A Wet-season Geoelectrical Investigation for Groundwater Development at a Built-Up Property at the Western Bye-Pass, Minna, Nigeria

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A Wet-season Geoelectrical Investigation for Groundwater Development at a Built-Up Property at the Western Bye-Pass, Minna, Nigeria

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Abstract

In the desire to explore approaches that are not generally conventional, but ones that have good foundational basis, a wet-season geoelectrical investigation for groundwater development at a built-up property at the Western Bye-Pass, Minna, Nigeria, was planned and completed. The client had already commissioned a dry-season spell survey at the same built-up property, but the result was not known to the present survey crew beforehand. The result of the present endeavour would be essentially corroborative. The vertical electrical sounding (VES) mode of the resistivity type of geoelectrical survey employing the Schlumberger array was the preferred format for this exercise. The survey schedule was to do VES to a total depth of 100m, where possible, although that depth is well beyond the effective water-bearing subsurface environment and into the local bedrock proper. Nonetheless, the built-up nature of the neighbourhood of the survey locations precluded the 100m-target. In interpreting for possible locations of groundwater, two constraints are used, viz: the “ideal” log-log plot and the “Olasehinde Protocol:” such a log-log plot must have almost all plotted points alternately “rising-and-falling” along the curve and the Olasehinde Protocol states that resistivity values between 180Ωm and 250Ωm at the 20m to 25m depth mark is indicative of possible groundwater prospect. Only the third and last survey location approximates these impositions at the 20m - 30m depth mark with a smoothly-varying resistivity profile observed to the 40m depth mark, and its corresponding plot indicates a three-layer sequence. Based on the imposed constraints, the survey crew posits that the location of latitude 09°39′36.2″and longitude 006°30′30.2″ is the best prospect location identified from this survey. If drilling must be done at all, the survey crew recommended that this location should be drilled to a total-depth (TD) of 50m.

Keywords: Wet-season; built-up; geoelectrical; resistivity; groundwater

1.0 Introduction

Presently, at Minna, Niger State, Nigeria, householders put a lot of stock in the results of geoelectrical surveys carried out at their lots to locate the presence of groundwater sources because of the need to maximize returns on investment committed to borehole development. Nearly everyone will agree that mankind, at this point in time more than ever before, is saddled with the critical responsibility of sustainably managing the earth’s resources that are beginning to show signs of decline. Water is one such very important resource, and thus the search for underground water sources as supplements to the surface water sources to meet the demand of a burgeoning population is central to individual endeavours and government policies. In science, this search is encompassed in the earth sciences' disciplines of geology and applied geophysics (Jonah *et al.*, 2014A; 2014B; 2014C; 2013). The client's property was a built-up, walled and gated compound on a gentle slope of land fronted by a body of outcrop; this land-slope, however, appears to dip toward a truncated valley that was more or less a burrow pit.

2.0 The Geoelectric Survey

2.1 The Method Employed. The vertical electrical sounding (VES) mode of the resistivity type of geoelectrical survey employing the Schlumberger array was the sole preferred format for this exercise (Kearey and Brooks, 1988; Parasnis, 1986). Generally, an electrical resistivity method involves the artificial introduction of current into the ground through point electrodes. Potentials are subsequently measured at other electrodes in the vicinity of the current flow. By this means, it is then possible to measure or determine an effective or apparent resistivity of the subsurface. Low resistivity in a given area is a likely indicator of the presence of groundwater (Ako and Olorunfemi, 1982; Bonde, 1997; Dangana, 2002; Gana, 1995; Okwueze and Ezeanyi, 1985; Okwueze *et al.*, 1981; Olorunfemi and Fasuyi, 1993; Olorunfemi and Okhue, 1992).

Jonah *et al.* (2013) adopted a different approach from the conventional in order to do reconnaissance for a planned survey at the Dan Zaria Academic Estate, Federal University of Technology, Minna, Central Nigeria. The resistivity type of geoelectrical survey in the vertical electrical sounding (VES) mode of the Schlumberger array was employed for the reconnaissance and final stages of this investigation. The objective of this study was the search for possible location of aquifer at a defined lot at this estate. This "unconventional" approach was the acquisition of VES data at shallow depths (i.e. progressively down to 10m) over the area of study in order to determine the point of lowest resistivity instead of the approach to determine the lateral variation of resistivity at these shallow depths using the constant separation traversing (CST) method. The point of lowest resistivity thus identified was surveyed to a final depth of 100m. The authors based their interpretation for aquifer prospect at this point on the "Geoexplore Empirical Standardization for Minna Area." Based on this standardization, it was observed that the 30-40m depth interval at this point is the possible groundwater yield zone.

Jonah *et al.* (2014A) carried out a geoelectrical investigation for groundwater development at a wetland lot at the Bosso Estate, Minna, Central Nigeria. Initially, the target objective (i.e. client's property) was visually reconnoitered; the extent, local geology, and preferred traverse directions of the area of survey were noted. The survey crew proposed a southwest-southeast profile to be the longitudinal traverse (LT) at 10m-separation between survey stations and 10m-separation between profile lines for the initial low-resistance reconnaissance scheme to a depth of 15m. Thence, detailed vertical electrical sounding (VES) survey was conducted for locations of "low-ohmic interest" to a depth of 70m. In essence, this exercise was treated as a blind geoelectrical prospecting by the team members because the client had exclusive possession of the result of an earlier, independent survey conducted for aquifer prospect at this lot. On-the-field inspection of the CST dataset revealed that the lowest resistance value of 2.1919Ω was obtained at "LT3-5" corresponding to the following geographic co-ordinate: $09^0$39'15.8", $006^0$30'46.6"; an arbitrary field benchmark of <3Ω was selected for this fieldwork. The survey crew based their interpretation for aquifer prospect at the VES locations on an informal and fairly successful empirical rule to determine the likely presence of groundwater in the basement complex geological province, called the "Olasehinde Protocol." Based on this standardization, the survey crew observed the prospect for groundwater yield is encouraging at location "LT3-5." This location is actually circa 5-6m displaced from the position of the initial survey carried out two years before as verified by the client. The survey party recommended that a borehole be sunk at this location, down to an effective depth of 50m. Really, beyond the 20m depth mark, the resistivity varies smoothly down to the total depth (TD) surveyed.

Jonah *et al.* (2014B) reported that, when the owner of a property located on a knoll, tasked the survey crew to prospect for aquifer at his lot, no clue was provided as to what the result of an earlier survey by an independent crew was: thus, members of the present crew were required to independently plan and execute a geoelectrical survey at this same location, the result of which is expected to corroborate or weaken the conclusions reached in the earlier survey. At the outset, the client's property was visually reconnoitered; the extent and preferred traverse directions were noted. The survey crew proposed a north-south (i.e. longitudinal traverse, LT) profiling scheme at 10m-separation between survey stations and 10m-separation between profile lines for the reconnaissance phase to a depth of 15m. Thence, detailed vertical electrical sounding (VES) survey was conducted for locations of "low-ohmic interest" to a depth of 100m. The result of the reconnaissance phase indicated the lowest resistance value of 1.6348Ω at "LT4-1." Upon final VES surveys, and based on an empirical protocol for the likely presence of groundwater in the basement complex geological province, it was concluded that the prospect for aquifers of good yield at the area of study was very poor indeed: this conclusion actually corroborated the one drawn from the initial survey.

Jonah *et al.* (2014C) identified the three corners of a brick fence enclosing a bungalow away from the corner where a cesspool was situated, defined in one north-south (longitudinal traverse, LT) and two east-west (transverse traverse, TT) modes, as ideal locations selected for a survey conducted at a built-up compound at the Barkin-Sale Ward, Minna, Niger State, Central Nigeria. A four-layer sequence was identified for VES TT1, a four-layer sequence for VES LT1, and a three-layer sequence for VES TT2. The authors based their interpretation for aquifer prospect at the three VES locations on a combination of informal and fairly successful dual empirical rules to determine the likely presence of groundwater in the basement complex geological province. Based on these rules, TT1 indicated the best prospect for groundwater yield in the area of survey with good showings from the 30m-depth mark down to the 50m-depth. Also, it was observed that the 50m-depth mark for TT1 and TT2 correlated very well as a prospective aquifer zone. If drilling must be done at all, then it was recommended that point TT1 be considered a good prospect for groundwater yield over the 20-m "yield window." Because of the smoothly-changing continuum of resistivity values down to the 100m-depth mark, it was recommended that drilling should be terminated at this maximum or total depth (TD) of survey in order to tap into the fractured basement at this TD. Incidentally, TT1 is upslope of the sewer pit, which was a plus for this VES station over the possible prospect of TT2.

2.2 Data Collection Procedure. This property was visually reconnoitered and the extent, local geology, and preferred survey points were noted. Only three locations were earmarked here; the first point of survey, naturally, was the one by the main entrance to the property. The remaining two points were behind the compound. Each of these locations was carefully fixed so straight-line traverses could be defined about them as mid-points. The survey schedule was to do VES to a total depth of 100m, where possible: it should be pointed out here that, for the Basement Complex geology, that depth is well beyond the effective water-bearing subsurface environment and into the local bedrock proper. Nonetheless, the built-up nature of the neighbourhood of the survey locations precluded the 100m-target.

3.0 Data Presentation

The depths marks for the three points that survey was terminated are as presented in Tables 1-3.

Table 1. **GEOELECTRICAL DATA RECORD SHEET FOR POINT 1**

TYPE OF SURVEY: Resistivity...**MODE:**.Vertical Electrical Sounding **ARRAY:.**Schlumberger…

PLACE: Western Bye-Pass, Minna **WEATHER:**Sunny**EQUIPMENT:**ABEM Terrameter SAS 4000

LOCATION: (i) **N:**.. 09°39′36.0″.......(ii) **E:**.... 006°30′29.7″...... **GPS UNIT:**… Garmin GPSmap78

OPERATOR:…Godwin…**RECORDER:**… Godwin **DATE:**… 20/07/2014…**TIME:**… 04:02 P.M..

SURVEY POINT DESIGNATION:…EDGE OF ENTRANCE GATE…….

AB/2 (m)	MN/2 (m)	GEOM. FACTOR, K	RESISTANCE	STANDARD DEVIATION	CURRENT (I)	STACKS	RESISTIVITY
1	.50	2.36	28.410Ω	0.005	10mA	2	67.047Ωm
2	.50	11.8	8.2372Ω	0.235	10mA	2	97.198Ωm
3	.50	27.8	4.1772Ω	0.250	10mA	2	116.12Ωm
5	.50	77.8	1.9048Ω	0.886	10mA	2	148.19Ωm
6	.50	112	1.4012Ω	4.480	10mA	4	156.93Ωm
6	1.00	55	2.5295Ω	2.000	10mA	4	139.12Ωm
8	1.00	99	1.5795Ω	5.970	10mA	4	156.37Ωm
10	1.00	156	1.1807Ω	5.910	10mA	4	184.18Ωm
10	2.50	58.9	4.5701Ω	1.490	10mA	4	269.17Ωm
15	2.50	137	892.22mΩ	9860	10mA	4	122.23Ωm
20	2.50	245	7.2561Ω	0.535	10mA	4	1777.7Ωm
30	2.50	562	329.36mΩ	1014	10mA	4	185.10Ωm
40	2.50	1001	3.4954Ω	189.0	10mA	4	3498.8Ωm
40	7.50	323	185.12mΩ	2995	10mA	4	597.93Ωm
50	7.50	512	6.7102Ω	49.20	10mA	2	3435.6Ωm
60	7.50	742	3.5042Ω	189.0	10mA	4	2600.1Ωm
70	7.50	1014	543.60mΩ	56.80	10mA	4	551.21Ωm
80	7.50	1329	3.4622Ω	189.0	10mA	4	4601.2Ωm
80	15.00	647	3.2851Ω	114.0	10mA	4	2125.4Ωm
90	15.00	825	BUILT-UP	BARRIER	BUILT-UP		BARRIER
100	15.00	1024	BUILT-UP	BARRIER	BUILT-UP		BARRIER

Table 2. **GEOELECTRICAL DATA RECORD SHEET FOR POINT 2**

TYPE OF SURVEY: Resistivity....**MODE:**…Vertical Electrical Sounding… **ARRAY:**Schlumberger

PLACE: Western Bye-Pass, Minna **WEATHER:**Sunny.**EQUIPMENT:**ABEM TerrameterSAS 4000

LOCATION: (i) **N:**.. 09°39′36.7″.....(ii) **E:**.... 006°30′29.0″...... **GPS UNIT:**… Garmin GPSmap78

OPERATOR:…Fidelis…**RECORDER:**… Fidelis …**DATE:**… 20/07/2014…**TIME:**… 04:41 P.M..

SURVEY POINT DESIGNATION:REAR OF COMPOUND BEHIND CHICKEN COOP (NW OF GATE)

AB/2 (m)	MN/2 (m)	GEOM. FACTOR, K	RESISTANCE	STANDARD DEVIATION	CURRENT (I)	STACKS	RESISTIVITY
1	.50	2.36	266.77Ω	0.086	10mA	2	629.57Ωm
2	.50	11.8	15.659Ω	2.650	10mA	4	184.77Ωm
3	.50	27.8	4.0567Ω	0.239	10mA	4	112.77Ωm
5	.50	77.8	3.7494Ω	0.049	10mA	4	291.70Ωm
6	.50	112	819.65mΩ	5.220	10mA	4	91.800Ωm
6	1.00	55	1.2934Ω	1.240	10mA	4	71.137Ωm
8	1.00	99	744.23mΩ	0.910	10mA	42	73.678Ωm
10	1.00	156	497.80mΩ	9.600	10mA	4	77.656Ωm
10	2.50	58.9	1.4035Ω	3.730	10mA	4	82.666Ωm
15	2.50	137	700.44mΩ	13.80	10mA	4	95.960Ωm
20	2.50	245	518.06mΩ	7.990	10mA	4	126.92Ωm
30	2.50	562	179.57mΩ	79.50	10mA	4	100.91Ωm
40	2.50	1001	6.5261Ω	25.00	10mA	4	6532.6Ωm
40	7.50	323	3.2518Ω	26.70	10mA	4	1050.3Ωm
50	7.50	512	1.6651Ω	22.90	10mA	4	852.53Ωm
60	7.50	742	1.4826Ω	12.01	10mA	4	1100.0Ωm
70	7.50	1014	BUILT-UP	BARRIER	BUILT-UP		BARRIER
80	7.50	1329	BUILT-UP	BARRIER	BUILT-UP		BARRIER
80	15.00	647	BUILT-UP	BARRIER	BUILT-UP		BARRIER
90	15.00	825	BUILT-UP	BARRIER	BUILT-UP		BARRIER
100	15.00	1024	BUILT-UP	BARRIER	BUILT-UP		BARRIER

Table 3 .**GEOELECTRICAL DATA RECORD SHEET FOR POINT 3**

TYPE OF SURVEY: Resistivity....**MODE:**Vertical Electrical Sounding… **ARRAY:**Schlumberger

PLACE: Western Bye-Pass, Minna**WEATHER:**Partly Sunny **EQUIPMENT:**.ABEM Terrameter SAS 4000

LOCATION: (i) **N:**.. 09°39′36.2″.......(ii) **E:**.... 006°30′30.2″...... **GPS UNIT:**… Garmin GPSmap78

OPERATOR:…Freedom…**RECORDER:**… Freedom…**DATE:**… 20/07/2014…**TIME:**5:15 P.M.

SURVEY POINT DESIGNATION:EDGE OF FENCE DIRECTLY BEHIND THE SHOP (NE OF GATE)

AB/2 (m)	MN/2 (m)	GEOM. FACTOR, K	RESISTANCE	STANDARD DEVIATION	CURRENT (I)	STACKS	RESISTIVITY
1	.50	2.36	39.038Ω	1.79	10mA	4	92.129Ωm
2	.50	11.8	9.3930Ω	0.22	10mA	2	110.84Ωm
3	.50	27.8	3.5767Ω	1.35	10mA	4	99.412Ωm
5	.50	77.8	1.2332Ω	0.90	10mA	4	95.942Ωm
6	.50	112	825.16Ω	1.37	10mA	4	92.418Ωm
6	1.00	55	1.3374Ω	2.73	10mA	4	73.557Ωm
8	1.00	99	903.33mΩ	0.92	10mA	2	89.429Ωm
10	1.00	156	611.71mΩ	2.65	10mA	4	95.427Ωm
10	2.50	58.9	1.7506Ω	4.11	10mA	4	103.11Ωm
15	2.50	137	991.85mΩ	4.78	10mA	4	135.76Ωm
20	2.50	245	641.52mΩ	0.97	10mA	2	157.05Ωm
30	2.50	562	486.01mΩ	0.250	10mA	2	273.42Ωm
40	2.50	1001	361.89mΩ	22.4	10mA	4	361.36Ωm
40	7.50	323	1.0398Ω	3.45	10mA	4	335.86Ωm
50	7.50	512	169.73mΩ	3144	10mA	4	86.900Ωm
60	7.50	742	BUILT-UP	BARRIER	BUILT-UP		BARRIER
70	7.50	1014	BUILT-UP	BARRIER	BUILT-UP		BARRIER
80	7.50	1329	BUILT-UP	BARRIER	BUILT-UP		BARRIER
80	15.00	647	BUILT-UP	BARRIER	BUILT-UP		BARRIER
90	15.00	825	BUILT-UP	BARRIER	BUILT-UP		BARRIER
100	15.00	1024	BUILT-UP	BARRIER	BUILT-UP		BARRIER

4.0 Data Analysis

In interpreting for possible locations of groundwater, two constraints are used, viz: the "ideal" log-log plot and the "Olasehinde Protocol." Such a log-log plot must have almost all plotted points alternately "rising-and-falling" along the curve and the Olasehinde Protocol states that resistivity values between 180Ωm and 250Ωm at the 20m to 25m depth mark is indicative of possible groundwater prospect. Table 3 produced the "ideal" log-log plot shown in Fig.1, and this table nearly approximates this protocol at the 20m - 30m depth mark with a smoothly-varying resistivity profile observed to the 40m depth mark.

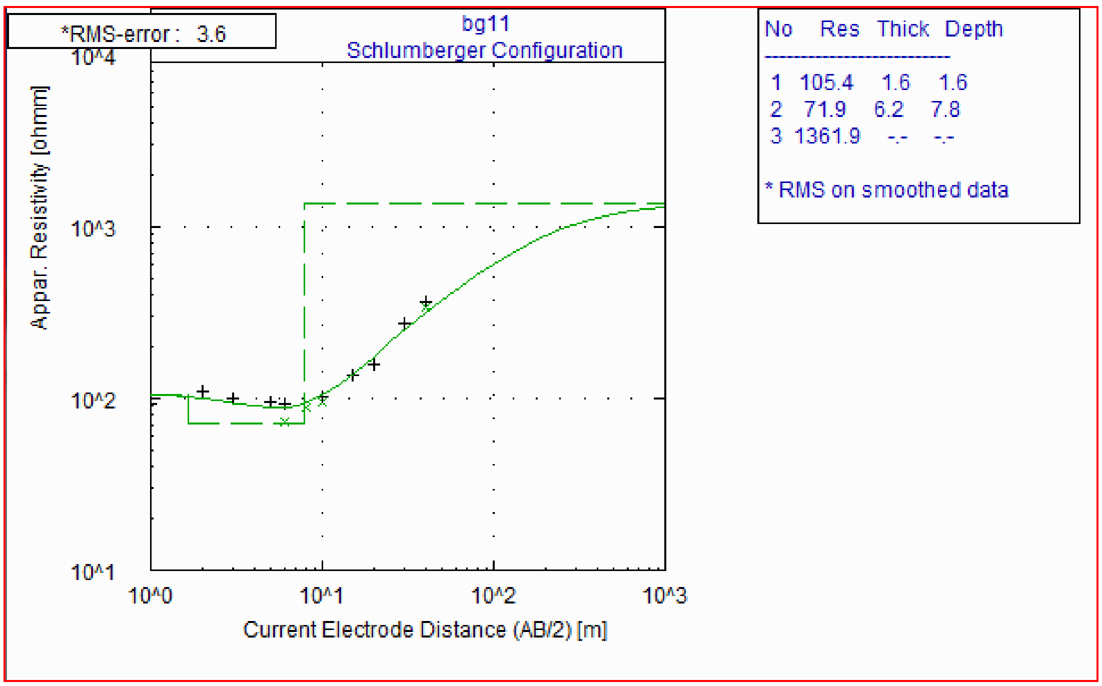

Fig.1. Log-log plot corresponding to Table 3

5.0 Discussion, Conclusion, and Recommendation

5.1 The Continuous Variation of Resistivity with Depth. A continuous variation of resistivity with depth curve is easily derived from multilayer step-function curve by drawing a curve that passes through the logarithmic midpoint of each vertical and horizontal line on the multilayer step function model. In view of the fact that the layer depths are logarithmically closelyshaped, the derived continuous variation of resistivity with depth model is equivalent to the original model (Zohdy, 1989).

5.2 Vertical Electrical Depth Sounding Result. The plot of Fig. 1 indicates a three-layer sequence. The survey crew based their interpretation for aquifer prospect on the Olasehinde Protocol. The Olasehinde Protocol is a fairly successful empirical rule to determine the likely presence of groundwater in the basement complex geological province (Olasehinde, 1989; 1999).

5.3 Conclusion. Based on the imposed constraints enunciated Sec. 4.0, the survey crew posits that the location of Table 3 (latitude 09°39′36.2″ and longitude 006°30′30.2″) corresponding to the edge of fence directly behind the shop at the north-east end of the entrance gate is the best prospect location identified from this survey.

5.4 Recommendation. If drilling must be done at all, the point of latitude 09°39′36.2″ and longitude 006°30′30.2′ should be drilled to a total-depth (TD) of 50m.

References

Ako, B.J. and Olorunfemi, M.O. (1982). Geoelectric survey for groundwater in the New Basalt of Vom, Plateau State. *Journal of Mining and Geology*, 8(2), 273-280.

Bonde, D.S. (1997). *Geoelectrical survey for groundwater resources in Egba, Shiroro Local Government Area, Niger State*, M.Tech. dissertation, Federal University of Technology, Minna.

Dangana, L.M. 2002. *Electrical resistivity survey of Tunga Kawo Dam, Wushishi, Niger State, Nigeria*, M.Tech. dissertation, Federal University of Technology, Minna.

Gana, J.S. 1995. *Geophysical exploration for groundwater in Yakila, Niger State*, M.Tech. dissertation, Federal University of Technology, Minna.

Jonah, S.A., James, G.O., Adeku, D.E., Ahmed, F., Alhassan, A., Hamza, S., Igbideba, O. I., Kwaghhua, F.I., Kyari, M., Macaulay, V. F., Olarewaju, S.I., Onyeodili, G., Popoola, G.B., Sofeso, O.A., Switzer, F.K., and Umoh, U.E. (2013). A survey for groundwater at a lot at the Dan Zaria Academic Estate, Federal University of Technology, Minna, Central Nigeria. *Journal of Science, Technology, Mathematics, and Education (JOSTMED)*, **9**(**3**), 26 – 38.

Jonah, S.A., James, G.O., Adeku, D.E., Ahmed, F., Alhassan, A., Hamza, S., Igbideba, O. I., Kwaghhua, F.I., Kyari, M., Macaulay, V. F., Olarewaju, S.I., Onyeodili, G., Popoola, G.B., Sofeso, O.A., Switzer, F.K., and Umoh, U.E. (2014C). Pre-Drilling Geoelectrical Survey at a Built-up Compound at Barkin-Sale Ward, Minna, Niger State, Nigeria. *Journal of Information, Education, Science, and Technology (JIEST)*: **Accepted for publication**.

Jonah, S.A., Umoh, S.E., James, G.O., Adeku, D.E., Ahmed, F., Alhassan, A., Hamza, S., Igbideba, O. I., Kwaghhua, F.I., Kyari, M., Macaulay, V. F., Olarewaju, S.I., Onyeodili, G., Popoola, G.B., Sofeso, O.A., Switzer, F.K., and Umoh, U.E. (2014A). A wetland lot geoelectrical investigation for groundwater development at Bosso Estate, Minna, Central Nigeria. *Journal of Information, Education, Science, and Technology (JIEST)*: **Accepted for publication**.

Jonah, S.A., Umoh, S.E., James, G.O., Adeku, D.E., Ahmed, F., Alhassan, A., Hamza, S., Igbideba, O. I., Kwaghhua, F.I., Kyari, M., Macaulay, V. F., Olarewaju, S.I., Onyeodili, G., Popoola, G.B., Sofeso, O.A., Switzer, F.K., and Umoh, U.E. (2014B). A blind geoelectrical survey commissioned to affirm or deny the presence of aquifer at a compound at Minna, Central Nigeria. *Journal of Information, Education, Science, and Technology (JIEST)*: **Accepted for publication**.

Kearey, P. and and Brooks, M. 1988. *Fundamentals of Geophysics*, Cambribge University Press, Cambridge.

Okwueze, E.E. and Ezeanyi, V. 1985. The vertical electrical sounding (VES) method in laterite region and iron-rich area. Journal of Mining and Geology, 22 (1 and 2), 173-280.

Okwueze, E.E., Ebeniro, J.O., and Mbogning, M. 1981. The geoelectric structure of Late Nyos Dam, Cameroon, and its geoelectric implication. *Journal of Mining and Geology*, 8(2), 273-280.

Olasehinde, P.I. (1989). Elucidating fracture patterns of the Nigerian Basement Complex using electrical resistivity methods. *Z. Agnew Geowiss Heft*, **8**, 109 – 120.

Olasehinde, P.I. (1999). An integrated geologic and geophysical exploration technique for groundwater in the basement complex of west-central part of Nigeria. *Water Resources*, **10**, 46-49.

Olorunfemi, M.O. and Fasuyi, S. A. 1993. Aquifer types and the geoelectric/hydrogeological characteristics of part of the Central Basement Terrain of Nigeria (Niger State). Journal of African Earth Sciences, 16(3), 309-317.

Olorunfemi, M.O. and Okhue, E.T. 1992. Hydrogeological and geological significance of geoelectric survey at Ile-Ife. *Nigerian Journal of Mining and Geology*, 28(2), 221-228.

Parasnis, D.S. 1988. *Principles of Applied Geophysics (4ed.),* Chapman and Hall, London.

Zohdy, A.A.R. (1989). A new method for the automatic interpretation of Schlumberger and Wenner sounding curves. *Geophysics*, 54(2), 245-253.