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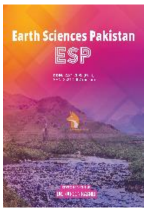


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*RESEARCH ARTICLE*

# ASSESSMENT OF GROUNDWATER POTENTIALS AT UDI LOCAL GOVERNMENT AREA, ENUGU STATE, NIGERIA

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**ABSTRACT**

A geophysical study comprising vertical electrical soundings was carried out in four (4) locations (Udi 1, Udi 2, Udi 3 and Udi 4) in Udi L.G.A. to assess groundwater potentials. The method involves the use of resistivity equipment (ABEM Terrameter), the field data were obtained utilizing Schlumberger configuration. The WINRESIST software was utilized in the data processing. According to the study's findings, the geological formations present in these locations contain five to seven layers. Layers 1 has resistivity values ranging from 158.1 – 418.1 Ωm at depths of 0.6 – 1.6 m, layer 2 has resistivity values ranging from 1103.9 – 41387.3 Ω m at depths of 0.8 – 8.9 m, layer 3 has resistivity values ranging from 313.0 – 4782.9 Ωm at depths of 6.9 – 28.2 m, layer 4 has resistivity values ranging from 1847.9 – 6956.8 Ωm at depths of 11.8 – 154.6 m, layer 5 has resistivity values ranging from 115.0 – 2838.4 Ωm at depths of 101.2 – 219.2 m, layer 6 has resistivity values ranging from 51.1 – 261.7 Ωm at a depth 190.6 m, and layer 7 have a resistivity value of 47.1 Ωm at an unknown depth. Layer 4 from all locations shows a prolific aquifer where enormous groundwater can be explored due to its high resistivity values, depth and thickness. The aquifer is estimated to be at the depths of 90.0 – 120.0 m. The results of this geophysical examination revealed that the studied region has good groundwater potential, which if properly utilized, will go a long way toward alleviating the effects of water insufficiency in Udi L.G.A.

**KEYWORDS**

Aquifer, Geophysical, Vertical Electrical Sounding, Resistivity, Electrode Spacing.

## 1. INTRODUCTION

"Groundwater is found in aquifers, which are permeable geologic formations with features that allow a significant amount of water to pass through them under normal field conditions. The word aquifer can be traced to its Latin origin. Aqui is a merging form of aqua, meaning water, and fer originates from ferre meaning to bear. Hence, an aquifer is a water bearer. A subsurface layer of water-bearing porous rock, rock fractions, or unconsolidated materials (silt, sand, or gravel) from which groundwater can be drawn by a well is known as an aquifer" (Abbey et al., 2022). Enugu State is in Nigeria's South-eastern region, having seventeen (17) L.G.A. with an area of approximately 556 km$^2$ (Wikipedia, 2004). It has a rapidly growing population. Because surface water can no longer be relied upon in all areas due to development, the demand for drinkable and sustainable groundwater has skyrocketed. The essential nature of water to life has made its unavailability a catastrophic one. Groundwater is a vital source of water for people all around the world. It is being used in irrigation, industry, governments, and rural residences. Groundwater shortages caused by the constant influx of people and companies in this area highlighted the significance of accurate estimations as well as effective supply development, control, and protection to assure the availability of this vital natural resource (Abbey et al., 2022). Due to these characteristics, different geophysical investigations have been conducted in Udi L.G.A. in order to identify the groundwater potential, and possibly drill such rocks in order to solve the needs of water shortages of the area's ever growing population and industry, which rely significantly on groundwater. Geoelectric techniques (vertical electrical sounding-VES) have a wide range of applications in earth sciences, such as subsurface geology, hydrogeology, and environmental research. Many researchers in Nigeria's South-eastern region have used this technique to investigate groundwater (Nwankwor et al., 1988; Chukwudi and Gabriel, 2010; Obiabunmo et al., 2014; Abbey and Digbani, 2020; Abbey and Onyebueke, 2020; Azi et al., 2020). The strategy (electrode configuration) to be used in this technique is determined by the nature of the underground surface and the mineral being investigated. Because of the solid knowledge of regional geology and the planned investigated depth, the Schlumberger configuration was used in this work. At four (4) locations in the Udi L.G.A., geoelectric experiments were conducted and fully explained. The purpose of this study is to obtain underground surface information of Udi L.G.A. using the electrical characteristics of rocks, as well as estimate groundwater potentials by evaluating the underlying geologic formations/layers.

## 2. MATERIALS AND METHODS

### 2.1 Geology and Hydrogeology of the Area

Our research area is the Udi L.G.A. in Enugu State of Nigeria (Figure 1). Udi L.G.A. is located within the coordinates (6°18'57.31" - 6°30'42.52" N, 7°21'19.26" - 7°26'23.0" E,) and covers an area of 897 km$^2$ with population of 370,002 at the 2015 census (Wikipedia, 2009). The terrain is undulating, and the elevation is around 310 m above sea level (ASL) (Abbey et al., 2021). The Enugu State, also known as the coal city, is naturally gifted with a significant reserve of coal on which the State's

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economy was based in the early twentieth century through coal mining. This mining operation, however, has been rendered obsolete as a result of enormous devastation caused by the Nigerian civil war, which has resulted in a decrease in coal production due to equipment damage (Wikipedia, 2004). Its average annual rainfall is roughly 2000 mm, which falls in sporadic bursts and can be rather heavy during the rainy season (Egboka, 1985). The Mamu, Ajali, and Nsukka formations are the three geological formations (Table 1) that make up the study area (Abbey et al., 2021). The Mamu formation, which dates from the Maastrichtian period, is made up of two parts: a sandstone interspersed with shale and a lower coal measure made up of shale, sandy shale, and coal (Reyment, 1965; Abbey et al., 2021). The Ajali formation lies directly on top of the Mamu formation. Many studies have referred to this formation as bedded sandstone (Groove, 1951; Simpson, 1955), and it is made up of red earth (laterite), friable white, and sandstone (Abbey et al., 2021). The Nsukka formation lies above the Ajali sandstone. Sandstone, dark shale and sandy shale make up the lithology of this formation, which was previously known as the upper coal measure (Reyment, 1965; Abbey et al., 2021).

The confine, semi-confined, unconfined, and perched aquifers are among the hydrological aquifer forms in this area. According to (Egboka and Onyebueke, 1990; Akudinobi and Egboka, 1996; Abbey et al., 2021), confine environments exist over the Ajali sandstone in parts overlain by the Nsukka formation, as well as in the Mamu formation, where the thickness of the overlying Ajali sandstone and the Nsukka formation is significantly reduced. Various substantial aquifers in this group can be found in the Ajali sandstone formation (upper-middle horizons) and the Mamu formation (upper horizons) in the semi confine zone (Abbey et al., 2021). In these locations, unconfined aquifers are generally found in the Ajali sandstone formation, whereas perched aquifers in the Nsukka formation are mostly found in the laterite and the higher sandy levels.

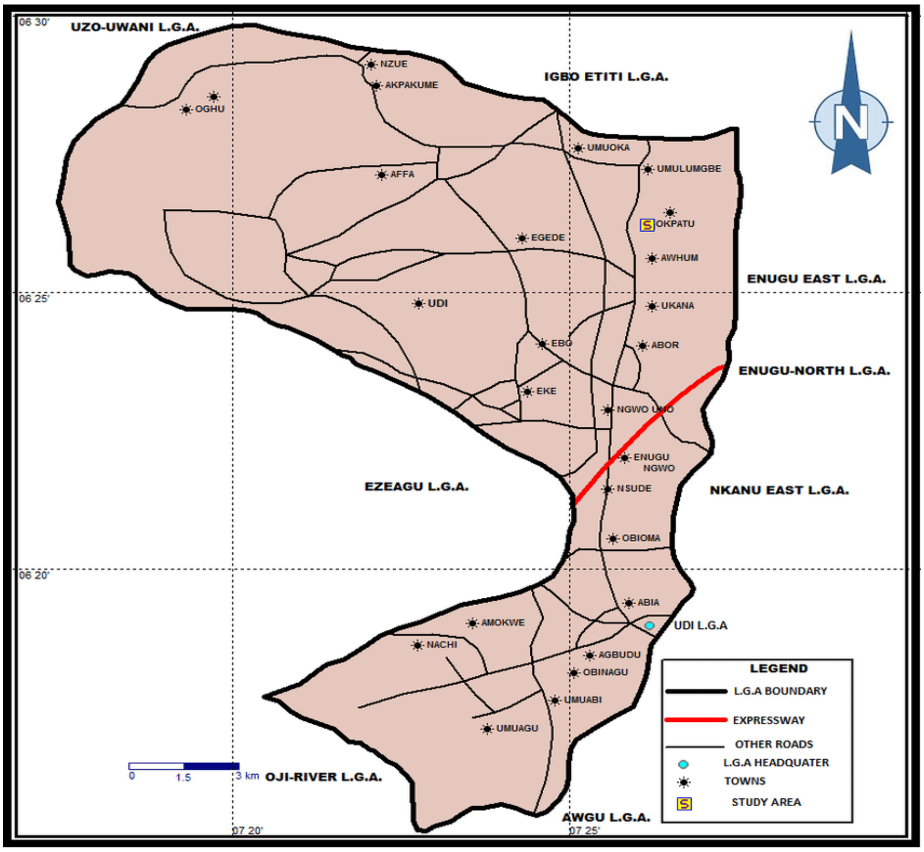


**Figure 1:** Map of Udi L.G.A. (Modified from Google map)

| **Table 1:** The Stratigraphic Units of Enugu State | | | |
|---|---|---|---|
| ***Epoch*** | ***Age*** | ***Formations*** | ***Net Sea Movement*** |
| ***Tertiary*** | Paleocene | Imo Shale | Transgression |
| ***Cretaceous*** | Danian | Nsukka Formation | Regression |
| ***Cretaceous*** | Maastrichtian | Ajali Formation Mamu Formation | Regression |
| ***Mid to Upper Senonian*** | Campanian | Nkporo Shale/Owellisst/ Enugu Shale | Transition to a new Basin/ Transgression |
| ***Mid to upper Senonian*** | Santonian Coniacian | Awgu Formation | Regression |
| | Turonian | Eze-Aku Shale | Regression |

Source: Modified from Reyment, 1965; Short and Stauble, 1967; Abbey et al., 2021

### 2.2 Theory of Electrical Resistivity Method

The theory of the electrical resistivity approach involves introducing an artificially generated electric current into the earth to investigate the variation of electrical characteristics of the earth material (rock) (Abbey et al., 2021). The apparent resistivity value is calculated by sending an artificially produced electrical current into the ground and multiplying the corresponding potential difference by a geometric factor (Telford et al., 1990). The electrical resistivity approach uses the earth's electrical resistivity/conductivity contrast to its advantage. This method determines the resistivity variations both horizontally and vertically at various locations on the surface of the earth (Abbey et al., 2021). The ground surface can then be used to measure the potential distribution, which will offer information on the shape and the electrical properties of such subsurface inhomogeneities. In this study, geophysical techniques involving vertical electrical sounding were used based on their ease and simplicity of interpretation. Above all, it has been known to work in resolving the majority of groundwater issues all over the world (Zohdy et al., 1973; Koefoed and Dirk, 1979; Abbey and Digbani 2020; Abbey et al., 2021). In each location, geoelectric soundings were conducted, using an electrode spacing (AB/2) of 350 m with approximately 117 m of probed depth. This process involves a current injection into the subsurface via two electrodes (A & B), while two pairs of potential electrodes (M & N) measure the reaction of the earth subsurface materials to the injected current.

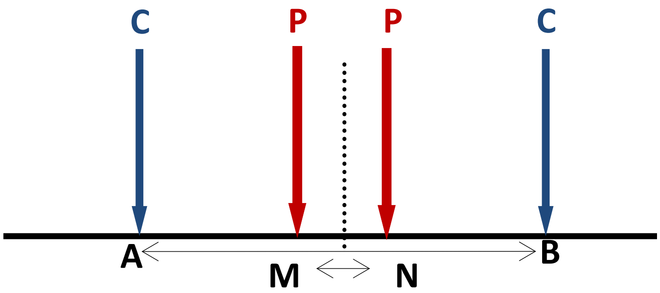


**Figure 2:** Schlumberger Configuration

Where current electrodes are A and B, while potential electrodes are M and N, according to the Schlumberger configuration (Figure 2).

The subsurface's apparent resistivity ($\rho_a$) was determined utilizing the formula:

$$\rho_a = \pi R \left[\frac{\left(\frac{AB}{2}\right)^2 - \left(\frac{MN}{2}\right)^2}{MN}\right]$$

$$K = \left[\frac{\left(\frac{AB}{2}\right)^2 - \left(\frac{MN}{2}\right)^2}{MN}\right]$$

$$\rho_a = \pi R K$$

Where: apparent resistivity is $\rho_a$ (Ohm-m), resistance is R (Ohm), distance between current electrodes is AB (meter), distance between potential electrodes is MN (meter), and geometric factor is K.

The data was collected using an ABEM Terrameter SAS 1000, which presented the results of the geologic material's resistivity. Apart from the Terrameter, two pairs of electrodes (current and potential), global positioning system (GPS), measuring tape, ream of cables, peg sticks, whistle, and hammer were employed in this study. The graph of apparent resistivity against electrode spacing was plotted using computer iterative software (WINRESIST) to generate the VES curves. During the course of this survey, certain measures were taken, they are:

1. Prior to the start of the survey, the battery was fully charged.
2. For adequate contact with the earth, the electrode (current and potential) was driven to a good depth.
3. The wire connections and joints were examined for appropriate contact regularly.
4. Tarred roadways and hidden metal pipes were avoided.

## 3. Result and Discussion

The results of this geophysical survey are presented both in figures and in a table as shown below.

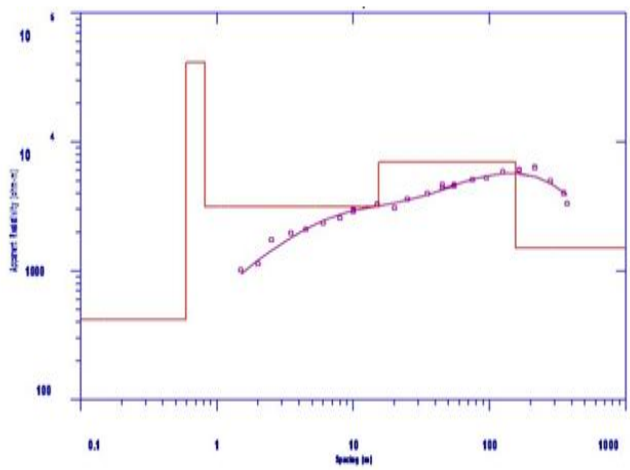

**Figure 3:** VES curve at UDI 1

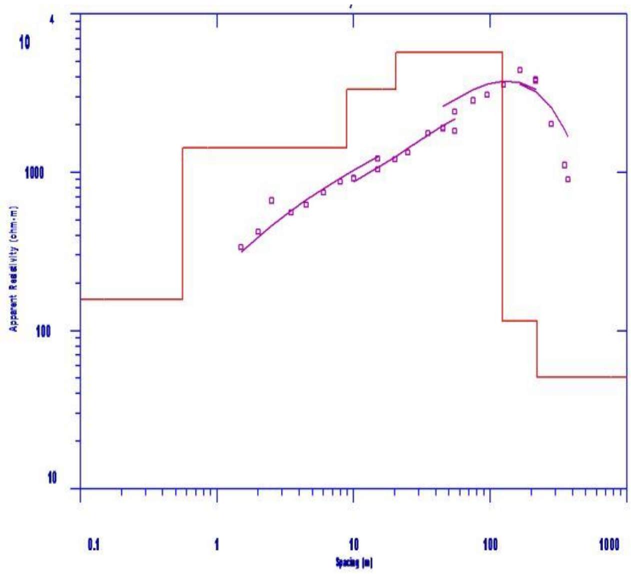

**Figure 4:** VES curve at UDI 2

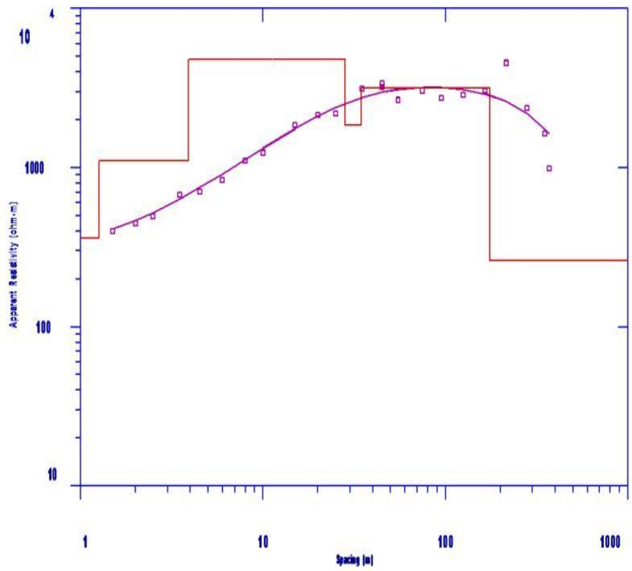

**Figure 5:** VES curve at UDI 3

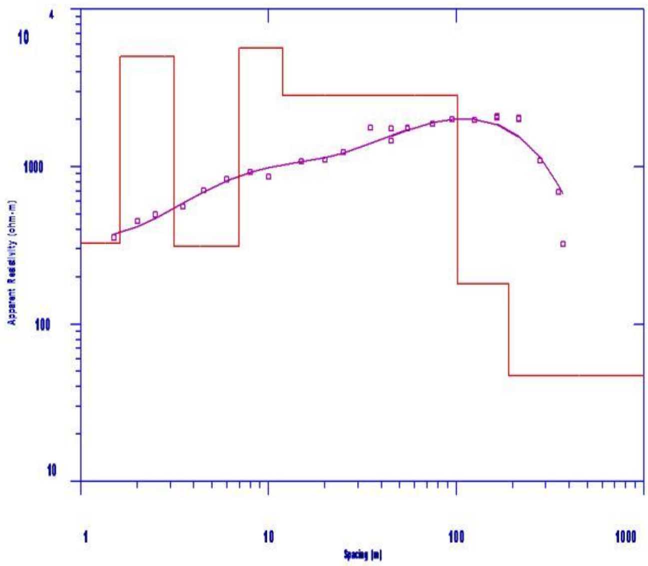

**Figure 6:** VES curve at UDI 4

**Table 2:** VES Interpreted Results

| VES LOCATION/ COORDINATE | RESISTIVITY (Ωm) | THICKNESS (m) | DEPTH (m) |
|---|---|---|---|
| UDI 1<br>6°27'26.1972″ N<br>7°21'38.3292″ E | 418.1<br>41387.3<br>3155.4<br>6956.8<br>1511.6 | 0.6<br>0.2<br>14.5<br>139.3 | 0.6<br>0.8<br>15.3<br>154.6 |
| UDI 2<br>6°38'17.9988″ N<br>7°15'43.8372″ E | 158.1<br>1432.5<br>3329.4<br>5729.7<br>115.0<br>51.1 | 0.6<br>8.3<br>11.4<br>101.8<br>97.1 | 0.6<br>8.9<br>20.3<br>122.2<br>219.2 |
| UDI 3<br>6°26'24.2448″ N<br>7°25'35.0868″ E | 358.6<br>1103.9<br>4782.9<br>1847.9<br>3166.8<br>261.7 | 1.3<br>2.7<br>24.2<br>6.6<br>140.5 | 1.3<br>3.9<br>28.2<br>34.8<br>175.3 |
| UDI 4<br>6°38'32.6076″ N<br>7°9'57.2112″ E | 326.6<br>4990.5<br>313.0<br>5669.9<br>2838.4<br>180.9<br>47.1 | 1.6<br>1.5<br>3.8<br>4.9<br>89.4<br>89.4 | 1.6<br>3.1<br>6.9<br>11.8<br>101.2<br>190.6 |

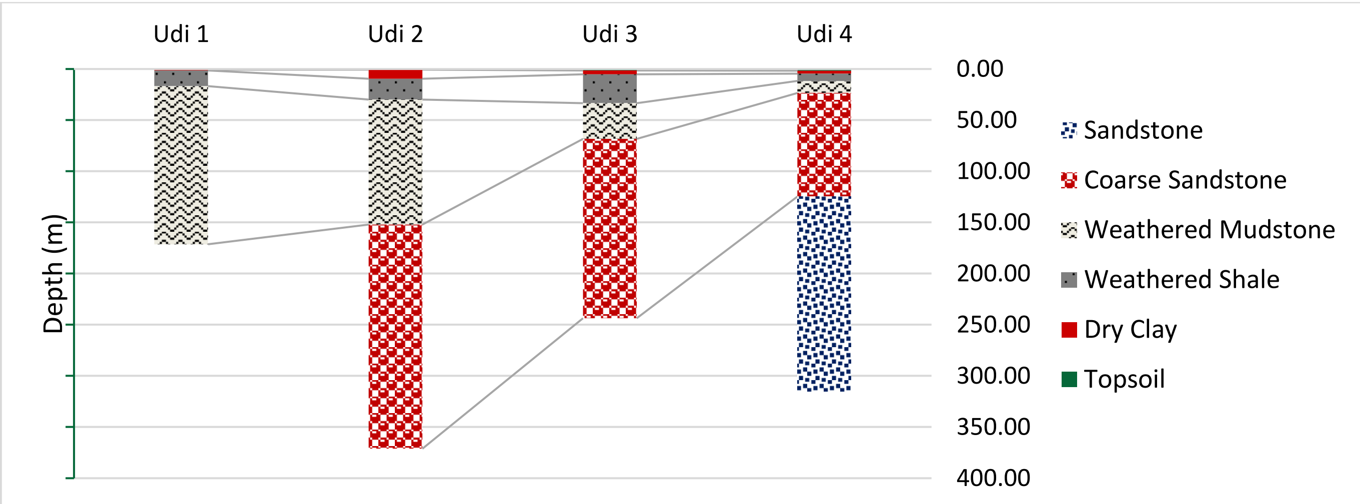


**Figure 7:** Interpreted Lithology with depth

At Udi L.G.A., the study location/town was picked at random. Table 2 presents a numerical overview of VES data indicating subsurface layers, their related resistivity and depth as determined by field research for the four locations, whereas Fig 3 – 6 displays the VES curve plotting apparent resistivity ($\rho_a$) versus electrode spacing (AB/2). From VES 1 - 4, KHK, AAKQ, AKHK, and KHKQQ were the interpreted curve types for the four locations (Udi 1 – 4) respectively.

At Udi 1, five (5) subsurface layers were outlined with apparent resistivity values ranging from 418.1- 41387.3 Ωm. This location shows highly variable aquifer thickness (0.6 – 139.3 m) with depth (0.6 – 154.6 m). A potential aquifer can be located at the 4th layer due to its high resistivity value, depth and thickness. Although the 3rd layer can also produce groundwater it will be irregular due to depth and the water table rise and fall.

At Udi 2 which serves as the second location, from the VES curve six (6) subsurface layers were observed, having apparent resistivity values ranging from 51.1 – 5729.7 Ωm, thickness ranging from 0.6 – 101.8 m and a depth ranging from 0.6 - 219.2 m. This location shows two potential aquifers at the 3rd and 4th layers. The 3rd layer aquifer is shallow in nature and it is encouraged for hand-dug well for domestic uses while the 4th layer aquifer is deep and is encouraged for commercial production.

At Udi 3 which serves as the third location, six (6) subsurface layers were outlined, having apparent resistivity values ranging from 261.7 – 4782.9 Ωm, thickness ranging from 1.3 – 140.5 m and a depth ranging from 1.3 - 175.3 m. This location shows three potential aquifers in the 3rd, 4th and 5th layers. The 3rd and 4th layers aquifers are shallow with the 4th layer having the smallest thickness. The 5th layer aquifer is deep with very high resistivity value, thickness and appreciable depth. In this aquifer enormous amount of groundwater can be extracted via a well and it is highly prolific in nature.

Udi 4 is the fourth location comprising seven (7) subsurface layers with apparent resistivity ranging from 47.1 to 5669.9 m, thickness ranging from 1.6 – 89.4 m and a depth ranging from 1.6 – 190.6 m. This location's aquifer is identified at the 5th layer with high yielding capacity.

The lithologies are distributed according to the thickness and depth of the individual layer in the interpreted lithology (Figure 7) for the four municipals. It also shows that the first aquifer unit in the three locations (Udi 1, Udi 2, and Udi 3) is randomly distributed as shown in figure 6 with their lithologies as coarse Sandstone with appreciable thickness. Also at Udi 4, the lithology of the second aquifer unit is sandstone with noticeable thickness. The four locations show consistency in their lithologies, with a decreasing thickness from Udi 1 to Udi 4 as seen in their fourth and fifth strata.

## 4. Conclusion and Recommendations

Over time, the vertical electrical sounding (VES) approach has proven to be a viable method of evaluating groundwater resources. The aquifer in this study location appears prolific, and all VES points hold some favorable hydrogeological parameters for water borehole siting. Upon the qualitative analysis of VES data gathered in several selected locations in Udi L.G.A. The depth of the groundwater in the studied area varies between 90 and 120 meters, according to the findings of this study. This knowledge will be useful in developing an operational water system in Udi L.G.A. as well as in other nearby locations influenced by the same formation. This study, therefore, recommends as follows:

i. Hand-dug wells should be avoided, since they will result in irregular water supply, especially during the dry season.

ii. For a high yielding aquifer, a commercial borehole should be drilled to an average depth of 105 m.

## References


Abbey, M.E., Digbani, T., 2020. Determination of Ground Water Potential Using Electrical Resistivity Method. International Journal of Science and Research, 9(4), Pp. 878-882. https//:doi: 10.21275/SR20407204907. (IJSR) ISSN: 2319-7064.

Abbey, M.E., Onyebueke, D.E., 2020. Geoelectric evaluation of groundwater potential: a case study at Omuma local government area, Rivers State, Nigeria. Journal of Petroleum Exploration and Production Technology, https://doi.org/10.1007/s13202-020-01001-4.

Abbey, M.E., Onyebueke, D.E., Ashaka, G.O., Ezeife, C.K., 2021. Evaluation of Groundwater in Udi L.G.A. in Enugu State, Nigeria. PREPRINT (Version 1) available at Research Square [https://doi.org/10.21203/rs.3.rs-1072998/v1]

Abbey, M.E., Tamunoberetonari, I., Horsfall, O.I., 2022. Aquifer Delineation using Seismic Refraction Method in Rumuohia Community, Emohua L.G.A, Rivers State, Nigeria. Earth Sciences Pakistan (ESP), 6(1), Pp. 17-21.

Akudinobi, B.E.B., Egboka, B.C.E., 1996. Aspects of hydrogeological studies of the escarpment regions of southeastern Nigeria. Water Resources J. NAH, 7(1-2), Pp. 12-25.

Azi, A.O., Onyebueke, D.E., Abbey, M.E., Ahige, U.U., 2020. Assessment of Groundwater Potentials at Ishielu L. G. A. of Ebonyi State, Nigeria. Asian Journal of Geological Research, 3(4), Pp. 45-53.

Chukwudi, C.E., Gabriel, Z.U., 2010. Geoelectrical sounding for estimating groundwater potential in Nsukka L.G.A. Enugu State, Nigeria. International Journal of the Physical Sciences, 5(5), Pp. 415-420.

Egboka, B.C.E., 1985. Water resources problems in the Enugu area of Anambra State, Nigeria. Water Resources and Environmental Pollution Unit (WREPU), Department of Geological Anambra State University of Technology, Pp. 98.

Egboka, B.C.E., Onyebueke, F.O., 1990. Acute hydrogeological problems Vis-à-Vis- planning and management of a developing economy: A case study of Enugu area, Nigeria. Water Resources J. NAH, 2(1), Pp. 43-55.

Eze, C.C., Ugwu, G.Z., Okonkwo, A., Okanpka, J. 2013. Using the relationships between geoelectrical and hydrogeological parameters to assess aquifer productivity in Udi L.G.A, Enugu State, Nigeria. International Research Journal of Geology and Mining, 3(1), Pp. 9-18.

Groove, A.T., 1951. Land use and Soil Conservation in parts of Onitsha and Owerri Provinces. Geological Survey of Nigeria, Bulletin, Pp. 21.

Koefoed, O., Dirks, F.J.H., 1979. Determination of Resistivity Sounding Filters by the Wiener Hopf. Least square method. Geophys. Prospect, 27, Pp. 245 – 250.

Nwankwor, G.I., Egboka, B.C.E., Orajaka, I.P., 1988. Groundwater occurrence and flow pattern in the Enugu coal-mine area, Anambra State, Nigeria. Hydrological Sciences Journal, 33(5), Pp. 465-482,

Obiabunmo, O.C., Umego, M.N., Obiekezie, T.N., Chinwuko, A.I. 2014. Application of Electrical Resistivity Method for GroundwaterExploration in Oba and Environs, Anambra State, Nigeria. Advances in Physics Theories and Applications, Pp. 37.

Reyment, R.A., 1965. Aspects of Geology of Nigeria, Ibadan University Press, Ibadan, Pp. 145.

Short, K.C., Stauble, A.J., 1967. Outline Geology of the Niger Delta. AAPG Bull 51, Pp. 761-779.

Simpson, A., 1955. The Nigerian Coalfield: The Geology of parts of Onitsha Owerri and Benue provinces. Bull. GSN v.24, Pp. 85.

Telford, W.M., Geldart, L.P., Sheriff, R.E., 1990. Resistivity Methods. In: Applied Geophysics, 2nd Edition, Cambridge Univ. Press, Cambridge, UK, 353-358.

Wikipedia (2004). Enugu, In Wikipedia, the free encyclopedia. Retrieved 03:45, June 10, 2021, from https://en.wikipedia.org/w/index.php?title=Enugu&oldid=1026311866.

Wikipedia (2009) Udi, Enugu, In Wikipedia, the free encyclopedia. Retrieved from 03:25, June 10, 2021, from https://en.Wikipedia.org/w/index.php?title=Udi,_Enugu&oldid=102544 7644.

Zohdy, A.A.R., Anderson, L.A., Mufller, L.P.J., 1973. Resistivity, self-potential, and induced polarization surveys of a vapor-dominated geothermal system. Geophysics, 38, Pp. 1130-1144.