inversion codes, and easy access to powerful and fast computers has tremendously increased the practical applicability of the geophysical method. The lithological characterization approach through geoelectrical resistivity imaging is increasingly being used in environmental, engineering and hydrological investigations as well as geothermal and mineral prospecting, where detailed knowledge of the subsurface is sought.

Surface methods, for probing depth to zones of hydrogeological interest include electromagnetic methods, seismic refraction and resistivity surveys. Selemo, *et al*., (1995) believed that the electrical resistivity method is preferred to other methods of geophysical investigation. In the sedimentary terrain like in the study area, the electrical resistivity method for investigation was regarded as appropriate, because of its ability to resolve sedimentary layers with increasing depth.

It also helps to locate aquifers and identify the subsurface layers, their resistivity, and thickness and possibly provide information about the quality of water in the aquifer. In all the geophysical survey methods aforementioned, the electrical resistivity method is the simplest and most reliable technique in a geophysical survey. The main input of an electrical resistivity survey for

Electrical methods have been important in the field of Applied Geophysics for about a century, particularly for shallow and near-surface investigations. The use of resistivity surveys for investigating subsurface layered media has its origin in 1912 due to the work of Conrad Schlumberger who conducted the first resistivity experiment in the field of Normandy; and about 1915, a similar idea was developed by Frank Wenner in the United State of American (USA) (Kunetz, 1966). Ever The classical methods of resistivity surveys have undergone significant changes in the last three decades. Data acquisition was more or less carried out manually till the 1980s, and this is labour-intensive and slow, and the quality of the measured data might be poor. A range of fast automated multi-electrode data acquisition systems now exists that allow flexibility in the acquisition of resistivity data (Barker, 1981; Stummer and Maurer, 2001; Auken et al., 2006). Traditionally, electrical resistivity surveying was limited to either delineating the variation of apparent resistivity over a surface or compiling quasi-2D sections from a rather limited number of vertical electrical soundings (VES).

The uncertainties in subsurface evaluation due to the non-availability of geophysical information about the lithological characterization of the Earth's subsurface layers have led to many wrong interpretations of the true geological facet of a given area. However, this research seeks to use the acquired resistivity data for proper lithological characterization of the subsurface layers in the study area.

The study is aimed at the lithological characterization of subsurface layers at 'The NASS' field, Choba, Rivers State with the view of understanding the resistivity parameters of the subsurface lithologies that groundwater as a resource focuses on the location and evaluation of sites for capturing flow and availability of groundwater for human use.

since, resistivity surveying has greatly improved and has become an important and useful tool in hydrogeological studies, mineral prospecting and mining, as well as in environmental and engineering applications (e.g. Griffiths *et al*., 1990; Griffiths and Barker, 1993; Dahlin and Loke, 1998; Olayinka, 1999; Olayinka and Yaramanci, 1999; Amidu and Olayinka, 2006; Aizebeokhai *et al*., 2010).

The use of the Schlumberger array configuration system for data acquisition in the resistivity survey has led to a dramatic increase in field productivity as well as increased quality and reliability of subsurface resistivity information obtained. Initially, Schlumberger arrays with manual switching (Barker, 1981) were used before the emergence of computer-controlled multielectrode systems with automatic measurements and data quality control, which has a tremendous impact on the quality of the data and the speed with which they are collected. Intelligent systems with analog-to-digital converters, and digital transmission lines can now be effectively used for data acquisition

can house portable water for domestic and industrial use.

Data acquisition was carried out using the geophysical survey (Schlumberger Array Configuration / Vertical Electrical Sounding) method. The survey involves acquiring resistivity data for aquifer evaluation. The apparent resistivity (ρa) values obtained from the measurements of the Schlumberger array configuration were plotted against half the electrode spacing (AB/2) using the software. The field curve was interpreted by partial curve matching and the corresponding auxiliary curves. The resistivities and thicknesses obtained from the partial curve matching were used for computer iteration using the IPI2Win software.

Integration of the results from Vertical Electrical Sounding and groundwater analysis enabled the understanding of the aquifer Formation in the study area based on the depth to the freshwater interface, the thickness of the sedimentary units within the Geoelectric section, the lithologic characteristics and variation in resistivity parameters.

Before the commencement of fieldwork in the study area, permission was obtained from the inhabitants and security personnel around the study areas to allay fears that the work is purely research work for academic purposes, which will not pose any environmental threat. Having chosen a suitable site for the sounding, the necessary electrical connections were made.

Theory of Vertical Electrical Sounding Method

The data used for this research was acquired using the vertical electrical sounding (VES) method for various VES stations in parts of Etche. The procedure involved the use of an ABEM 1000 series Terrameter and its accessories. The Schlumberger electrode arrangement was used with the number of sounding stations varying from one location to another depending on the geology and accessibility of the area. The half current electrode separation (AB/2) varied from 1m – 150m. On getting to each location, equipment’s were set up according to the Schlumberger arrangement.

Firstly, four electrodes were driven into the ground with the use of hammer. The two electrodes at the middle are potential electrodes, the two other electrodes at both ends are called current electrodes. Installed cables are connected to both the current and potential electrodes to the terminals (positive and negative) of the tetrameter which is positioned adjacent to the center of the arrangement of the electrodes. When the circuit is properly set up and the electrodes configuration is found to be alright, the tetrameter is then switched on to obtain readings which is referred to as resistance value for each sounding station. The values obtained from the tetrameter are then seen and read from it.

The Schlumberger array, which is often preferred for speed and convenience, was adopted for this study. The mid-point of the array (potential electrodes) was kept fixed in each case while the current electrodes were progressively increased. This is because current lines penetrate increasingly at greater depths just as the current electrode separation is increased.

The Schlumberger array has a geometric factor given by:

$$Pa = \frac{n\,(L^2 - a^2)}{4}\frac{V}{1}$$

However, for most purposes

$L^2 >> a^2$ hence $\rho a = \frac{\Pi L^2}{4}\frac{V}{I}$

Geometric factor K

$$K = \frac{\Pi L^2}{4}$$

thus, $\rho a = KR$ where $v/I = R$

L = current electrode separation

a= potential electrode separation “a” is constant as “L” is increasing during measurement. For accurate results “a” should be equal to or less than 1/5 of L. The geometric factor can only be applicable when the difference between current and potential are great.

MATERIALS AND METHOD

Materials used in the Geophysical Survey

The following materials used in the resistivity survey

a.) Hammer
b.) Resistivity Terrameter
c.) Current and Potential Electrodes
d.) Measuring Tapes
e.) Data sheet and Pen

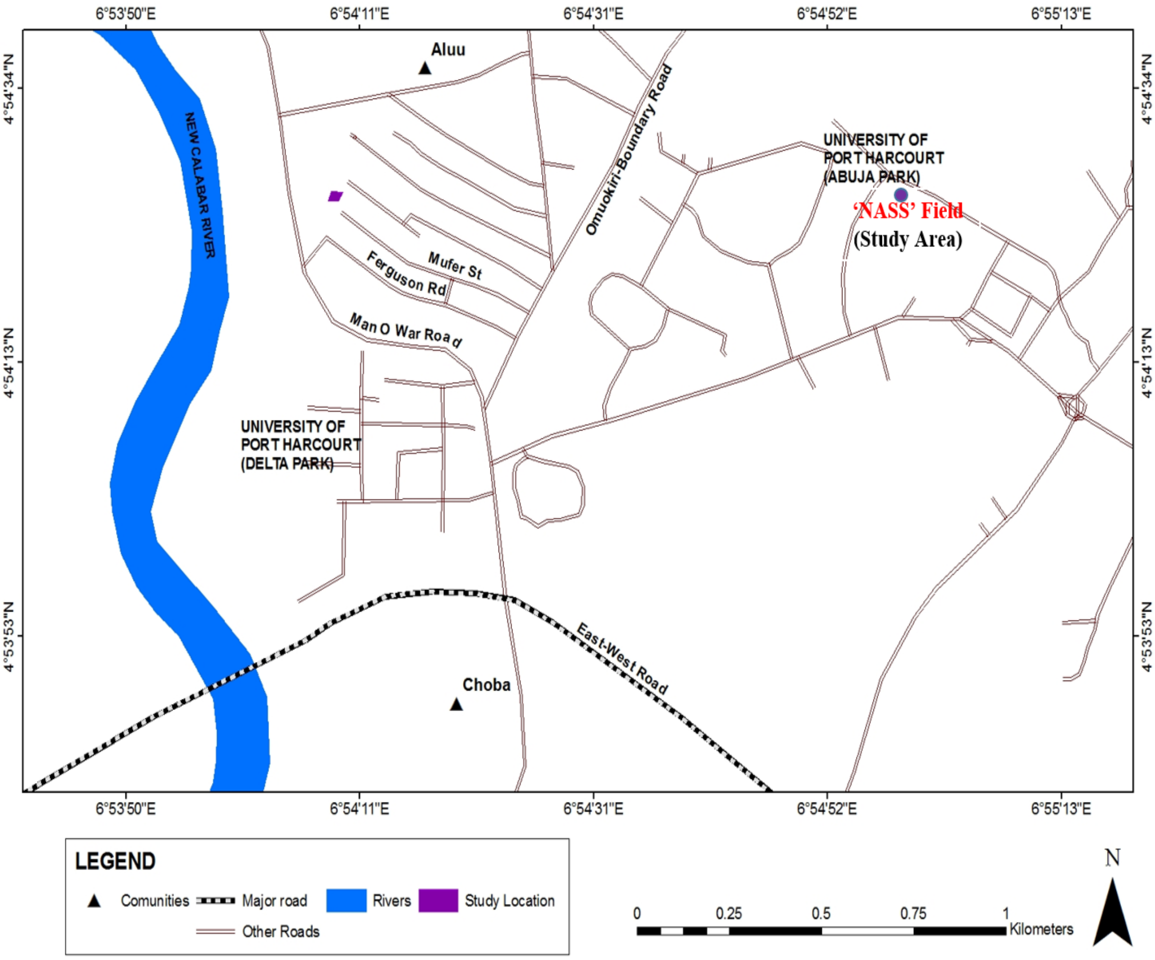

Figure 1: Road map showing the study area (NASS Field)

METHODOLOGY

The method used in carrying out this project work was vertical electrical sounding (VES) and the type of array used was Schlumberger electrode configuration. In the method, a direct current (D.C) from a charged car battery of 12 volts was connected to ABEM - Terrameter (signal Averaging system) SAS 1000 which regulated the voltage used to 20A. The current was injected into the ground through a pair of current electrodes which were connected to current cables and the potential electrode was also connected to potential cables. The potential difference was measured between a pair of potential electrodes. The current and potential electrodes were generally arranged in a linear array, with the potential electrodes inside, while the current electrode was outside the array. The potential electrodes were kept fixed until the measured voltage decreased to low values as the potential gradient in the ground fell with increasing current electrode separation. The ABEM-Terrameter (signal Averaging System) SAS 1000 was positioned at the centre of the linear array.

Schlumberger Array Configuration

This is the most widely used electrode configuration in electrical resistivity prospecting. The electrodes are arranged in a linear array such that AB is the current electrode and MN is the potential electrode. This measures the potential gradient between two closely spaced potential electrodes M and placed mid-way between current electrodes A and B. In the field survey, the spacing between current electrodes arc progressively increased, while the potential electrodes were adjusted when needed because of decreasing sensitivity of measurements.

Data Acquisition

The Schlumberger electrode configuration was such that the separation between the potential electrodes MN was smaller than the current electrodes AB. The current AB was passed through the two outer electrodes at a fixed distance apart. The resulting potential difference was measured between the potential electrodes. A record of the current (1) and voltage (v) as well as MN/2 and AB/2 was made, the measurements were repeated with a fixed MN and AB was increased symmetrically until the response from the meter became too small, then MN was increased and the readings repeated with the previous AB/2 so that the reading overlaps. The Terrameter resolved and recorded the resistivity value of each point on the linear array. The apparent resistivity data was acquired by the multiplication of the geometric constant (K) and the resistance recorded from the Terrameter.

Where the Geometric constant K is;

Where:

π=3.142

AB/2=Half-Current Electrode Spacing

MN/2=Half-Potential Electrode Spacing

Data Processing

The data processing began with the multiplication of the values of the geometric constant (K) and the resistivity values recorded from the ABEM-Terrameterto get the apparent resistivity. Example (6.28) x (19.426) ohms 122.00 (ohm-m).

The data analysis began with a master curve plotting, which depicted the relative thickness of the different layers when interpreted and their relative resistivity which varied systematically over the ranges of thickness and resistivity for each layer that were expected area of practical interest. Where (AB/2 is the Half-current electrode separation).

The graph paper was then superimposed on the sheet containing the set of curves chosen for comparison, and its position was shifted horizontally and vertically to obtain the best possible fit. Another form of data processing was the computer iteration method, which consisted of both forward modelling and inverse modelling. The process began when the data acquired was keyed into the Schlumberger Automatic Analysis Version 0.92 Computer Software which processed the data and finally produced results which were further used for interpretations. However, after the interpretation, it was expected that the Root Mean Square (RMS) error should not be greater than 10%, if this occurred then the field curve representing the data was re-iterated to reduce error.

Instrumentation

The following was the set of instruments used while carrying out this fieldwork.

(a) ABEM-Terrameter(Signal Averaging System) SAS 1000

(b) Current and Potential Cable sets

(c) A pair of current Electrodes

(d) A pair of potential Electrodes

(e) Measuring Tapes

(f) Two Geologic Hammers

(g) A (12 Volts) charged Car Battery

(h) Two pairs of Crocodile clips

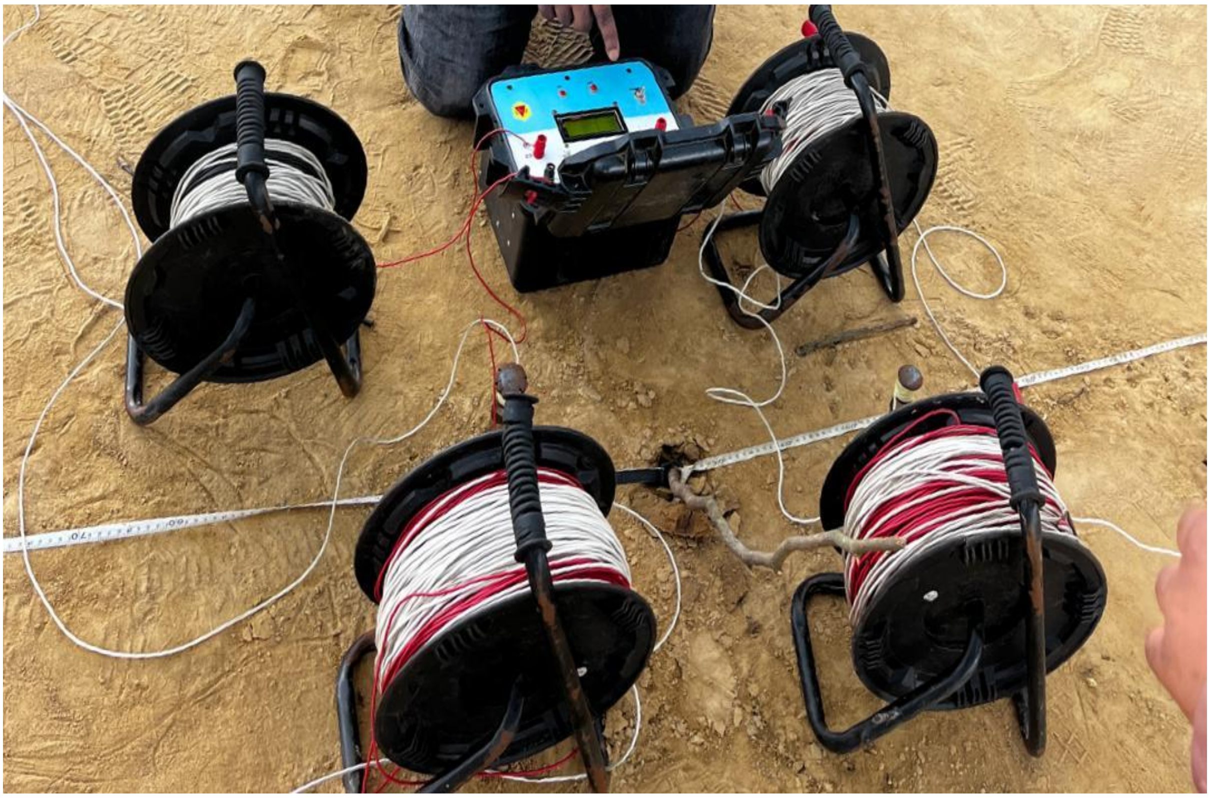

Plate 1: Geophysical Survey Equipment (Terrameter).

RESULTS AND DISCUSSION

Interpretation of Resistivity Curve

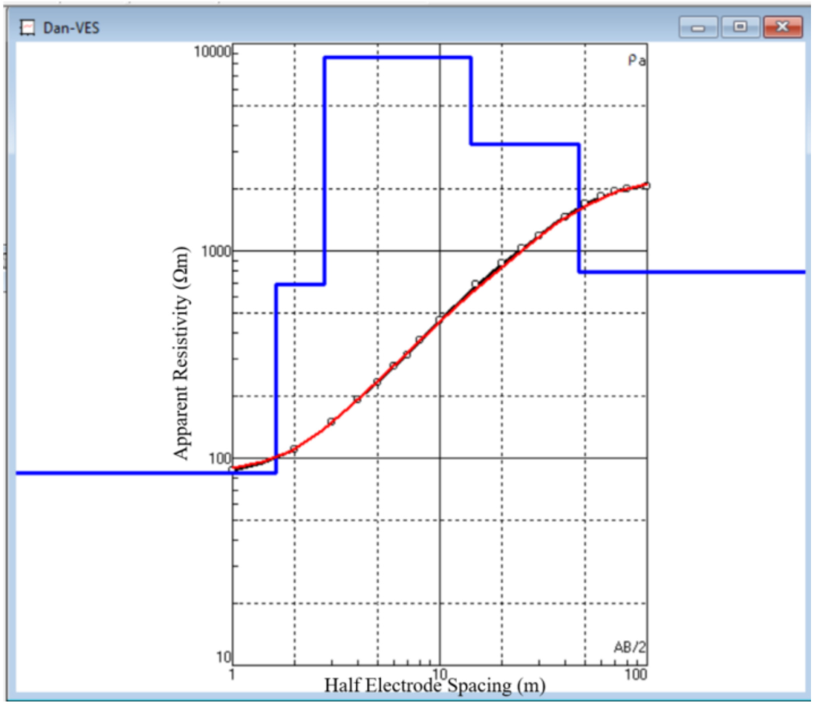

Figure 2: Resistivity curve of the subsurface layers showing an AK type-curve

Table 1: Resistivity parameter of the subsurface layers

S/N	Resistivity, ℓ (Ωm)	Depth (m)	Thickness (m)
1	84.7	1.6	1.6
2	689.2	2.7	1.1
3	8593	14.1	11.3
4	3273	46.8	32.7
5	791.1		

Lithological Characterization of the subsurface layers

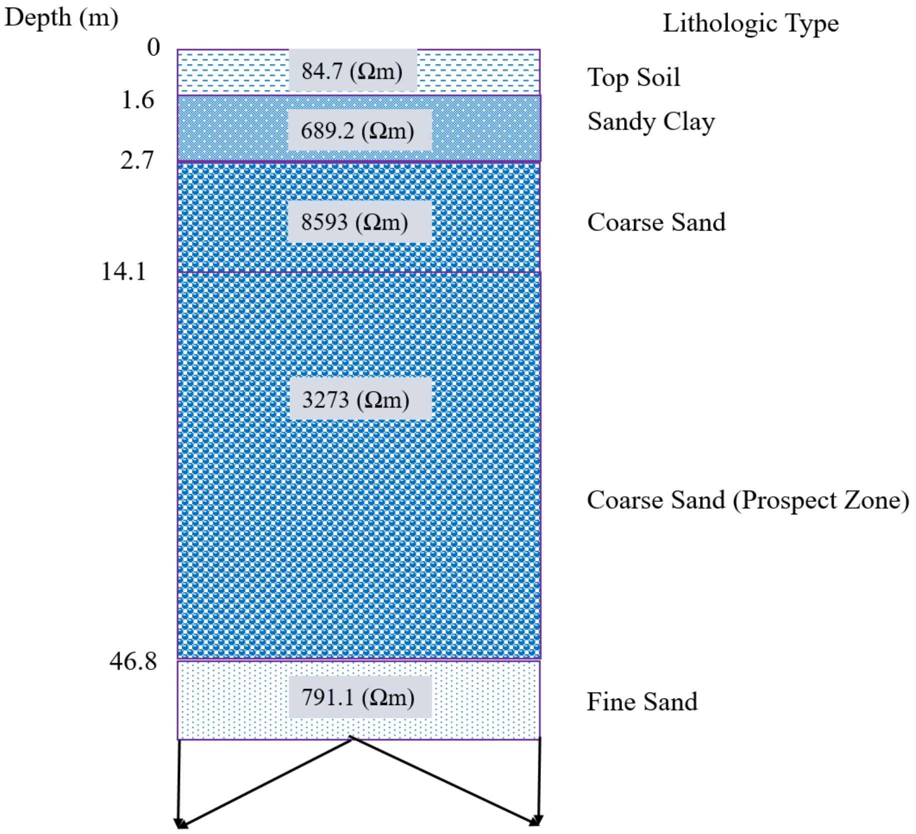

Figure 3: A geoelectric section of the subsurface layers showing its lithology

DISCUSSION

The resistivity curve (Figure 1) revealed a five-layered stratigraphic earth model, four thickness and depth to potential aquifer formation was at 46.8m, the resistivity trend was in the form of $\ell_1<\ell_2<\ell_3>\ell_4<\ell_5$. The least resistivity property is the first layer and this could be due to the presence of conductive materials at the top soil layer. At a depth of 46.8m, the resistivity property was as high as 3,273Ωm, indicating potential potable water accumulation.

The curve type is accelerating with an increase in resistivity parameters. Thus, the curve type is an AK-type curve.

CONCLUSION

The lithological characterization of the subsurface layers within the study area is made possible through the use of the resistivity method (i.e., the Schlumberger Array Configuration). The method revealed a layered earth model (geoelectric section) with variations in resistivity properties and depth to the interface of the layers. The lithologies investigated from the geoelectric section include Topsoil, Sandy clay, Coarse sand, Fine sand, etc. The fourth layer in the section is believed to be the prospect zone.

REFERENCES

Aizebeokhai A.P., Olayinka A.I., and Singh V.S. (2010). Application of 2D and 3D geoelectrical resistivity imaging for engineering site investigation in a crystalline basement terrain, southwestern Nigeria. Journ. Environ. Earth Science., DOI: 10.1007/s12665-010-0474-z, 1359-1481.

Aizebeokhai, A.P., Oyeyemi, K.D., Noiki, F.R., Etete, B.I., Arere A.U.E., Eyo, U.J. and Ogbuechi, V.C. (2017). Geoelectrical resistivity data sets for subsurface characterization and aquifer delineation in Iyesi, Southwestern Nigeria. *Data in Brief,* 15: 828-832.

Amidu SA, Olayinka AI (2006): Environmental assessment of sewage disposal systems using 2D electrical resistivity imaging and geochemical analysis: A case study from Ibadan, Southwestern Nigeria. Environ. Eng. Geosci., 7(3): 261-272.

Barker, R. D. (1981). The offset system of electrical resistivity sounding and its use with multicore cable. *Geophysics Prospecting,* 29: 128-143.

Dahlin T, Loke MH (1997). Quasi-3D resistivity imaging-mapping of three-dimensional structures using two-dimensional DC resistivity techniques. Proceedings of the 3rd Meeting of the Environ. Eng. Geophy. Soc., 143-146.

Griffiths DH, Turnbull J, Olayinka AI (1990). Two-dimensional resistivity mapping with a complex controlled array. *First Break,* 8: 121-29.

Griffiths, D. N. and Barker, R. D. (1993). "Two-Dimensional Resistivity Imaging and Modeling in areas of Complex Geology". *Journal of Applied Geophysics,* 29, 211-226.

Kunetz G (1966). Principles of Direct Current Resistivity Prospecting. Gebruder Borntraeger, Berlin, 98-103.

Loke, M. H. (2000). Topographic Modeling in Resistivity Imaging Inversion. *62nd EAGE Conference, Glasgow, UK, Extended Abstracts,* 134-212.

Olayinka AI (1999): Advantage of two-dimensional geoelectrical imaging for groundwater prospecting: case study from Ira, southwestern Nigeria. Water Res. J. Nig. Assoc. Hydrogeol. 10: 55-61.

Olayinka AI, Yaramanci U (1999). Choice of the best model in 2-D geoelectrical imaging: case study from a waste dump site. Eu. J. Environ. Eng. Geophy., 3: 221-244.

Selemo, A. O. I., Okeke, P. O., Nwankwor, G. I. (1995). "An Appraisal of the usefulness of VES in groundwater exploration in Nigeria". *Water Resource Journal,* 6(1): 61-67.

Stummer P, Maurer HR (2001). Real-time experimental design applied to high-resolution direct-current resistivity surveys. International Symposium on Optical Science and Technology, Expanded Abstracts, 143-150.