Evaluation of Groundwater in Udi L.G.A. in Enugu State, Nigeria

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Abstract

Groundwater has remained indispensable in Enugu state Nigeria owing to industrialization, lack of surface water, and significant depth to aquifer in the area. A geophysical investigation involving vertical electrical soundings was conducted in order to evaluate groundwater potential at some locations in the Udi Local Government Area of Enugu State. With the aid of resistivity instrument ABEM Terrameter, four (4) Vertical Electrical Sounding using Schlumberger configuration were conducted, and the data acquired was interpreted using WINRESIST software. Information obtain from the survey shows that the underlying geological formation in those areas has between 5 – 7 layers. The apparent resistivity obtained in all the layers of the locations ranges from 47.1 – 6956.8 Ωm, while the aquifer was interpreted to exist at a depth between 90 – 120m. Result obtained from this geophysical investigation has shown that the survey area possesses a good groundwater potential which will go a long way in cushioning the effect associated with water scarcity in the area if exploited.

1.0 Introduction

Water is essential to life and its unavailability will be catastrophic. Enugu state with an ever-increasing population is located in the South-Eastern part of Nigeria, with seventeen (17) local government areas and a total area of about 556 km$^2$ [1]. Due to urbanization, surface water cannot be overly dependable in all the areas, hence the need for potable and sustainable groundwater supply in this area has become intense. These have compelled the conduct of some geophysical studies in the area to ascertain the aquifer potential and possibly drilling of such formations in a way to meet the water needs of these ever-growing populations and industries in the area since almost all depends majorly on groundwater.

Geoelectric techniques have found a wide application in areas of earth sciences, addressing sub-surface geology, hydrogeology, and environmental issues among others. Details of groundwater investigations using geoelectric techniques such as vertical electrical sounding (VES) have been carried out by many researchers in the South-Eastern part of Nigeria [2–4]. In this technique, the method to be used (electrode configuration) is determined by the nature of the subsurface and the mineral been investigated. However, due to the good knowledge of the area geology and the targeted probed depth in this study, the Schlumberger configuration was used. Geoelectric investigations covering four (4) stations at Udi L.G.A were carried out and interpreted fully. This study is aimed at using the electrical properties of the rocks to obtain the subsurface information in the area and also to evaluate the subsurface geologic layer with a view of determining the groundwater potentials.

2.0 Geology And Hydrogeology Of The Area

The Udi Local Government Area of Enugu state in Nigeria is our study area. It is enclosed by the coordinate (6° 19’ 0”N, 7° 26’ 23.0’E), with an expanse area of 897 km$^2$ [5] as shown in Fig. 1. The area has an undulating topography (Fig. 2) and is about 310 meters above sea level (ASL). Enugu state which is nicknamed the coal city is richly blessed with a large deposit of coal from which the economy of the state is depended on in the early 20th century through the mining of this solid mineral. However, this mining
facility has gone moribund as a result of widespread devastation that forced a decline in coal production from the damage of equipment’s which was brought about by the Nigerian civil war [1]. The average annual precipitation in Enugu is around 2000 millimeters, which arrives erratically and becomes very heavy during the rainy season [6]. Stratigraphically, the study area consists of three geological formations: The Mamu, Ajali, and Nsukka formations (Table 1). The Mamu formation which is of Maastrichtian in age is comprised of two members namely: the sandstone which is interpolated with shale and the lower coal measure which consists of shale, sandy shale, and coal [7]. Conformably overlying the Mamu formation is the Ajali formation. This formation has been described by many researchers as bedded sandstone [8–9], and consists of red earth (laterite), friable white, and sandstone. Above the Ajali sandstone is the Nsukka formation. The lithology in this formation consists of sandstone, dark shale, and sandy shale and is previously known as the upper coal measure [8].

Hydrologically, the aquifer formations in this area include the confine, semi confine, unconfined, and perched aquifer. According to [10–11], the confine conditions exist over the Ajali sandstone in areas overlain by Nsukka formation and also in Mamu formation where overlying Ajali sandstone and Nsukka formation are considerably reduced in thickness. In the semi confine region, various aquifers in this group occur in the upper to middle horizons of Ajali sandstone and the upper section of the Mamu formation. Unconfined aquifer in these areas occurs mostly in the Ajali sandstone while the perched aquifer condition occurs mostly in the laterite over the Nsukka formation and in the upper sandy units of the formation.

Table 1
The Stratigraphic Units of Enugu state.
Modified from [7], [13]

| Epoch     | Age            | Formations             | Net sea Movement            |
|-----------|----------------|------------------------|----------------------------|
| Tertiary  | Paleocene      | Imo Shale              | Transgression              |
| Cretaceous| Danian         | Nsukka Formation       | Regression                 |
| Cretaceous| Maastrichtian  | Ajali Formation        | Regression                 |
|           |                | Mamu Formation         |                           |
| Mid to Upper Senonian | Campanian | Nkporo Shale/Owellisst/ | Transition to a new Basin/ Transgression |
|           |                | Enugu Shale            |                           |
| Mid to upper Senonian | Santonian | Awgu Formation         | Regression                 |
|           | Coniacian      |                        |                           |
| Turonian  |                | Eze-Aku Shale          | Regression                 |
3.0 Theory Of Electrical Resistivity Method

The theory of electrical resistivity method involves investigating the variation of electrical properties of the earth material (rock) by injecting an artificially generated electric current into the earth. This artificially generated electrical current is inputted into the ground and the resulting potential difference is then converted into apparent resistivity value by multiplying with appropriate geometric factor [14]. The electrical resistivity method capitalizes on the contrast in the electrical resistivity/conductivity of the earth. This method measures both lateral and vertical variation in ground resistivity from different points on the earth’s surface. The potential distribution so generated can then be measured from the ground surface and these will provide information on the form and electrical properties of such subsurface inhomogeneities.

From the Schlumberger configuration (Fig. 3), A & B are current electrodes, while M & N are potential electrodes. Where \( \Delta V \), is the measured potential difference and \( K \) is the geometric factor.

The apparent resistivity (\( \rho_a \)) of the subsurface was calculated using the formula:

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

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

is the geometric factor

Where: \( \rho_a \) = apparent resistivity (Ohm-m), \( R \) = resistance (Ohm), \( AB \) = distance between current electrodes, \( MN \) = distance between potential electrodes.

4.0 Material And Method

A geophysical technique using vertical electrical sounding was carried out in this survey using Schlumberger configuration. This technique was employed due to its simplicity and ease of interpretation. Above all, it has been tested and proven in solving most groundwater problems around the world [15-17]. A total of four (4) geoelectric soundings were carried out with electrode spacing \( AB/2 = 350 \text{m} \) and an approximate probed depth of about \( 117 \text{m} \). The procedure involves injecting current via a pair of electrodes (A & B) into the subsurface, while the response of the subsurface earth materials to the introduced current is measured by two pairs of potential electrodes (M & N). ABEM Terrameter SAS 1000
was used in the data acquisition, and it displayed the results of resistivity of the geologic material. Other accessories used in this survey other than Terrameter include two pairs of electrodes (Current and potential), Measuring tape, Peg sticks, Global positioning system (GPS), Ream of cables, Hammer, whistle. The VES curves were obtained by plotting the calculated apparent resistivity values against electrode spacing via a computer iterative software WINRESIST. Certain precautions were taking in the course of this survey and they include:

1. The battery was charged to a full capacity before the commencement of the survey
2. The electrode was hammered to a good depth for proper contact with the earth
3. The cable connections and joints were constantly checked for proper contact.
4. Avoid tarred roads, buried metal pipes.

5.0 Result And Discussion

The study location/Town was chosen randomly at Udi L.G.A. The numerical summary of geoelectric sounding data showing the subsurface layers and their corresponding resistivity and depth as obtained from the field investigation for the four stations are presented in Table 2, while the VES curve shows the apparent resistivity plotted against electrode spacing AB/2 is also presented in Fig. 4 – 7. The following sounding curve types were interpreted: KHK, AAKQ, AKHK, and KHKQQ for VES 1 - 4 respectively.

At Eke town, five (5) subsurface layers were delineated with apparent resistivity values ranging from 418.1- 6956.8 Ωm. This study area shows highly variable aquifer thickness with depth to the potential aquifer averaging 85 m.

At Udi town, the interpreted sounding curve revealed six (6) subsurface layers, with apparent resistivity and thickness ranging from 51.1 – 5729.7 Ωm and 0.6 – 101.8 m. This study area shows the potential aquifer at an average depth of 120 m.

Six (6) subsurface layers were delineated at the third location (Enugu Ngwo). The location geology reveals a formation with a high aquifer potential at the average depth of 105 m, with the resistivity of the location ranging from 261.7 – 4782.9 Ωm.

At Akpatu town, the geology of the formations followed the same sequence as the other locations. A total of seven (7) subsurface layers were delineated, with apparent resistivity ranging from 47.1 – 5669.9 Ωm. While the average depth of aquifer in this area is 89 m.

The interpreted lithology (Fig. 8) for the four towns shows the distribution of the lithologies with respect to the depth and thickness of each layer. It further, shows that the first aquifer in the three towns (Udi, Enugu Ngwo and Akpatu) is randomly distributed in terms of its depths and thickness, and its lithologies as shown in Fig. 8 is coarse Sandstone at very appreciable thickness; while in Akpatu town the lithology of the second aquifer unit was observed to be sandstone with appreciable thickness. The four towns
depict uniform trends in the fourth and fifth layers of their lithologies with a decreasing thickness from Eke to Akpatu town.
| VES LOCATION/COORDINATE | RESISTIVITY (Ωm) | THICKNESS (m) | DEPTH (m) | CURVE | REMARK |
|-------------------------|------------------|---------------|-----------|-------|--------|
| EKE TOWN 6° 27' 26.1972¹N 7° 21' 38.3292¹E | 418.1 41387.3 3155.4 6956.8 1511.6 | 0.6 0.2 14.5 139.3 1511.6 | 0.6 0.8 14.5 15.3 15.46 | KHK | Topsoil, with an alternating sequence of Sandstone and shale – |
| UDI TOWN 6° 38' 17.9988¹N 7° 15' 43.8372¹E | 158.1 1432.5 3329.4 5729.7 115.0 511 | 0.6 8.3 11.4 101.8 97.1 51.1 | 0.6 8.9 20.3 122.2 219.2 | AAKQ | Topsoil, with an alternating sequence of Sandstone and Shale |
| ENUGU NGWO TOWN 6° 26' 24.2448¹N 7° 25' 35.0868¹E | 358.6 1103.9 4782.9 1847.9 3166.8 261.7 | 1.3 2.7 24.2 6.6 140.5 261.7 | 1.3 3.9 28.2 34.8 175.3 | AKHK | Topsoil with an alternating sequence of sandstone and shale |
| AKPATU TOWN 6° 38' 32.6076¹N 7° 9' 57.2112¹E | 326.6 4990.5 313.0 5669.9 2838.4 180.9 47.1 | 1.6 1.5 3.8 4.9 89.4 89.4 47.1 | 1.6 3.1 6.9 11.8 101.2 190.6 | KHKQQ | Topsoil with an alternating sequence of Sandstone and Shale |

**6.0 Conclusion**
The vertical electrical sounding (VES) technique over the years has been proved a useful method in the evaluation of groundwater resources. Based on the qualitative interpretation and VES data obtained in some selected towns in Udi L.G.A, the aquifer in these areas seems prolific and all the VES points hold some good hydrogeological parameters for water borehole siting. This research has provided information on the depth of the groundwater which is at a varying depth of 90 – 120 m in the study area. This information is going to be relevant to the development of an effective water scheme in the area and possibly other areas underlain by the same formation. Also due to the absence of a shallow aquifer in the area, hand-dug well is discouraged as it will continue to experience intermittent availability of water, especially during the dry season.

Declarations

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

Figure 2
Surface Map of Udi L.G.A. [12]

Figure 3
Schlumberger Configuration

Figure 4
VES curve at EKE TOWN

Figure 5
VES curve at UDI TOWN

Figure 6
VES curve at ENUGU NGWO TOWN
Figure 7

VES curve at AKPATU TOWN

Figure 8

Interpreted Lithology with depth