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# Aquifer depths and thickness in Ogba/Egbema/Ndoni local government area of Rivers State, Nigeria from vertical electrical soundings

Peter Ogochuku Eke *, Frankline Dagogo Ibim and Peace Ugechi

*Department of Physics, Ignatius Ajuru University of Education, Port Harcourt, Nigeria.*

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## Abstract

Most parts of the world depend on groundwater for domestic and other uses. Different geophysical methods can be used to exploit these groundwater. In this study aquifer depths and thickness spread in parts of Ogba/Egbema/Ndoni Local Government Area of Rivers State, Nigeria have been determined from 30 vertical electrical sounding survey. An ABEM Terrameter (SAS 300C) was used with Schlumberger array configuration of maximum electrode spread of 500 m. The data were analyzed with an IP2WIN ID software to obtain the strata resistivities, geoelectric layers, aquifer depths and thickness from which the isopach and iso-resistivity maps of the region were obtained. The results show two to four layer formations with resistivity values ranging from 350 Ω to 3895Ω. Aquifer depths of between 20 m to 75 m and thickness varying from 17 m to 48 m. The isopach map indicates that regions in the north-central part of the study area have shallower aquifer thickness with an average value of 25 m while in the other parts of the study area, the average value is 41 m. The iso-resistivity contour maps at depth intervals of 50 m, 100 m, 150 m and 200 m reveal the trending of the resistivity values for these depths across the region. The general results indicate that the study area has productive aquifers of reasonable thickness at moderate depths from 20 m as in the other parts of the Niger delta region, therefore portable boreholes can be drilled from this depth.

**Keywords:** Groundwater; Isopach map; Iso-resistivity map; Geoelectric layers; Aquifer

## 1 Introduction

Increasing populations and economic developments have resulted in greater need for potable water in urban cities all over the world. Although water covers over 70% of the earth surface, most of it cannot be utilized for domestic purposes [1]. Except from surface waters, precipitation that falls on the ground soaks into the Earth crust and accumulates in rocks and soil layers as fresh water forming groundwater that exist in naturally habitats called aquifers. For several reasons groundwater is the largest reserve of drinkable water in regions where humans live. This makes the exploitation of groundwater common and rampant in most parts of the world. If the extraction of groundwater for a long time exceeds the recharge for extensive areas, overexploitation will occur and depletion of the groundwater sets. This may lead to problems like drying of wells, increased pumping test, land subsidence, sinkhole formation and induced saltwater intrusion for coastal aquifers [2; 3]. It is therefore necessary that good knowledge of groundwater resources in a region and its management is important to avoid these problems.

Groundwater can effectively be managed without these adverse effects to the environment if information on aquifer locations, depths and thickness are known to guide in the drilling of boreholes. Location of aquifer depths, thickness and other characteristics can be obtained from geophysical methods, especially with the electrical method which has been proven to be the most versatile and effective method of determining subsurface features as aquifer characteristics [4; 5; 6].

* Corresponding author: Peter Ogochuku Eke
Department of Physics, Ignatius Ajuru University of Education, Port Harcourt, Nigeria.

Ogba kingdom in Ogba/Egbema/Ndoni Local Government Area of Rivers State, Nigeria, is an urban area with increasing population and economic activities. The area is rich in hydrocarbon and host-community to Total Exploration and Production of Nigeria and Nigerian Agip Oil Company, which are hydrocarbon exploratory companies. It is the central business hub of the Orashi region of Rivers State, Nigeria. There is a continuous influx of associated companies and people into the area and the hydrocarbon exploration in the region has contaminated and polluted the massive surface water bodies in the area [7]. Aside the contamination and pollution of the surface water bodies in the region, some persons in the area still continually depend on surface water for domestic and agricultural activities, but these surface waters always almost dry up during the dry seasons [8]. Thus groundwater has become the major source of portable water in the region and this has resulted in unregulated drilling of boreholes for water supply by individuals without basic knowledge of the subsurface strata and aquifer information.

This work aims at proffering information to assist in effective management of the groundwater resources of Ogba/Egbema/Ndoni area of Rivers State, Nigeria by investigating the subsurface of the region using Schlumberger array method of vertical electrical sounding to obtain some aquifer information of the area as a guide for future exploitation of groundwater in the area.

### 1.1 Location of the Study Area

Ogba Egbema Ndoni local government Area of Rivers State, Nigeria lies between latitudes 5°10'. 96''N and 5°11'.92''N of the equator and longitudes 6°4'.70''E and 6°41'.01''E of the Greenwich meridian. It has an average elevation of 18 m above the sea level or datum with Omoku town as its capital. The area of study (Fig.1) is within the tropical rainforest belt of Nigeria and is characterized by dense vegetation. The area has a gentle topographic layout which is marked by shallow valleys that often accommodate streams and rivers. However the study area is drained by numerous tributary rivers and seasonal streams which flow towards the creek. The drainage pattern is dendritic which a reflection of lack of structural control.

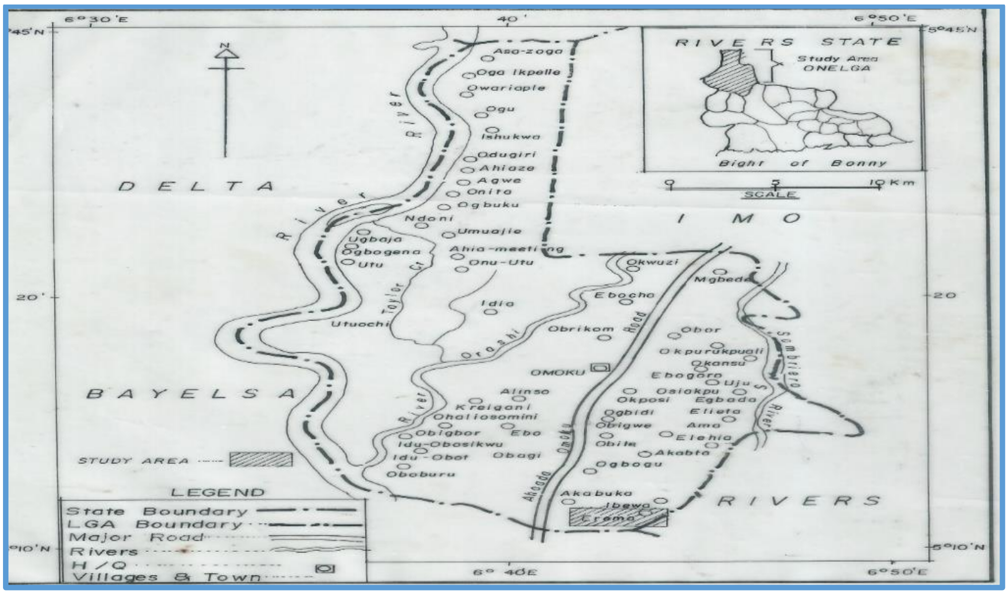


**Figure 1 S**tudy Areas

The geology and geomorphology of the Niger Delta have been described in details by various authors [9]. Its history dates from the Early Paleocene that resulted in the sedimentation build-up of over 10,000 m with three distinct formations identified from top to bottom as the Benin, Agbada and Akata formations.

The Benin formation is composed of over 70% sand/sandstone with shale intercalations thickness of over 2000 m in some regions and contains the aquifers of the region [7; 10].

Agbada Formation consists mainly of sands, sandstones and siltstones of varying thickness up to 4,500 m and constitutes the main hydrocarbon reservoirs in the Niger delta. The base sediment formation before the basement rocks is the Akata formation with thickness of over 3,000 m in some regions of the delta [11].

## 2 Material and methods

The apparent resistivity obtained from a vertical electrical sounding (VES) survey can be plotted against the electrode spread to obtain the true resistivity of an area [12]. As indicated in Eke and Ekpelu [13] the soil resistivity and the moisture content of pore spaces within a rock or soil salinity, the degree of saturation of pore, clay content, number, size and shape of the joining pores and compaction factor are all related as

$$\rho_e = a\vartheta^{-m}S^{-n}\rho_w \quad \text{……………..1.}$$

Where $\rho_e$ is the resistivity of the rock, $\vartheta$ is the porosity, $S$ is the fraction of the pores containing water, $\rho_w$ is the resistivity of water; and $a$, $m$ and $n$ are empirical constants with values of 0.5 ≤ $a$ ≤ 2.5, 1.3 ≤ $m$ ≤ 2.5 and $n$ = 2.

By use of the Schlumberger array [14] we can obtain the apparent resistivity which from interpretation can be used to obtain the approximate true resistivity of a formation. Thirty (30) Schlumberger Vertical Electrical Sounding (VES) surveys were carried out at a number of points fairly distributed over the area and dense enough for the determination of rock property information related to groundwater aquifer delineation. The total traverse length of 500 m (that is 250 m either way) was used at each sounding station. The measurement started with the two potential electrode 0.30 m apart from the mid-point of the spread and the two current electrode at 1.00 m from the mid-point of the spread. The potential electrode were maintained at 0.30 m while current electrodes moved to 2.00 m, 3.00 m and 4.00 m respectively, while keeping the current electrodes constant. This procedure was continued until the whole area was mapped. The maximum electrode spread was $AB/2$ = 250 m $MN/2$ = 25 m for current and potential electrodes respectively.

## 3 Results

Table 1 summarizes the field data analysis. It indicates the various geoelectric units, there thickness and depths of occurrences. The VES stations numbered 1 to 30 were located in the various towns listed in Tables 2, 3, and 4.

**Table 1** Results from the Modeling for VES Locations 1 -10

| VES No. | No. of Layer | Thickness (m) | Depth (m) | Resistivity (Ωm) | Curve Type | Elevation (m) | Lat. | Long; | Lithology |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 2.00 | 2.00 | 1269.99 | HA | 18 | 5°13'0.001' | 6°42'0'' | Laterite |
| | 2 | 5.50 | 7.50 | 824.960 | | | | | Laterite sand |
| | 3 | 44.5 | 52.0 | 1592.64 | | | | | Gravelly sand |
| | 4 | ---- | ---- | 2740.44 | | | | | Gravel |
| 2 | 1 | 2.50 | 2.50 | 367.710 | A | 18 | 5°14'4.992'' | 6°40'45.479' | Top laterite |
| | 2 | 22.5 | 25.0 | 968.160 | | | | | Coarse sand |
| | 3 | - | >25 | 1849.78 | | | | | Gravelly sand |
| 3 | 1 | 4.00 | 4.00 | 525.830 | A | 17 | 5°13'0.001'' | 6°37'59.998'' | Top laterite |
| | 2 | 26.0 | 30.0 | 1784.86 | | | | | Gravelly sand |
| | 3 | - | >30 | 2746.36 | | | | | Gravel |
| 4 | 1 | 4.00 | 4.00 | 588.090 | AA | 19 | 5°20'42.86'' | 6°39'25.245'' | Top laterite |
| | 2 | 8.50 | 12.5 | 912.020 | | | | | Gravelly sand |
| | 3 | 31.5 | 40.0 | 2782.47 | | | | | Gravel |
| | 4 | - | >40 | 3367.49 | | | | | Pebble |
| 5 | 1 | 1.50 | 1.50 | 1381.87 | HA | 18 | 5°17'39.466'' | 6°39'8.804'' | Laterite |
| | 2 | 3.50 | 5.00 | 835.530 | | | | | Laterite sand |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 3 | 36.5 | 40.0 | 1661.04 | | | | | Gravelly soil |
| | 4 | - | >40 | 2857.75 | | | | | Gravel |
| 6 | 1 | 2.00 | 2.00 | 1350.15 | HA | 18 | $5^0$144'2.077'' | $6^0$40'2.036'' | Laterite sand |
| | 2 | 5.50 | 7.50 | 901.260 | | | | | Gravel |
| | 3 | 44.5 | 50.0 | 1746.12 | | | | | Gravelly soil |
| | 4 | - | >50 | 2578.57 | | | | | Pebble |
| 7 | 1 | 2.00 | 2.00 | 1450.84 | HA | 19 | $5^0$19'53.652'' | $6^0$42'9.683'' | Laterite sand |
| | 2 | 3.00 | 5.00 | 943.530 | | | | | Coarse sand |
| | 3 | 27.0 | 22.0 | 1743.20 | | | | | Gravel |
| | 4 | - | >22 | 319.47 | | | | | Pebble |
| 8 | 1 | 3.00 | 3.00 | 536.030 | A | 13 | $5^0$32'60'' | $6^0$34'59.998'' | Laterite sand |
| | 2 | 27.0 | 30.0 | 1203.44 | | | | | Coarse sand |
| | 3 | --- | >30 | 2126.78 | | | | | Gravel |
| 9 | 1 | 2.00 | 3.00 | 1276.41 | HA | 18 | $5^0$13'0.001'' | $6^0$37'59.98'' | Laterite |
| | 2 | 12.0 | 15.0 | 1005.08 | | | | | Coarse sand |
| | 3 | 28.0 | 43.0 | 2085.55 | | | | | Gravelly soil |
| | 4 | - | >43 | 2631.35 | | | | | Gravel |
| 10 | 1 | 3.50 | 3.00 | 1195.22 | A | 17 | $5^0$14'5. 992'' | $6^0$40'45.779'' | Laterite sand |
| | 2 | 71.5 | 75.0 | 1834.52 | | | | | Gravel |
| | 3 | - | >75 | 3499.79 | | | | | Pebble |

**Table 2** Results from the Modeling for VES Locations 11 – 20

| VES No. | No. of Layer | Thickness (m) | Depth (m) | Resistivity (Ωm) | Curve Type | Elevation (m) | Lat. | Long; | Lithology |
|---|---|---|---|---|---|---|---|---|---|
| 11 | 1 | 2.00 | 3.00 | 1276.41 | AA | 18 | $5^0$15'42.077'' | $6^0$40'2.436'' | Laterite sand |
| | 2 | 10.5 | 15.0 | 1005.08 | | | | | Coarse sand |
| | 3 | 29.5 | 43.0 | 2085.55 | | | | | Gravelly sand |
| | 4 | ---- | >43 | 2631.35 | | | | | Gravel |
| 12 | 1 | 2.00 | 2.00 | 362.110 | A | 18 | $5^o$14'4.992'' | $6^o$40'45.479' | Laterite sand |
| | 2 | 48.0 | 50.0 | 1276.24 | | | | | Coarse sand |
| | 3 | - | >50 | 1849.78 | | | | | Gravel |
| 13 | 1 | 2.00 | 2.00 | 424.380 | A | 18 | $5^0$17'39.804'' | $6^0$39'49.998'' | Top laterite |
| | 2 | 28.0 | 30.0 | 1055.63 | | | | | Gravelly sand |
| | 3 | - | >30 | 2109.52 | | | | | Gravel |
| 14 | 1 | 2.00 | 2.00 | 349.990 | AA | 18 | $5^0$16'0.001'' | $6^0$42'1'' | Top laterite |
| | 2 | 28. 0 | 30.0 | 1030.83 | | | | | Coarse sand |
| | 3 | 22.0 | 50.0 | 1746.60 | | | | | Gravel |
| | 4 | - | >50 | 3895.34 | | | | | Pebble |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 15 | 1 | 2.00 | 2.00 | 1366.96 | HA | 18 | 5⁰17'39.466'' | 6⁰39'8.804'' | Laterite |
| | 2 | 3.00 | 5.00 | 919.670 | | | | | Coarse sand |
| | 3 | 32.0 | 35.0 | 1924.53 | | | | | Gravel |
| | 4 | - | >35 | 3255.34 | | | | | Pebble |
| 16 | 1 | 3.50 | 3.50 | 1088.35 | HA | 17 | 5⁰13'0.001'' | 6⁰39'49.8'' | Laterite |
| | 2 | 16.5 | 20.0 | 1006.11 | | | | | Coarse sand |
| | 3 | 33.5 | 50.0 | 1739.21 | | | | | Gravel |
| | 4 | - | >50 | 3181.22 | | | | | Pebble |
| 17 | 1 | 2.50 | 2.00 | 419.670 | A | 18 | 5⁰19'53.652'' | 6⁰42'9.683'' | Laterite sand |
| | 2 | 27.5 | 30.0 | 1232.48 | | | | | Coarse sand |
| | 3 | 27.0 | 22.0 | 2322.50 | | | | | Gravel |
| 18 | 1 | 5.00 | 5.00 | 573.910 | A | 20 | 5⁰27'5'' | 6⁰41'52.271'' | Laterite sand |
| | 2 | 35.0 | 40.0 | 1922.19 | | | | | Coarse sand |
| | 3 | --- | >40 | 3273.26 | | | | | Gravel |
| 19 | 1 | 1.80 | 1.80 | 1376.37 | H | 18 | 5⁰27'39.804'' | 6⁰39'9.964'' | Laterite |
| | 2 | 3.80 | 5.00 | 952.320 | | | | | Coarse sand |
| | 3 | 16.8 | 20.0 | 1679.93 | | | | | Gravelly sand |
| 20 | 1 | 3.00 | 3.0 | 431.650 | A | 18 | 5⁰17'39.884'' | 6⁰39'8.864'' | Laterite |
| | 2 | 17.5 | 20.0 | 1061.60 | | | | | Coarse sand |
| | 3 | - | >20 | 1914.95 | | | | | Gravelly soil |

**Table 3** Results from the Modeling for VES Locations 21 – 30

| VES No. | No. of Layer | Thickness (m) | Depth (m) | Resistivity (Ωm) | Curve Type | Elevation (m) | Lat. | Long; | Lithology |
|---|---|---|---|---|---|---|---|---|---|
| 21 | 1 | 2.50 | 2.50 | 608.120 | HA | 17 | 5⁰15'42.077'' | 6⁰40'2.436'' | Laterite |
| | 2 | 10.0 | 12.5 | 874.670 | | | | | Laterite sand |
| | 3 | 30.0 | 40.0 | 2342.25 | | | | | Gravelly soil |
| | 4 | ∞ | >40 | 3267.27 | | | | | Pebble |
| 22 | 1 | 2.50 | 2.50 | 635.990 | AA | 15 | 5⁰27'1.608'' | 6⁰33'33.192'' | Lateritic |
| | 2 | 10.0 | 12.5 | 876.920 | | | | | Gravel |
| | 3 | 30.0 | 40.0 | 3059.49 | | | | | Gravelly soil |
| | 4 | ∞ | >40 | 4066.33 | | | | | Pebble |
| 23 | 1 | 2.00 | 2.00 | 1657.92 | HA | 21 | 5⁰23'24.8'' | 6⁰40'21.44''' | Top laterite |
| | 2 | 13.0 | 15.0 | 959.310 | | | | | Gravelly sand |
| | 3 | 27.0 | 40.0 | 2172.92 | | | | | Gravel |
| | 4 | - | >40 | 5004.69 | | | | | Pebble |
| 24 | 1 | 2.00 | 2.00 | 1591.57 | HA | 18 | 5⁰18'46.254'' | 6⁰43'1.372'' | Top laterite |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2 | 18.0 | 20.0 | 1113.02 | | | | | Coarse sand |
| | 3 | 32.0 | 50.0 | 2351.75 | | | | | Gravel |
| | 4 | ∞ | >50 | 3287.62 | | | | | Pebble |
| 25 | 1 | 2.00 | 2.00 | 1524.87 | HA | 20 | $5^{0}$28'18.617'' | $6^{0}$43'44.332'' | Laterite |
| | 2 | 13.0 | 15.0 | 1242.87 | | | | | Coarse sand |
| | 3 | 37.0 | 50.0 | 2397.22 | | | | | Gravel |
| | 4 | ∞ | >50 | 3116.76 | | | | | Pebble |
| 26 | 1 | 2.00 | 2.00 | 622.21 | KHA | 18 | $5^{0}$19'50.665''' | $6^{0}$43'44.332'' | Laterite |
| | 2 | 2.00 | 4.00 | 1027.67 | | | | | Coarse sand |
| | 3 | 10.5 | 12.5 | 887.16 | | | | | Gravel sand |
| | 4 | 39.5 | 50.0 | 1724.79 | | | | | Gravel |
| | 5 | ∞ | >50 | 3539.88 | | | | | Pebble |
| 27 | 1 | 2.00 | 2.00 | 405.950 | AA | 18 | $5^{0}$16'26.973'' | $6^{0}$42'8.308'' | Laterite sand |
| | 2 | 5.00 | 7.50 | 1150.21 | | | | | Coarse sand |
| | 3 | 45.0 | 50.0 | 1656.99 | | | | | Gravelly soil |
| | 4 | ∞ | >50 | 2734.17 | | | | | Gravel |
| 28 | 1 | 2.00 | 2.00 | 601.590 | AA | 15 | $5^{0}$21'1.608'' | $6^{0}$33'33.112'' | Lateritic sand |
| | 2 | 13.0 | 15.0 | 976.000 | | | | | Coarse sand |
| | 3 | 37.0 | 50.0 | 1515.17 | | | | | Gravelly sand |
| | 4 | ∞ | >50 | 3669.79 | | | | | Pebble |
| 29 | 1 | 1.50 | 1.50 | 488,880 | AA | 20 | $5^{0}$28'59.999'' | $6^{0}$43'59.998'' | Laterite |
| | 2 | 8.50 | 10.0 | 755.290 | | | | | coarse sands |
| | 3 | 41.5 | 50.0 | 1932.76 | | | | | gravelly sand |
| | 4 | ∞ | >50 | 3933.06 | | | | | Pebble |
| 30 | 1 | 2.00 | 2.00 | 1386.12 | HKH | 18 | $5^{0}$29'604' | $6^{0}$33'34.197' | Laterite |
| | 2 | 13.0 | 15.0 | 894.340 | | | | | Gravel |
| | 3 | 27.0 | 40.0 | 2027.95 | | | | | Coarse sand |
| | 4 | 23.0 | 50.0 | 866.680 | | | | | Gravelly sand |
| | 5 | ∞ | >50 | 3187.22 | | | | | Pebble |

Figure 2 is the isopach map of the region indicating the variation in aquifer thickness within the region.

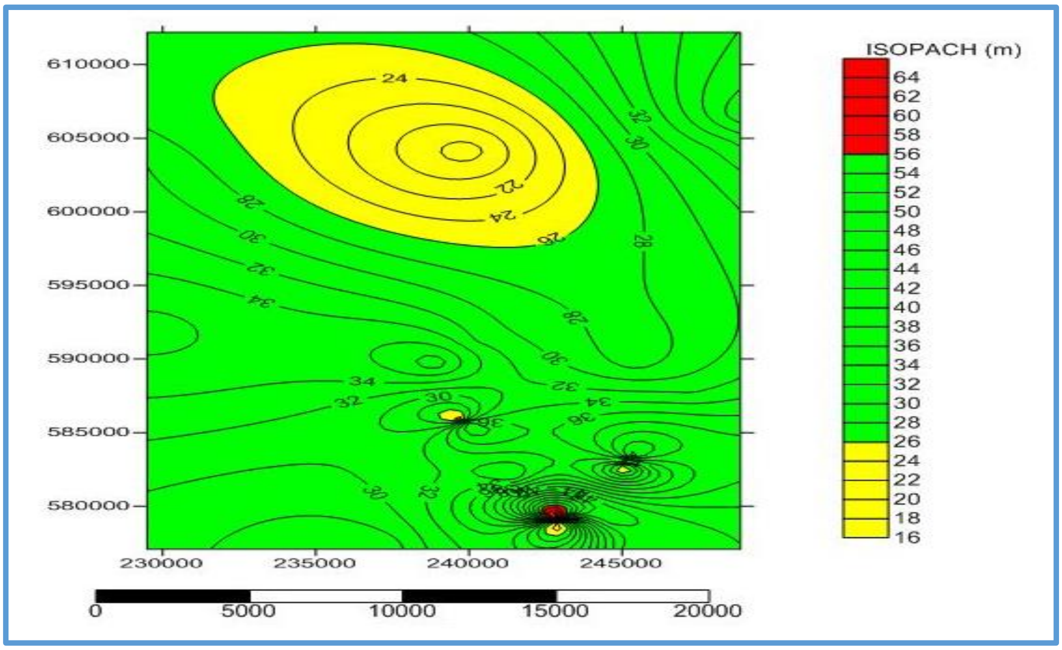


**Figure 2** Isopach Map showing the aquiferous layer thickness of the study area

The iso-resistivity map for various depths is shown in Figures 3 to 6.

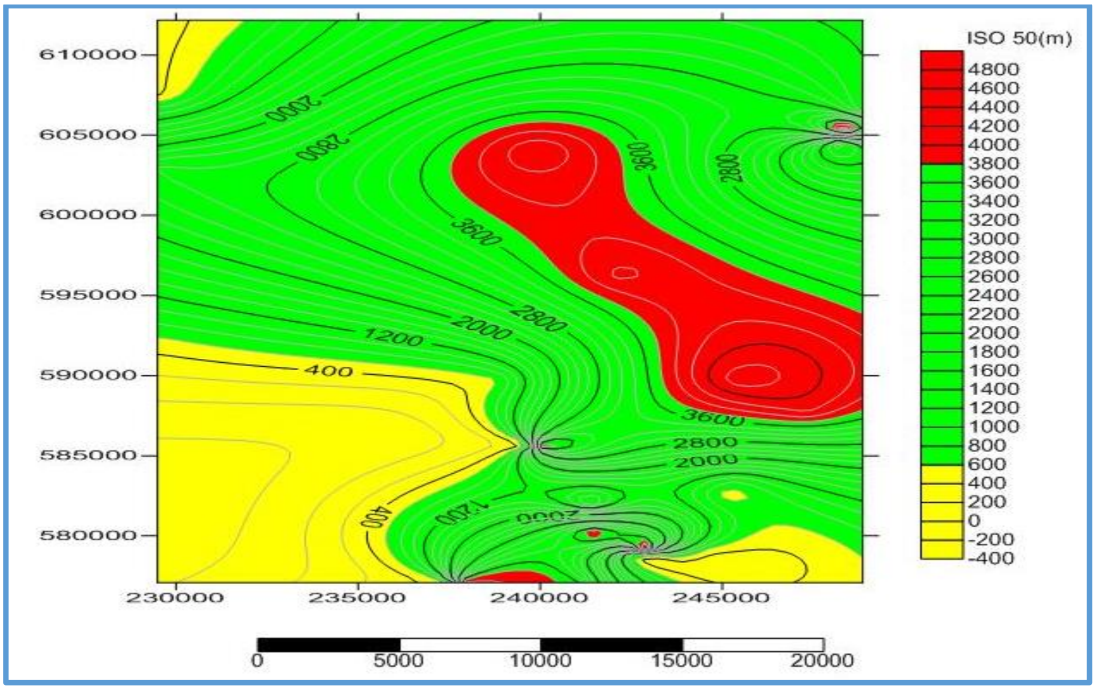


**Figure 3** Iso-resistivity contour map at AB/2 = 50 m

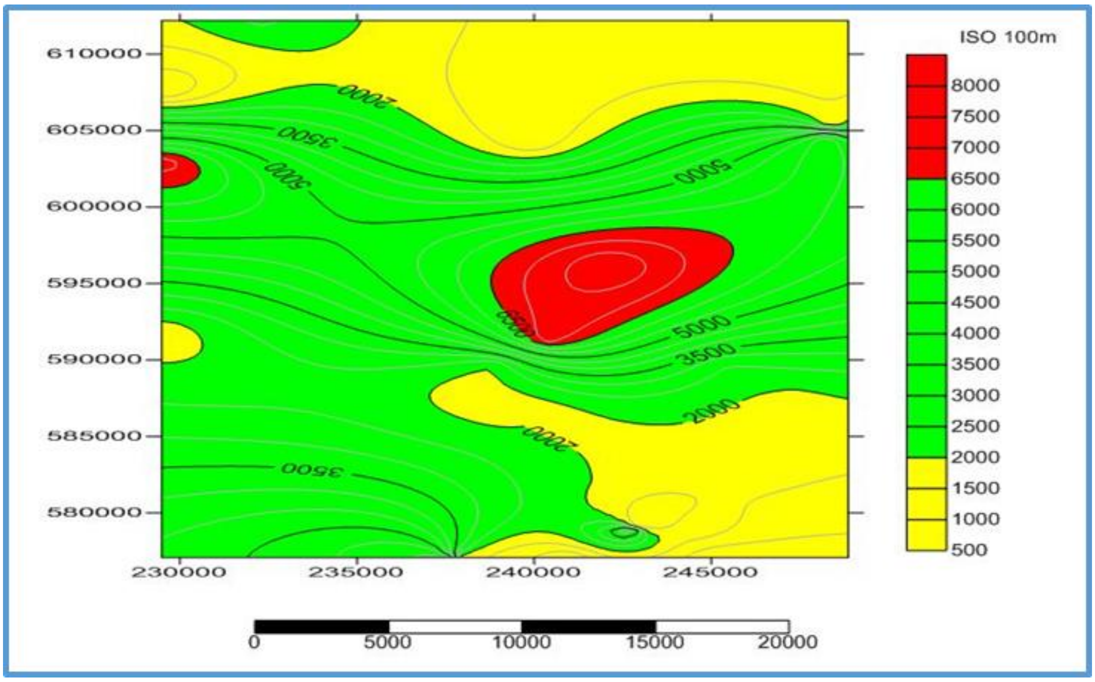


**Figure 4** Iso - resistivity contour map at AB/2 = 100 m

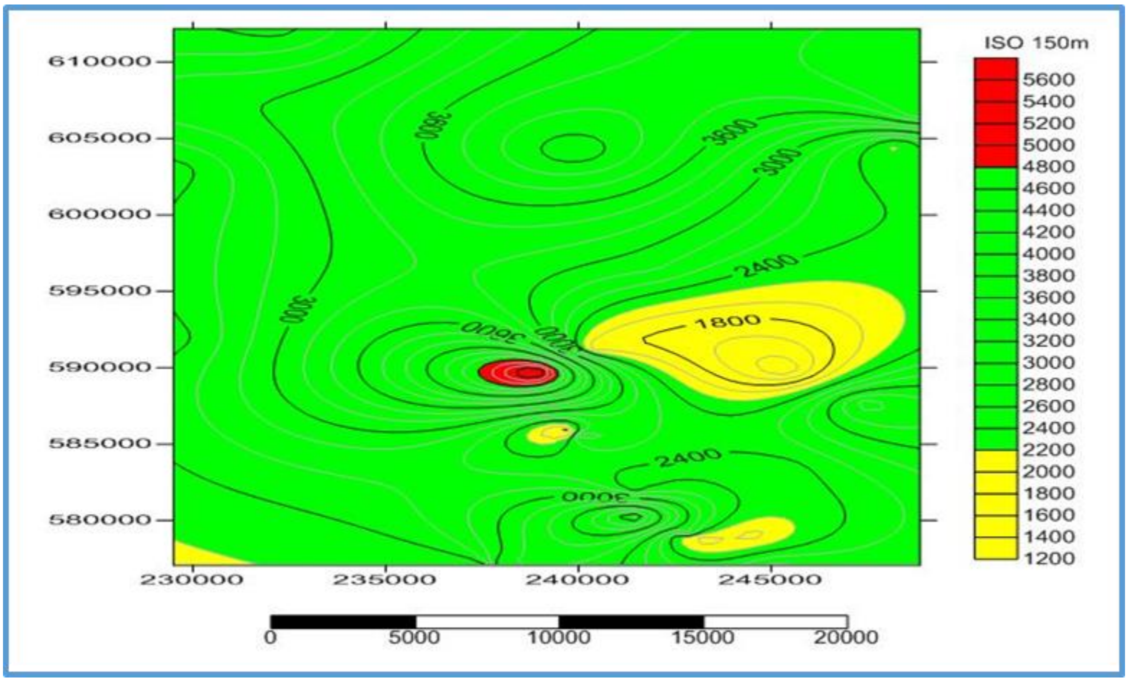


**Figure 5** Iso - resistivity contour map at AB/2 = 150 m

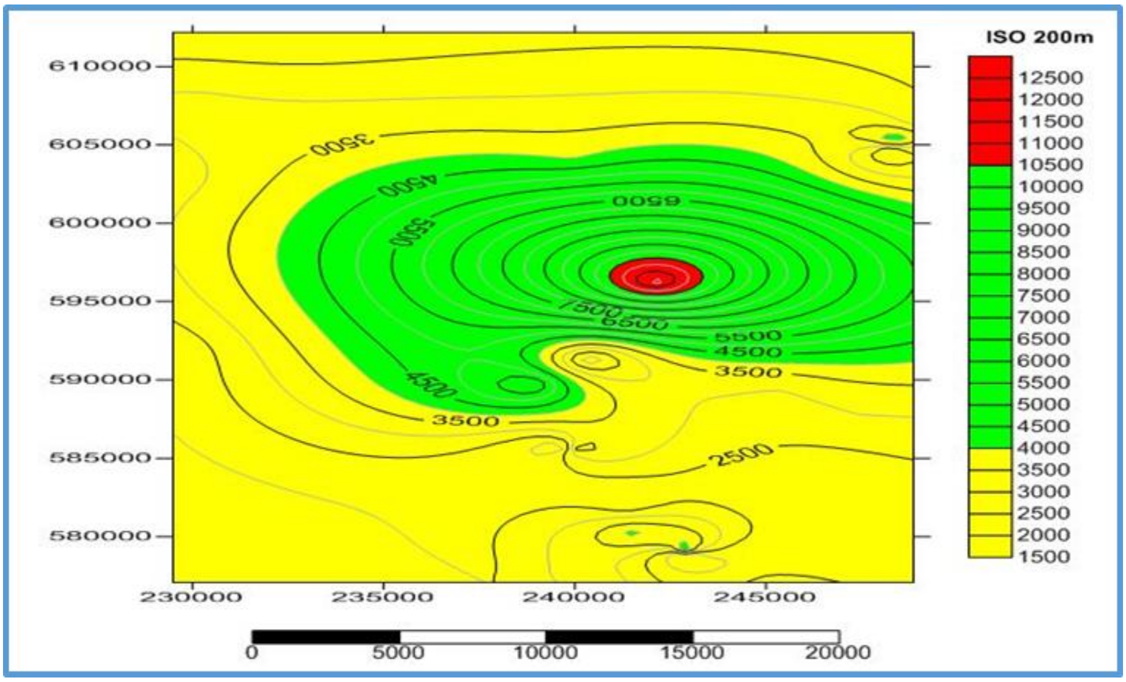


**Figure 6** Iso - resistivity contour map at AB/2 = 200m

Table 2 shows a summary of the isopach and iso-resistivity at various depths.

**Table 4** Summary of Isopach and Iso-Resistivity Values for Locations 1 to 10

| Location | Iso AB/2 = 50/m | Iso AB/2 = 100/m | Iso AB/2 = 150/m | Iso AB/2 = 200/m | Aquifer Depth | Aquifer Thickness | Easting Location | Northing Location |
|---|---|---|---|---|---|---|---|---|
| | Resistivity/Ω | | | | Meters | | UTM | UTM |
| Erema | 366.52 | 479.1 | 2879.6 | 2716.8 | 50 | 45 | 245052.805 | 577079.856 |
| Ibewa | 496.9 | 1758.4 | 1932.5 | 1991.8 | 25 | 23 | 242764.938 | 579085.469 |
| Akabuka | 542.4 | 6294.1 | 2237.9 | 1833.4 | 30 | 26 | 237597.247 | 591321.470 |
| Omoku | 2109.8 | 7296.2 | 1870.9 | 1507.1 | 40 | 32 | 240338.745 | 591321.470 |
| Ogbidi | 4249.4 | 1729.3 | 29977.4 | 3816.9 | 37 | 40 | 239815.881 | 585697.897 |
| Ogbogu | 4092.7 | 2085.5 | 4491.5 | 4166.9 | 50 | 45 | 241430.284 | 580230.076 |
| Egbeda | 4727.5 | 2562.7 | 1227.5 | 3079.3 | 30 | 27 | 245397.985 | 589790.197 |
| Ndoni | 652.1 | 2636.5 | 2304.9 | 1991.8 | 30 | 27 | 232251.809 | 612181.804 |
| Ogbagi | 4092.7 | 1900.1 | 3153.9 | 2566.8 | 40 | 28 | 237658.310 | 577107.252 |
| Obezimini | 4884.3 | 1648.0 | 2794.9 | 4591.9 | 75 | 72 | 242773.739 | 579116.167 |
| Obite | 498.5 | 2064.7 | 2295.0 | 4591.9 | 75 | 29 | 241387.872 | 582074.095 |
| Itu | 498.5 | 1966.8 | 1932.2 | 2004.3 | 40 | 48 | 244612.761 | 579075.588 |
| Ohalielu | 492.2 | 1966.8 | 1531.3 | 2029.3 | 50 | 28 | 239807.564 | 585697.929 |
| Obiyebe | 498.5 | 1648.0 | 2295.0 | 1533.3 | 30 | 22 | 245103.905 | 582611.120 |
| Egita | 4884.3 | 1648.0 | 2794.9 | 2045.9 | 50 | 32 | 242776.729 | 579091.572 |
| Oboburu | 3669.5 | 479.2 | 3013.1 | 4633.6 | 35 | 34 | 241047.768 | 577094.597 |
| Akabuta | 810.4 | 1758.4 | 1932.5 | 3200.2 | 50 | 28 | 237597.247 | 577107.481 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Mgbede | 542.4 | 6294.1 | 2143.7 | 1991.3 | 30 | 35 | 248265.507 | 604641.030 |
| Obigwe | 4406.2 | 1020.9 | 4377.8 | 1833.4 | 40 | 17 | 239917.520 | 604136.381 |
| Ede | 2630.2 | 1143.8 | 1647.4 | 3966.9 | 20 | 18 | 239812.810 | 585700.367 |
| Obukaegi | 543.9 | 6302.4 | 2143.7 | 2471.9 | 20 | 30 | 242764.998 | 579085.161 |
| Idu Osobele | 2630.2 | 7325.4 | 2298.6 | 1833.4 | 40 | 30 | 229541.221 | 603003.765 |
| Obrikom | 4257.3 | 7979.6 | 2777.3 | 2746.0 | 40 | 27 | 242088.557 | 596291.402 |
| Osiakpu | 4202.4 | 1900.1 | 3505.9 | 12317.3 | 50 | 32 | 247343.655 | 587711.836 |
| Ebocha | 4854.3 | 1648.0 | 2794.9 | 4591.9 | 50 | 37 | 248371.208 | 605296.659 |
| Kreigani | 592.5 | 2064.7 | 5825.6 | 6200.4 | 50 | 39 | 238903.248 | 589722.921 |
| Ikiri | 812.0 | 1987.6 | 2284.5 | 2029.3 | 50 | 45 | 245332.111 | 583439.135 |
| Ohiagu | 498.4 | 1648.0 | 2295.0 | 2046.0 | 50 | 37 | 229494.400 | 591939.900 |
| Okuezi | 1976.6 | 1654.3 | 4195.8 | 2679.5 | 50 | 42 | 248857.900 | 606566.260 |
| Idu obisukwu | 366.5 | 479.2 | 3013.1 | 3200.2 | 40 | 27 | 229590.640 | 607552.060 |

## 4 Discussions

The survey array was able to obtain depth information up to 75 m below the earth surface as shown in Tables 1, 2 and 3. The results reveal two/three geoelectric layers in most parts of the study area, however in Krigani and Idu Obosikwu locations four geoelectric layers were penetrated. In all, the general lithology from top to bottom are laterites, coarse sands, gravels and pebbles. These sedimentary thicknesses range from 1.5 m to as much as 71.5 m in Obezimini. Most of the lithologies are ideal environment for groundwater reservoirs and flow. The isopach map ( Figure 2) indicates that the aquifer thickness in the north-central part of the study area have values of from 16 m to 26 m while in the other parts of the region, it ranges from 26 m to 48 m with maximum aquifer thickness of 72 m in obizimini location. This results reveal that most parts of the region have aquifers close to the surface. For example at Ede, Ohalialu, Akabuta and Obiezimini, the aquifers are close to the surface from depths of 2 m, while at Mbede it is 5 m from the surfaces. At places like Omoku, Obukeagi and Krigani, aquifers can be found at depths of 10 m. From the iso-resistivity maps (Figures 3 to 6) we have a contour of resistivity values at depths of 50 m, 100 m, 150 m and 200 m. The maps reveal regions where the resistivity values coupled with the aquifer thickness can be used to identify points and depths to which boreholes can be drilled to obtain ground water. The importance of this is that within a region boreholes can be drilled to different depths to avoid overexploitation at a particular depth. For example at a place like Obiezimini (Table 2) with aquifer thickness of 72 m, aquifers can be drilled at varying depths of from 2m up to 50 m. results for regions in the study are also shown in the table.

The results from this work general agrees with similar works in some parts of the Niger delta where aquifer depths have been determined as close to the surface as 5 m [10]. It is advised that boreholes in this region should be drilled at least 30 m below the surface to get clean groundwater as oil prospecting is rampant in most parts of the region.

## 5 Conclusion

This study determined aquifer depths and thickness in Ogba/Egbema/Ndoni in Rivers State, Nigeria, using vertical electrical sounding. The results reveal that the regions have good subsurface aquifers that are productive with aquifer depths in some parts 2 m below the surface and some regions having aquifer thickness as much as 72 m. Portable boreholes can be drilled in the region at depths of 20 m to get good domestic ground water.

## Compliance with ethical standards

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*Disclosure of conflict of interest*

No conflict of interest.

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