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Evaluation of Groundwater potential status in Nkanu-west Local Government Area, Enugu State, Nigeria.

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Abstract: *The Evaluation of the groundwater potential status in Nkanu-west Local government area of Enugu State has been undertaken. The project area lies within latitudes 06^0 25^I 00^{II}N to 06^0 38^I 00^{II}N and Longitudes 007^0 13^I 00^{II}E to 007^0 24^I 00^{II}E with an area extent of about 489.4sqkm, over two main geological formations. A total of Seventy-Eight Vertical Electrical Sounding (VES) were acquired, employing the Schlumberger configuration. Resistivity and thickness of aquiferous layers were obtained from the interpreted VES data. Contour variation maps of Apparent resistivity, depth, traverse resistance, Longitudinal conductance, Electrical conductivity, aquifer transmissivity and hydraulic conductivity were constructed. Computed aquifer transmissivity from VES data, indicates medium to low yield aquifer. The latter was used to evaluate the groundwater potential status. Two groundwater potential were mapped; the moderate and low potential zones. The various contour maps and groundwater potential zone map will serve as a useful guide for groundwater exploration in the study area.*

Keywords*: Aquifer yield, Contour maps, Groundwater potential status, Resistivity, Transmissivity, Transverse resistance.*

I. Introduction

Knowledge of groundwater potential status in regions is key useful guide to a successful groundwater exploration and abstraction. Groundwater potential is a function of complex inter-relationship between, geology, physiography, groundwater flow pattern, recharge and discharge processes (Ezeh, 2012). However, the use of relationships and comparisons between aquifer properties, hydrogeological and geophysical parameters (Ezeh, et al, 2013), has also proved useful for groundwater potential modeling. Amadi, et al, (2011) and Abiola, et al, 2009 used resistivity data and overburden thickness to evaluation the groundwater potential in a basement complex terrain. Ezeh and Ugwu (2010) utilized transmissivity inferred from resistivity information to study groundwater potential in a sedimentary aquifer. Oseji and Ujuanbi (2009) also utilized resistivity information and local geology to evaluate the groundwater potential in a deltaic plain deposit. Okonkwo and Ujam (2013) evaluated the groundwater potential in a low permeability aquifer based on aquifer geoelectrical parameters. In the present study, attempts has been made to use the interplay between computed aquifer resistivity and thickness, overburden depth and aquifer transmissivity from geoelectrics to model the groundwater potential status in the study area.

II. Location and Physiography

The study area is located in Nkanu-west local government area, southeast of Enugu state, Nigeria (Fig. 1). The area lies within latitudes 06^0 25^I 00^{II}N to 06^0 38^I 00^{II}N and longitudes 007^0 13^I 00^{II}E to 007^0 24^I 00^{II}E with an area extent of about 489.4sqkm. The project domain is bordered to the north by Enugu-south LGA, while to the northwest and west by Udi LGA. To the southwest, it is bordered by Awgu LGA and to the North-East, East and South, by Nkanu-East LGA (Fig.1). The topography in the study area is undulating (Fig.2). Akagbe-Ugwu and Akpugo is about 240meters (800ft) above sea level (ASL) while Obeagu and Agbani are about 150meters (500ft) ASL.

3. Local Geology

The study area falls within the geologic complex (Fig.3a) known as the Lower Benue Trough (Obaje, 2009). Locally, it is underlain by the Awgu Shale units, which is coniacian in age and the Agbani Sandstone unit (Fig.3b). The Agbani Sandstone unit is a lateral equivalent of Awgu Shale units. The sandstone is laterally not extensive, as it outcrops only within the country around Agbani. It consist of medium to coarse grained, white to reddish brown, moderately consolidated at depth and highly consolidated at outcrop areas. Thickness variation and lateral gradation is predominant in areas (towns) far from Agbani town center. The Awgu Shale unit consists of bluish grey, well bedded shales with occasional intercalations of fine-grained, pale yellow, calcareous sandstones and shaly limestones (Reyment, 1965). It is about 900meters thick and gently folded.

4. Hydrogeology

The study area falls within the Cross River Basin, which had been described as a problematic groundwater basin (Offordile, 2002). This is as a result of poor yield and saliferous groundwater. More than 90% of the basin is underlain by cretaceous rocks of the Asu River, Ezeaku, Awgu, Nkporo and Mamu Formations, with the oldest, the Asu River Formation, underlain by the Basement Complex rocks. With the exception of Awgu and Ezeaku Formations, all these rock units are very poor aquifers. The sandstones within the Awgu Formation are thin and generally limited in extent and as a result, give moderate to low yields. Aneke (2007) proposed an exploration strategy for the groundwater from the fractured shaley units which are the main water bearing units in the study area.

5. Theory and Methods

Evaluation of groundwater potential was done using information from Electrical Resistivity (ER) method. The ER method is utilized in diverse ways for groundwater water exploration (Zohdy, 1976; Choudhury, et al, 2001; Frohlich and Urish, 2002). Electrical surveys are usually designed to measure the ER of subsurface materials by making measurements at the earth surface. Currents are introduced into the ground by a pair of electrodes, while measuring the subsurface expression of the resulting potential fields with an additional pair of electrodes at appropriate spacing.

III. Data Acquisition and Interpretation

A total of Seventy-Eight Vertical Electrical Sounding (VES) was acquired in more than thirty locations within the study area (Fig.3). Some VES stations were very close to existing boreholes for correlation purposes. The Schlumberger electrode configuration (Fig. 4) was used, with a maximum current and potential electrodes separation of AB=800meters and MN=40meters respectively. The equipment used for the fieldwork was the versatile ABEM terrameter SAS 1000 resistivity meter. After acquiring the data, measured field resistance (R) in Ohms was converted to apparent resistivity (ρ_a) in Ohm-meter by multiplying resistance (R) by the geometric factor (k). A log-log graph plot of apparent resistivity (ρ_a) against current electrode distance (AB/2) was plotted for each VES station to generate a sounding curve. Using the conventional partial curve matching technique, in conjunction with auxillary point diagrams (Orellana and Mooney, 1966; Koefoed, 1979; Kellar and Frischknecht, 1966), layer resistivities and thickness were obtained, which served as a starting point for computer-assisted interpretation. The computer program INTERPEX was used to interprete all the datasets obtained. From the interpretation of the resistivity data, it has been possible to compute for every VES station, the Transverse resistance (T)

$T = h \times \rho_a$……………………………………………………………………………………………… (1)

And longitudinal conductance (S)

$S = h/\rho_a$………………………………………………………………………………………………. (2)

Where h and ρ_a are thickness and apparent resistivity of the aquiferous layer. These parameters T and S are known as the Dar-Zarrouk variable and Dar-Zarrouk function respectively (Maillet, 1947).

Estimating Aquifer Transmissivity from Dar-Zarrouk parameters

Both parameters T and S and the derived concept of Dar-Zarrouk curves (Maillet, 1947) are of prime significance in the development of interpretation theory for VES data. Niwas and Singhal (1981) established an analytical relationship between aquifer transmissivity and transverse resistance on the one hand and between aquifer transmissivity and aquifer longitudinal conductance on the other. Taking into account a prism of aquifer material having unit cross-sectional area and thickness (h), they combined equations 1 and 2 to obtain the following relationship between Transmissivity (Tr) and the so called Dar-zarrouk parameters.

$Tr = K\sigma R = K/\sigma \times S$……………………………………………………………………………… (3)

Where σ is the aquifer conductivity or electrical conductivity and K, the hydraulic conductivity of aquifer. In equation 3, the quantities $K\sigma$ and K/σ are assumed to remain fairly constant in areas of similar geologic setting and water quality (Niwas and Singhal, 1981). Therefore, with known values of K for the existing boreholes and with σ values extracted from the sounding interpretation at the borehole locations, it is possible to determine transmissivity and its variation within a geologic formation including places where no boreholes are available.

IV. Results and Discussion

8.1. Geoelectrical Sounding

Contour maps of the apparent resistivity, the isopach, the overburden depth, the transverse resistance, the longitudinal conductance, the transmissivity and the hydraulic conductivity of the aquiferous horizons has been constructed using the results of the resistivity sounding interpretation. Apparent resistivity variation (Fig.5) indicates a high resistivity within Agbani town and a low resistivity trend in a NW-SW direction, occupying towns around Akagbe-Ugwu, Ozalla, Obe and Amurri. Aquifer thickness (Fig.6) is variable, increasing from the northwest and Northeast to the central part of the study area. However, areas with thicker aquifer did not correlate with areas of high resistivity values. This is because resistivity depends more on the saturation of the layers and not necessarily on the thickness of the aquifer. The overburden depth (Fig.7) includes all rock materials above the aquiferous horizon or bedrock. The depth to the aquiferous horizion varies from 40meters to 180meters. The distribution of the transverse resistance, longitudinal conductance and the electrical conductivity computed from the VES interpretation are shown in Figs.8, 9 and 10 respectively. Maximum values of transverse resistance are observed around Amurri – Agbani – Akpugo axis. Electrical conductivity is the inverse of resistivity. High electrical conductivity (Fig.10) values occur around Amodu and Obe axis. This indicates that the country around Amodu and Obe is a shaley terrain. Computed aquifer transmissivity (Fig.11) and hydraulic conductivity (Fig.12) from VES interpretation, show similar trend, with good signals stretching the axis of Amurri –Agbani – Akpugo, with a recorded aquifer transmissivity value of $140m^2$/day. Hence, indicating a moderate permeability aquifer.

8.2. Groundwater Potential Evaluation

The present evaluation of the groundwater potential status of the study area has been based on aquifer geoelectrical parameters (resistivity, overburden and transmissivity) obtained from VES interpretation results and aquifer potential classification rating (Gheorghe, 1978). The observed thickness and nature of the weathered layer are important parameters in the groundwater potential evaluation (Clerk, 1985; Bala and Ike, 2001). However, areas with thick overburden and low percentage of clay in which intergranular flow is dominant are known to have high groundwater potential (Okhue and Olorunfemi, 1991). Based on the foregoing, two groundwater potential zones (Fig.13) were delineated. The zones are moderate and low potentials status. The country around Agbani – Akpugo in the central part of the study area, are of moderate potential status, while areas to the Northwest – South – Southwest and Southeast around Obe, Amodu, Amurri, Obeagu and Akagbe-Ugwu are of low potential status. Generally, about 30% of the study area falls within the moderate groundwater potential rating, while 70% make up low potential rating.

V. Conclusion

Based on the computed parameters from resistivity studies, the groundwater potential status of the study area has been evaluated. The evaluation shows moderate and low potential aquifer rating. This indicates that development of groundwater resources in the study area may be for private use. However, this should not stall further groundwater exploration in the study area but more detailed hydrogeological and geophysical investigations must be carried out to determine deeper prospects for better groundwater development.

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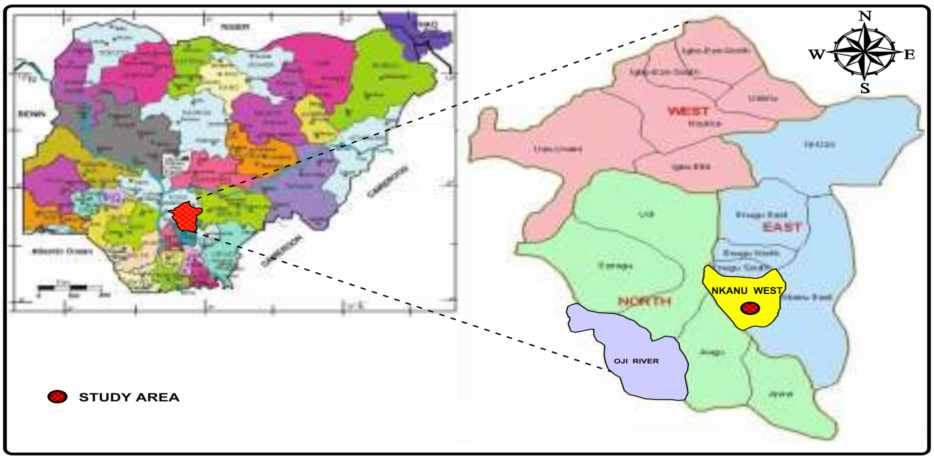

Figure 1: Map of Enugu State showing the location of the study area. Inset, map of Nigeria (Modified from Obaje, 2009).

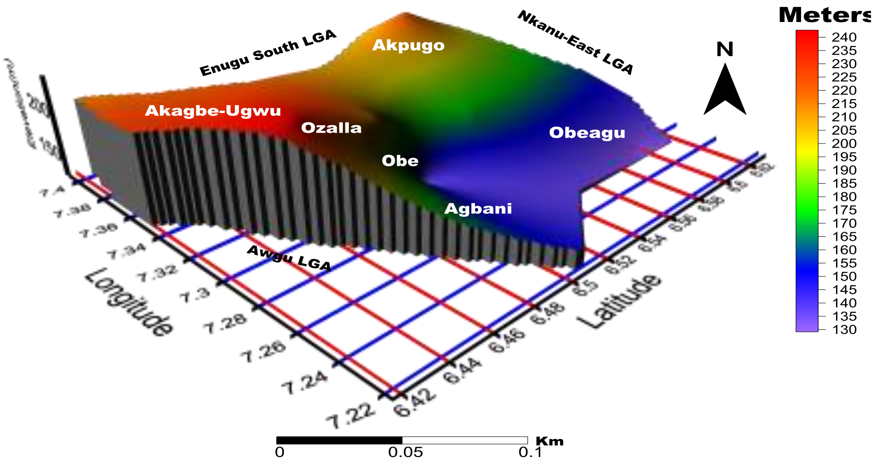

Figure 2: Surface map of the study area.

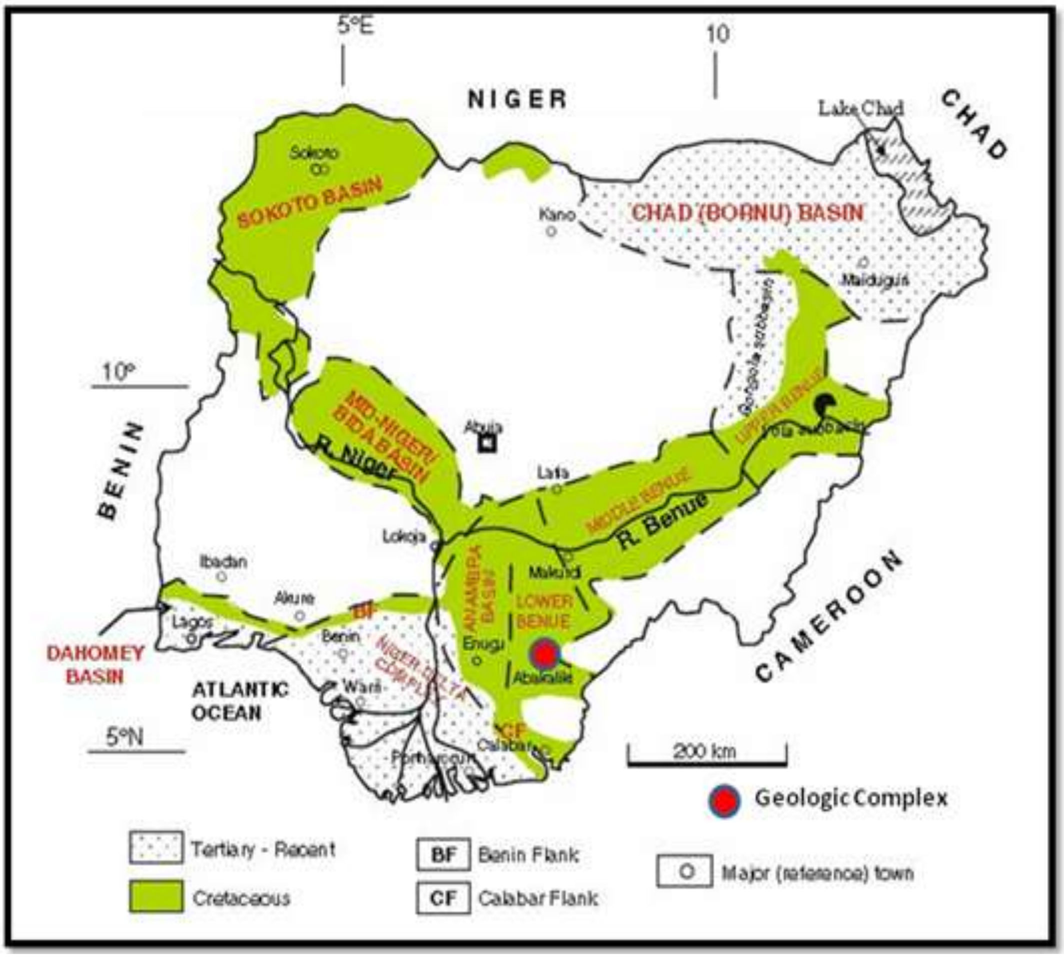

Figure 3a: Sedimentary basins of Nigeria (Obaje, 2009).

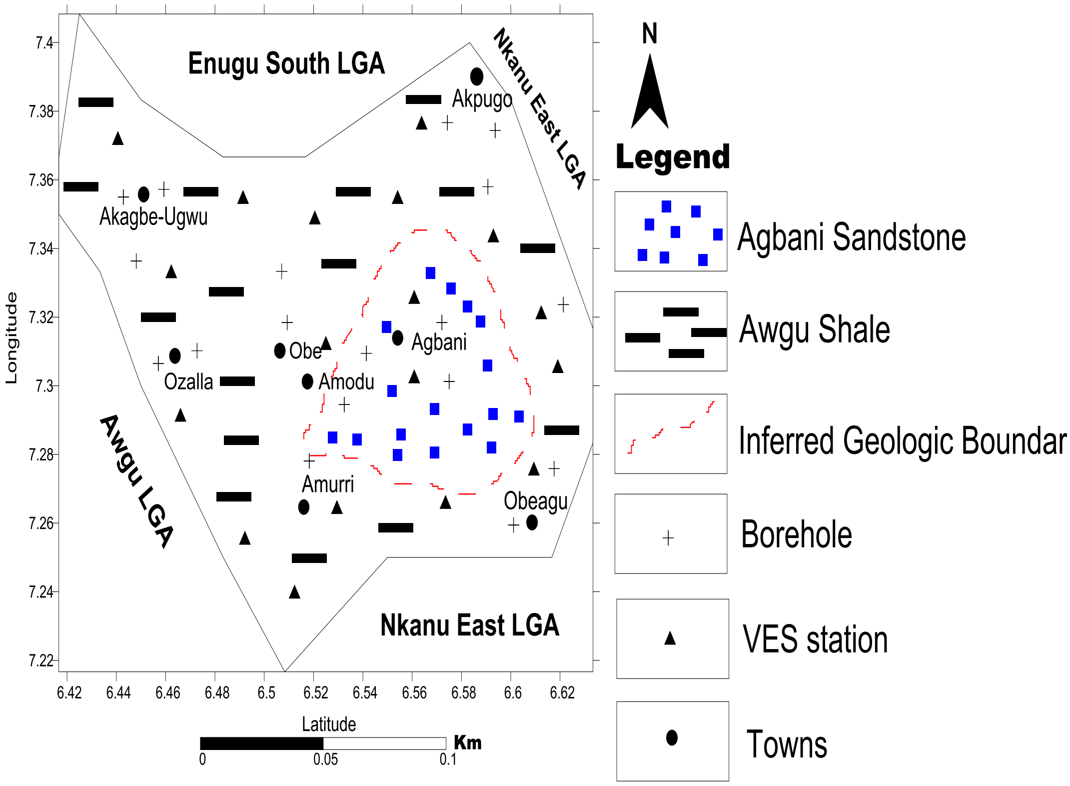

Figure 3b: Geologic map of the study area.

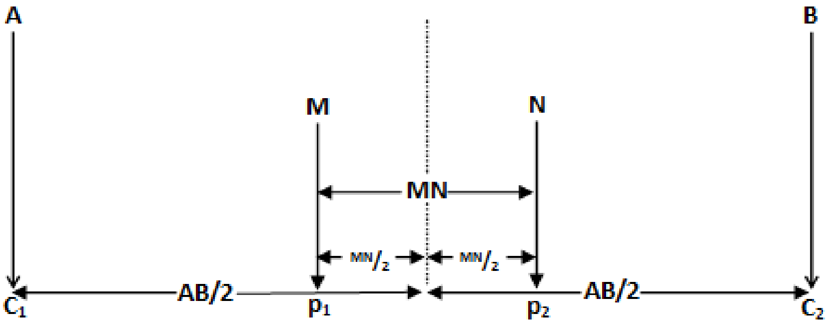

Figure 4: Schlumberger electrode configuration.

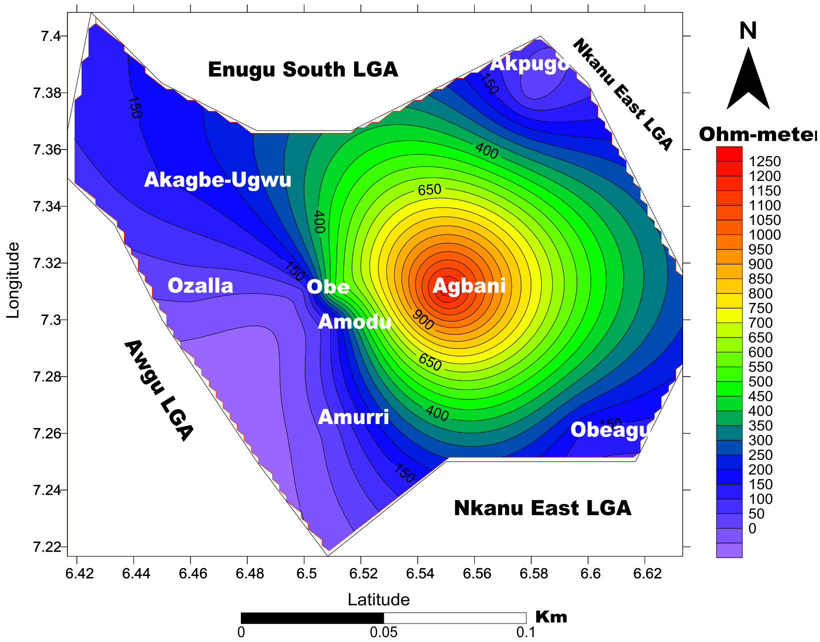

Figure 5: Apparent resistivity Map of the study area.

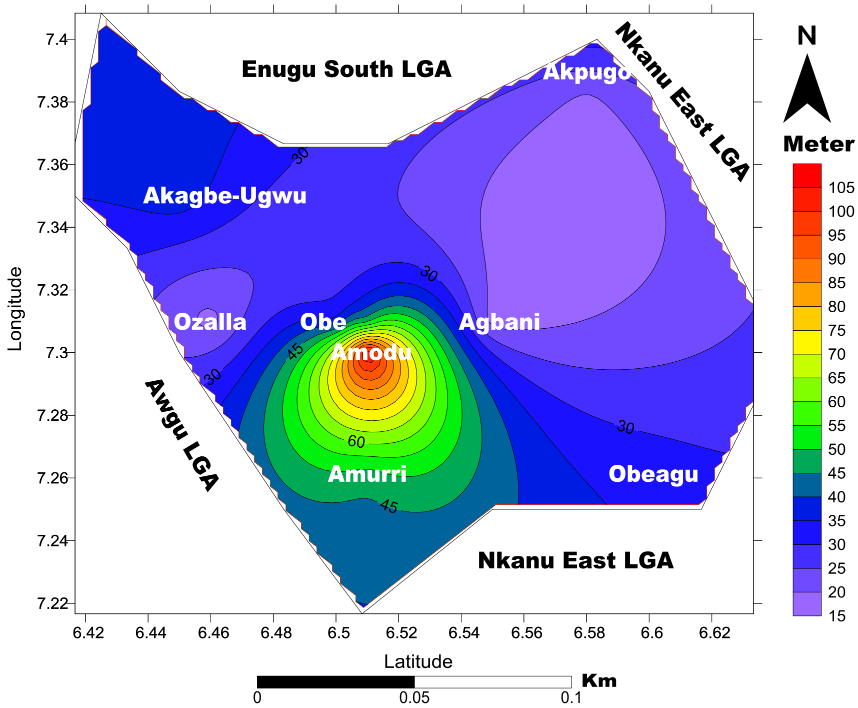

Figure 6: Aquifer isopach map of the study area.

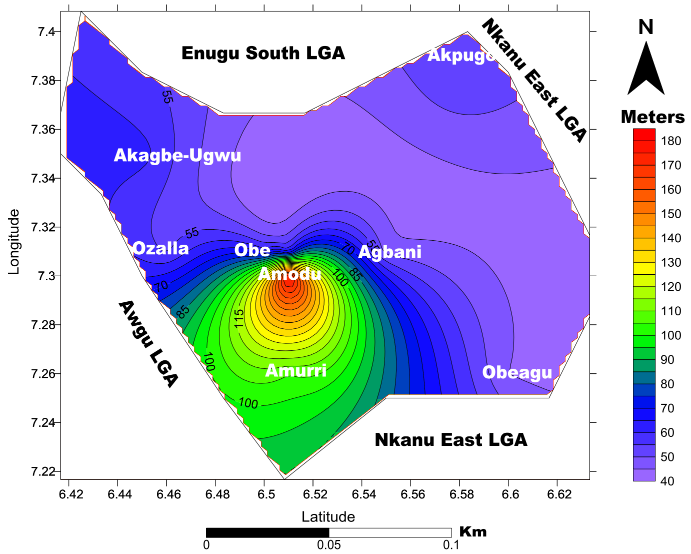

Figure 7: Overburden depth map of the study area.

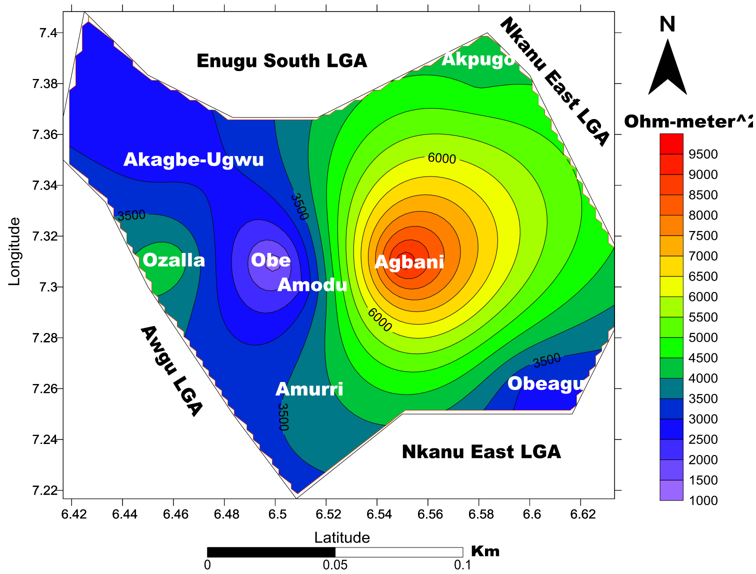

Figure 8: Transverse resistance map of the study area.

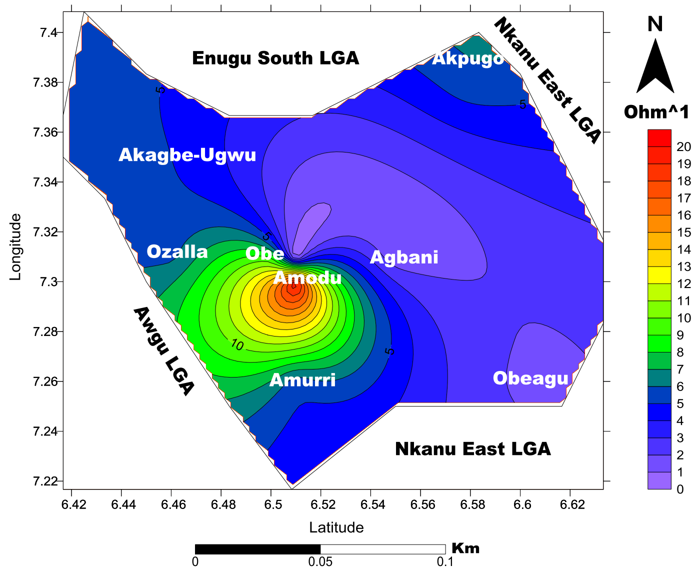

Figure 9: Longitudinal conductivity map of the study area.

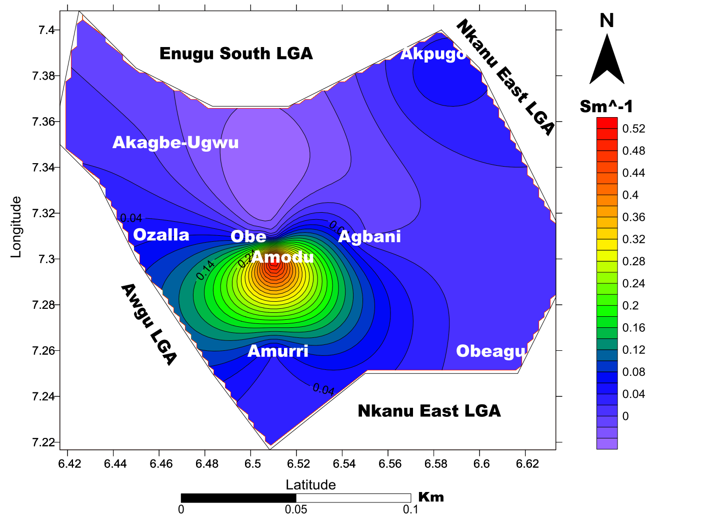

Figure 10: Electrical conductivity map of the study area.

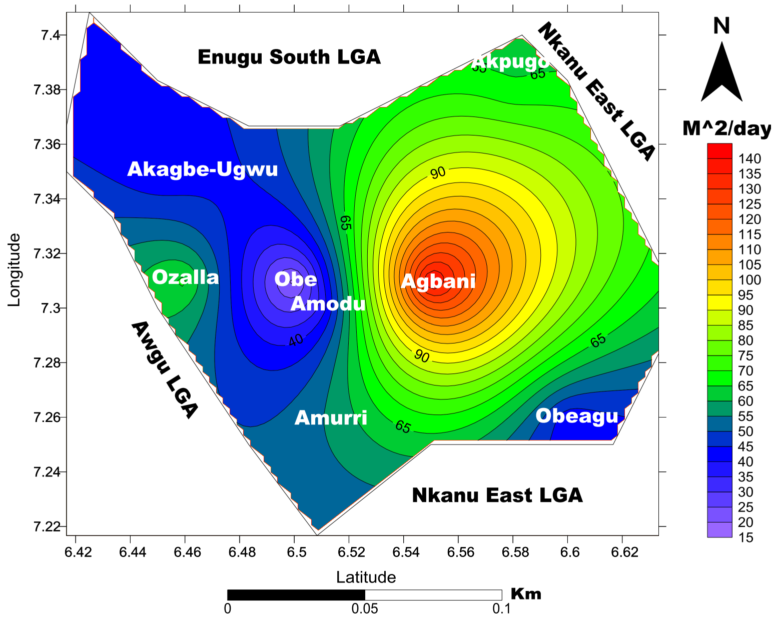

Figure 11: Aquifer transmissivity map of the study area.

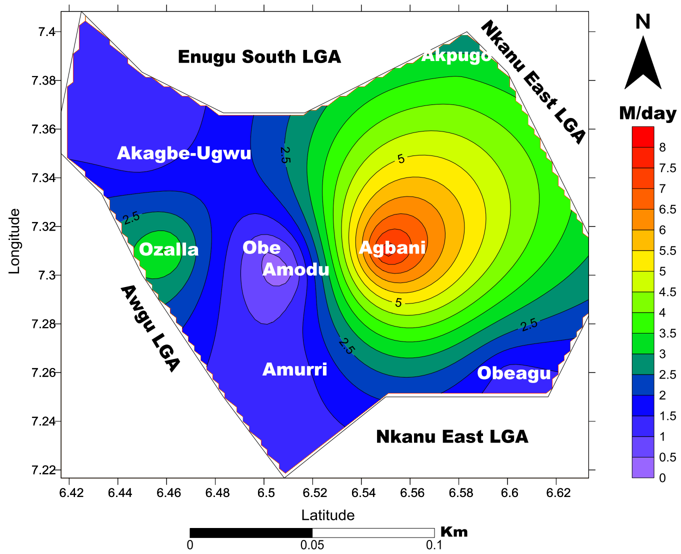

Figure 12: Hydraulic conductivity map of the study area.

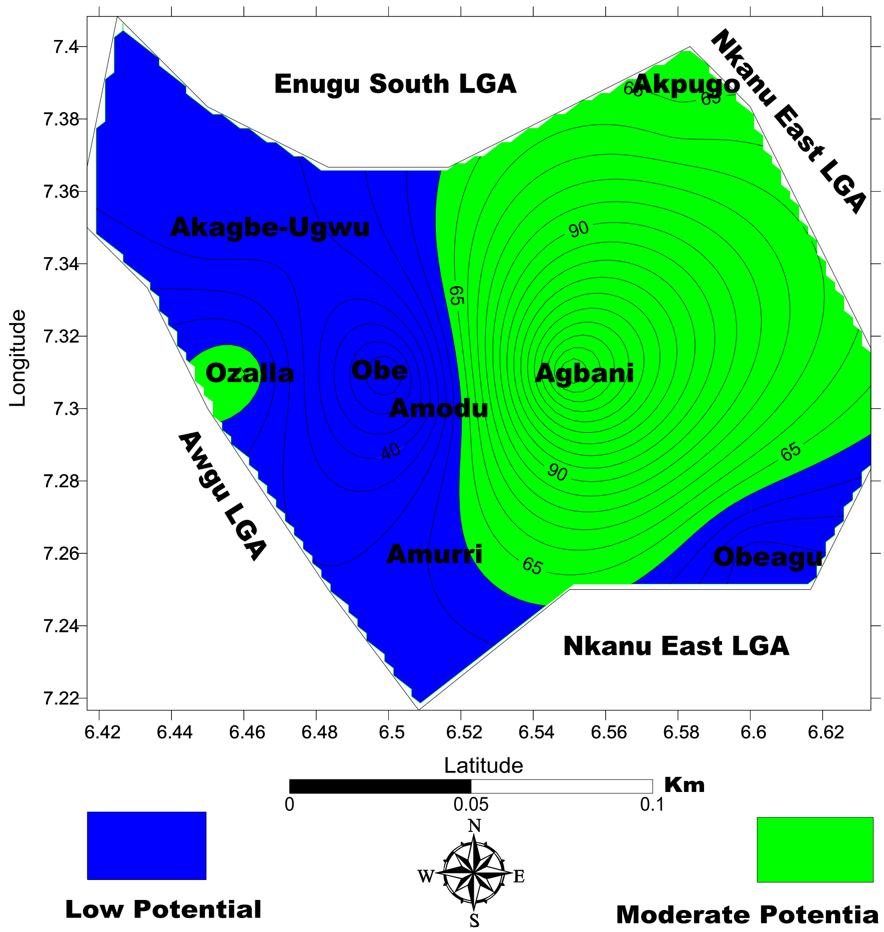

Figure 13: Groundwater potential status map of the study area.