

RESEARCH ARTICLE

GEOELECTRICAL EVALUATION FOR GROUNDWATER ASSESSMENT AT OWAN EAST LOCAL GOVERNMENT AREA OF EDO STATE, SOUTHERN NIGERIA, USING SCHLUMBERGER ARRAY

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ABSTRACT

Geoelectrical investigation was carried out in Otuo Community of Edo State, Southern Nigeria, with the aim of delineating the best aquifer bearing zone, and as well the vertical and lateral variation of subsurface lithology with depth and distance respectively. Schlumberger electrode configuration was employed in obtaining four (4) VES data. In determining the capacity bearing rating and groundwater potential of the area, the Dar Zarrouk Parameters were tools used in characterizing the aquifer viz: Resistivity Contrast (RC), Resistivity Reflection Coefficient (RRC), Total Transverse Resistance (T) and Total Longitudinal Conductance (S). From the results obtained, VES 3 is the showed high potential source for groundwater compared to other VES points. It has the highest T value of 73,050.27 Ωm^2 (showing a very good transmissivity of the layer), RC (3.045) and RRC (0.500), however, all parameters fell within good prospect for groundwater development. VES 1, 2 and 4 having values of 4787.22, 4003.95 and 28106.1005 (ohm-m^2) respectively. The results obtained also show that VES 3 had the highest fracture thickness of 61.26 m meaning it has the highest groundwater potential, since VES 1, 2 and 4 having values of 22.02 m, 27.34 m, 48.91 m respectively.

KEYWORDS

Basement, Dar Zarrouk parameters, Otuo, Lithology, Configuration

1. INTRODUCTION

The study area (Otuo) lies within the Southwestern Basement Complex of Nigeria (Fig. 2). Otuo makes up part of the major lithology component captured in the Nigerian geology. According to Agomuo and Egesi (2016), the Basement Complex of Nigeria lies within the Pan African mobile belt to the northwest of the Gabon Congo Craton (GCC) and east of West Africa Craton (WAC). According to recent study, this Basement Complex has been classified into two provinces; the Eastern province is migmatite-gneiss complex which is being intruded by larger volumes of Pan-African granite in association with the Mesozoic ring complexes of central Nigeria, while the western province comprises a N-S trending metasediment (schist) (Ajibade and Wright, 1988). They further informed that the Pan African belt resulted from plate tectonic processes, as shown by evidence in the eastern and northern margins of West Africa Craton.

Several developed and developing countries rely heavily on groundwater, and as a matter of health concern, the quality of water consumed by this vast majority of humans should be assessed for potability.

Electrical method of geophysical survey has over decades, been a useful technique in groundwater studies, as the signatures of electrical conductivity are able to decode the geological formation properties that are integral to the hydrogeology of the study area. Several authors have shown the integrity of the use of electrical resistivity techniques for siting wells and boreholes in crystalline basement aquifers (Hazel et al., 1988; Beeson and Jones, 1988; Caruther and Smith, 1992; Hazel et al., 1992).

This research work was carried out in the study area using the Schlumberger array method to determine the geo-electrical characteristic of the sub-surface layers and identifying suitable areas with high yielding aquifers.

2. MATERIALS AND METHODS

Brief Geology & Hydrogeology of the Study Area

The study area is geographically located within latitudes 7°11'46"N-7°12'29"N and longitudes 6°0'9"E-6°0'32"E of Edo State, Southern Nigeria (Fig. 1, on a scale of 1:12,000).

The understudied region is part of the Precambrian Basement Complex of Southwestern Nigeria and it comprises a series of rock types which contain joints and mineral veins, suggestive of Pan-African granites origin (Oden and Udinnwun, 2014). More than 80 % of the region is underlain by strongly folded crystalline rocks assigned to the Nigerian Basement Complex and which range from Precambrian to Paleozoic age (Rahaman, 1988). The study area is underlain by Metaconglomerate, Metasediments and Porphyritic Granite (Fig. 2) which form the local geology. The characteristic folding of the rock within the study area results in the development of joints, fractures and faults which enhances the rock matrix permeability and thus aiding the movement of groundwater. Studies have shown that the rock types within the study area are good storage of groundwater and thus it is expected that good groundwater zones will exist within the study area.

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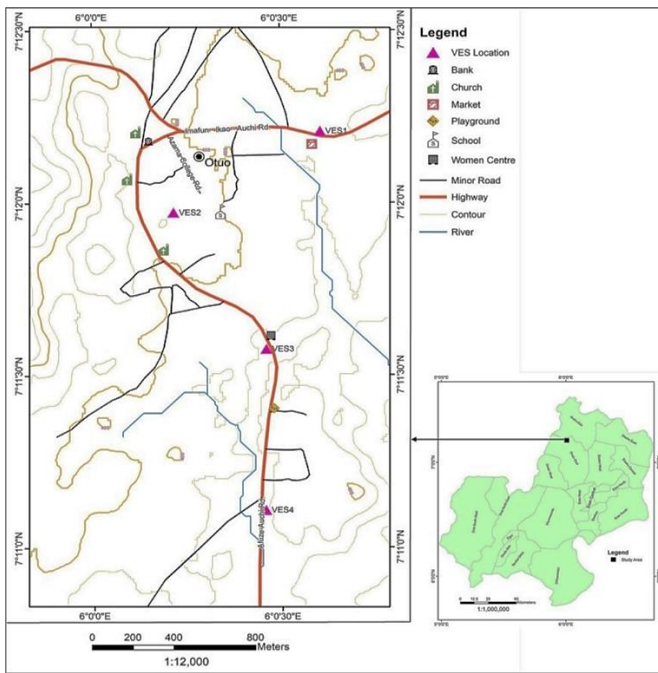


Figure 1: Showing the map of the study area

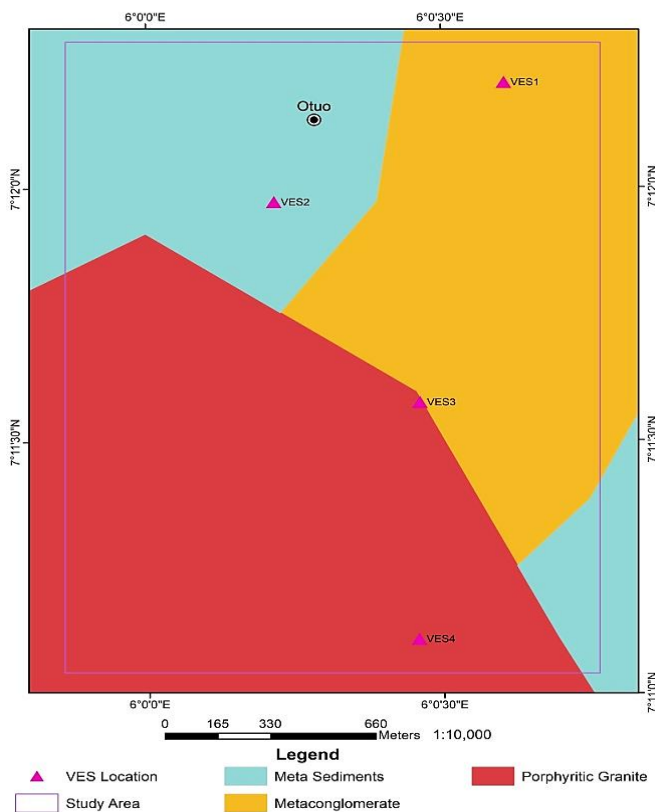


Figure 2: Geology of the study area

Method: Schlumberger array in electrical resistivity method was employed (Bassey et al., 2019). According to the latter, the PASI 16GL-N Earth resistance meter was the basic field equipment for this study. It displays apparent resistivity values digitally as computed from ohms law. It is powered by a PASI P100-NX (12.5v) D.C Battery as power source. Other accessories attached to the meter includes the cables for current and potential electrodes, booster, four metal electrodes. Other field tool employed include measuring tapes, hammers, walking talking or phones for very long spread.

In this array, the four (4) electrodes used were symmetrically aligned along a straight line; the potential electrodes on the inside and the current electrodes on the outside. in a way to changing the depth range of the measurements, the current electrodes were displaced outwardly while the potential electrodes in general are left at the same position (Bassey et al., 2019). The resistance readings were used for computing the apparent resistivity using Schlumberger electrode configuration based on the

following relationship:

$$\rho = k \left[\frac{V}{I} \right] \quad (1)$$

Where, ρ is the apparent resistivity (ohms/m), V is the potential difference (volt, V) and I is the electric current (ampere, A), and k represent a constant.

$$V = U_M - U_N = \frac{\rho l}{2\pi} \left[\frac{1}{AM} - \frac{1}{BM} + \frac{1}{BN} - \frac{1}{AN} \right] \quad (2)$$

Where, U_M and U_N = potentials at M and N ; AM = distance between electrodes A and M , etc.

These distances are always the actual distances between the respective electrodes, whether or not they lie on a line, moreover, the quantity inside the brackets is a function only of the various electrode spacing (Bassey et al., 2019). The quantity is represented by $1/K$, which favours rewriting the equation as:

$$V = \frac{\rho l}{2\pi} \left[\frac{1}{K} \right], \quad (3)$$

Where K = array geometric factor that depends on the arrangement of the four electrodes A , B , M and N .

To obtain the resistivity, ρ :

$$\rho = 2\pi K \frac{V}{I}, \quad (4)$$

The resistivity of the medium can be found from measured values of V , I , and K .

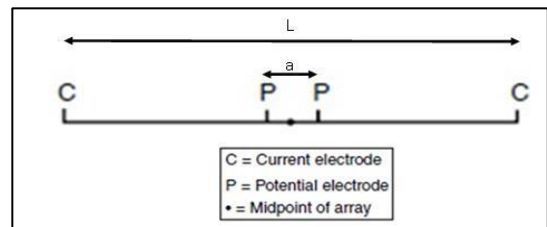


Figure 3: Schlumberger Field Electrode Configuration.

Where "a" is the distance between the potential electrodes, "L" is the distance between current electrodes (Okwueze and Ezeanyim, 1985; Zohdy 1988).

According to previous study, the above relationships holds provided that the current electrode spread $AB/2$ is equal to or greater than five times the potential electrode spread $MN/2$ with the depth of investigation as a function of electrode spacing (Bassey et al., 2019). Based on the prevailing geologic condition during the survey, a maximum outer electrode spacing of 215m was made at the sounding station. They also informed that when the ratio of the distance between the current electrodes to that between the potential electrodes becomes overly large, the potential electrodes must also undergo an outward displacement so that the potential difference can match up to sufficient accuracy. Measurements of the potential and current electrode positions are recorded such that:

$$AB/2 \geq MN/2, \quad (5)$$

Where; $AB/2$ = current electrode spacing; $MN/2$ = potential electrode spacing.

Bassey et al. (2019) method was adopted in plotting and inverting the Vertical Electrical Sounding data using IPI2win software which creates a 1-D model from the sounding data. The geological interpretation was done using the representative values of resistivity while Strater 3 software was used to draw the 1D subsurface model for visualization. Dar Zarrouk parameters, longitudinal conductance and Transverse resistance of each geo-electric layer were computed. According to the transmissivity of an aquifer is a direct function of its transverse resistance. The longitudinal conductance is directly proportional to the conductivity of geologic material (Ward, 1990). The electrical reflection coefficient of each geo-electric boundary; longitudinal conductance and transverse resistance were computed using the formulas:

$$RRC = [(\rho_n - \rho_{n-1}) / (\rho_n + \rho_{n-1})] \quad (6)$$

$$RC = [(\rho_n / \rho_{n-1})] \quad (7)$$

$$T = \sum h_i \rho_i = h_1 \rho_1 + h_2 \rho_2 + \dots h_n \rho_n \text{ (ohm-m}^2\text{)} \quad (8)$$

$$S = \sum h_i / \rho_i = h_1 / \rho_1 + h_2 / \rho_2 + \dots h_n / \rho_n \text{ (mho)} \quad (9)$$

Where: RRC = Resistivity reflection coefficient; RC = Resistivity contrast; T = Total transverse resistance, S = Total longitudinal conductance; ρ_n = Resistivity of the nth layer; ρ_{n-1} = Resistivity of the (n-1)th layer, h_n = Thickness of the nth layer

3. RESULTS

The following results (as shown in the tables below) were obtained from the geophysical survey carried out in the study area.

Table 1: Showing the Various Calculated and Plotted Variables

S/N0	Fracture Thickness (m)	RRC *	RC *	T (ohm m ²)	S (mho)	Easting (m)	Northing (m)
VES 1	20	0.81	9.42	5444.8	0.68212	169753.58	797322.10
VES 2	27.1	0.61	4.18	3785.5	0.56386	169030.34	796893.42
VES 3	61.3	0.500	3.045	90150	0.28115	169477.14	796158.88
VES 4	48.9	1.031	4.59	28102.9	0.26078	169464.55	795296.01

* = No unit

Table 2: Subsurface Interpretation For VES1

Geoelectric Layer	Resistivity Ohm-M	Thickness (m)	Depth (m)	Lithology
1.	149.7	0.5	0.5	Wet top soil
2.	64.6	1.1	1.6	Completely weathered bedrock.
3.	29.9	2.5	4.1	Completely weathered bedrock
4.	78.2	9.1	13.2	Highly weathered bedrock
5.	69.5	22.6	35.8	Highly weathered bedrock
6.	146.8	20.0	55.8	Fractured basement (aquifer)
7.	2234.4		-----	Fresh bed rock

Table 3: Subsurface Interpretation For VES2

Geoelectric Layer	Resistivity Ohm-M	Thickness (m)	Depth (m)	Lithology
1.	6-7.2	0.5	0.5	Dry top soil
2.	563.2	1.2	1.7	Lithified laterite pan
3.	42.1	4.4	6.1	Completely weathered bedrock
4.	72.4	7.6	13.7	highly weathered bedrock
5.	76.9	27.1	40.8	Moderately weathered bedrock (aquifer)
6.	335.6		Infinity	Fractured bedrock

Table 4: Subsurface Interpretation For VES3

Geoelectr ic Layer	Resistivit y Ohm-M	Thickne ss (m)	Depth (m)	Lithology
1.	948.8	0.5	0.5	Dry top soil
2.	733.1	0.8	1.3	Completely weathered bedrock.
3.	230.4	2.6	3.9	Highly weathered bedrock
4.	212.1	5.0	8.9	Moderately weathered bedrock
5.	108.0	11.0	19.9	Moderately weathered bedrock
6.	272.7	26.0	45.9	Fractured bedrock (aquifer).
7.	1292.8	61.3	107.2	Fresh basement
8.	1301.6	Infinity	Infinity	Fresh basement

Table 5: Subsurface Interpretation For VES 4

Geoelectric Layer	Resistivity Ohm-M	Thickness (m)	Depth (m)	Lithology
1.	897.3	0.6	0.6	Dry top soil
2.	606.8	1.1	1.7	Completely weathered bedrock
3.	213.2	9.6	11.3	Highly weathered bedrock
4.	51.8	6.0	17.3	highly weathered bedrock
5.	502.6	48.9	66.2	Moderately weathered bedrock (aquifer)
6.	1337.7	Infinity		Fractured bedrock

Maps Generated for the Data Obtained

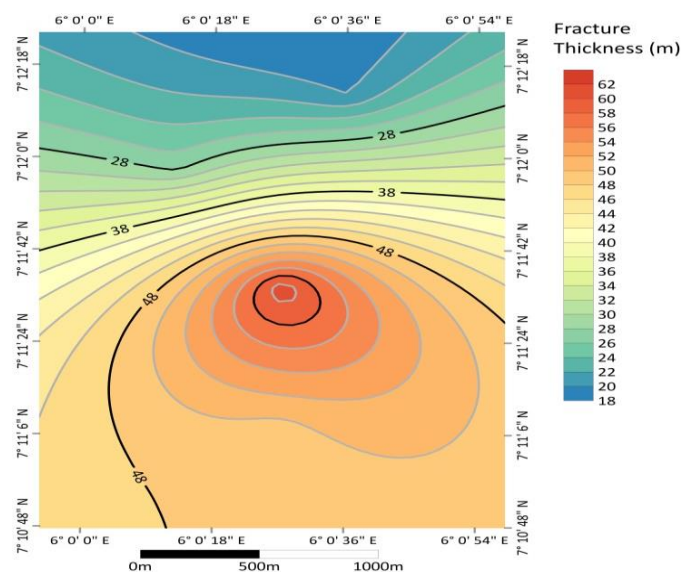


Figure 4: Map showing variation in Fracture Thickness in the study area.

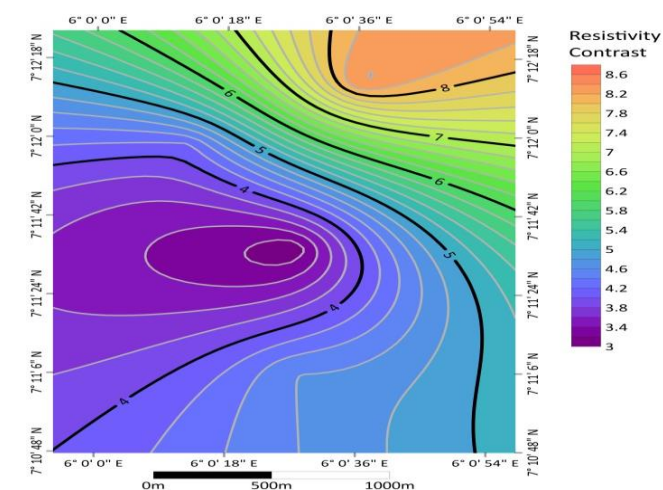


Figure 5: Contour map of the study area showing aquifer Resistivity Contrast

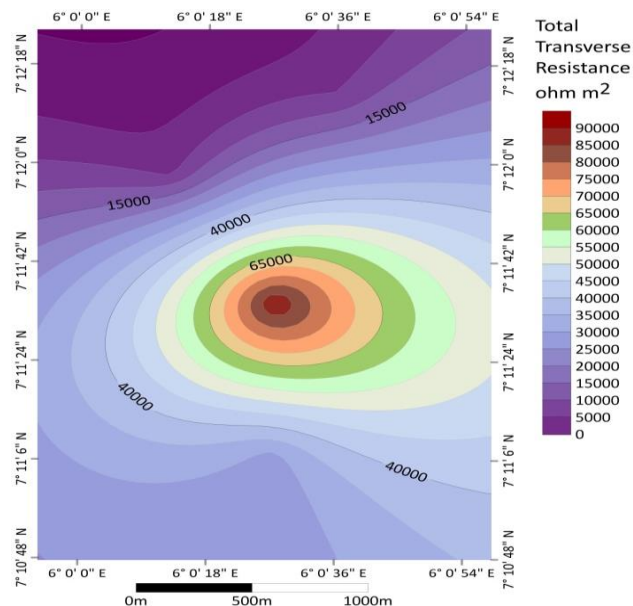


Figure 6: Contour map showing the distribution of Total Transverse Resistance (T) in the study area.

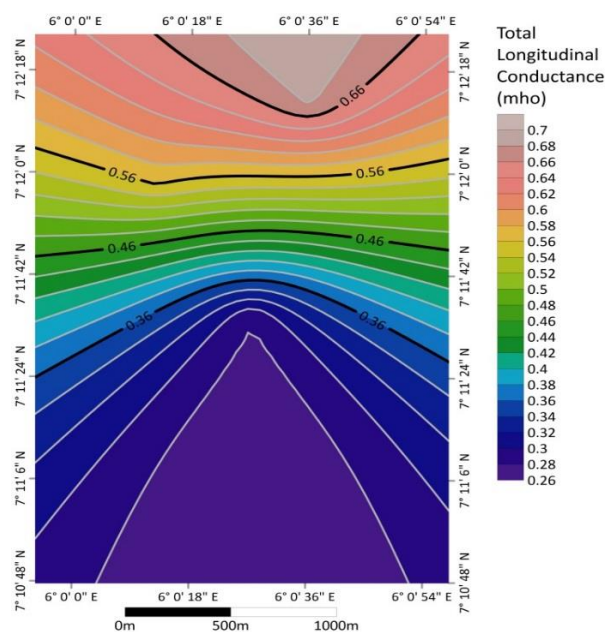


Figure 7: Contour map showing the Total Longitudinal Conductance (S) in the study area.

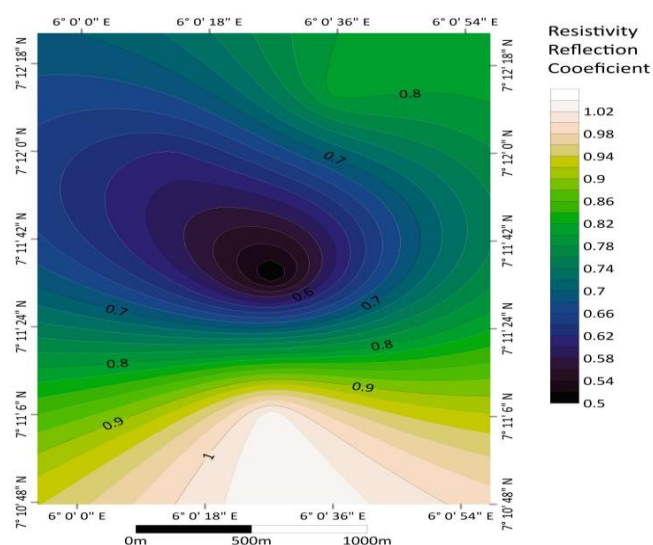


Figure 8: Map showing the variation in Resistivity Reflection Coefficient (RRC)

4. DISCUSSION

Data obtained from the survey at VES 1 revealed that the depth to aquifer was about 55.8 m, thus suggestive that exploitation should be from 55.8 m to about 60 m. Aquifer depth for VES 2 was found at about 40.734 m, VES 3 aquifer showed depth of 81.174 m while VES 4 aquifer had depth of 66.169 m.

The results obtained show that VES 3 had the highest fracture thickness of 61.3 m meaning it has the highest groundwater potential, since VES 1, 2 and 4 showed values of 20 m, 27.1 m, 48.9 m respectively.

VES 1, 2 and 3 had values of 0.81, 0.61 and 0.5 respectively for resistivity reflection coefficient RRC which were within the required range for a good aquifer and indicate high density water-filled fractures except that of VES 4 which was beyond the desirable range with the value of 1.031. Values of resistivity contrast (RC) for all VES were within the required threshold for a good aquifer (RC <19) (Olayinka *et al.*, 2000) with VES 1, 2, 3 and 4 having values of 9.42, 4.18, 3.045 and 4.59 respectively.

The distribution of the Transverse Resistance (T) of the study area shown in figure 6 revealed that VES 3 had the highest value of 90,150 indicative of the most viable potential for groundwater accumulation (Obiora *et al.*, 2016) with VES 1, 2 and 4 having values of 5444.8, 3785.5 and 28102.9 (ohm-m²) respectively.

Although the Total Longitudinal Conductance did not reflect very high values in VES 3 (0.28115 mho), compared to VES 1 and 2 having values of 0.68212 mho and 0.56386 mho respectively, the former was still considered the area with the most reliable potential for groundwater accumulation due to its values for fracture window thickness of 61.3 m.

5. CONCLUSION

Results obtained from this geophysical investigation revealed the most dependable aquifer bearing zone. The result was also able to detect the vertical and lateral variation of subsurface lithology with depth and distance respectively. Results also revealed that the surveyed region has a subsurface generally characterized by weathered and fracture basement, which considerably favor factors which will evolve a high yielding aquifer.

6. RECOMMENDATION

It is recommended that the most viable aquifer be developed due to its greatest potential for groundwater resources compared to all other VES points within the area of study. However, there is the need for environmental protection and routine monitoring for contamination due to its weak aquifer protective capacity.

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REFERENCES

- Agomuo, M. S. and Egesi, N. 2016. Petrology And Structural Geology of Ikpeshi and It's Environ of Igarra Schist Belt Southwestern Nigeria. *International Journal of Science Inventions Today*. 5(4), 303-319.
- Ajibade, A.C. and Wright J.B. 1988. Structural Relationship in the schist Belts of North-Western Nigeria. In P.O. Oluyide *et al.* (Eds). *Precambrian Geology of Nigeria*. A publication of Geological Survey, Pp 103-109.
- Bassey, P., Lawrence, O.O. and Ailego, J. 2019. Geoelectrical Resistivity Evaluation of Ground Water Potential at University of Benin Ugbowo Campus, Benin-City, Edo State of Nigeria, Using the Schlumberger Array. *J. of Appl. Sci. Env.Manag.*, Vol. 23 (9) 1757-1766.
- Caruther, R.M. and Smith, I.F. 1992. The use of Ground Electrical Methods in sitting water supply boreholes in shallow crystalline basement terrains. *Geological Society Special Publication*, 66: 203-220.
- Grant, N.K. 1978. Structural Distribution between Metasedimentary cover and underlying basement in the 600-my.Old Pan African of Northern Nigeria, *West African Geol. Soc. America Bull.* Vol.89, pp.50-58.
- Hazel, J.R.T., Cratchley, C.R. and Jones, C.R.C. 1992. The Hydrogeology of Crystalline Aquifers in Northern Nigeria and Geophysical techniques used in their exploration. *Geological Society Publication*, 66: 155-182.

Hazel, J.R.T., Cratchley, C.R. and Preston, A.M. 1988. The location of crystalline rocks and Alluvium in Northern Nigeria using combined Electromagnetic and Resistivity techniques. *Quarterly Journal of Engineering Geology*. 21: 159-175.

Koefoed, O. 1979. *Geosounding Principles 1: Resistivity Sounding Measurements*. Elsevier Science Publishing Company, Amsterdam.

Obiora, D.N., Ibut, J.C. and George, N.J. 2016. Evaluation of Aquifer Potential, Geoelectric and Hydraulic Parameters in Ezza North, Southeastern Nigeria, Using Geoelectric Sounding. *Int. J. Environ. Sci. Technol.* 13:435-444.

Oden, M.I. and Udinmwun, E. 2014. Fracture characterization, mineral vein evolution and the tectonic pattern of Igarrasyntectonic granite, Southwestern Nigeria. *British Journal of Applied Science and Technology*; 4:17:2418.

Okwueze, E.E. and Ezeanyim, V.I. 1985. The Vertical Electrical Sounding (VES). Method in Laterite regions and in iron rich glaciated areas. *J. Mining Geol.*, 22(1-2): 193- 198.

Olayinka, A.I., Obere, F.O. and David, L.M. 2000. Estimation of Longitudinal Resistivity from Schlumberger Sounding Curves. *J Min Geol.* 36(2): 22 – 28.

Rahaman, M.A. 1988. Recent Advances in the study of Basement complex of Nigeria. In: *Precambrian Geology of Nigeria*. Geological Survey of Nigeria; 11-43.

Ward, S.H. 1990. *Resistivity and Induced Polarization Methods in Geotechnical and Environmental Geophysics*. Society of Exploration Geophysicists, Tulsa, 147-189.

Zohdy, AAR 1988. *Groundwater Exploration with Schlumberger Sounding Near Jean Nevada USGS open file Rep.*, 66: 188-291.

APPENDIX

Presentation of the Curves and Geoelectric Model for (VES 1-4)

Model VES Curve: VES -2

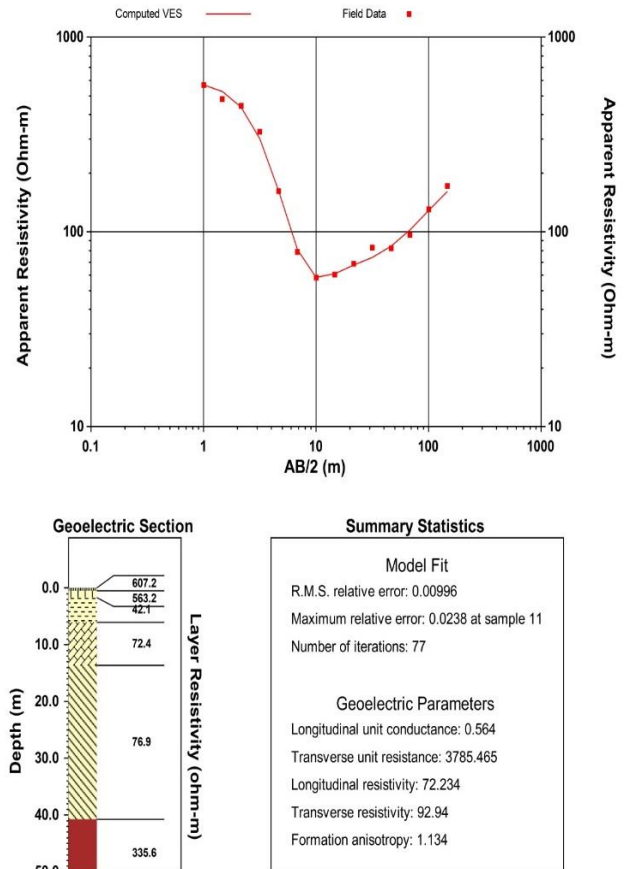


Figure 10: VES 2

Model VES Curve: VES -1

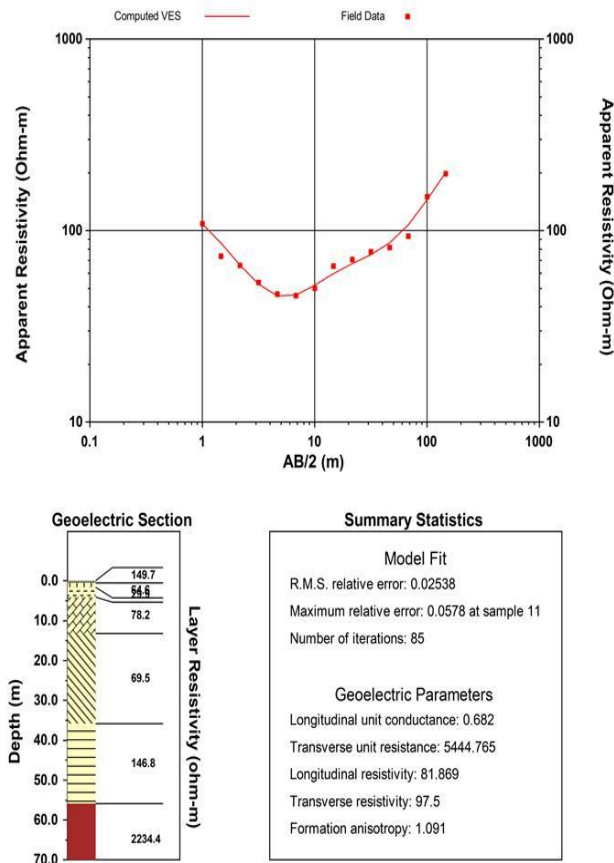


Figure 9: VES 1

Model VES Curve: VES -3

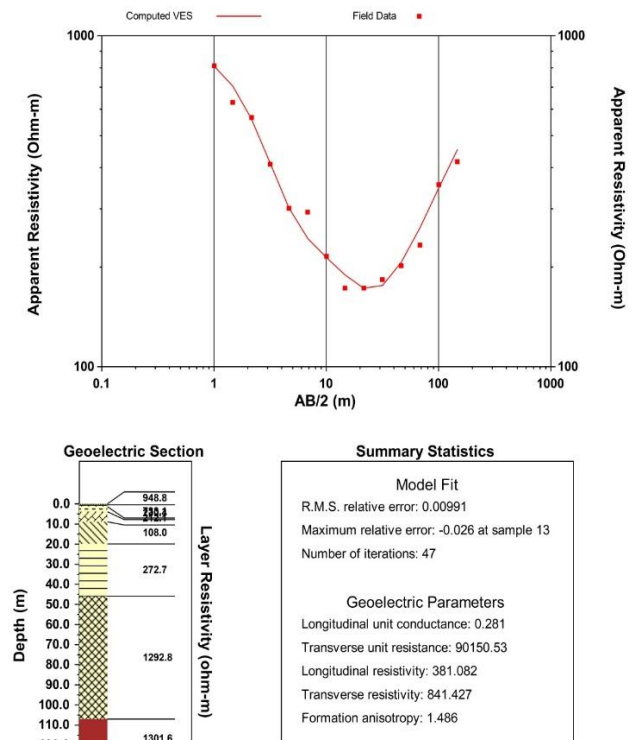


Figure 11: VES 3

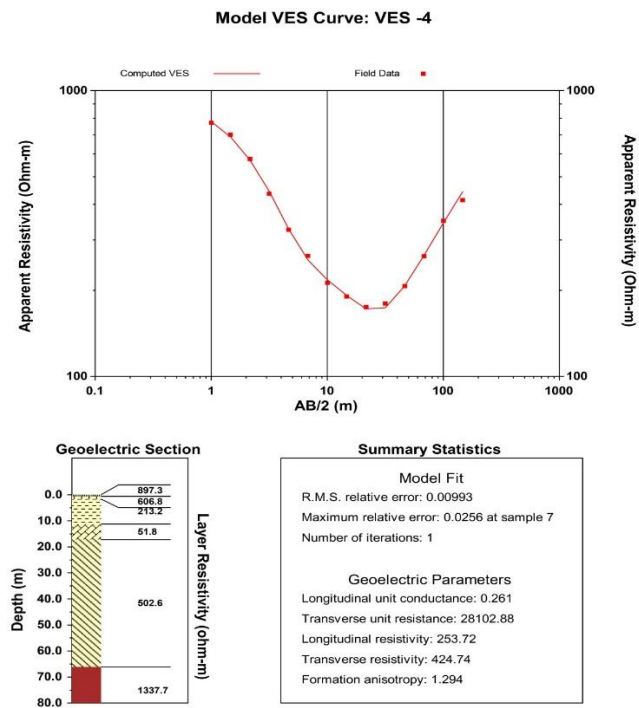


Figure 12: VES 4

