Groundwater Prospecting in Oru, Southeastern Nigeria Using Vertical Electrical Sounding Data

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DOI: 10.56201/rjpst.v6.no3.2023.pg23.32

ABSTRACT
Groundwater prospecting in Oru area, Southeastern Nigeria was carried out using Vertical Electrical Sounding (VES). The study area is located within the geographic coordinates: Latitude $5^0 39^I$N to $5^0 50^I$N and Longitude $6^0 50^I$E to $6^0 59^I$E. The aim of this work is to delineate the shallow aquifers from the deep zones. The study area is underlain by the Benin Formation which is within the Niger Delta Basin. Twenty-Seven (27) VES data were acquired using a Schlumberger array with a maximum electrode separation of AB/2=350 metres and interpreted using 2D-inverse interpretation resistivity software. The results revealed that the lithology of the area is mainly composed of sands and alternating sequence of clays and silts. The thickness of sands increases from Awo-Omamma to Ohakpu while it decreases towards Ura-Akatta and Amagu communities. Results show that the value of the apparent resistivity ranges from 2000Ωm to 22,000Ωm. The aquifer thickness in the study area varies from one location to another. In terms of depth of occurrence of the aquiferous layer/medium, there are shallow aquifers at Amagu and Amiri at 16m and 15m respectively; while at Ura-Akatta, Akwada-Aji, Ubachima etc, the aquifers occur at 32m, 39.9m and 38m respectively; but, at Umuokwe Awo-Omamma, Eziani-Mgbidi, Eziama-Ubulu, Umuezike Amadehi Oburu etc. the aquifers occur at 50.3m, 54m, 56.5m, and 63.5m respectively. Based on the information obtained from the resistivity models, it showed that the groundwater potential in the study area is very promising and prolific and this was based on the fact that the depth of occurrence of the aquifer and its thickness is large.

Key words: *Groundwater, Resistivity, Vertical Electrical Sounding, Lithology, Aquifer, Depth, Interpretation*

1.0 INTRODUCTION

An **aquifer** is an underground layer of permeable rock or sediment that contains water or a rock layer that stores and allows the flow of ground water; while a groundwater can be defined as water that is collected and is stored underground (Austin C. Okonkwo and Gabriel Z. Ugwu,2015). Some aquifers lie deep under layers of impermeable rock while other aquifers lie just beneath the topsoil.

Aquifers can be found all over the world. They lie under deserts as well as wet regions. An aquifer might be a bed of sand or gravel only a few metres thick. It might also be an enormous layer of sandstone, several hundred metres thick, holding water in countless pore spaces.

The problem of portable water supply to the inhabitants of rural areas of Nigeria has persisted for quite a long time. Efforts made by previous governments have not yielded good results. With the non-availability of portable water in these areas, environmental sanitation has degenerated to a level where water borne diseases are very rampant in many communities. In determined efforts to alleviate the rural water supply problems, many private or individual and various governments (both federal, states and local governments in Nigeria) have engaged in geophysical investigations for groundwater supply in most parts of South-Eastern Nigeria in order to ameliorate the hardship. Groundwater exploration and exploitation is generally carried out with the use of Vertical Electrical sounding (VES) (Obiajulu O. O,et al 2016). This is because the successful exploitation of both the basement and sedimentary terrains in Nigeria in the area of groundwater requires a detailed understanding of the hydro-geological characteristics of the aquifer units. This is particularly important in view of the localized nature of the basement and sedimentary aquifers. The most probable use of the electrical resistivity survey is in the hydro-geological investigation in a relation to the aquifer delineations, lithologic boundaries and geological structures to provide subsurface information. This very method has been in use so extensively in the groundwater investigation in the basement complex terrains and also in the sedimentary basins. Hence, drilling programmes for groundwater development in areas of sedimentary terrain are generally preceded by detailed geophysical investigations (C. N. Nwankwo, and G. O. Emujakporue, 2012).

The study area is underlain by Benin formation. These rocks are inherently characterized by high porosity and high permeability. The highest groundwater yield in sedimentary terrains is found in areas where thick sand/sandstone underlies in the subsurface.

However, water is vital to all life on Earth. No human, animal or plant can live without it. It is essential and there is no substitute. Water consumption has doubled at least twice this century and some estimated it could double again within the next 20 years. Next to air, water constitutes the most essential resource need to man (Brown, 1984). He can survive longer without food than water

2.0 THE GEOLOGY OF THE STUDY AREA

The study area is part of the Benin Formation which consists of lenticular, unconsolidated and sandy sediments. The Benin Formation has been described as “coastal plain sands”. The Benin Formation is continental in origin. The sediments of the Benin Formation were deposited during the Late Tertiary to Early Quaternary Period. The age of the Benin Formation is from Miocene to Recent and it consists of the friable sands with intercalation of shale and clay lenses (Onyeagocha: 1980). It also contains some isolated units of gravels, conglomerates, very coarse-grained sands and sandstone, Ahiarakwem, C.A. and Ejimadu, O.G. (2002). The Formation has a thickness ranging from 0 – 2100 metres. The sands and sandstones are coarse to fine and commonly granular in texture and can be partly unconsolidated, Onyekuru (1998). The sediments represent upper deltaic plain deposits. The sands may represent braided system point bars and channel fills, Apakama (2010). The shales are few and thin and they may represent black swamp deposits. The shale is the locus of several river systems; these rivers are fed by small seasonal tributaries from the shale as well as by the perennial river fed by springs that issue from the margins of sand bodies.

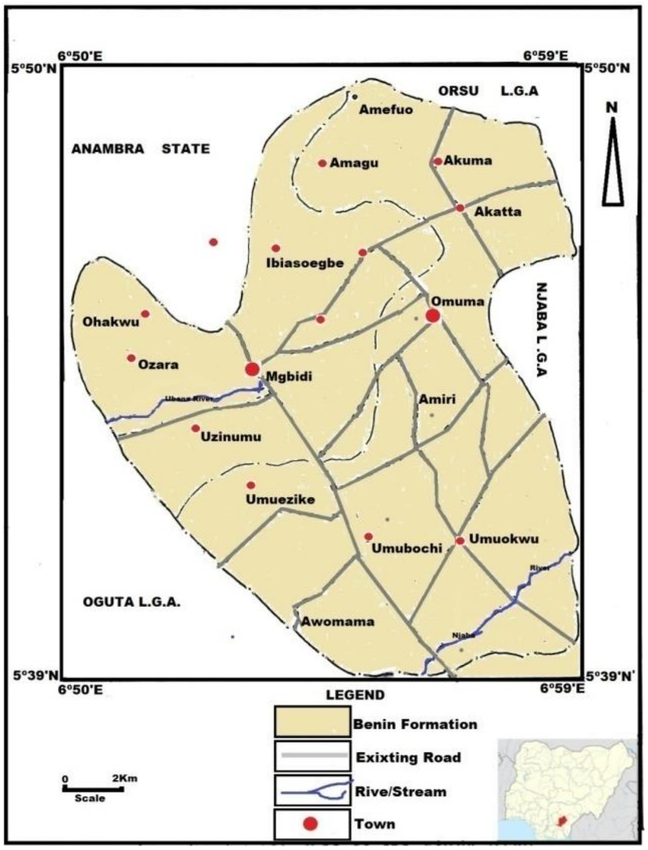

Figure 1: Geological Map of the Study Area

2.1 Hydrogeology

The source of groundwater in the study area is from the underlying coastal plain sands. This Formation has good groundwater potentials being dominantly sandy with high permeability and porosity, Ahiarakwem, C.A. and Ejimadu, O.G. (2002). A lot of boreholes have been drilled into the coastal plain sands. Data of an existing borehole drilled in the neighbouring villages and towns indicate that the depth to water table in the borehole is around 60.36m. The aquifer is quite prolific and groundwater exploitation in this community is very promising.

3.0 METHODOLOGY

The instruments employed for the data acquisition include: ABEM Terrameter SAS1000 resistivity metre, Etrex GPS, and Compass. Interpretation made use of resistivity computer modeling software by Henker (1985), IPIWIN and Sufer 12 software. The schlumberger array of the vertical electrical sounding technique was employed at maximum current electrode spacing of AB/2 of 400m for the twenty seven locations, Mohammed I. N., et al (2008). The theories of are well explained in standard texts such as Telford et al, (1976); Griffiths and King (1983), Dobrin M.S. and Savit (1988).

4.0 RESULTS AND INTERPRETATION

The data acquired are in resistance and they were transformed to resistivity by subjecting each measurement to the corresponding geometric factor. Based on Zohdy (1989), the computed apparent resistivity values were modeled using IP2WIN 2D software to produce true resistivities of the various geoelectric layers and the depths. The results of the geophysical data acquired were processed to obtain the curve types. The quantitative description of the curves identified reveal A, K, Q, H, KH, HK and KHK types of which HK and A are more predominant (Uma,1989; Mbonu, 1991).

The A type are underlain mainly by sands, sand and clay or saturated sand, H type is sand, clay and sand. The corresponding depths as determined described the curve types A, AK, KHK which constitute about 18.5% each of the total curve types. Others are: HK which has a total of 11.1% of occurrence to rank the second highest curve type. K with 7.4% occurrence, Q with an occurrence of 7.4% also, KH which also have a 7.4% curve type occurrence, HKH with an occurrence of 7.4% making them the third highest curve type and HA with a total of 3.7% curve type occurrence and which makes it the least and the fourth highest curve type among all the curve types that were identified in the study area. The general sequence of the entire curve types indicates a sequence that alternates between resistive to conductive layers, Table 1.

Table 1: Curve types and the Probable lithology

S/N	VES NO.	CURVE TYPE	CURVE CHARACTERISTICS	PROBABLE LITHOLOGY	PERCENTAGE (%)
1	1,5,6,7,8,12,26,27	A	$\ell_1<\ell_2<\ell_3$	Sand,Sand,Sand	29.6296
2	2,11,16,17,18,22	K	$\ell_1<\ell_2>\ell_3$	Sand,Sand,Sand/ Clay	22.2222
3	10,13,14,15,19,20,21,23,25	HK	$\ell_1>\ell_2<\ell_3>\ell_4$	Sand,Clay,Sand,Sand/Clay	33.3333
4	4	KHK	$\ell_1<\ell_2>\ell_3<\ell_4>\ell_5$	Sand,Sand,Clay,Sand,Clay	3.7037

5	9	KH	$\ell_1<\ell_2>\ell_3<\ell_4$	Sand,Sand,Clay,Sand	3.7037
6	3	H	$\ell_1>\ell_2<\ell_3$	Sand,Clay,Sand	3.7037
7	24	Q	$\ell_1>\ell_2>\ell_3$	Sand,Sand,Clay	3.7037

The modeled curves were interpreted based on the basic curve matching principles that yielded various curve types. The curve and models revealed the underlying lithologies/ geo-electric sections within the subsurface at these locations. The A-type are sands from surface to great depths, K-type are sands, sands and saturated sands or clay while H-types are sands, clay and sand. The corresponding depths were determined from the modeled profiles, Figures 2, 3.in the N – S and NE-SW directions. The area is underlain by sands as shown by the resistivity values and the corresponding geo-electric sections in different directions, Apakama, E.O. (2010).

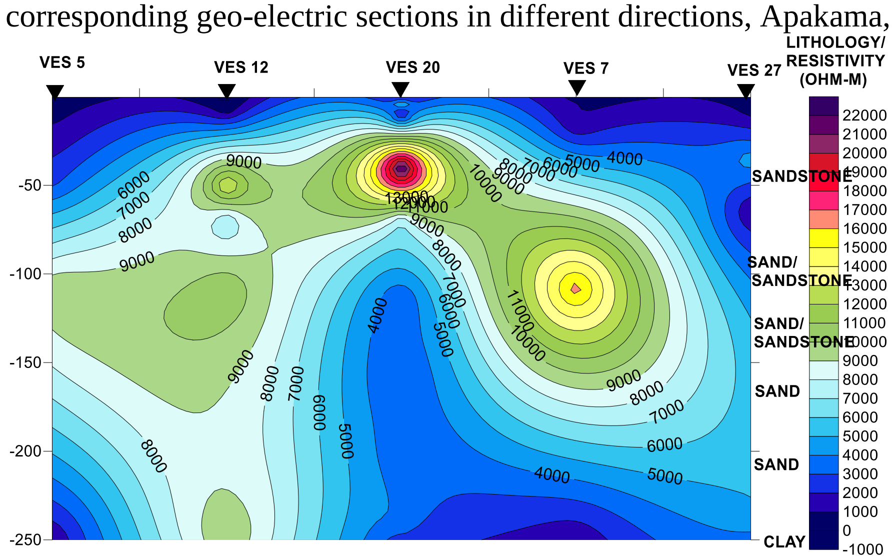

Figure 2: The Profile of the Study Area in the N – S Direction Showing the Lithology

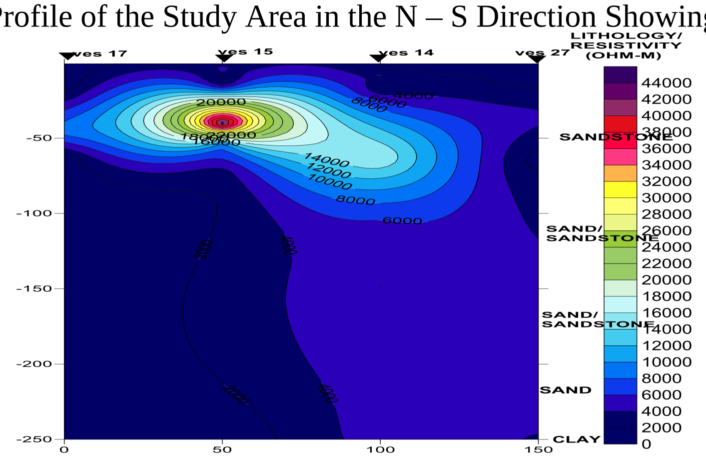

Figure 3: The Profile of the Study Area in the NE – SW Direction Showing the Lithology

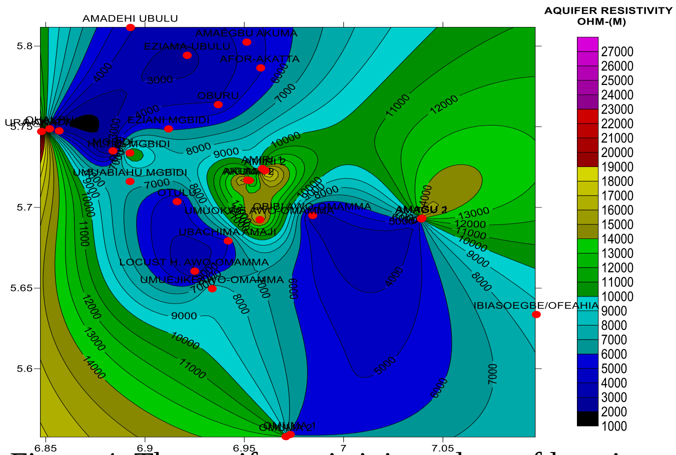

Figure 4: The aquifer resistivity values of location across the study area

The resistivities of the aquifers vary from 1000Ωm to 27000Ωm with average value of 18000Ωm. Most of the locations have aquifer resistivities from 2000Ωm to 6000Ωm in places like Ubulu, Akuma, Akata, Oburu, Otulu, Ubachima, Mgbidi and Omuma. Other places such as Ibiasoegbe, some parts of Awo-omamma, Amiri, Mgbidi have resistivities from 6000Ωm to 14000Ωm, Figure 4.

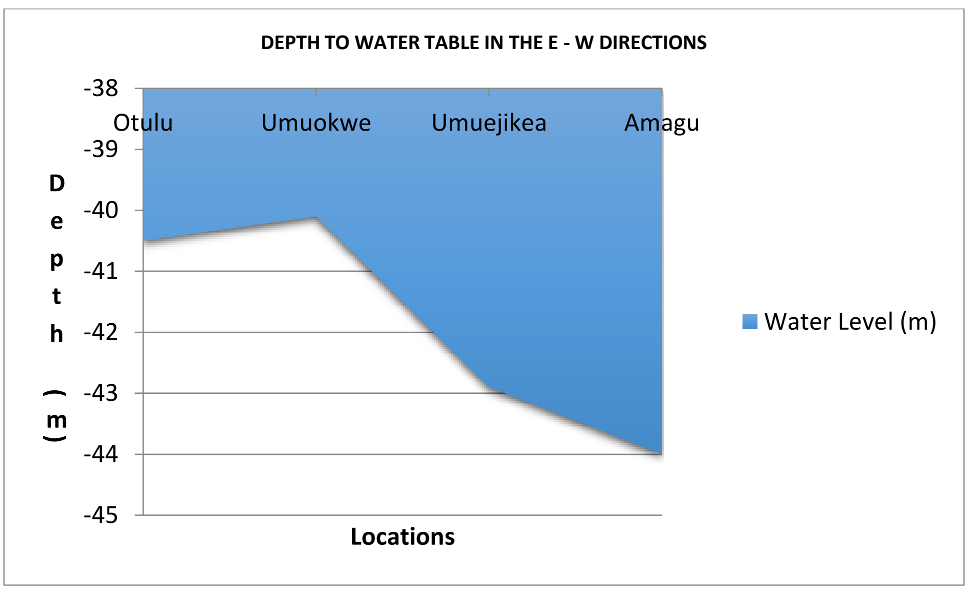

Figure 5: Depth to water table in the East – West Direction

The depth to water table decreases from east to west within the study area. Figure 5 reveals that the water level at Amagu is 44m, Umuejikea 42.9m, Umuokwe 40.1m and Otulu 40.5m. The average water level is 41.9m within this axis. The depth to water table decreases slightly in the northern part of the area to average of 40.1m. The depths to the bottom of aquifer vary from 118m to >200m describing reasonable aquifer thickness of 60m to 230m, for prolific water supply,

Figure 6. Aquifer conductivity is in the range of $6E.005^{-}\Omega$ to $0.00052^{-}\Omega$,. This implies that the locations of low conductivity are overlain by sands mainly.

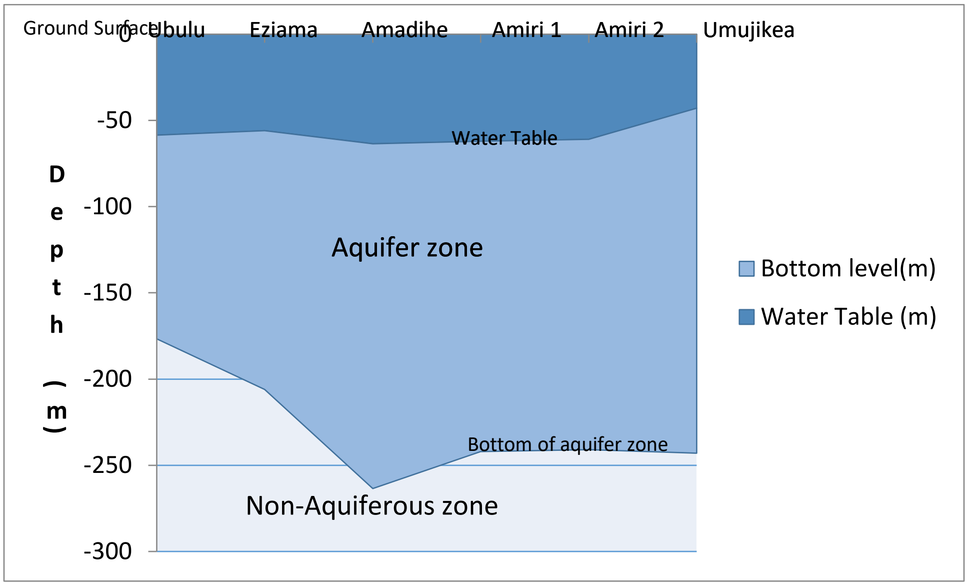

Figure 6: Depth to water table in the NorthWest – SouthEast Direction

Transverse resistance is the measured resistance along the horizontal profiling of an area of study. What that means is the resistance of an area or a ground surface varies from place to place as one moves away from his original position. The values vary from $1,000,000\Omega/m^2$ to $3,200,000\Omega/m^2$ which is good for distribution of groundwater, Figure 7.

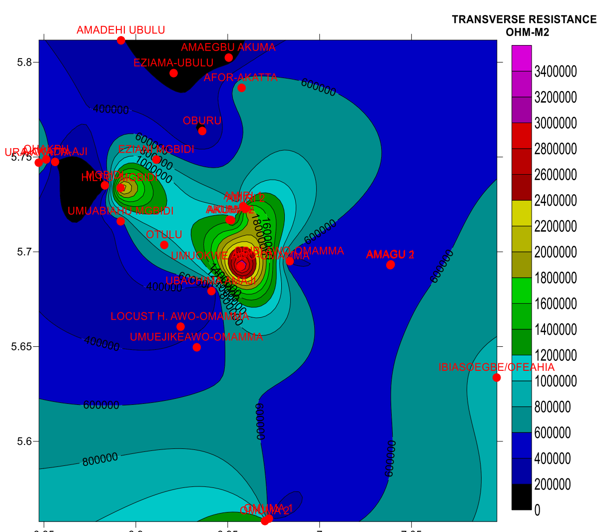

Figure 7: Image Map of Transverse Resistance (1/ohm2) of the Study Area

The conductivity is low, in the range of $6E.005^{-}\Omega$ and $0.00052^{-}\Omega$. The values in the western part vary from $0.00016\Omega^{-1}$ to $0.0005\ \Omega^{-1}$ while the eastern region $0.0001\ \Omega^{-1}$ to $0.00014\Omega^{-1}$. The clay content is minimal and has little or no effect on the quality of water, Ahiarakwem, C.A. and Ejimadu, O.G. (2002). The materials that contaminate the water are minute. This implies that there is less mineralization within the area is suitable for groundwater exploitation as the aquifers are prolific.

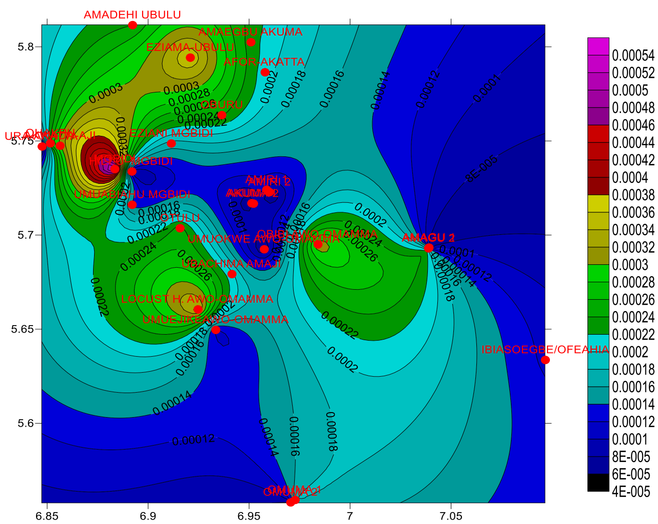

Figure 8: Image Map of Longitudinal Conductivity, Ω^{-1} of the Study Area

Transmissivity is the ability of a rock unit/layer to allow fluid to pass through it. For a rock unit to be said to have a high transmissivity, what it means indirectly, is that the rock unit/layer in question must and should be porous and permeable, Akaolisa, C., 2006. Aquifer Transmissivity is measured in m^2/day and it is a product of Hydraulic Conductivity and Thickness of an Aquifer unit. The transmissivity here was estimated by taking both the products of the Dar-Zarrock parameter of transverse resistance and the diagnostic constant K**σ**. The range of transmissivity values is from 200000 m^2/day to 3200000m^2/day, Figures 9. This means that transmissivity is high acroos the study area.

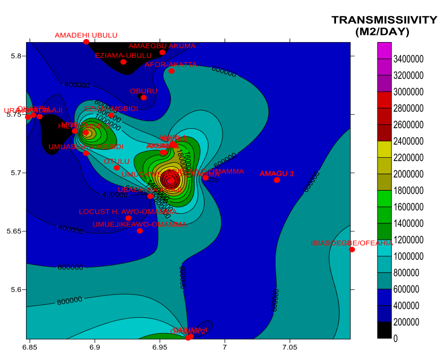

Figure 9: Showing the Image Map of Transmissivity (m^2/Day) of the Study Area

Conclusion

The area is underlain by sediments of sand and clay. The top soils have average values of resistivities between 1000Ωm to 44000Ωm (Aboh and Osazuwa, 2000), Nwugha et al, 2017. The sand zones have resistivities of 2000Ωm to 22000Ωm and the clay resistivities are 10Ωm to 400Ωm. The resistivities of layers of undefined depths are in the range of 4000Ωm to 10000Ωm for the sands and 100Ωm to 500Ωm for the clay units. The aquifer resistivities are in the range of 1000Ωm to 27000Ωm and average of 18000Ωm. The aquifers identified in these locations are mainly unconfined. The depths to the top of aquifers are from 40m to about 64m, the thicknesses range from 100m to 231m. The conductivity is low, in the range of $6E.005^{-}\Omega$ and $0.00052^{-}\Omega$. This implies that there is less mineralization within the area is suitable for groundwater exploitation as the aquifers are prolific. The range of transmissivity values is from 200000 m^2/day to 3200000m^2/day

REFERENCES

Ahiarakwem, C.A. and Ejimadu, O.G. (2002) Geochemical Properties of Groundwater in Orlu Area of Imo State, South-eastern Nigeria. Water Resources Journal of Nigerian Association of Hydro-geologists (NAH), Vol.13, pp 19-22.

Akaolisa, C., 2006. Aquifer Transmissivity and Basement Structure Determination using Resistivity Sounding, Jos, Plateau State, Nigeria, Environmental Monitoring and Assessment, Pages 27-34.

Apakama, E.O. (2010) Determination of the surface deposit of Orsu South L.G.A. and its environs using VES. Unpublished B.Tech research, FUT, Owerri.

Austin C. Okonkwo1 and Gabriel Z. Ugwu2 (2015). Determination of Dar-zarrouk parameters for prediction of Aquifer protective capacity: A case of Agbani Sandstone Aquifer, Enugu State, Southeastern Nigeria. International Research Journal of Geology and Mining (IRJGM) (2276-6618) Vol. 5(2) pp. 12-19, March, 2015 Available online http://www.interesjournals.org/irjgm

Brown, H., (1984):The Challenge of Man's Future; The Viking Press, New York.

C. N. Nwankwo and G. O. Emujakporue (2012). Geophysical Method of Investigating Groundwater and Sub-Soil Contamination,–A Case Study https://www.researchgate.net/publication/272770617 **Article** May 2012 DOI: 10.5923/j.ajee.20120203.02 DOI: http://dx.doi.org/10.14303/irjgm.2015.107

Ekwe, A.C., Onu, N.N., and Onuoha, K.M., 2006: Estimation of Aquifer Hydraulic Characteristics from Electric Sounding Data: The Case Study of Middle Imo River Basin Aquifers, South Eastern Nigeria. Journal of Spatial Hydrology; Vol. 6, No 2, pages 121-132.

Fetter, C.W., 1990: Applied Hydrogeology, CBS Publishers and Distributors, New Delhi, India, 567p.

Lohman, S.W., 1972: Well Hydraulics; US Geological Survey Professional Paper 708

Mbonu, P.D.C., Ebeniro, J.O., Ofoegbu, C.O. and Ekine A.S., 1991: Geoelectric Sounding for the Determination of Aquifer Characteristics in Parts of Umuahia Area of Nigeria, Geophysics, 56(2): 284-291.

Obiajulu O. O., Okpoko E. I. and Mgbemena C. O. (2016). Application Of Vertical Electrical Sounding To Estimate Aquifer Characteristics Of Ihiala And Its Environs, Anambra State, Nigeria 493XARPN Journal of Earth Sciences VOL. 5, NO. 1, JUNE 2016 ISSN 2305-493X www.arpnjournals.com

Opara, A.I., Onu, N.N. and Okereafor, D.U., 2012: Geophysical Sounding for the Determination of Aquifer Hydraulic Characteristics from Dar-Zurrock Parameters: A Case Study of Ngor Okpala, Imo River Basin, Southeastern Nigeria, Pacific Journal Science Tech. 13:590-603.

Uma, K.O., 1989: An Appraisal of the Groundwater Resources of the Imo River Basin: Nigerian Journal of Mining and Geology, Vol.25 No. 1 and 2, pp305-315

Zodhy, A.A.R., Eaton, G.P., and Mabey, D.R., 1974: Application of Surface Geophysics to Groundwater Investigations, United States Geological Survey Papers, 123p.