Journal of Science Research (2013) Vol. 12: 285-297

Geoelectric Investigation for Groundwater Development in Oroki Estate, Osogbo, Southwestern Nigeria

Joshua, E.O.[1], Adelowo, A.A.[1] and Oladunjoye, M.A.[2]

Abstract

The rapid development of Oroki Estate in Osogbo, Osun State has warranted the need to develop the water supply in the area. The area lies within the Basement Complex terrain of southwestern Nigeria typified by quartzites/quartz schist. This study was carried out to characterize the aquifer units for evaluation of groundwater development in the area. Twenty Schlumberger vertical electrical soundings were carried out to determine the different subsurface lithounits with the aim of delineating the thickness and continuity of the aquiferous zone. Hydro-resistivity maps such as Isoresistivity of topsoil, weathered layer, basement and overburden thickness maps were generated. Interpretation of the twenty Schlumberger vertical electrical soundings data generally show a system of three to four layered earth structure notably topsoil, saturated/sandy/lateritic clay and weathered basement and fractured/fresh basement which are mostly of the type “H” curve. Overburden isopach map revealed that the depth to bedrock varies from 9.5 to 37.8m indicating some degree of deep weathering. The main water-bearing unit in the area of study is the weathered and fractured basement which is within the second/third and the last geoelectric layers respectively. The weathered/fractured basement resistivity values vary from 16 Ohm-m and 84 Ohm-m with thickness values ranging from 3.8 m to 37.3 m. Locations with thick weathered/fractured basement were delineated to be the most promising sites for borehole drilling at the estate.

Key words: Oroki Estate, groundwater exploration, geo-electric properties, aquiferous unit, prospect areas.

Introduction

Groundwater in Nigeria is restricted by the fact that more than half of the country is underlain by crystalline Basement Complex rocks of pre-Cambrian age. Electrical resistivity method was employed in imaging the distribution of electrical properties which is of hydrogeological significance in a damsite investigation [6], while [8] used a multi-electrode resistivity profiling array for groundwater exploration in Okene area. The electrical resistivity method was used to delineate different subsurface geoelectrical layers, aquifer unit and their characteristics, the subsurface structure and its influence on the general hydrogeological condition in the north central part of Kaduna State, Nigeria [2]. The Electrical resistivity method is widely used in the determination of depth to bedrock and nature of superficial deposit, and structural mapping.

Geophysical investigation and ground-water evaluation have been discussed by many authors [7, 12]. It was observed that the occurrence of groundwater is primarily related to geology and its availability emphasized by deep weathering and fracturing. Also, [4] used the method to study groundwater conditions such as depth, thickness and aquifer boundaries. The electrical resistivity method is the most widely used geophysical method in the basement terrain. In [5] electrical sounding in coastal plain of Okitipupa area, Southwestern Nigeria were conducted to delineate shallow aquifers, their subsurface disposition and promising areas for elaborate groundwater development in the area. The acquifer characteristics and groundwater potential of the subsurface formation of Moniya, Oyo State, Nigeria has been investigated [3]. They were able to identify locations best suited for well sitting. Also, a similar study carried out by [1] revealed deep aquifers having good quality water and high productivity. The present investigation is aimed at producing

Joshua, E.O.[1], Adelowo, A.A.[1] and Oladunjoye, M.A.[2]
[1]*Department of Physics, University of Ibadan*
[2]*Department of Geology, University of Ibadan*

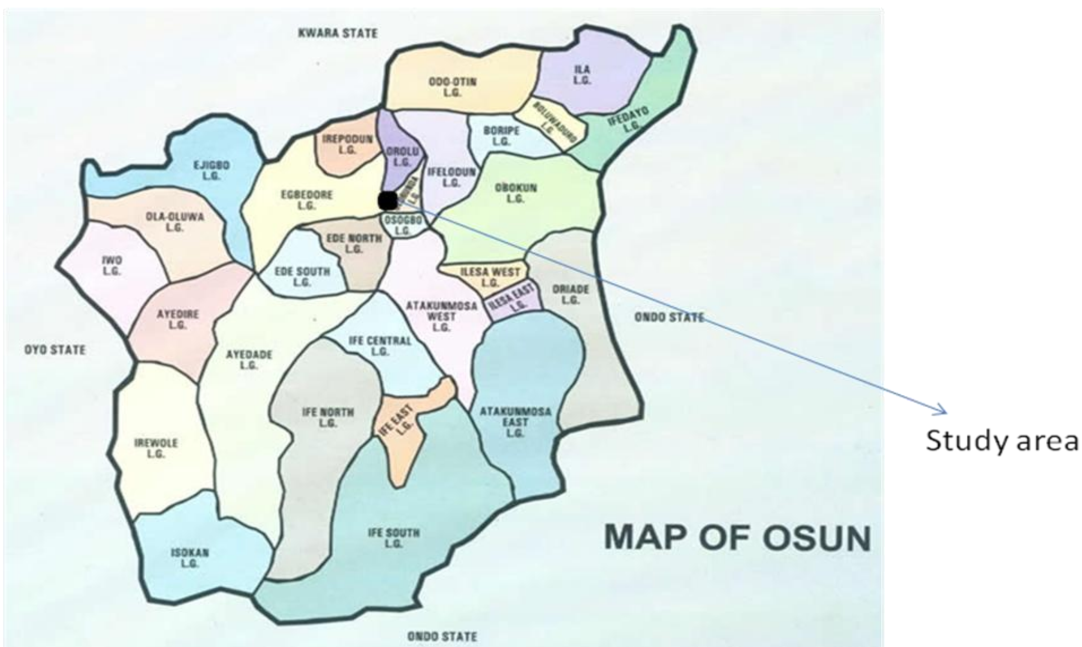
ISSN 11179333

the data which could serve as a basis for more detailed groundwater exploitation activities in Oroki esatate, Osogbo, Osun State.

Site Description and Geological Setting

The study area (Oroki Estate) is located in Olorunda Local Government Area of Osun State, southwestern Nigeria. It lies within latitude 7°47’25”N and 7°47’40”N and longitude 4°31’58”E to 4°32’20”E (Fig. 1). Olorunda Local Government is bounded in the north by Orolu Local Government, in the east by Ifelodun Local Government, in the south by Osogbo Local Government and in the west by Egbedore Local Government.

The topographic elevation of the study area varies from 319m to 375 m above mean sea level. The estate is readily accessible by road networks. South-western Nigeria is underlain by crystalline basement complex rocks of precambrian age, comprising the migmatite gneiss, the older granites and the meta-sediments [11]. The study area is underlain mainly by quartzite/quartz schist. Fresh basement complex rocks are known to have very low porosity and negligible permeability. Consequently, the development of aquifers is limited to the overburden resulting from the *in-situ* chemical weathering of the bedrock and the fissure/ fracture systems in the underlying bedrock.



Scale: Horzontal 1cm:12.24 Km; Vertical 1 cm: 11.43Km

Fig. 1: Map of Osun State showing the study area (*http://www.nigerianmuse.com*).

Field Procedure and Data Analysis

To characterize the groundwater potential of the study area, vertical electrical soundings (VES) using the Schlumberger array were conducted at twenty locations using Campus Ohmega Resistivity meter (Fig. 2). The points were carefully selected to have a fairly uniform distribution of the area under consideration. From the field data, apparent resistivity values were calculated and plotted against AB/2 on log-log paper. The interpretation of each VES curve was carried out in two steps. First, an approximate interpretation was obtained by the curve-matching method described by [10], and another interpretation was obtained through the use of an automatic interpretation computer program [13].

ISSN 11179333

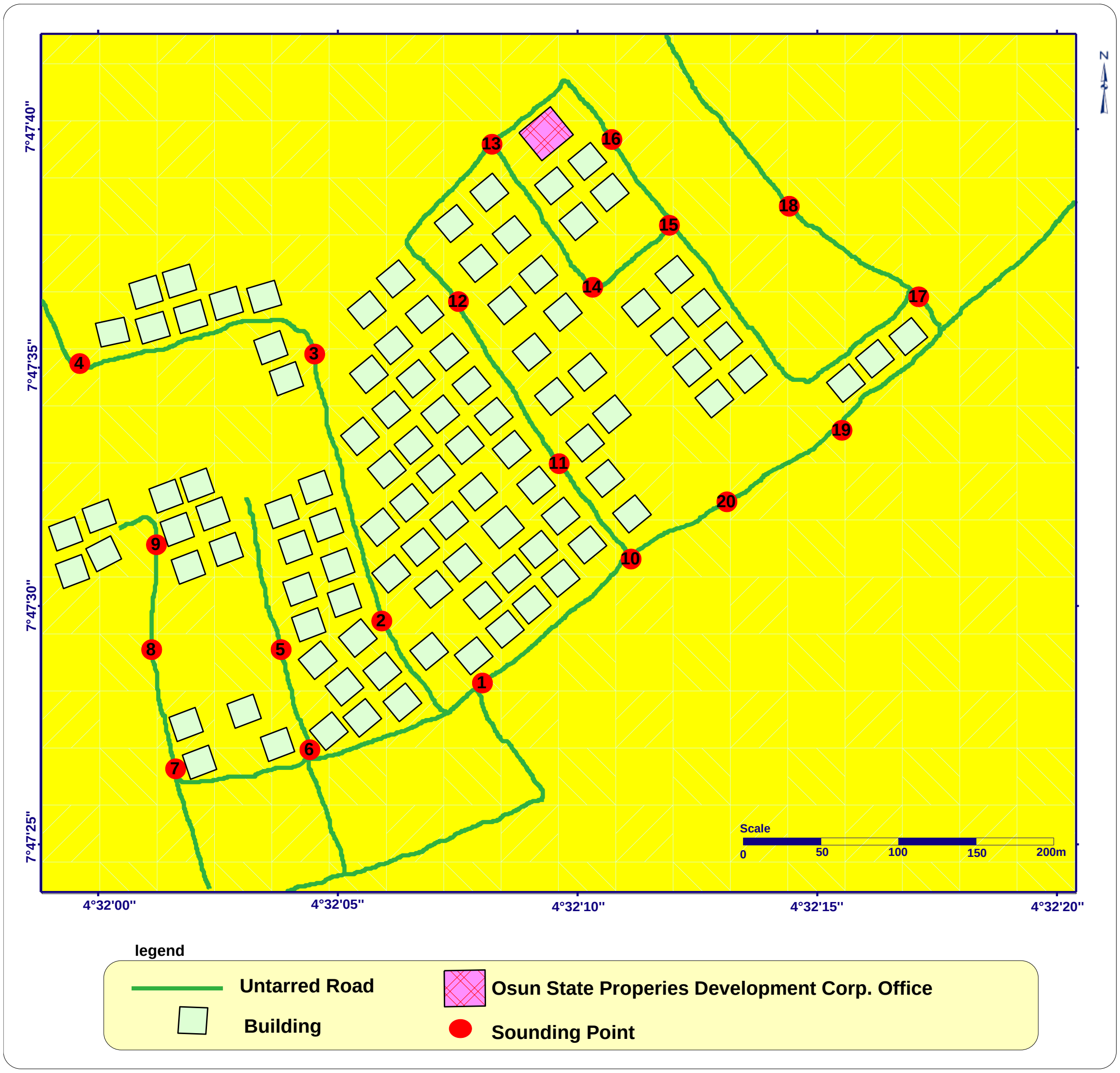


Fig. 2: Map of the study area showing the VES points.

Reflection Coefficient and Resistivity Contrast

The reflection coefficient and resistivity contrast at the basement rock interface can provide some insight into the aquiferous nature of the basement rock, since reflection coefficient value less than 0.9 may be indicative of high density water filled fractures [9]. Thus, based on this, the reflection coefficients and resistivity contrasts at the basement rock interface were calculated for the study area using the relations:

Reflection coefficients = $\{(\rho_n - \rho_{n-1}) / (\rho_n + \rho_{n-1})\}$ and

Resistivity contrasts = (ρ_n / ρ_{n-1})

where ρ_n is resistivity of nth layer and ρ_{n-1} is the resistivity of (n-1)th layer.

Results and Discussion

The results of the geophysical investigation revealed three subsurface geoelectrical layers in all the VES points except VES 3 and 19. A summary of the VES interpretation is presented in Table 1. The top layer resistivity value ranges from 84 to 604 Ohm-m, with a mean of 259 Ohm-m. The iso-resistivity map of the topsoil is shown in Figure 3. The wide range in resistivity values could be as result of lateral variation in the degree of compaction of the topsoil. The top layer thickness ranges from 0.1 to 7.3 m, with mean thickness of 2.1 m. For VES 3 and 19 which have four layers, the second layer constitute the lateritic clay and its resistivity was 215 Ωm in VES 3 and 207 Ωm in VES 19, while its thickness was 3.9 m in VES 3 and 3.0 m in VES 19.

The second layer which is the weathered zone has resistivity values that range from 11 to 120 Ohm-m, with a mean of 51 Ohm-m. The iso-resistivity map of the weathered layer is shown in Figure 4. The thickness of the weathered layer ranges from 3.8 to 37.3 m, with a mean of 18.4 m. This implies that the thickness of the weathered layer is enough for groundwater accumulation. The weathered layer thickness map is shown in Figure 5. The thickness of the overburden is an important hydro-geologic consideration in groundwater development in the basement terrain because water gets into the saturated zone through the overburden. The thickness of the overburden ranges from 9.5 m to 37.8 m with a mean of 21.1 m. This indicates that there is evidence of deep weathering in the area under investigation which also agrees with the rock type which is predominantly quartz schist that is usually weathered easily. The overburden thickness map is shown in Figure 6.

Table 1: Summary of VES Interpretation

VES station	Layer	Resistivity (Ωm)	Thickness (m)	Depth (m)	Probable Lithology
1	1	281	3.5	3.5	Topsoil
	2	120	20.2	23.7	Weathered basement(clayey)
	3	5633	-	-	Fresh basement
2	1	124	7.3	7.3	Topsoil
	2	16	3.8	11.2	Weathered basement(clayey)
	3	224	-	-	Fractured basement
3	1	84	0.9	0.9	Topsoil
	2	215	3.9	4.8	Lateritic clay
	3	26	9.9	14.7	Weathered basement(clayey)
	4	309	-	-	Fractured basement
4	1	188	3.0	3.0	Topsoil
	2	25	12.2	15.2	Weathered basement(clayey)
	3	557	-	-	Fractured basement
5	1	424	0.5	0.5	Topsoil
	2	100	37.3	37.8	Weathered basement(clayey)
	3	4066	-	-	Fresh basement
6	1	546	0.5	0.5	Topsoil
	2	56	26.9	27.4	Weathered basement(clayey)
	3	1515	-	-	Fresh basement
7	1	567	0.3	0.3	Topsoil
	2	94	29.6	29.9	Weathered basement(clayey)
	3	2712	-	-	Fresh basement
8	1	393	0.1	0.1	Topsoil
	2	90	28.0	28.1	Weathered basement(clayey)
	3	1710	-	-	Fresh basement

ISSN 11179333

Table 1 contd.

VES station	Layer	Resistivity (Ωm)	Thickness (m)	Depth (m)	Probable Lithology
9	1	220	1.9	1.9	Topsoil
	2	80	21.8	23.8	Weathered basement(clayey)
	3	1546	-	-	Fresh basement
10	1	95	2.4	2.4	Topsoil
	2	19	8.0	10.4	Weathered basement(clayey)
	3	2216	-	-	Fresh basement
11	1	604	2.4	2.4	Topsoil
	2	54	21.6	24.0	Weathered basement(clayey)
	3	2150	-	-	Fresh basement
12	1	385	1.5	1.5	Topsoil
	2	25	27.6	29.1	Weathered basement(clayey)
	3	191	-	-	Fractured basement
13	1	89	1.3	1.3	Topsoil
	2	17	15.5	16.8	Weathered basement(clayey)
	3	143	-	-	Fractured basement
14	1	104	4.1	4.1	Topsoil
	2	11	11.0	15.1	Weathered basement(clayey)
	3	385	-	-	Fractured basement
15	1	276	1.9	1.9	Topsoil
	2	38	16.9	18.8	Weathered basement(clayey)
	3	84	-	-	Fractured basement
16	1	133	0.6	0.6	Topsoil
	2	57	24.7	25.3	Weathered basement(clayey)
	3	1264	-	-	Fresh basement
17	1	175	5.9	5.9	Topsoil
	2	44	6.4	12.4	Weathered basement(clayey)
	3	245	-	-	Fractured basement
VES station	**Layer**	**Resistivity (Ωm)**	**Thickness (m)**	**Depth (m)**	**Probable Lithology**
18	1	155	1.0	1.0	Topsoil
	2	73	26.2	27.2	Weathered basement(clayey)
	3	287	-	-	Fractured basement
19	1	118	0.7	0.7	Topsoil
	2	207	3.0	3.7	Lateritic clay
	3	65	5.8	9.5	Weathered basement(clayey)
	4	254	-	-	Fractured basement
20	1	223	2.5	2.5	Topsoil
	2	17	14.8	17.2	Weathered basement(clayey)
	3	1936	-	-	Fresh basement

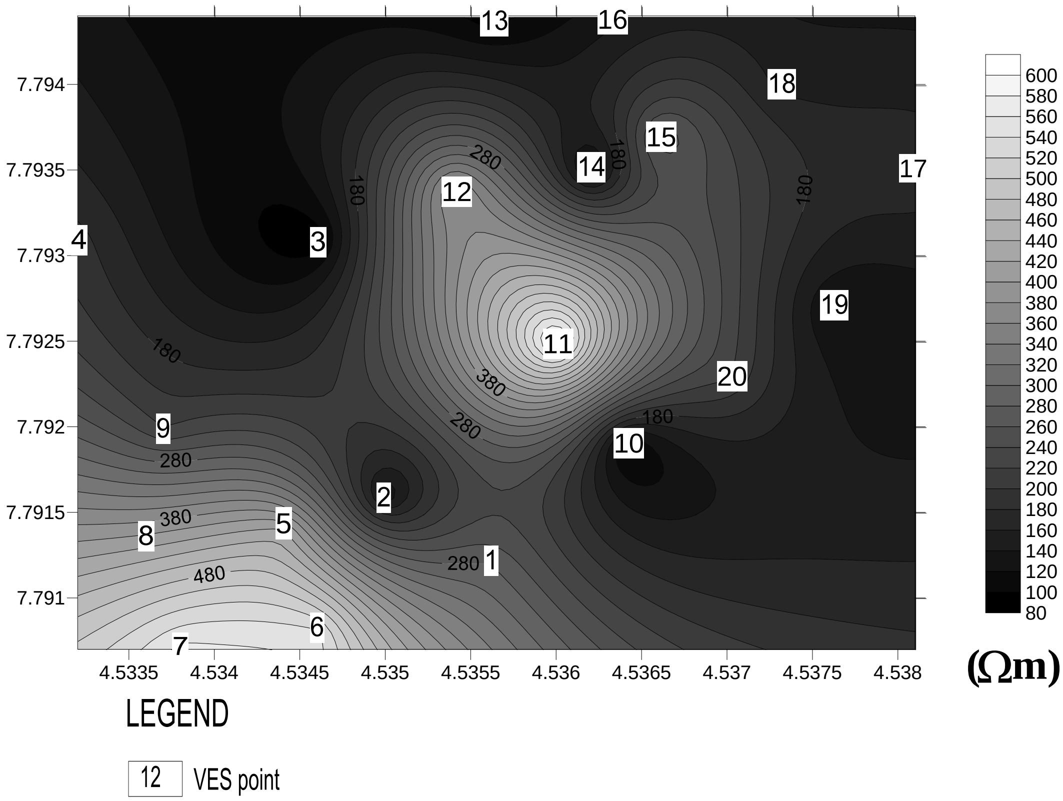


Fig. 3: Iso-resistivity map of top soil.

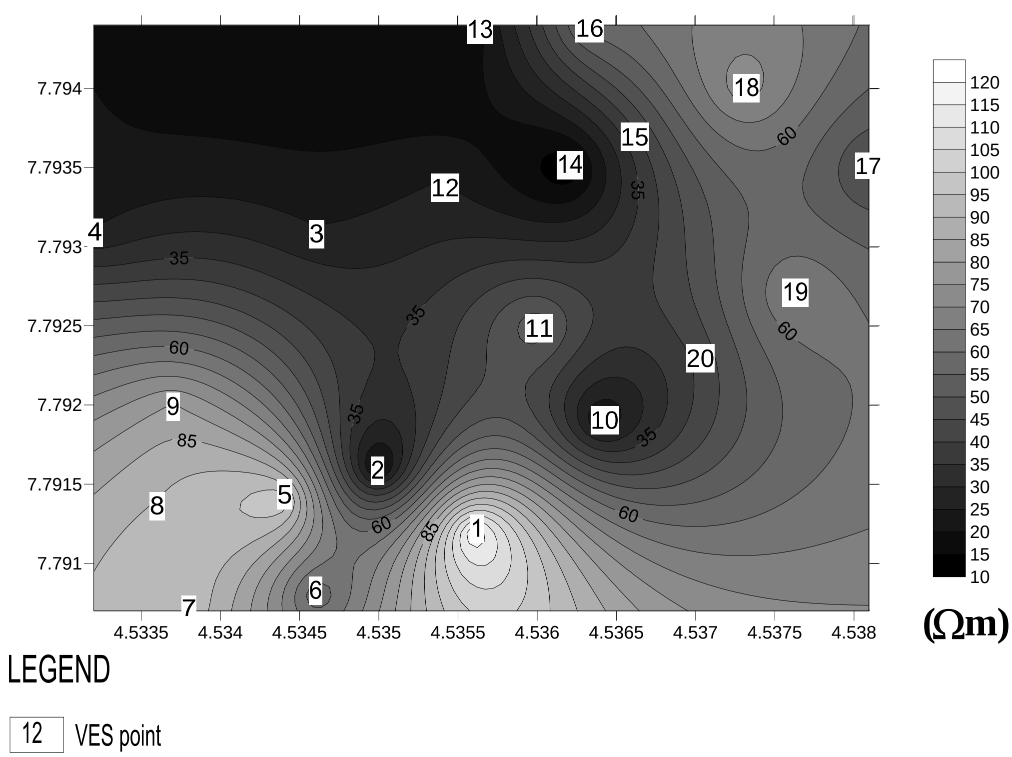


Fig. 4: Iso-resistivity map of the weathered layer.

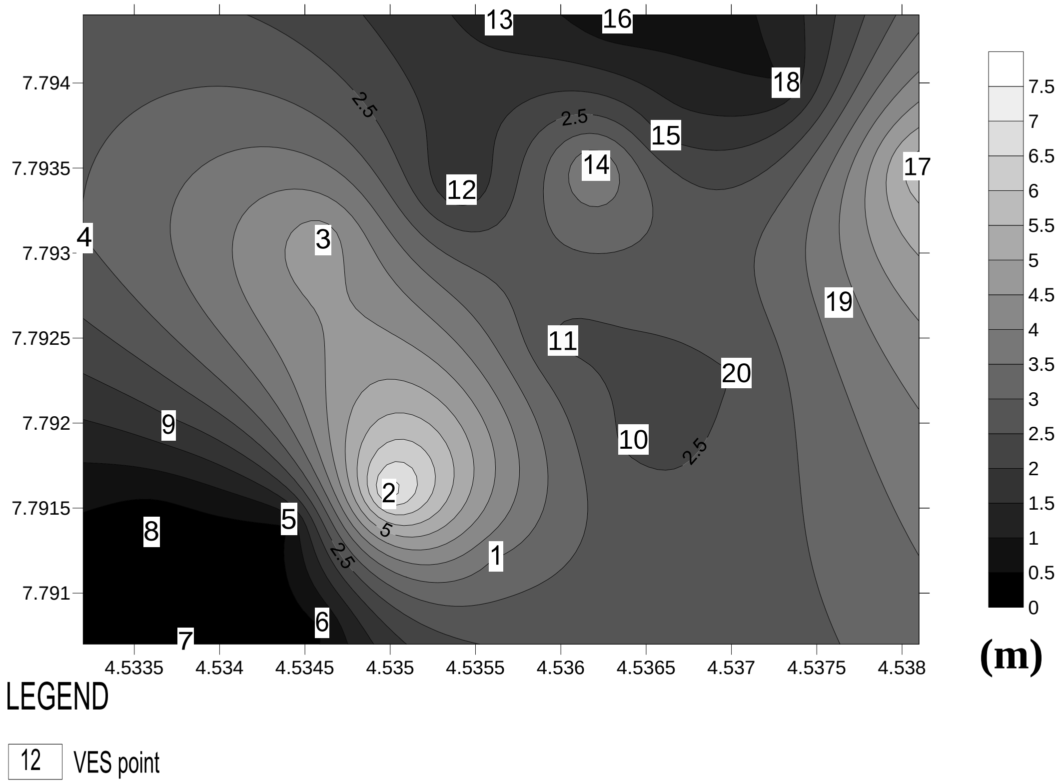


Fig. 5: Weathered layer thickness map of the study area.

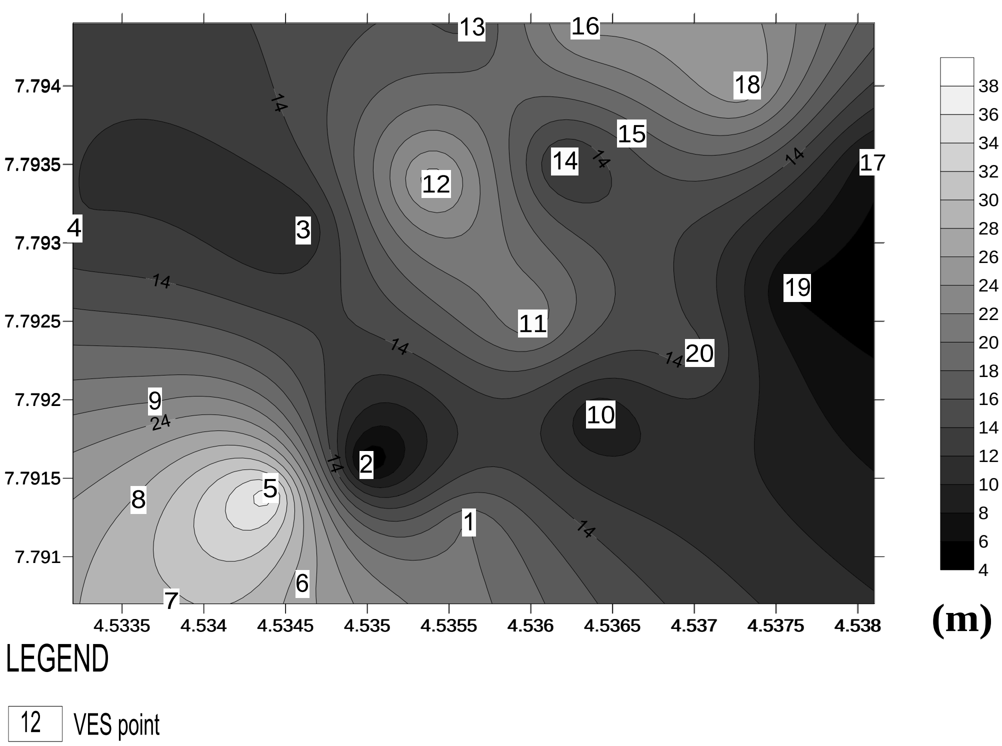


Fig. 6: Overburden thickness map of the study area.

The third layer at all the VES points except VES3 and 19 (which is the fourth layer in their own case) constitutes the fractured/fresh basement. At VES 2, 3, 4, 12, 13, 14, 15, 17, 18 and 19, the basement is fractured with resistivity values ranging between 84 and 557 Ohm-m, with a mean of 268 Ohm-m while at VES 1, 5, 6, 7, 8, 9, 10, 11, 16 and 20, the basement is fresh with resistivity values that range from 1264 to 5633 Ohm-m, with a mean of 2475 Ohm-m indicating poor saturation. The basement resistivity map is shown in Figure 7.

VES stations 2, 3, 4, 12, 13, 15, 17, 18 and 19 might be areas with high-density water-filled fractures since their reflection coefficient and resistivity contrast values are less than 0.9 and 19 respectively [9] (Table 2). There is no significant correlation between the cross plot of reflection coefficient and resistivity contrast.

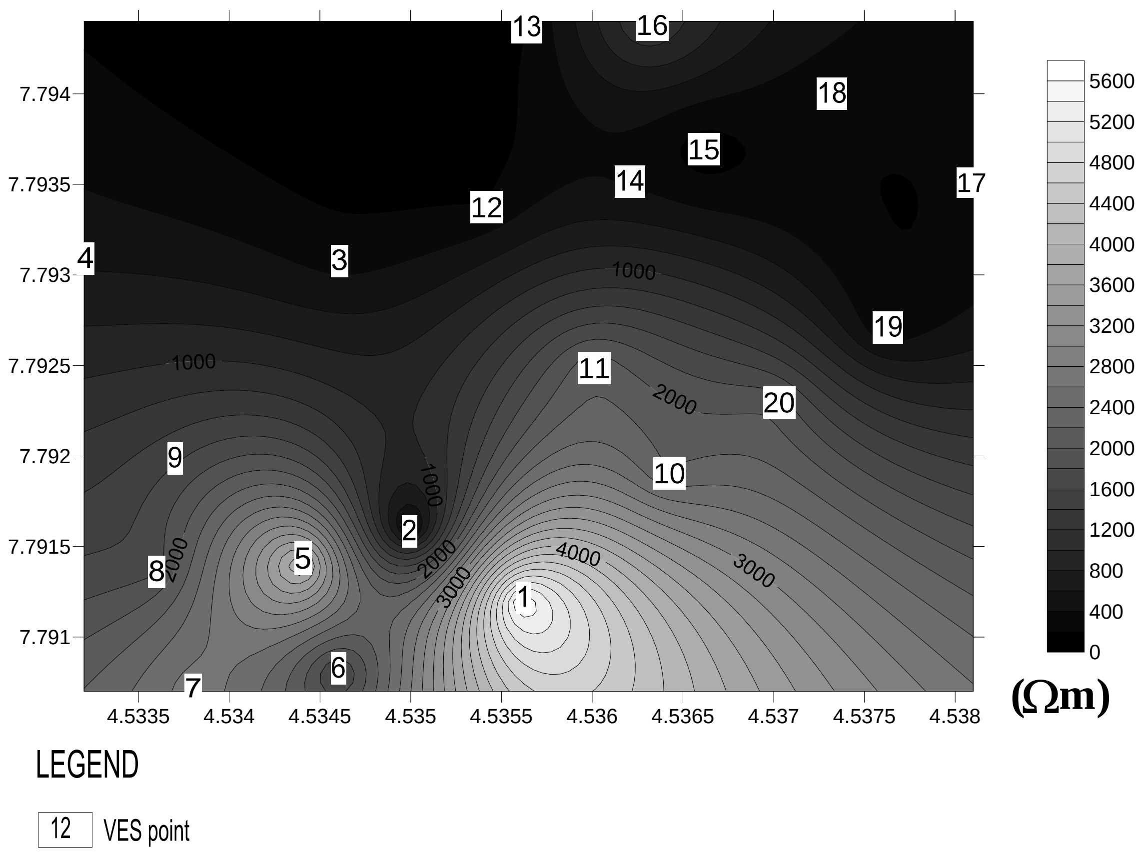


Fig. 7: Iso-resistivity map of the basement.

Table 2: Reflection Coefficient and Resistivity Contrast Values at Basement Rock Interface in the Area

VES Station	Reflection coefficient	Resistivity contrast
1	0.96	46.9
2	0.87	14.3
3	0.85	12.1
4	0.91	22.1
5	0.95	40.8
6	0.93	27.2
7	0.93	29.0
8	0.90	19.0
9	0.90	19.2
10	0.98	115.4
11	0.95	39.7
12	0.77	7.5
13	0.79	8.4
14	0.95	36.7
15	0.38	2.2
16	0.91	22.3
17	0.70	5.6
18	0.59	3.9
19	0.59	3.9
20	0.98	112.6

Geoelectric Sections

Geoelectric sections across some selected VES points in the study area are shown in Figures 8-12. Geoelectric layers obtained after a careful interpretation of the layer parameters from the study area range from three to four, with three layered type curve (H) $(\rho_1 > \rho_2 < \rho_3)$ being the most dominant. The resistivity values of top soil, lateritic clay, weathered basement and the fractured/fresh bedrock varies considerably (Table 1). The thickness of each litho-unit varies considerably across the area. The cross-section revealed some degree of continuity of each layer indicating fairly uniform weathering pattern. Areas with thick overburden and fractured basement have been identified as priority area for groundwater development.

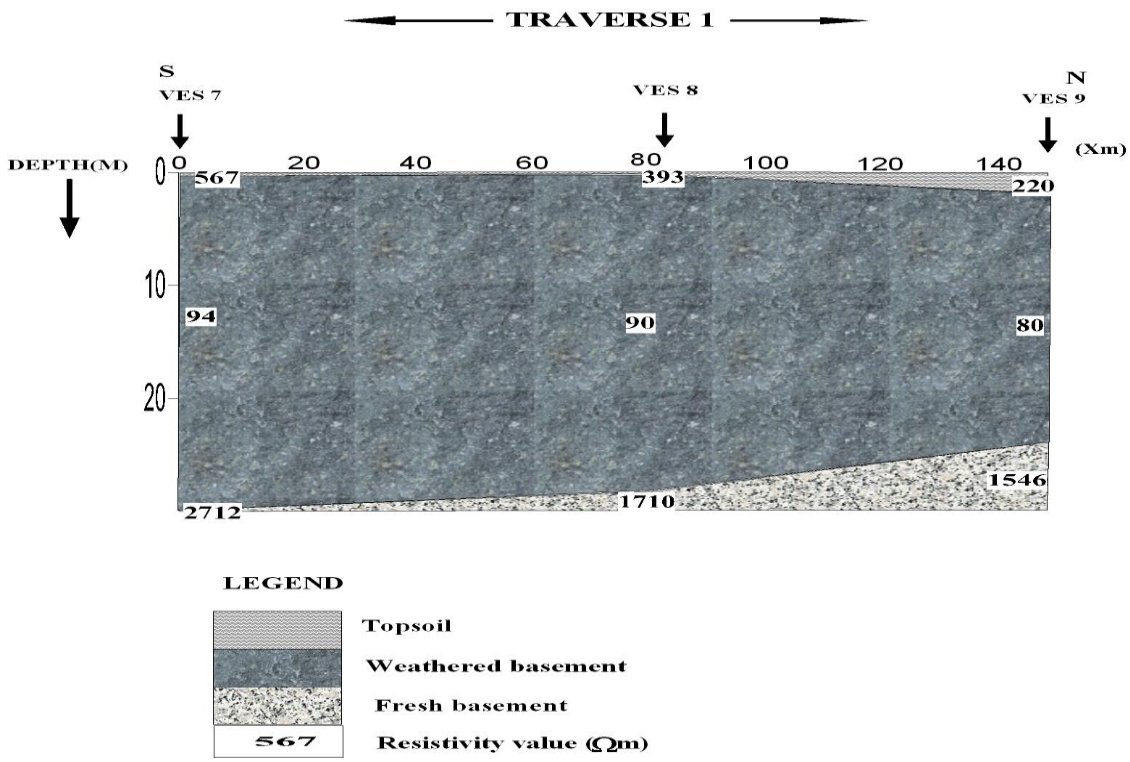


Fig. 8: Geoelectric section across VES 7, 8 and 9.

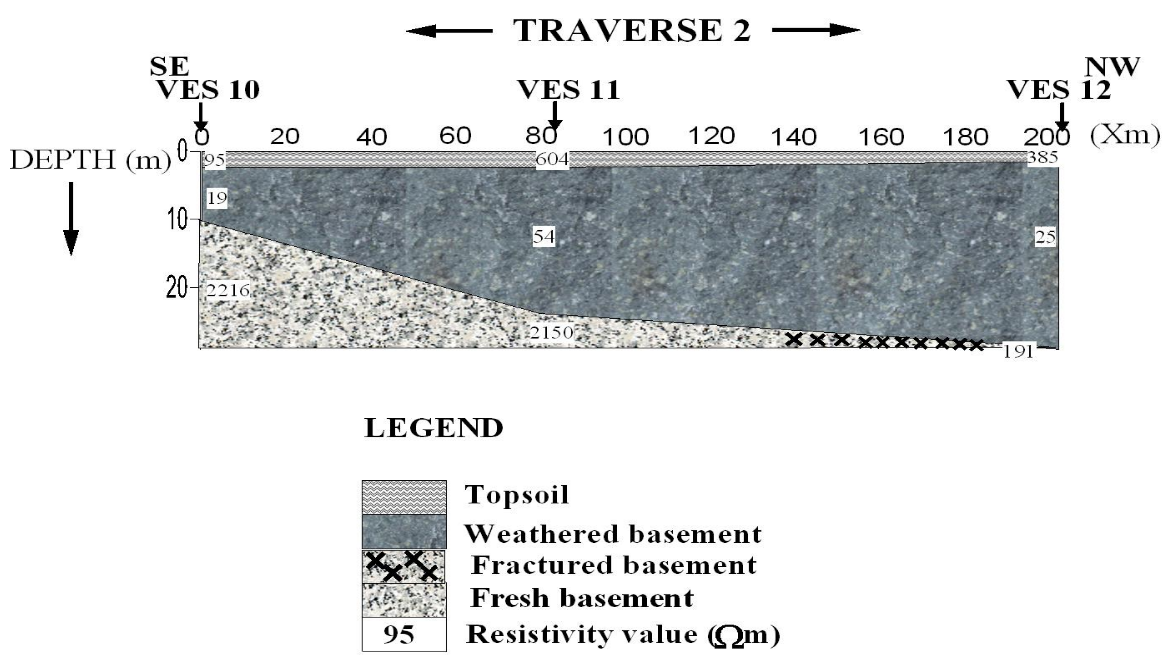


Fig. 9: Geoelectric section across VES 10, 11 and 12.

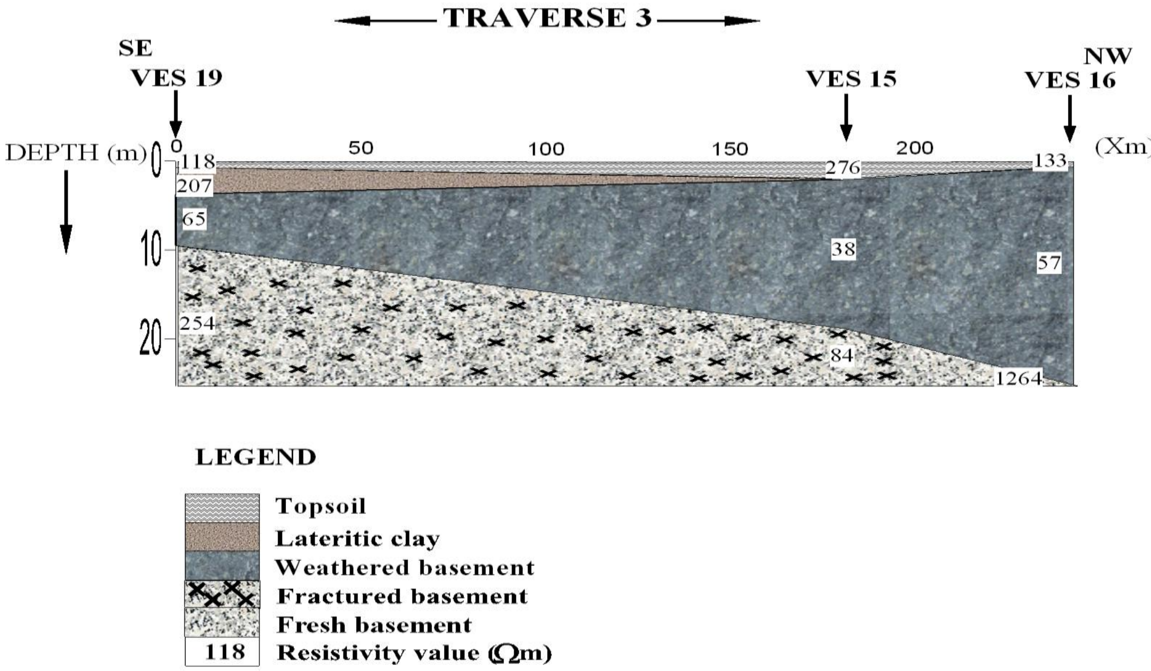


Fig. 10: Geoelectric section across VES 19, 15 and 16.

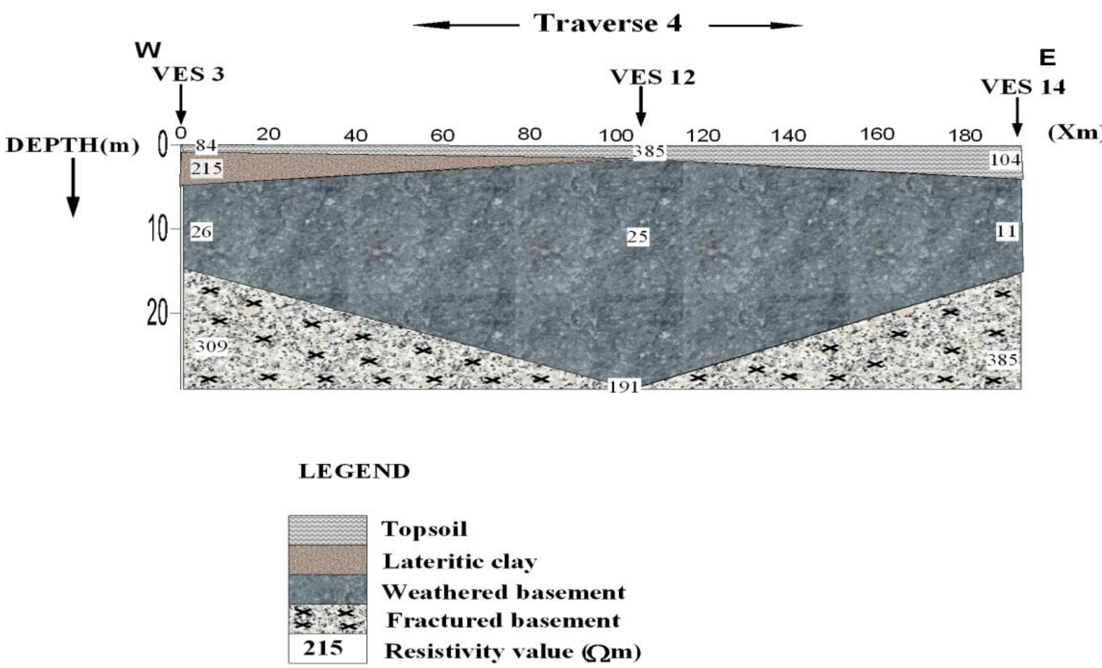


Fig. 11: Geoelectric section across VES 3, 12 and 14.

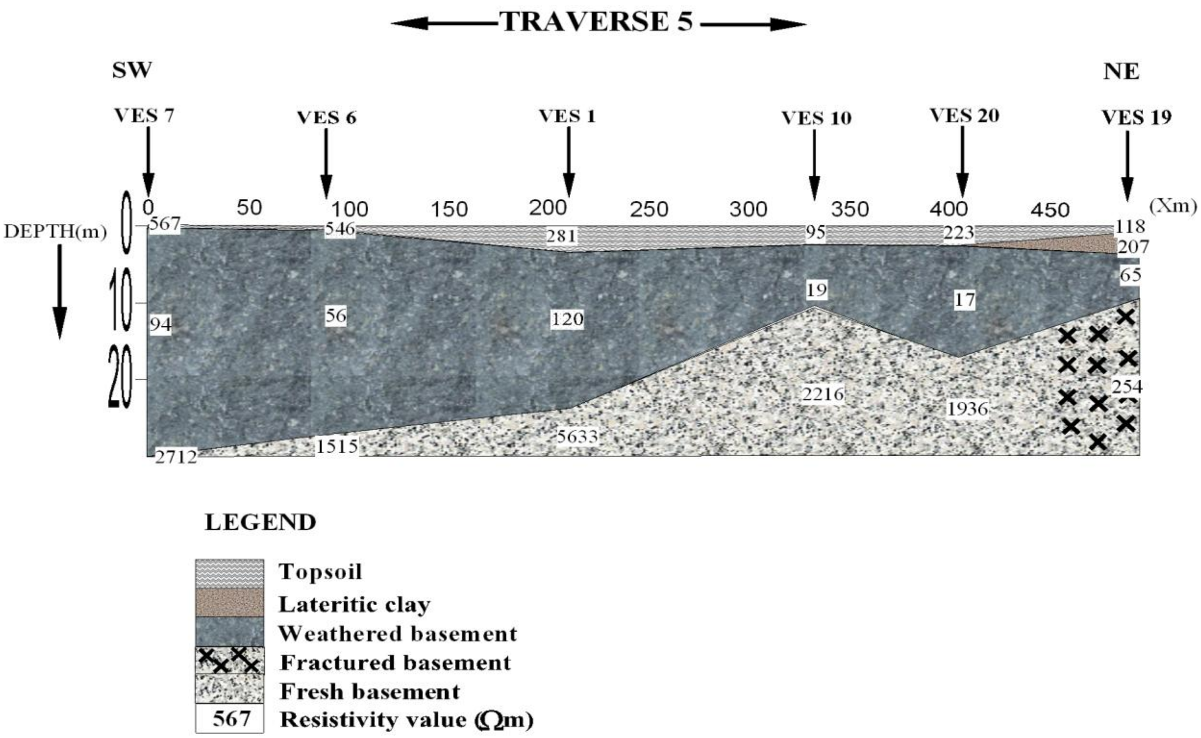


Fig. 12: Geoelectric section across VES 7, 6, 1, 10, 20 and 19.

Conclusion

The results from geoelectric sounding for groundwater exploration around Oroki Estate area of Osogbo in Osun State, southwestern Nigeria have been presented. The results obtained from the study area show the sequences and relationships between the subsurface lithologies. VES result revealed three to four subsurface geoelectric layers (top soil, weathered layer and fracture/fresh basement) in all the stations. It is important to note that the conclusion arrived at in this study was based on the results of the geophysical measurements only as there was no control (bore holes or wells) information during the study.

Integrating all the geoelectric parameters determined, the best sites for sitting wells or boreholes are VES stations 2, 3, 4, 12, 13, 14, 15, 17, 18 and 19 because these VES stations have both relatively thick overburden and fractured basement which aids groundwater accumulation.

The research has shown that in basement environment, Vertical Electrical Soundings (VES) have proved to be very reliable for underground water studies.

References

[1] Adeoti, L., Alile O.M., Uchegbulam and Adegbola R.B. 2012. Geoelectrical Investigation of the Groundwater Potential in Mowe, Ogun State, Nigeria. *British Journal of Applied Science and Technology 2(1), pp. 58 – 71.*

[2] Dan-Hassan, M.A. and Olorunfemi M.O. 1991. Hydrogeophysical investigation of basement terrain in the north central part of Kaduna state, Nigeria. *Journal of Mining and Geology*, 35 (2) 189-206.

[3] Joshua, E.O., Odeyemi, O.O. and Fawehinmi, O.F. 2011. Geoelectric Investigation of the groundwater potential of Moniya Area, Ibadan. *Journal of Geology and Mining Research*, Vol. 3(3), pp. 54-62.

[4] Gholam, R.L. and Mohamed, N. 2005. Geoelectric investigation for the assessment of groundwater condition, a case study. *Journal of Geophysics,* Vol. 48(6), pp 137-139.
[5] Ojo, J.S., Olorunfemi, M.O. and Omosuyi, G.O. 2007. Geoelectric sounding to delineate Shallow acquifer in coaster plain sands of okitipupa area, Southwestern Nigeria. *Online Journal of Earth Sciences,* Vol. 1(4): 170-179.
[6] Ojo, J.S., Ayangbesan, T.A. and Olorunfemi, M.O. 1990. Geophysical survey of dam site. A case study. *Journal of Mining and Geology,* Vol. 26(2), pp. 201-206.
[7] Omosuyi, G.O., Ojo, J.S. and Enikanselu, P.A. 2003. Geophysical Investigation for Groundwater around Obanla-obakekere in Akure area within the basement complex of Southwestern Nigeria. *Journal of Mining and Geology,* Vol. 39(2), pp.109 – 116.
[8] Olayinka, A.I. 1990. Case histories of multi-elecrrode resistivity profiling array for Groundwater in basement complex areas of Kwara State, Nigeria. *Journal of Mining and Geology* Vol. 26 (1), pp 27-30.
[9] Olorunfemi, M.O. and Okhue, E.T. 1992. Hydrogeology and geology significance of geoelectric survey at Ile-Ife, Nigeria. *Journal of Mining and Geology*, Vol. 28(2), 221-229.
[10] Orellana, E. and Mooney, H.M. 1966. Master tables and curves for vertical electrical sounding over layered structures. *Interciencia Madrid* , pp 125.
[11] Rahaman, M.A. 1976. A review of the basement geology of southwestern Nigeria. In: Kogbe, C.A. (ed), *Geology of Nigeria.* Elizabethan Publ. Co., Lagos. pp 41–58.
[12] Ushie, F.A. and Osadebe, C.C. 2005. Geoelectrical exploration for groundwater crystalline basement terrain. Case study of Ohudu, S.E. Nigeria. *Global Journal of Geological Sciences,* Vol. 3(1), pp. 49 – 53.
[13] Zohdy, A.A.R. 1972. A new method for interpretation of Schlumberger and Wenner sounding curves. *Geophysics* 54: p. 245 – 253.