Near Surface Aquifer Characteristics and Groundwater Potential in Onicha-Ukwuani, Delta State, Nigeria.

Julius Otutu Oseji, Ph.D.

Department of Physics, Delta State University, Abraka, Nigeria.

*E-mail: oseji2002@yahoo.com

ABSTRACT

The execution of water borehole projects are not only expensive but the existence of failed boreholes and dry wells pose a great concern to the inhabitants of Onicha-Ukwuani. In order to have a reliable and good-quality source of drinking water, many age grades, communities, and private individuals embarked on borehole projects. A lot of these projects were incorrectly sited; some function seasonally, and others have been abandoned. These failures are mainly due to the inability to carry out geophysical surveys that could delineate near surface aquifers and groundwater potential within Onicha-Ukwuani.

Vertical Electrical Sounding (VES) data were acquired from seven locations evenly distributed within Onicha-Ukwuani communities. The apparent resistivity values obtained in the field were plotted against half electrode spacing. Interpretation of data was done quantitatively and qualitatively and brought into bare the knowledge of the local geology of area. Based on the geoelectric section, which shows the contrast between the drillers log and the resistivity measurements at a common depth of penetration, three near surface aquifers that are not confined were identified in Onicha-Ukwuani.

Prospective groundwater exploitation is therefore recommended in the second aquifer at a depth of between 20.00 m – 40.00 m within the medium to coarse grained sand formation. This depth must not be exceeded at Onuga and Amoji for sustainable groundwater development.

The contour map of Onicha-Ukwuani and environs revealed that groundwater flow direction is toward the southeastern region. Hence, the aquifer system acts as a recharge to the streams and lakes within the area. In the event of pollution, groundwater within the southeastern part of Onicha-Ukwuani will be densely contaminated. Therefore communities within the North, Northeast, as well as the West, and Southwest regions should take steps to ensure that land use activities will not pose threat on the quality of groundwater.

(Keywords: groundwater potential, vertical electrical sounding, VES, aquifer, contour map, driller log, and geoelectric section)

INTRODUCTION

Onicha-Ukwuani is in the Ndokwa land area of Delta State, Nigeria. The inhabitants are mostly subsistence farmers who depend on the slow running water from the streams, creeks, and hand-dug wells for their domestic water needs. In order to have a reliable and good quality source of drinking water, many communities, private individuals, and age grades embarked on borehole projects. Virtually all the borehole projects were executed for and on behalf of the ever growing population of Onicha-Ukwuani without geophysical surveys. Not surprisingly, many of them were unsuccessful. The existence of dry wells in Onuga at Ugiliamai and Amoji are evidences of failed boreholes.

Therefore, one of the major problems faced by most communities in Onicha-Ukwuani is the acute shortage of water. Water is not only a basic necessity to life but is essential for human existence on earth; its proximity has a great influence on human activities such as domestic, agriculture and recreation {13}. Potable water is not only commonly found and its provision limits the setting up of villages and towns to places where there is an existence of supply {13}.

Hence the need for Environmental Geophysical Surveys cannot be overemphasized in getting background information on the distribution, formation and type of the near surface aquifers in

Onicha-Ukwuani as a means of delineating the areas that may be prone to groundwater contamination and determine the locations and depths appreciable and potable water supply could be achieved.

This work was carried out to establish baseline geophysical data and hydrological characteristics using the Schlumberger arrangement (a Vertical Electrical Sounding) and drillers log from the study area. The vertical electrical method was chosen for this study because the instrumentation is simple; field logistics are easy and straightforward and the analysis of data is less tedious and economical {24, 25, 7, 1, 9, 10, 14, 11 and 19}.

The resistivity method has been used successfully in investigating groundwater potential. Previous studies {16} have used the method to investigate the aquifer characteristics and groundwater potential in Kwale, Delta State, Nigeria. Other researchers {17} have also used the method to determine the groundwater potential in Obiaruku and environs. Oseji et al. {16} used the same method to explore for groundwater in a sedimentary environment. Ako and Osunde {2} used the method to delineate aquifer units and established the thickness and depth of water bearing formation. Okwuese {15}, used the method to determine the groundwater potential at Obudu basement area.

The resistivity of water may vary from 0.20 Ohm-m to over 100.00 Ohm-m depending on its ionic concentration and the amount of dissolved solids. Resistivity of natural waters without clay varies from 1.00 Ohm-m to 1000 Ohm-m while that of clay only varies from 1.00 Ohm-m to 120 Ohm-m {25}. The type of curve and the modified table of resistivity of water and sediments by {11} were used as guides in the interpretation of the resistivity data in terms of probable aquifer.

Boreholes were drilled at some locations within the study area close to the VES location and the drillers log obtained were correlated with the geoelectric section to obtain geologic interpretation of the area. The Global Positioning System (GPS) of type 310 was used to measure the longitude, latitude and the surface elevations with respect to the mean sea level at points within the VES Stations for contour mapping.

LOCATION OF THE STUDY AREA

The study area (Onicha-Ukwuani) is in Ndokwa land area of Delta State, Nigeria. It comprised of five communities: Ike-Onicha, Eweshi, Amoji, Ibabu, and Ugiliamai and lies between latitudes 5^{0} 83^{1} N to 5^{0} 87^{1} N and longitudes 6^{0} 25^{1} E to 6^{0} 45^{1} E.

Onicha-Ukwuani is bounded in the north by Utagba-Uno; the south by Ogume and Utagba-Ogbe Communities; the east by Afor and Utagba-Ogbe communities; and in the west by Ebedei and Umukwata communities. The area is accessible by network of roads and footpaths that are not tarred. However, the Kwale/Ogwuashi-Uku express road to Asaba is the major tarred road within the study area. The base map of Onicha-Ukwuani Showing the VES, drilled hole and hand-dug well locations are shown in Figure 1.

CLIMATE AND VEGETATION

The term vegetation refers to the plant coverage of an area. Onicha-Ukwuani is in an area of low-lying sedimentary terrain, generally flat and has gentle slope. The vegetation is that of the tropical rainforest belt characterized by dense vegetation cover consisting of evergreen forest of tall trees with undergrowth of climbing plants that are closed together along the streams and creek channels and this normally typifies primary vegetation while the presence of grassland with sparse trees and shrubs typified the secondary vegetation pattern within the vegetation belt.

The superficial deposits of the top loamy soil reveal an overlying range between loose and smooth sandy soil to clayey soil formation and this gave the sediments its characteristics off-white to grey color. This is why the area is commonly referred to as *"Onicha Ikalakume Eja Nzu".*

The inhabitants of Onicha-Ukwuani are mostly subsistence farmers. They grow crops such as; yam, groundnuts, melon, and cotton as well as native beans called "*Otuku*". However, they also grow perennial crops like palm trees and rubber trees. Onicha-Ukwuani has local textile industries that produced cotton cloth "*Calico",* hence they are popularly known as "*Onicha-mkpuluoko*".

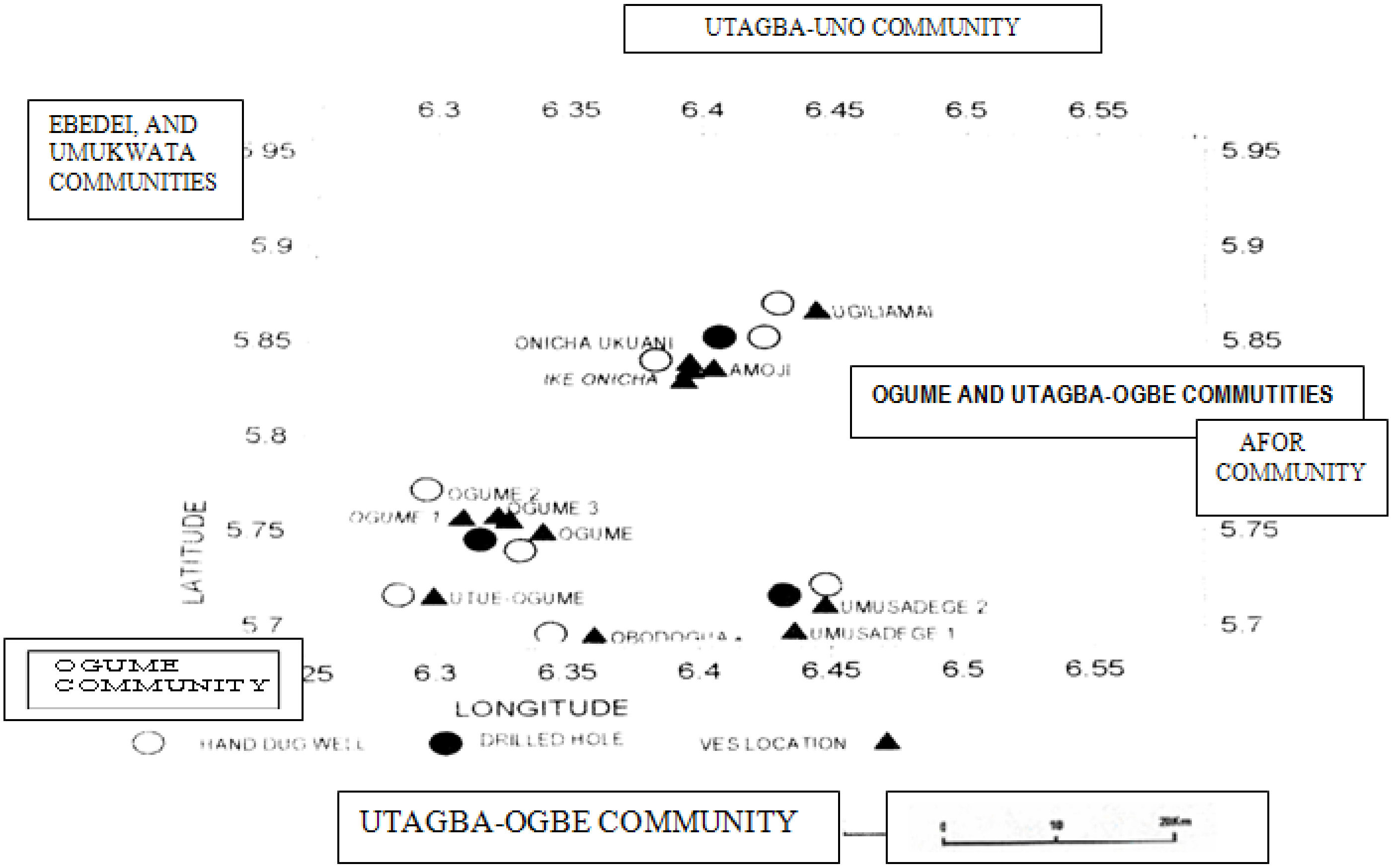

Figure 1: Base Map of Onicha-Ukwuani Showing VES, Drilled Holes, and Hand-Dug Well Locations.

There are no visible outcrops within the area. During rainfall, there is relatively high rate of infiltration into the subsurface through the unconsolidated soil. This reduces surface run-off.

The major streams in the area are the "*Odu*" (the stream between Onicha-Ukwuani and Umusam in Utagba-Uno), the "*Iyi-esuesu*", "*Iyi-Obiuku*", "iyi-Obinta "*Ugbo-Oluku*", "*Akpu-Adofi*", and "*Ugbo-Ezenigbo*" that linked "*Oyese*" in Ogume. However, a swamp that never dries up "*Okude*" and her tributaries "*Tukutuku*" are also within the study area.

The stream that supplies the major domestic water to the inhabitants has been polluted by the activities of the farmers (*washing of melon*) and fermentation of cassava (*Akpu*). Some people wash their clothes and other household effects into the stream and most septic discharges occur in the stream. The above activities made water from the stream unhygienic and unsafe for drinking and other domestic purposes.

Generally, two major wind systems influence the climate of Onicha-Ukwuani. They are the northeast trade wind blowing cold dry air from the Sahara and the southwest trade wind blowing cold moist air from the Atlantic. The south-west winds prevails almost throughout the year, that is from March – October, while the north-east trade wind is responsible for the cold dry period (Harmattan) which influences the area for about four months (November – February). This brings about two types of seasons within a year; the raining and dry seasons, respectively. During the raining season, the area experiences double rainfall maximal with a period of short break around August popularly called "August break". The dry season usually known as Harmattan period is cold, dry, and dusty with no rain. This is usually very severe in the months of December and January.

The major factor that is responsible for the changes in the climate of Onicha-Ukwuani includes the falling of trees (deforestation) and farming thereby causing the climate prevailing in the area to be quite distinct from that of the surrounding since the thermal equilibrium of the area have been altered {18}.

METHODOLOGY AND DATA ACQUISITION

Three major stages of field procedures were used in this research. The first stage is the surface resistivity sounding using Schlumberger configuration. In this method, current is introduced artificially into the earth through a pair of electrode pinned to the ground (current electrode) and the resulting potential difference due to the current is measured through another pair of electrode (potential electrode) that is also pinned to the ground. The arrangements of the current and potential electrodes were in such a way as to maintain a straight line {22}.

Any subsurface variation in resistivity alters the current flow, which in turn affects the distribution of electric potential at the surface {5]. This process yields a rapidly decreasing potential difference across P_1, P_2, which ultimately exceeds the measuring capabilities of the instrument. At this point, a new value for potential difference was established, typically five times greater than the proceeding value {19}. The systematic movement of the current and potential electrodes continued until the survey was completed {12}.

In the second stage, boreholes were drilled at some locations within the study area and the drillers log obtained were correlated with the geoelectric section to obtain geologic interpretation of Onicha-Ukwuani.

In the third stage, a GPS system of type 310 was used to measure the longitude, latitude and the surface elevations with respect to the mean sea level at points within the VES stations in Onicha-Ukwuani. The mean sea level is the lowest surface within the earth. All elevations are taken with respect to the mean sea level.

With the aid of a meter rule/tape, the depths to the water levels in the hand-dug wells within Onicha-Ukwuani and environs were measured and recorded (Direct Bore-Hole Logging). The surface elevations at different points varies due to topographic variations, the true water levels were obtained by subtracting the measured depths to the water level in the hand-dug wells (Direct Bore-hole logging) from the surface elevation to get uniform water level {11, 36, 10 and 14} and hence reduce topographic variations.

This uniform water level coincides with the static water level in the case of an unconfined aquifer while it is the piezometric surface if the aquifer is confined {4, 3 and 6}.

Let D_{wl} = the depth from the surface of the earth to the water level in the hand-dug wells (Direct Bore-hole logging)

E = the surface elevation with respect to the mean sea level

S_{wl} = the true or uniform water level otherwise known as the static water level in the case of an unconfined aquifer.

Therefore $S_{wl} = E - D_{wl}$

The values of the static water levels were contoured on the map of Onicha-Ukwuani and environs by joining equal values of static water levels with a line and making sure that none of the lines overlapped or cut a cross each other. These lines represent the water table contours. According to {11, 10, and 14}, groundwater flows from the highest values of contour lines to the lowest values in a direction perpendicular to the contour lines.

ANALYSIS OF THE FIELD DATA

The analysis of the field data were carried out for each of the stations and the curved matched results were presented in the field to gain first hand information on the nature of the curves. The resistivity and thickness obtained from the partial curve matching were improved upon by employing an iterative computer program following the main ideas of {23 and 24} to obtain the layers parameter (resistivity, thickness and depth). Samples of the curves are shown in Figures: 2, 3, 4, and 5. Here, the number of geoelectric layers and their corresponding specific resistivities were first taken to be equal to the number of measurable points and difference of adjacent current electrode spacing, respectively.

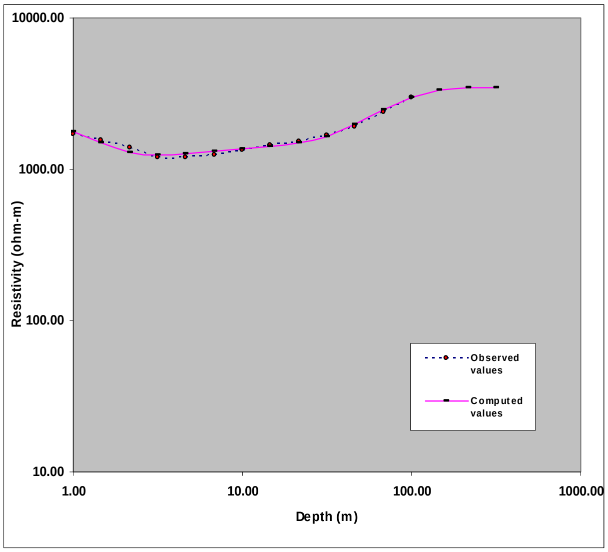

Figure 2: Resistivity Sounding Interpretation for VES 1 (Ugiliamai, Onicha-Ukwuani) showing Observed (Field) and Theoretical Resistivity Curves.

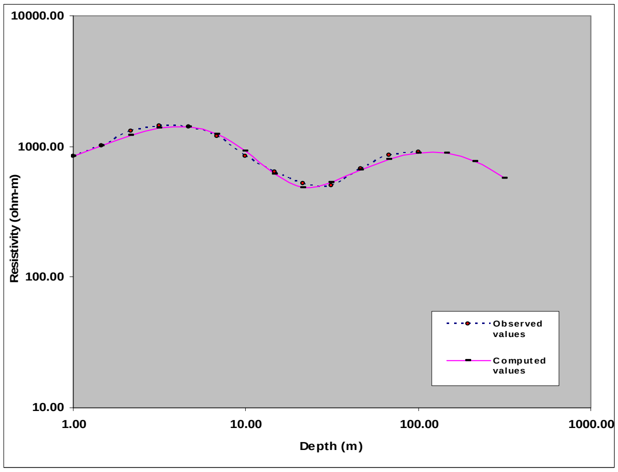

Figure 3: Resistivity Sounding Interpretation for VES 2 Along Onuga, Ugiliamai Onicha-Ukwuani, showing Observed (Field) and Computed Resistivity Curves.

Layer parameters were consequently modified in iterative manner until subsequent iteration yields no improvement on the root mean square rms) error values in percentage. The numbers of layers were notified based on the number of inflation points and it is modeled by showing the resistivity per layer versus depths in a step function.

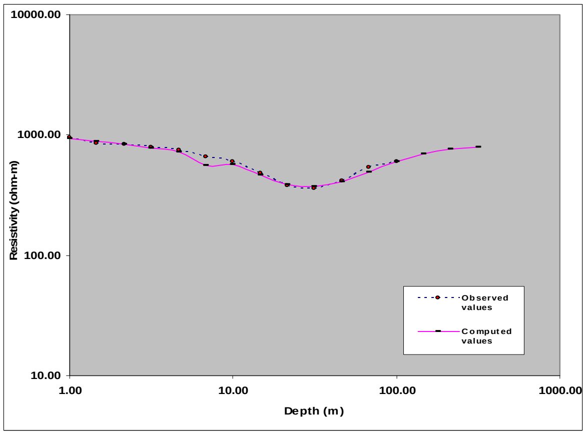

Figure 4: Resistivity Sounding Interpretation for VES 3 along the major Road in Amoji Onicha-Ukwuani, showing Observed (Field) and Computed Resistivity Curves.

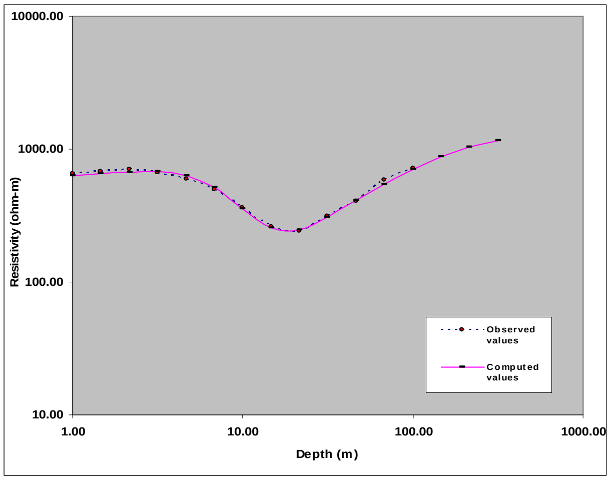

Figure 5: Resistivity Sounding Interpretation for VES 4 Ike-Onicha by Okpala-Uku's Palace, Onicha-Ukwuani showing Observed (Field) and Computed Resistivity Curves.

Samples of the corresponding step functions are shown in figures: 6, 7, 8 and 9.

The numerous layers that were generated by the computer were grouped into relevant geologic depth intervals called geoelectric sections {Plate1}.

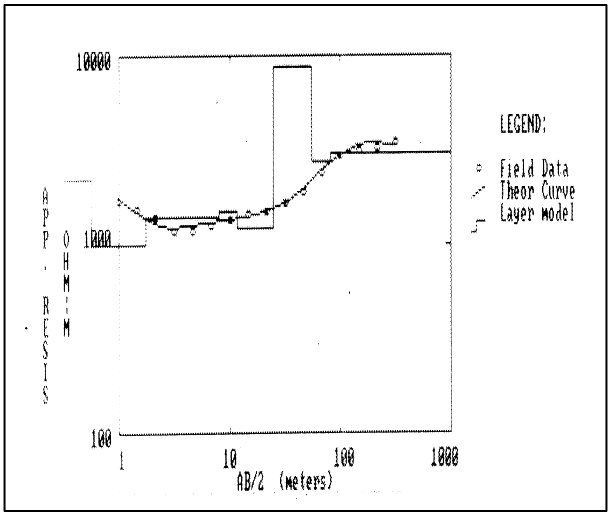

Figure 6: Field Data, Theoretical Curve, and the Layer Model of VES 1 (Ugiliamai, Onicha-Ukwuani) in a Step-Function.

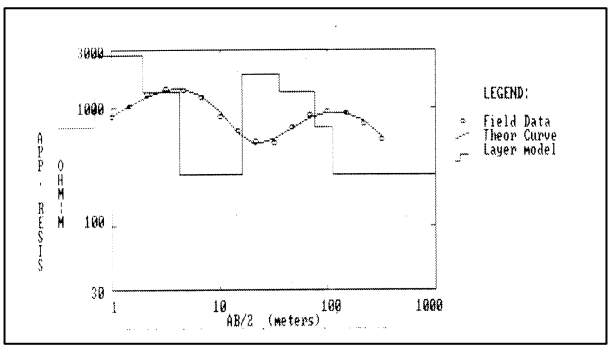

Figure 7: Field Data, Theoretical Curve, and the Layer Model of VES 2 along Onuga, Ugiliamai Onicha-Ukwuani in a Step Function.

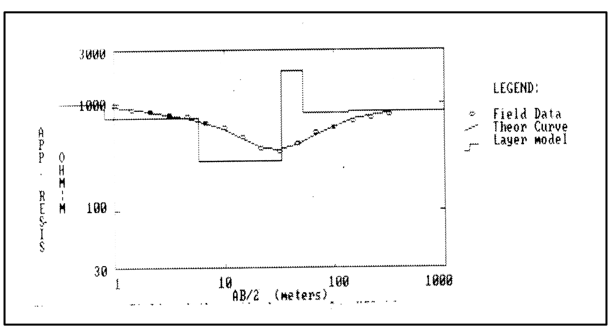

Figure 8: Field Data, Theoretical Curve, and the Layer Model of VES 3 along the major Road in Amoji Onicha-Ukwuani in a Step Function.

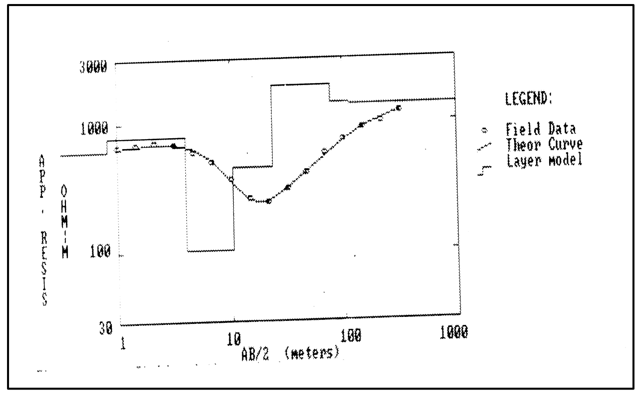

Figure 9: Field Data, Theoretical Curve, and the Layer Model of VES 4 Ike-Onicha by Okpala-Uku's Palace, Onicha-Ukwuani in a Step Function.

RESULTS AND DISCUSSIONS

Onicha-Ukwuani is in the Sombreiro Warri deltaic plain deposit invaded by mangrove. The interpreted sounding curves from the locations at Ugiliamai, Onuga, Amoji, Eweshi, and Okpala-Uku's palace, Oseji compound and along Ogume road within Ike-Onicha in Onicha-Ukwuani shown in VES 1, 2, 3, 4, 5, 6 and 7 revealed four – five geoelectric layers. (Plate 1).

Qualitative analysis of the curve types show that the area basically have HA and KHA type curves with the exception of Amoji and Onuga that has QH and KHQ type curves, respectively.

The first geoelectric layer is the topsoil with resistivity values ranging from 200.00 Ωm – 2000.00 Ωm and a thickness of between 0.10 m – 0.50 m. The high resistivity values of the first layer is due to the dried nature of the superficial deposits, which revealed an overlying range between loosed fine grained sand to sandy clay formation that gave the area its characteristics off-white to grey color.

The second geoelectric layer consists of clay to clayey sand formation. The clayey sand layer contains little water, but it is not a good aquifer. However, this is the first aquifer with resistivity values ranging from 24.00 Ωm – 81.00 Ωm within the clay region and 100.00 Ωm – 400.00 Ωm in the clayey sand region.

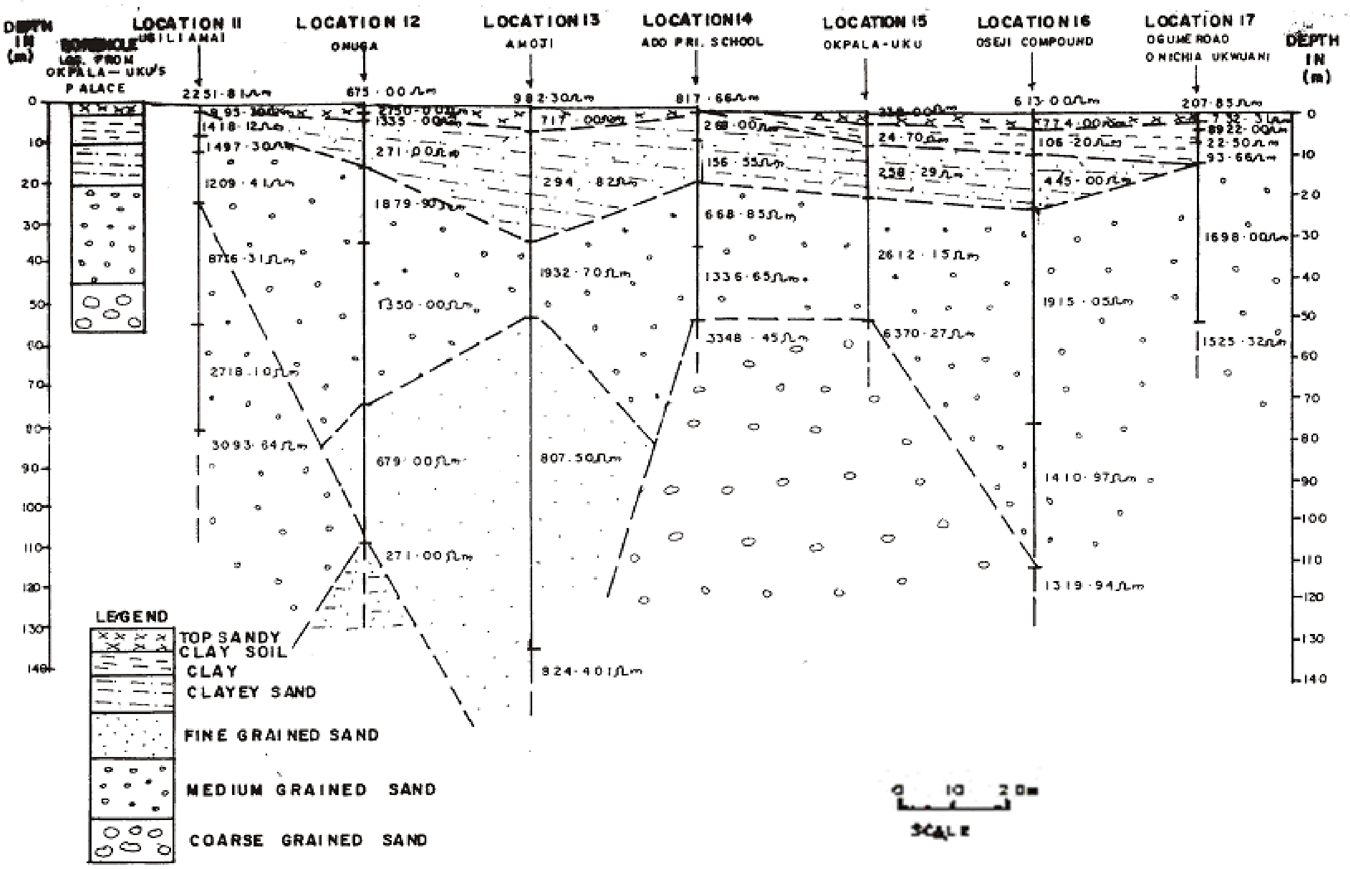

Plate 1: Geoelectric Section of Onicha-Ukwuani and Environs.

The thickness ranges from 0.2. m – 0.80 m in the clay formation and 0.50 m – 25.00 m in the clayey sand formation. The clay may act as a confining bed but because of its small thickness, groundwater may be contaminated in the event of pollution. It is therefore no an encouraging zone for groundwater development.

The third geoelectric layer consists of medium-grain to coarse-grained sand formations, which constitutes the second aquifer. This is the best aquifer across Onicha-Ukwuani. It has a thickness of between 15.00 m – 50.00 m. The depth to this aquifer is between 15.00 m – 35.00 m with resistivity values ranging from 1000.00 Ωm – 2000.00 Ωm.

The fourth geoelectric layer corresponds to a more coarse-grained sand formation and this is the last layer with the exception of Onuga that has a clayey sand formation in the fifth layer diagnostics of brackish water and/or clay. This high conductive layers overlying and underlying the aquifer at Onuga makes it a semi-confined aquifer while the rest aquifers are not confined.

From the above analysis, three near surface aquifers were identified in Onicha-Ukwuani and environs. The first aquifer consists of clayey sand formation, which is not an encouraging formation for groundwater development. The depth to this aquifer is between 1.00 m –10.00 m with a varying thickness of between 2.00 m-25.00 m.

The second aquifer consists of medium to coarse grained sand formations and occurs at an average depth of between 15.00 m – 35.00 m.

The third aquifer at Ugiliamai, Eweshi by Adoh primary School and Okpala-Uku's palace in Ike-Onicha consists of more coarse sand formation at a depth of about 55.00 m while that at Onuga and Amoji has fine-grained sand formation at a depth of about 110.00 m.

Meanwhile, the second and third aquifers are the best aquifers for groundwater development except in Onuga and Amoji that has fine-grained sand formations in the third aquifer, in which case, the best aquifer is only in the second aquifer.

Hence, the best region for groundwater development is the medium grain to the coarse-grained sand formations. Prospective groundwater exploitation is therefore recommended at a depth of between 20.00 m – 40.00 m in Onicha-Ukwuani and environs. This depth must not be exceeded at Onuga for sustainable groundwater development.

CONCLUSION

Based on the geoelectric sections, which shows the contrast between the drillers log and the resistivity measurements at a common depth of penetration (Plate 1), three near surface aquifers that are not confined were identified in Onicha-Ukwuani.

Prospective groundwater exploitation is therefore recommended in the second aquifer at a depth of between 20 m – 40 m wthin the medium to coarse grained sand formation. This depth must not be exceeded at Onuga and Amoji for sustainable groundwater development.

The contour map of Ndokwa land revealed that the groundwater flow direction in Onicha-Ukwuani is toward the southeastern region (Figure 10), hence the aquifer system act as a recharge to the streams and lakes within the area. In the event of pollution, groundwater within the southeastern part of Onicha-Ukwuani is densely contaminated. Therefore communities within the north, northeast, and west and southwest regions should take steps to ensure that land use activities will not pose a threat on the quality of groundwater.

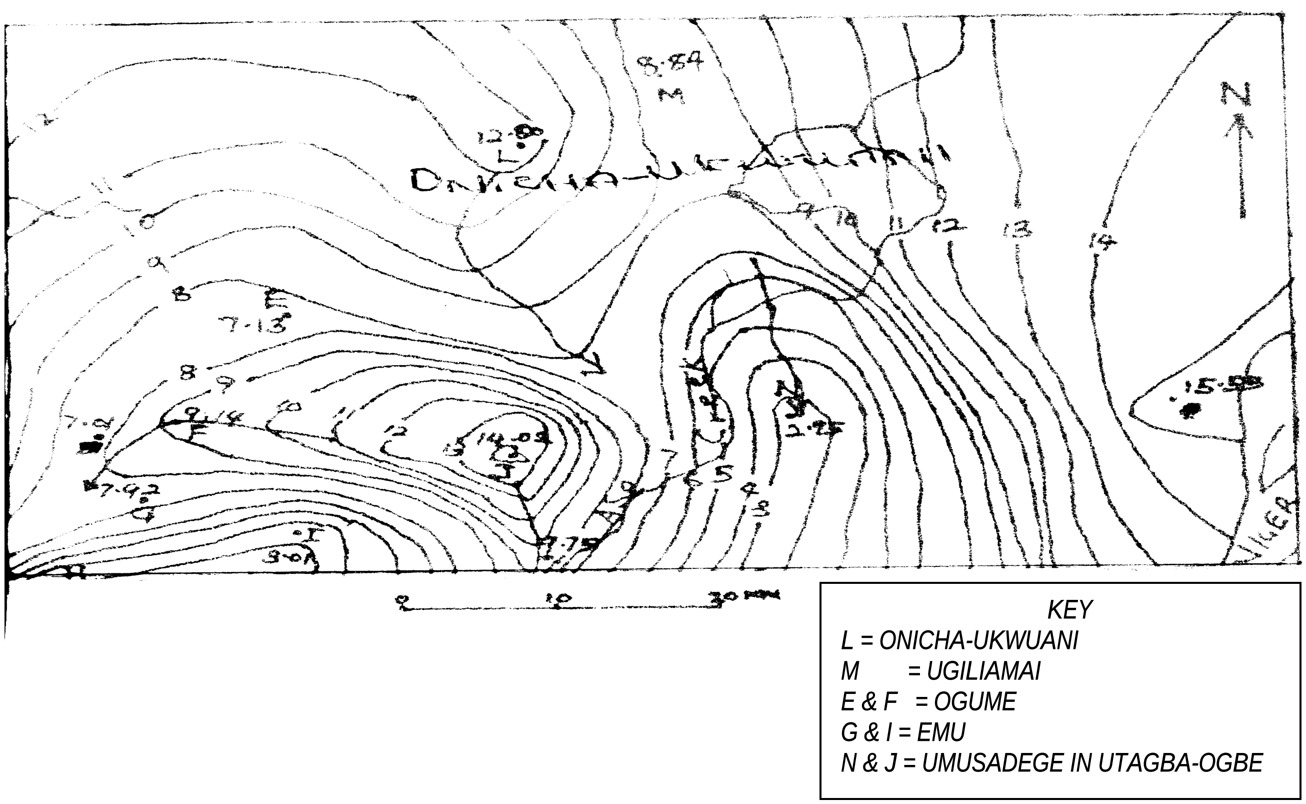

Figure 10: Contour Map of Onicha-Ukwuani showing Groundwater Flow Direction.

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ABOUT THE AUTHOR

OSEJI, JULIUS OTUTU, Ph.D. is a Lecturer in the Department of Physics, Delta State University, Abraka, Nigeria. His research focus is on groundwater and environmental geophysics, with special interest in aquifer delineation and vulnerability in sedimentary and crystalline basement terrains.

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