ISSN 2250-3153

Geophysical Investigation of the Subsurface Condition of the Permanent Site of Federal University Lokoja, Kogi State

[*] **Dr. M. O. Aku,** [**] **Mr. L. I. Gani**

[*]Department Of Physics, Bayero University Kano
[**]Department Of Physics, Federal University Lokoja

Abstract- A geophysical investigation of the subsurface condition of the Permanent Site of Federal University Lokoja, Kogi-state was carried out using electrical resistivity method with the aim of studying the subsurface geologic layers, with a view to determine the aquiferious zones, their depth and the thickness of the geologic layers. Vertical electrical sounding (VES) using Schlumberger array was conducted at twenty (20) VES stations along four profiles with the aid of ABEM SAS 300C terrameter and the field data obtained analyzed using computer software, IPI2win. The VES results revealed the heterogeneous nature of the subsurface geological sequence to contain four layers; topsoil (sandy and clayey laterite), weathered layer, partly weathered or fractured basement and fresh basement with two aquiferous zones (weathered basement and fractured basement). The resistivity value of the topsoil layer varies from 20Ωm to 250Ωm with thickness ranging from 1.0m to 3.0m, the weathered basement has resistivity value ranging from 25Ωm to 300Ωm and thickness between 2.0m to 41.5m, the partial/fractured basement has resistivity value of 100Ωm to 600Ωm with thickness of 5.0m to 50m across most part of the area. Lastly the fresh basement has resistivity of 900Ωm and above with infinite depth. However, the depth from the earth's surface to the aquiferious zone varies from 10m to 50m and the overburden in the area is low.

Index Terms- Geophysical Investigation, Subsurface, Electrical Resistivity, Aquiferous Zone and Basement.

I. INTRODUCTION

Geophysical surveys are generally identified by the property being measured—namely, electrical, gravity, magnetic, seismic, thermal, or radioactive properties. The electrical method is also subdivided into resistivity, induced polarization, and self polarization methods. Electrical resistivity methods of geophysical survey have been used for many decades in hydro geological, mining and geotechnical investigations following the accessibility and availability of its instrument and interpretation software. Vertical electrical sounding (VES) is an electrical resistivity method for measuring vertical changes of electrical resistivity (Todd, 2004 and Anomohanran, 2013). It detects the surface effects produced by the flow of electric current inside the earth.

A hydro geophysical investigation for groundwater in Lokoja metropolis, Kogi state, central Nigeria was carried out using vertical electrical sounding (VES) with two aquifer types delineated. An unconfined aquifer was found within the weathered basement and the second aquifer was found at the weathered/fractured basement. These aquifers are thin in some of the localities while in others they are appreciably thick, hence enormous groundwater storage and discharge capacity is observed (Omali, 2014). Other researcher, who conducted similar research using electrical resistivity method includes; (Emenike, 2001), (Obiora *et al*, 2005), (Anudu, 2011), (Ezomo, *et al*. 2011), and (Jatau *et al*, 2013).

The Felele community of Lokoja where the study area is situated is facing an increase in human population since the situation of the state polytechnic and the permanent site of Federal University Lokoja (study area) in the community. The area has no access to the township pipe-borne water as the residents of the area depend on untreated surface water, hand dug wells and private water supplies for their domestic activities. So to abate this problem of water scarcity and structural collapse in the permanent site of Federal University Lokoja (study area) which is a developing area, the need for a geophysical investigation of the subsurface condition arises. The study area is located at Felele - Lokoja, Kogi state, Nigeria, off Lokoja-Okene road. It is at the north western part of mount Patti, it lies between mount Patti and Agbaja plateau at latitude 07 ˚50' 05" N to latitude 07˚ 54' 04" N and longitude 06˚ 40' 22" E to longitude 06˚ 42' 02" E.

This study is aimed at using electrical resistivity method to study the subsurface geologic layers of the basement complex terrain of the study area in order to determine the aquiferious zones, identify their depth and to delineate the various lithologies within the study area for future exploration of groundwater and construction purpose.

II. GEOLOGY AND HYDROGEOLOGY OF THE STUDY AREA

The permanent site of Federal University Lokoja has almost the same geology as Lokoja in general. It is dominantly underlain by the Precambrian basement complex and part of the area is underlain by cretaceous sediments which uncomfortably over lay the basement complex. The study area is composed of the following; fieldspathic sand stone and siltstones, biotite hornblende gneiss and magmatite. The climatic data from the Nigeria metrological agency (NIMET, 2011) indicates that the study area falls within the tropical climate zone and is characterized by two distinct seasons; rainy season (April to October) and dry season (November to march). Mean annual temperature oscillates between 26ºc (July or august) to 35ºc in February or March while relative humidity ranges from 50- 63% (NIMET, 2011). The vegetation in the study area is classified as guinea savanna grassland characterized by shrubs with scattered orchard bush. The area is generally drained into river Niger due to the moderate sloping nature of the land.

III. ELECTRICAL RESISTIVITY THEORY

This method measures the subsurface resistivity by considering the flow of a continuous current through an isotropic homogenous media which forms an electric field E around the current source as in (figure 1). The current density J and electric field E are related through ohm's law.

$$J = \sigma E \quad (1.0)$$

where E is the electric field (V/m) and also the potential gradient, σ is the conductivity (is the reciprocal of resistivity ρ) and is measured in Siemens per meter (S/m). Considering the flow of current around electrodes which introduces current *I* at the surface of a uniform half-space (figure 1). Equation 1.0 gives

$$E = \rho J = -\nabla V = -\frac{dV}{dr}\hat{r} \quad (2.0)$$

J is the current density and is equal to current *I* divided by the surface area, which is $2\pi r^2$ for a hemisphere of radius *r* formed around each electrode. Therefore the potential at any point in the medium or on the boundary is given by

$$V = \frac{I\rho}{2\pi r} \quad (3.0)$$

r is the distance from the electrodes. For an electrode pair with current I at electrode A, and -I at electrode B (Figure 1), the potential at a point is given by the algebraic sum of the individual contributions (equation 4.0).

$$V = \frac{\rho I}{2\pi r_A} - \frac{\rho I}{2\pi r_B} = \frac{\rho I}{2\pi}\left[\frac{1}{r_A} - \frac{1}{r_B}\right] \quad (4.0)$$

r_A and r_B = distances from the point to electrodes *A* and *B*

In addition to current electrodes A and B, Figure 1 shows a pair of electrodes M and N, which carry no current, but between which the potential difference V may be measured. Following the previous equation, the potential difference *V* may be written.

$$\Delta V = V_m - V_n = \frac{\rho I}{2\pi}\left(\frac{1}{AM} - \frac{1}{BM} + \frac{1}{BN} - \frac{1}{AN}\right) \quad (5.0)$$

where V_m and V_n are potentials at M and N respectively. AM, BM, BN, AN, are distances between electrodes A and M, B and M, B and N, A and N respectively. Equation (5.0) can be written in terms of the resistivity ρ as

$$\rho = \frac{\Delta V}{I}\left[\frac{2\pi}{\frac{1}{AM} - \frac{1}{BM} + \frac{1}{BN} - \frac{1}{AN}}\right] = K\frac{\Delta V}{I} \quad (6.0)$$

where k is the geometric factor from the bracket in equation 6.0 above that is

$$K = \frac{2\pi}{\frac{1}{AM} - \frac{1}{BM} + \frac{1}{BN} - \frac{1}{AN}} = \pi\left(\frac{AB^2}{MN} - \frac{MN}{4}\right) \quad (7.0)$$

The resistivity in equation (6.0) above represents that of a homogeneous or uniform earth surface measurement. Whenever these measurements are taken over a real heterogeneous earth surface, equation 6.0 represents apparent resistivity of the earth with the symbol ρ_a which has no relation to the actual value of resistivity in a heterogeneous earth. The apparent resistivity may be greater, less or equal (in rare case) to the actual resistivity in a heterogeneous earth (Keller, 1966).

IV. METHODOLOGY

The use of ABEM SAS 300C terrameter was employed during the survey to carried out twenty (20) vertical electrical soundings (VES) along four profiles with five VES points on each profile using the Schlumberger electrode array (figure 1) at 20 VES points within the study area, with each VES point on a profile spaced 25m apart from each other. At each VES point a global positioning system (GPS) was used as a first step to measure the longitudes, latitudes and elevations. With the aid of the terrameter, 10amp current was sent into the ground at each $AB/2$ and $MN/2$ distance of the electrodes and the value of the resistance was displayed automatically on the terrameter and recorded. The maximum current electrode spacing (AB/2) is 100 meters. The resistivity data were analyzed using IPI2win and SURFER version 11 computer software.

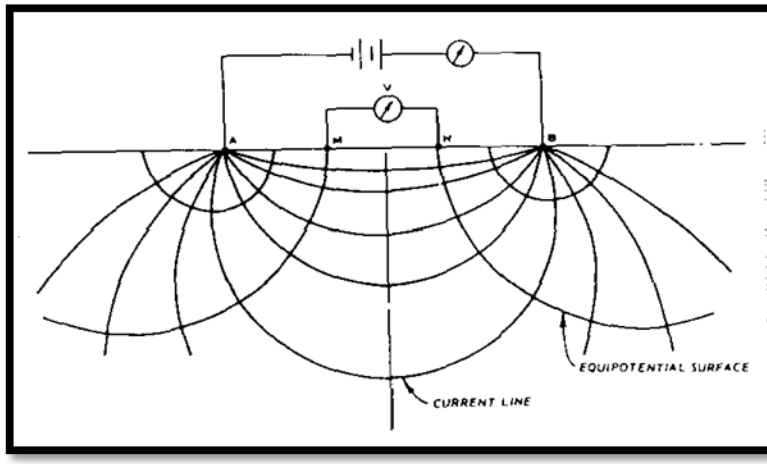

Figure 1: Potentials and Current Lines for Current Electrodes A and B on a Homogeneous Half-Space

V. RESULTS AND DISCUSSION

The data obtained from each VES point were recorded as in table I. using the equation 7.0, the geometric factors K in meters were calculated as a function of electrode spacing and multiplied by the resistance values R recorded to obtain the apparent resistivities ρ_a in (Ωm). Thus, putting the resistivity values and electrode spacing into IPI2win (computer programs) the sounding curves were obtained. Lastly the geologic sections for each profile figures (2, 3, 4, and 5) were obtained by putting the information from the sounding curves in SURFER V.11 software.

In Profile 1 (Figure 2), the first layer which is the top soil has resistivity values ranging from 50-240Ωm. It is evident that this layer does not consist of the same material across the entire length of the profile. The thickness of this layer ranges from 1.0m - 2.6m. This layer composed mostly of sandy/clayey soil with rich organic materials, hence the low resistivity within the layer. The second layer is the weathered basement which is composed mostly of loss gravel, sandy soil and clayey. The resistivity within this layer is about 100-240Ωm. And have an average thickness of 13.0m with wider depth at VES 2. The third layer is the partial weathered basement composed of mostly sand stone, gravel and sandy soil. This layer has a thickness of about 10-40m, at VES point 2 and 3, the layer extend beyond 50m. The resistivity value within this layer indicates that is it good for groundwater exploration. The last layer is the fresh basement (bedrock) with resistivity value of 1000Ωm and above. The layer is clearly seen at the first VES point and at a distance of 50-100m along the profile line.

In profile 2 (figure 3), the first layer has thickness of about 1-3m with resistivity value of about 20-150Ωm. This is the top soil. The low resistivity within this layer indicates the high concentration of organic material. The second layer which is the weathered basement has an average resistivity value of about 240Ωm and thickness of about 4.0m. The third layer is the partial weathered basement composed mostly of gravel and sand stone. It has an average resistivity value of about 300Ωm. This layer is generally seen occupying the entire section. And it serves as a good groundwater aquifer within the area. The last layer is visible at a depth of about 35.0m at 0-25m along the profile, it is the fresh basement.

In profile 3, (Figure 4) the top soil has an average resistivity value of about 80Ωm and thickness of about 1.5m. This layer is rich in organic compounds, hence the low resistivity. The second layer is the weathered basement. Weathering of the basement is high in this section hence the deepening of the layer at a distance of about 25-75m along the profile line. The third layer is the partial weathered basement; it starts from the beginning of the profile at a depth of about 10.0m to a distance of 75.0m along the profile. It has average resistivity value of about 270Ωm. It will serve as a good aquifer for groundwater as it extends beyond 50m across most of the profile line. The last layer is the fresh basement visible at a distance of 75-100m along the profile line and at a depth of about 25.0m.

In profile 4 (figure 5), the first layer is the top soil composed mostly of loss sandy soil/clayey soil and gravels. It has average resistivity value of about 150Ωm and thickness of about 1.7m. The second layer has a thickness of 2.0m from the surface, this is the weathered basement. The resistivity values ranges from 100-250Ωm. The third layer has a thickness of about 30.0m at a distance of 25-100m along the profile line. This layer extends beyond 50.0m as shown in the section at a distance of 0-25m. The fresh bedrock is evidence at a distance of about 25-100m along the profile.

Table I: Resistivity data for VES 1, Profile 1:

S/No	AB/2	MN/2	R (Ω)	ρ(Ωm)
1	1	0.5	169.0	398.84
2	3	0.5	17.4	478.15
3	5	0.5	3.6	276.68
4	8	0.5	0.73	146.13
5	10	0.5	0.45	143.46
6	15	0.5	0.24	166.55
7	20	0.5	0.11	141.84
8	20	5.0	0.87	102.80
9	25	5.0	1.08	203.47
10	30	5.0	0.84	231.34
11	40	5.0	0.46	225.52
12	50	5.0	4.17	3240.72
13	60	5.0	0.32	353.60
14	80	5.0	0.39	784.69
15	100	5.0	0.41	1312.37
16	100	10	0.71	1108.22

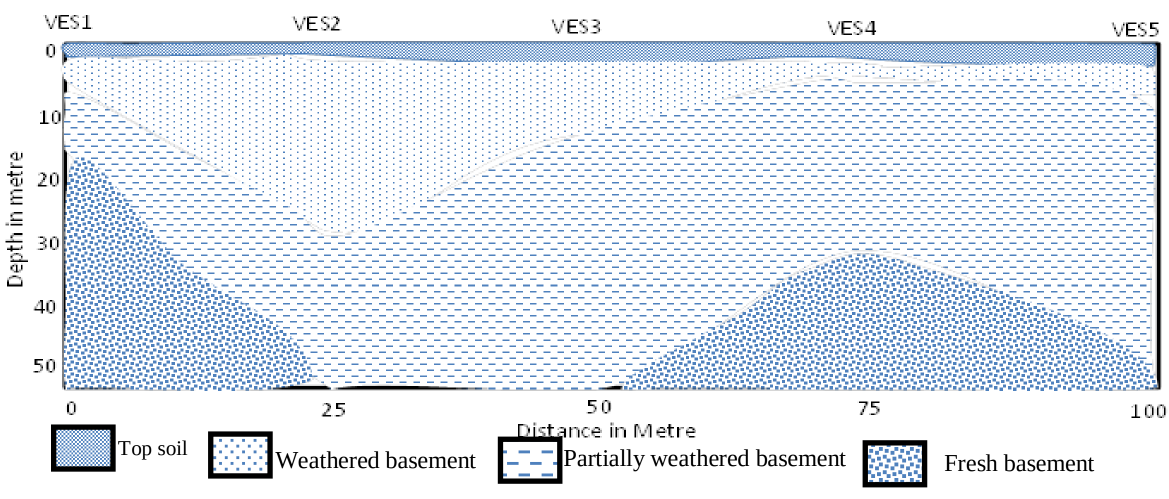

Figure 2: Geological section along profile 1

ISSN 2250-3153

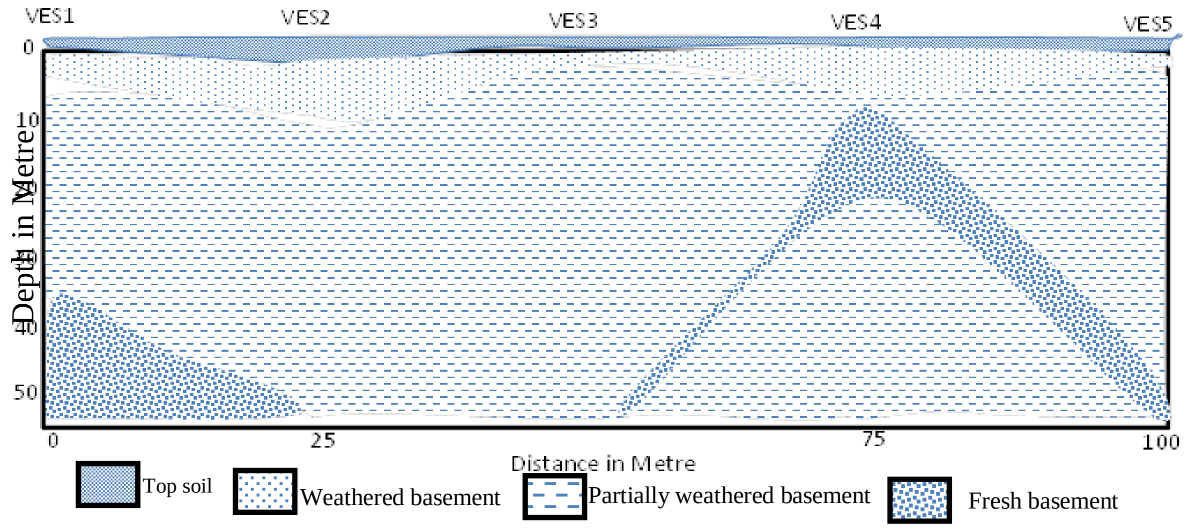

Figure 3: Geological section along profile 2

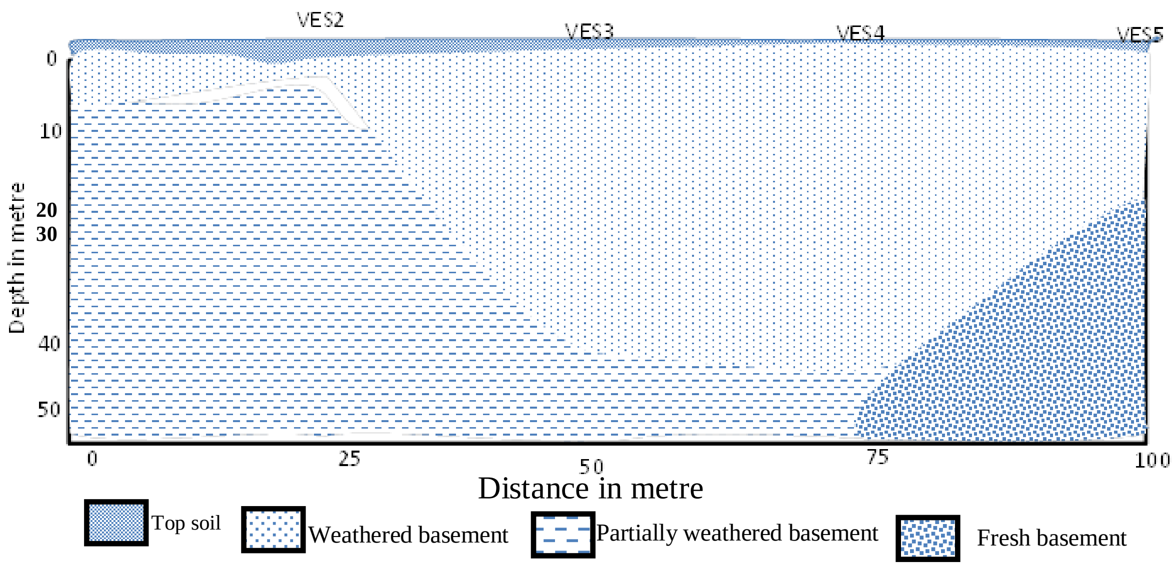

Figure 4: Geological section along profile 3

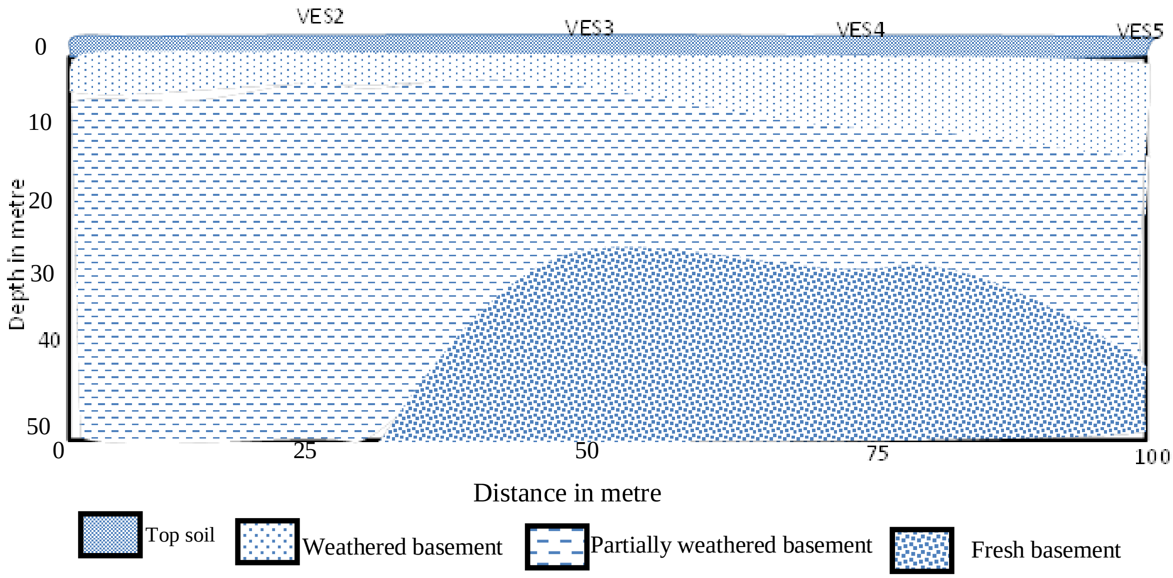

Figure 5: Geological section along profile 4

VI. CONCLUSION

The survey shows that there are four geologic layers in the study area. The layers sequence delineated are the topsoil, weathered basement, partially weathered/fractured basement and fresh basement. The topsoil has a resistivity value of 20-250Ωm and thickness of 1.0m to 3.0m; the weathered basement (second layer) is 2.0m to 41.5m thick with a wide domination at profile 3 (figure 4) and resistivity value between 25-300Ωm; the third layer (partially weathered/fractured basement) has resistivity value ranging from 100-600Ωm with thickness of 5.0m to 50m across most part of the area and the fourth layer is the fresh basement with resistivity of 900Ωm and above with infinite depth. It forms the bedrock of the study area but represents a small part of the area across the profiles. The study also delineates two aquifer types in the area, they are the weathered basement aquifer and partially weathered basement aquifer but most of the groundwater aquifers are located within the partially weathered basement at a good depth of about 40m. No major fractures within the area that will pose treat to groundwater due to contamination, so exploration of groundwater, structure construction of all kinds without serious excavation of the subsurface and further studies are recommended.

REFERENCES

[1] H. O. Aboh,“ A Regional Geophysical Investigation of the Groundwater Potentials at Iyara-Ijumu L.G.A, Kogi State using Electrical Resistivity and VLF (Unpublished Report submitted to Kogi State Government),” unpublished.

[2] O. Anomohanran, “Geoelectrical Investigation of Groundwater Condition in Oleh, Nigeria”, International Journal of Research Reviews in Applied Science, Vol. 15, No. 1, 2013, pp.102- 106.

[3] G. K. Anudu, L. N. Onuba, and L. S. Ufondu, “Geoelectric Sounding for Groundwater Exploration in the Crystalline Basement Terrain Around Onipe and Adjoining Areas, Southwerstern Nigeria,” Journal of Applied Technology in Environmental Sanitation, Vol 1, No 4, 2011, pp. 343-354.

[4] E. A. Emenike, “Geophysical Exploration for Groundwater in Sedimentary Environment, A case Study from Nnaka Formation in Anambra Basin, South Eastern Nigeria,” Global Journal of Pure and Applied Science, vol. 7,No 1, 2001, pp 1-12.

[5] F.O. Ezomo and C.N. Akujieze, “Geophysical Investigation of Groundwater in Oluku Village and its Environs of Edo State Nigeria,” Journal of Emerging Trends in Engineering and Applied Sciences (JETEAS), Vol 2, No. 4, 2011, pp. 610-614.

[6] B. S. Jatau, N. O. Patrick, A. Baba and S. I. Fadele, “The use of vertical electrical sounding (VES) for subsurface geophysical investigation around Bomo area, Kaduna state, Nigeria,” IOSR journal of engineering, vol. 3, No. 1, 2013, pp. 10- 15.

[7] G. V. Keller and F. C. Frischknecht, “Electrical methods in Geophysical Prospecting Pergamon press, New York, 1966, pp. 96 – 517.

[8] Nigeria Meteorological Agency, Temperature and Relative Humidity, Annual Records by Nigeria Meteorological Agency, Lokoja Station, Kogi State, Nigeria 2007.

[9] D. N. Obiora, and O.S. Onwuka, “Groundwater Exploration in Ikorodu, Lagos, A Surface Geophysical Survey Contribution,” The Pacific Journal of Science and Technology, Vol. 6, No 1, 2005, pp. 86-92.

[10] A. O. Omali, “Hydrogeophysical Investigation for Groundwater in Lokoja Metropolis, Kogi State, Central Nigeria,” Journal of Geography and Geology, vol. 6, No. 1, 2014, pp 81-95.

[11] D. K. Todd, Groundwater Hydrology, Second Edition, John Wiley & Sons Inc., New York (2004).

AUTHORS

First Author – Musa Ogah Aku, (Ph.D), Bayero University Kano, moaku.phy@buk.edu.ng
Second Author – Mr. Lukman Inuwa Gani, (M.Sc), Federal University Lokoja, ganilukman11@gmail.com

Correspondence Author – Mr. Lukman Inuwa Gani, ganilukman11@gmail.com, lukman.inuwa@fulokoja.edu.ng, +2347037775819 or 08117477748