



**Geo-electric Investigation for Groundwater Potential in Awka, Anambra State,
Nigeria**

¹Chinwuko, A. I., ²Anakwuba, E. K., ²Okeke, H. C., ²Usman, A. O., ¹Ovwasa, M. O. and
³Okoye, I. F.,

¹Department of Geological Sciences, Federal University Gusau, Nigeria;

²Department of Geological Sciences, Nnamdi Azikiwe University Awka. Nigeria.

³Department of Physics, Federal University Gusau, Nigeria

Corresponding Author E-mail: ozochinwuko1@yahoo.com

Received: November 2015 Revised and Accepted: December 2015

Abstract

Geoelectric investigations for groundwater exploration in Awka area were made using vertical electrical sounding technique. This study is aimed at delineating the aquiferous units in parts of Awka and environs by determining their depths, thicknesses, lateral extent, resistivity of the aquiferous layers and the potential borehole depth at various locations within the area. Twenty vertical electrical soundings were carried out during the geophysical survey using the Schlumberger Array. The data was interpreted using the conventional curve matching and computer iteration method. The results revealed eight different curve types namely; K, H, QH, HK, KH, QK, KQ and KHK-curve types. 65% of all the sounding curves belong to HK and H-types whereas the remaining 35% belongs to other six curve types within the study area. The results also revealed that depths to the water saturated sandstones (aquifer) within the study area range from 30.83m at Kenneth Dike memorial Secondary School Awka to 225.03m at UNIZIK Science Village. The aquifers are therefore capable of yielding enough water that would serve the immediate environs.

Key words: Awka, Vertical electric sounding, aquifer, Imo Formation and Nanka Sands.

1.0 INTRODUCTION

The availability and access to fresh water is an important issue all over the world and Awka town is no exception. Groundwater constitutes the only reliable water supply for drinking and irrigation purposes. It is exceptionally important as a source of relatively low-cost and high-quality municipal and domestic water supply in urban centers of the developing world (Okoro *et al.*, 2010). However, recent

studies have shown that special care and skill are needed for its exploration and exploitation. Even though a renewable resource, extra effort is necessary to determine the location(s) for development and the extent of the development in order to avoid over-exploitation which may lead to serious repercussions. It is therefore necessary to employ quick and efficient methods for

groundwater exploration especially in these days of scarce resources.

Therefore, electrical resistivity method which is one of the geophysical methods can now contribute substantially towards this initiative and can greatly reduce the number of necessary pumping tests, which are both, expensive and time consuming. The subsurface information inferred from this survey give a better knowledge of the aquifer systems and a more realistic picture of groundwater potential of any area (Anakwuba *et al.*, 2014,). This method has been

2.0 METHODOLOGY

2.1 Location of the Study Area

Awka is located between latitude 6°10'N to 6°13'N and longitude 7° 02' E to 7° 04' E and is the capital of Anambra State, one of the 36 States of the Federation and and one of the five States in the South-East geo-political zone

successfully used in investigating groundwater potential in different geological settings including sedimentary environment (Emenike, 2000).

This paper study describes the geo-electric investigation of groundwater potential undertaken in parts of Awka and Environs in Anambra State, Southeastern Nigeria. The primary objective of this investigation is to obtain from the geophysical characteristics of the study area, a meaningful delineation of the subsurface lithologies and hence the aquiferous units of the area.

of the country. The other states are Abia, Ebonyi, Enugu and Imo. Awka Capital Territory, occupying the middle of the eastern boarder of Anambra state, lies due west of the Mamu River which forms its eastern boundary (Figure 1).

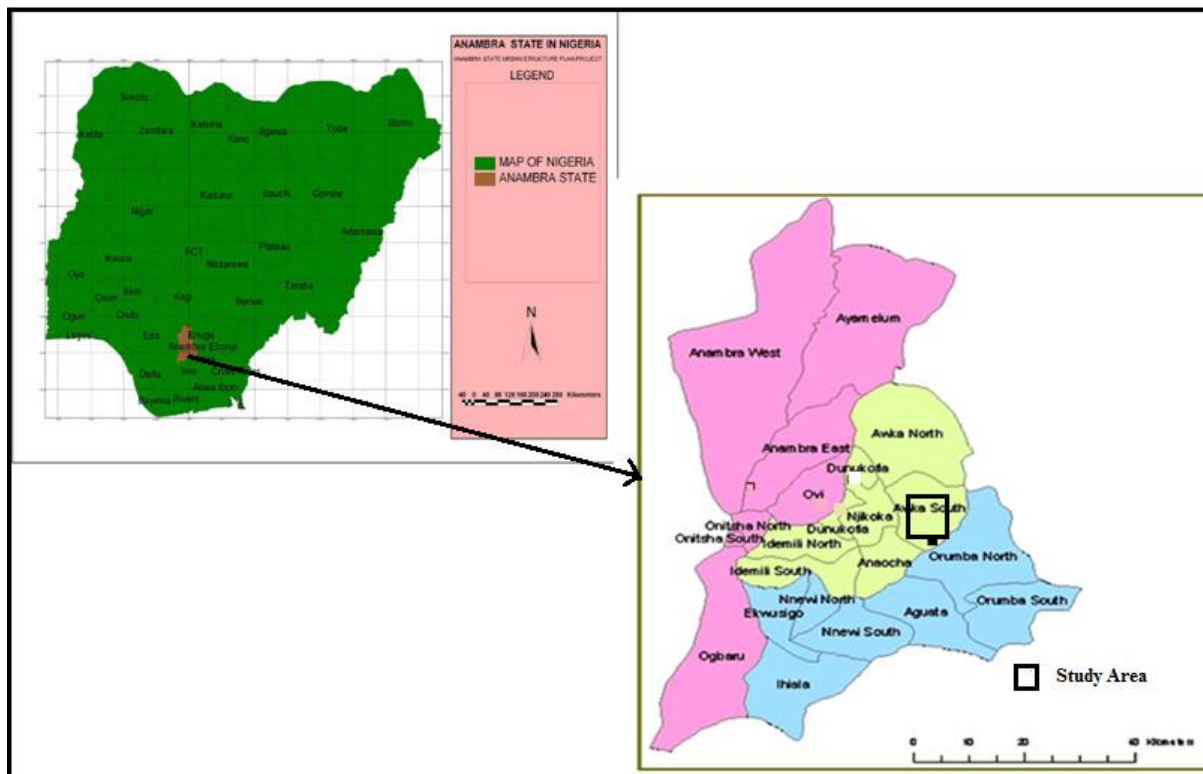


Figure 1: Map of Nigeria Showing Anambra State and the study area adapted from UN-HABITAT (2009).

The land area of the capital Territory covers 10km radius and could be regarded as a

heavily populated sub-region, with Awka occupying the centre at the junction of the old

Enugu- Onitsha road and Amawbia –Orlu road. This sub-region encircles many fast growing small and medium towns which include Awka, Amawbia, Isiagu, Nibo, Nise, part of Agulu, part of Awgbu, Mbaoku, Umuawulu, Ezinato, Isu- Aniocha, and part of Amansea, Okpuno, Mbaoku, Urum, and Nawgu. Others are Enugu- ukwu, part of Nimo, Nawfia, Nri and Adazi-Nnukwu. The Sub-region covers six Local Governments which include Awka Capital Territory, Awka South Local Government area accounting for more than half of the land area. Others are Awka North, Njikoka, Anaocha, Dunukofia and Orumba local Government Areas

2.2 Geological Setting

The study area lies within the Anambra Sedimentary basin. The formations encountered are Nanka Sand and Imo Shale (Figure 2), which were deposited in the Anambra Basin as a result of marine transgression that occurred during the Campanian-Maestrichtian sub-stages of second sedimentary cycle (Nwajide, 1979; Anakwuba *et al.*, 2014).

Nanka Sands (Eocene) forms the dominant geologic formation in the study area. The

Nanka Sands is approximately 305m at its type locality (Nwajide, 1979 ; Nfor *et al.*, 2007; Okoro *et al.*, 2010). It is a lateral equivalent of Ameki Formation. The Nnaka Sands consist of fine to coarse grained sands with abundant intercalations of calcareous shale and thin shaly limestone below, and of loose cross-bedded white or yellow sands, with bands of fine-grained sands and sandy clay above (Okoro *et al.*, 2010; Anakwuba *et al.*, 2014). The sand member of the formation constitutes the aquifer system. The aquiferous units have high pore water pressure exhibiting quick condition.

Subsequently, Nnaka Sands is underlain by thick Imo Shale (Paleocene), which is characterized by thick clayey shale with occasional admixture of clay ironstone and thin sandstone bands (Okoro *et al.*, 2010; Anakwuba *et al.*, 2014). The formation is fine textured and dark grey to bluish grey in colour. Its major lithology is the Shale which is impermeable to water and also is generally described as an aquitard however, the sand member of the formation constitutes the aquifer system.

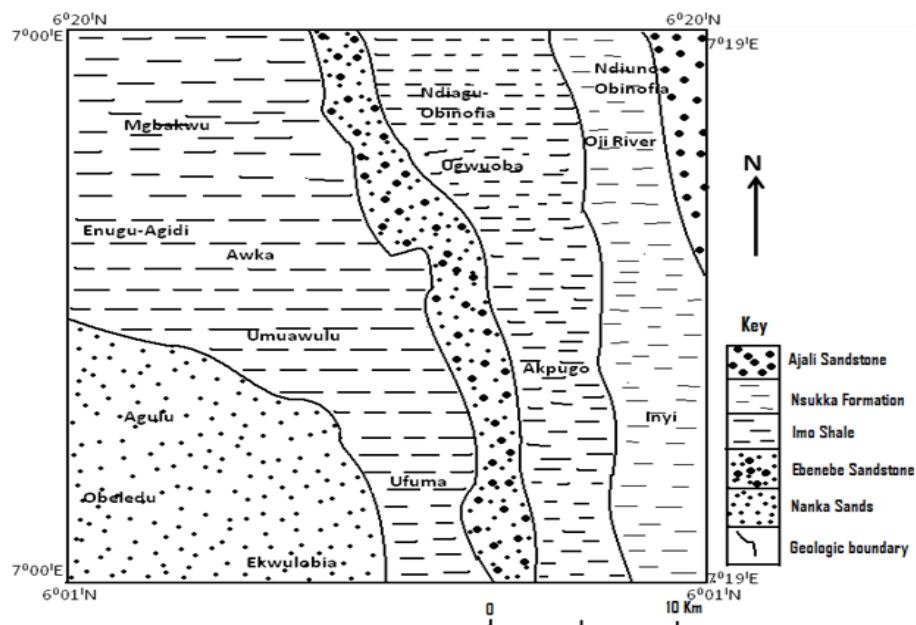


Figure 2: Geologic map of the study area adapted from Anakwuba *et al.* (2014).

2.3 Data Collection and Interpretation

The vertical resistivity sounding (VES) was carried out at twenty-five VES locations within the study area (Figure 3) using ABEM Terrameter SAS 1000 model for groundwater investigation purposes. The Schlumberger electrode configuration having a maximum current electrode spread of 300 m was used. The apparent resistivity values obtained from the measurement were plotted against half the current electrode spacing on a bi-logarithmic graph in order to determine the apparent resistivities and thicknesses of various layers penetrated. This technique has been functional in groundwater exploration by various

investigators such as Onwuemesi and Egboka (2006), Anudu *et al.* (2008), Oseji and Ujuanbi (2009), Okoro *et al.* (2010), Anakwuba *et al.* (2014), Ezeh (2011), Nfor, *et al.* (2007), Anizoba *et al.* (2015) and others. The resistivity curves were interpreted quantitatively by matching small segments of the field curves using two-layer model curves and the corresponding auxiliary curves. The resistivity data were interpreted manually using partial curve matching method as well as using IXID that was developed by Interpex Limited (http://www.interpex.com/ix1dv3/ix1dv3_version.htm).

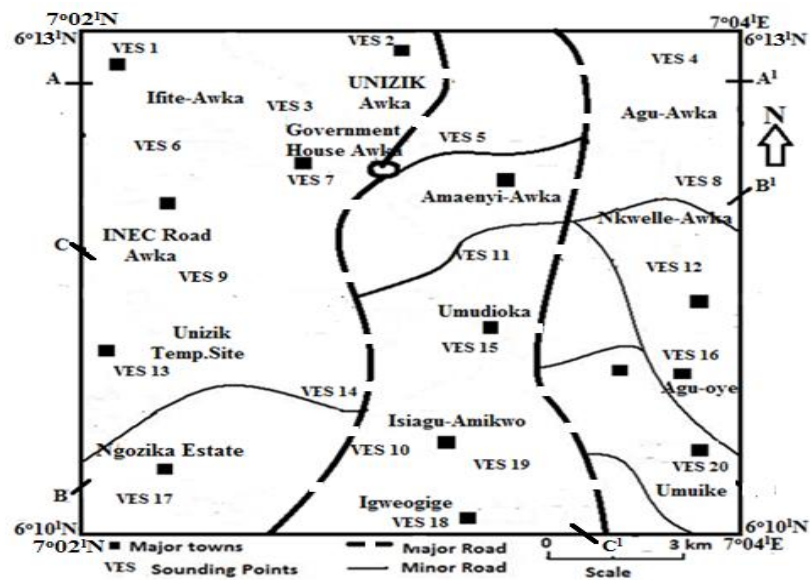


Figure 3: VES locations within the study area.

3.0 RESULTS AND DISCUSSION

3.1 Qualitative Interpretation

Twenty geo-electrical sounding curves obtained from the study area (Figure 4) were interpreted qualitatively. The result revealed four to eight geo-electrical layers. Also, the results revealed that the study area has six (6) typical curve types namely; H, Q, K, HK, AHK and KH (according to Telford *et al.*,

1998, Anakwuba *et al.*, 2014, Anizoba *et al.*, 2015). The most predominant among these curve types in the study area are HK and H-curve types with 35% and 30% respectively, whereas the remaining 35% belongs to the seven curve types within the study area (Fig. 6 and Table 1).

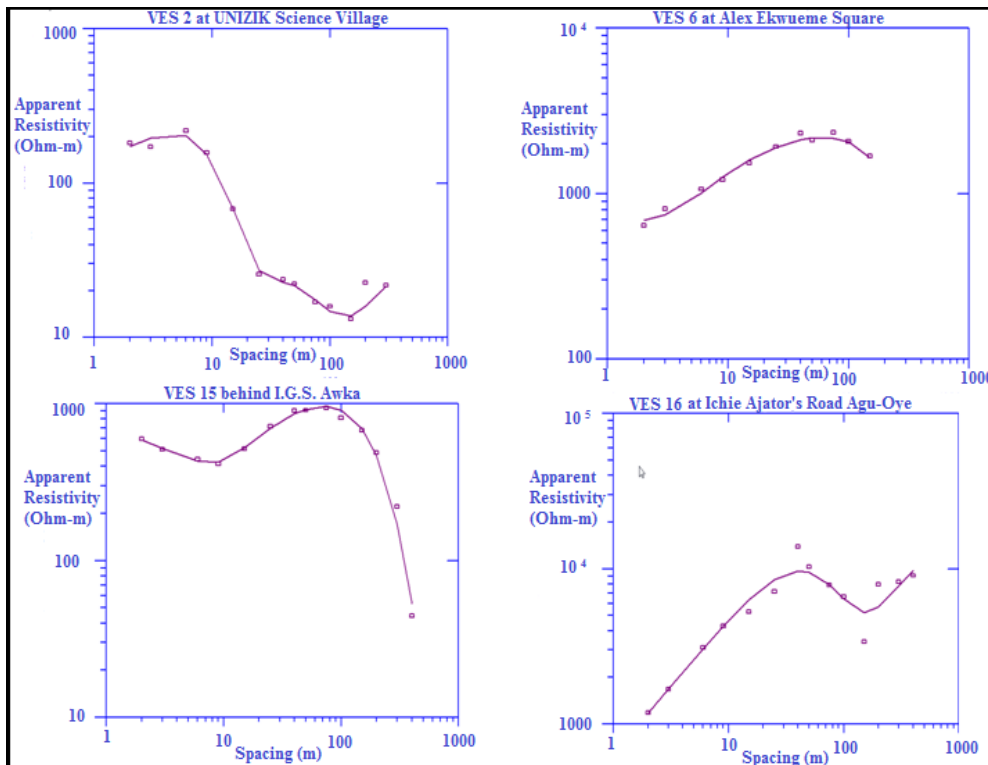


Figure 4: Representative geo-electric curves within the study area.

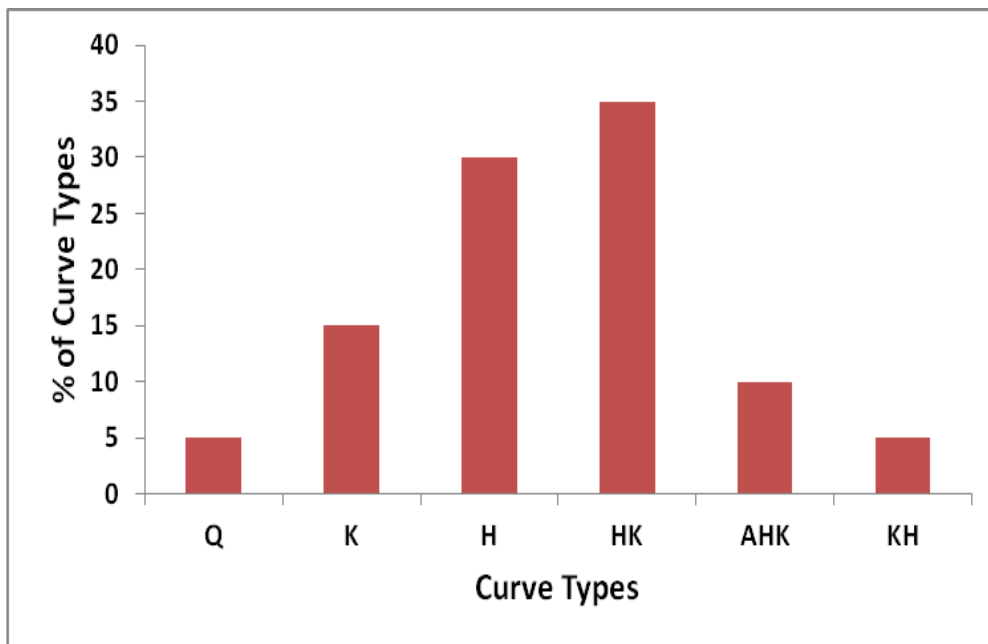


Figure 5: Bar Chart showing the various curve types within the study area.

Table 1 Summary of VES Interpretation with respect to Aquifer.

VES No	VES Location	No. of Layers	Curve Type	Thickness (m)	Depth to Aquifer (m)	Apparent Resistivity of Aquifer Layer (Ohm-m)
1	Beside UNIZIK Gate Ifite	8	HK	41.71	222.83	668.29
2	Science Village UNIZIK	6	Q	31.26	225.03	26.04
3	Commissioners' Quarter Ifite Women Development Centre	3	AHK	46.04	204.08	896.66
4	Awka	6	AHK	38.36	215.11	726.1
5	Alhocol Estate Awka	6	H	34.27	82.27	408.28
6	Alex Ekwueme Square Awka	4	K	39.25	58.32	1508.11
7	Real Estate Awka	5	HK	40.76	108.28	1087.44
8	Nkwelle Village Square	6	H	21.58	86.4	1069.15
9	INEC Road Awka	4	K	53.32	48.69	2106.08
10	Udoka Housing Estate Awka	5	HK	40.81	67.09	809.84
11	Ifite Road Amaenyi Awka St. Mary's Anglican Church	5	H	36.08	89.01	1209.15
12	Nkwelle	5	H	26.73	84.79	970.11
13	UNIZIK Temporary Site	5	K	46.29	31.65	1186.22
14	Crescent Spring Hotel Iyi-Agu	5	H	39.18	33.83	799.22
15	Behind I.G.S. Awka	5	HK	62.78	38.24	1091.54
16	Ichie Ajator Site Agu-Oye	5	KH	21.18	86.92	2810.09
17	Ngozika Housing Estate Awka Kenneth Dike Memorial	6	HK	37.01	70.08	407.18
18	Secondary School Awka Along Umuogbu Village	5	H	42.86	30.83	641.56
19	Awka Agulu Awka Community	5	HK	47.11	34.05	896.01
20	Secondary School Awka	6	HK	36.24	73.18	769.84

3.2. Qualitative Interpretation

3.2.1 Correlation of Geo-electric sections

Four to eight geo-electrical layers with their corresponding thicknesses and resistivities were interpreted in the area (Figure 4 and Table 1). The geo-electrical units include the top soil (lateritic soil), dry sand, shallow saturated sand, clay, sand interbedded with clay, silt interbedded with shale, and water saturated sands and shale. The results of the

geo-electric interpretation were used to construct two interpretive sections AA¹ and BB¹, taken in the west-east and west-south directions (Figures 6a and 6b). The sections revealed that the aquifers are overlain in places by materials with variable thickness and resistivity parameters. In section west-east (Figure 6a), the resistivity of materials overlying the aquiferous units which are shale ranges from 1.29 to 72.29 Ohm-m. This simply signifies that this region host high

possibility of artesian well which occur as a result of confined aquifer (where the aquifer is imbedded in two impervious layer such as shale). The depth to the top of the aquifer varies from 204.08m at VES 3 location to 225.03m at VES 2 location. More so in the west-south section (Figure 6b), the resistivity

of materials overlying the aquiferous layers which are dry sand ranges from 1039.81 to 6022.00 Ohm-m. This simply signifies that this region host mostly of unconfined aquifer (an aquifer that is overlain by a permeable layer such as sand). The depth to the top of the aquifer in section varies from 33.83 to 86.4m.

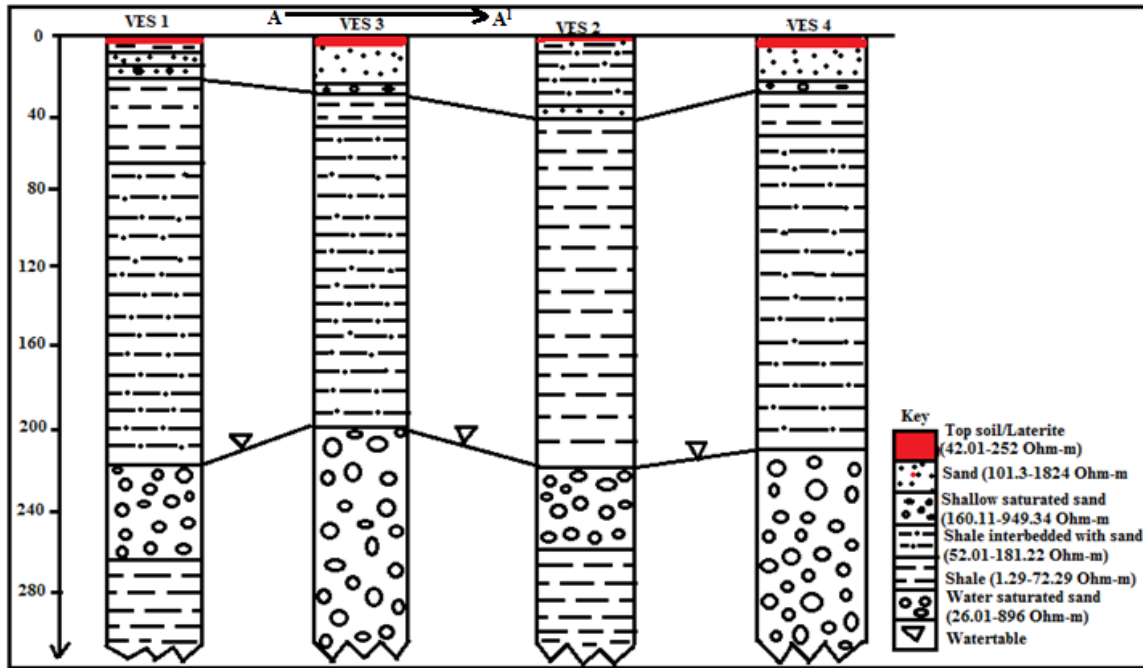


Figure 6a: Geo-electric cross section along west-east direction.

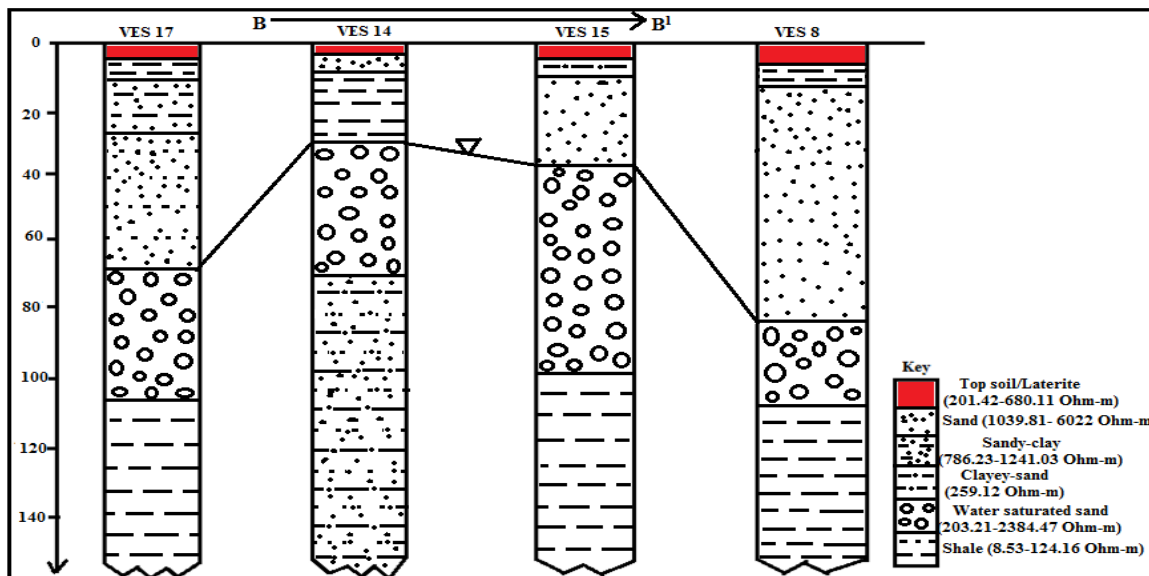


Figure 6b: Geo-electric cross section along west-south direction.

3.2.2 Aquifer Depth map

The depth to the top of the aquifer (water table) deduced from the geo-electric section was used to produce the aquifer map (Figure 7). The aquifer map clearly shows that three distinctive zone of aquifer depth within the study area namely; relatively far depth (130 to 230 meters), relatively moderate depth (70 to 130 meters) and relatively low/shallow depth (30 to 70 meters). This simply implies that depth to aquifer increases towards the northern parts of the study. Hence the aquifer is capable of yielding enough water that would serve the immediate environs. Also, the groundwater flow direction is southwest-northeast (SW-NE) within the study area.

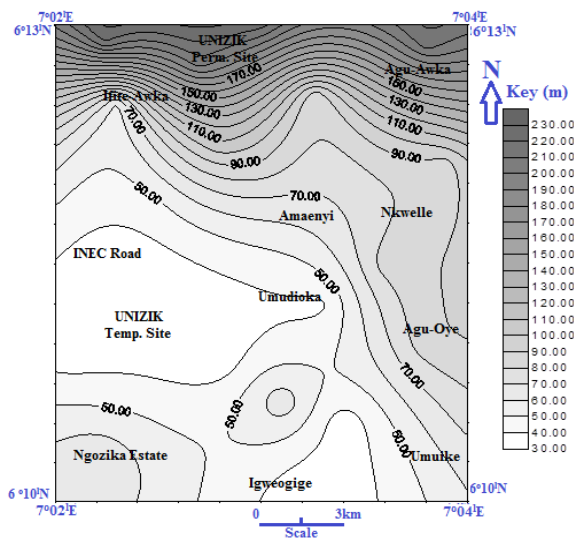


Figure 7: Aquifer Depth map in the study area (Contour Interval~10m)

3.2.3 Aquifer Thickness map

Using the aquifer thickness (Figure 8), as derived from the interpretation of resistivity soundings data, the map showing aquifer thickness distributions was constructed within the study area. The distribution of aquifer thickness values at contour interval of 2m indicates that two distinct zones can be identified within the area. The whitish colour which occurs at the eastern parts of the map reveals the existence of relatively moderate thickness of the aquiferous unit (20 to 34m), while the grey colour at other parts corresponds to relatively high thickness of the saturated unit (34 to 60m). The area is characterized by a thick and prolific aquiferous zone.

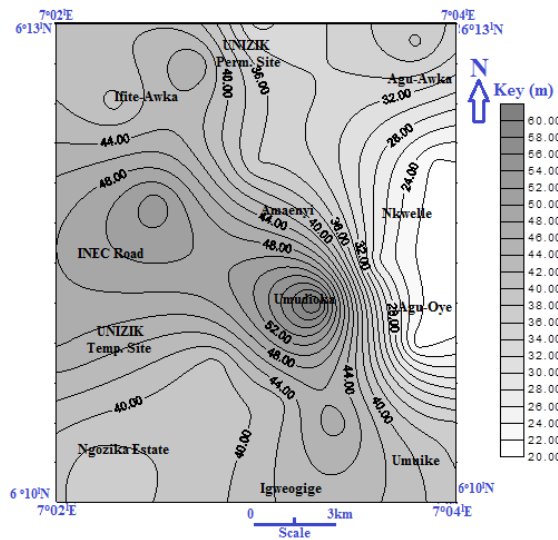


Figure 8: Aquifer thickness map in the study area (Contour Interval~2m)

3.2.4 Aquifer Resistivity map

Considering the aquifer resistivity values, as derived from the interpretation of resistivity soundings data, the map showing aquifer resistivity distributions was produced for the study area (Figure 9). This resistivity map shows clearly those aquiferous regions that

have low and high resistivity values with contour interval of 100Ω-m. At the western part, the resistivity of the aquiferous unit is moderately high (1000-2600Ω-m) while at the northern and southern parts, the resistivity of the aquiferous unit is relatively low (0-900Ω-m).

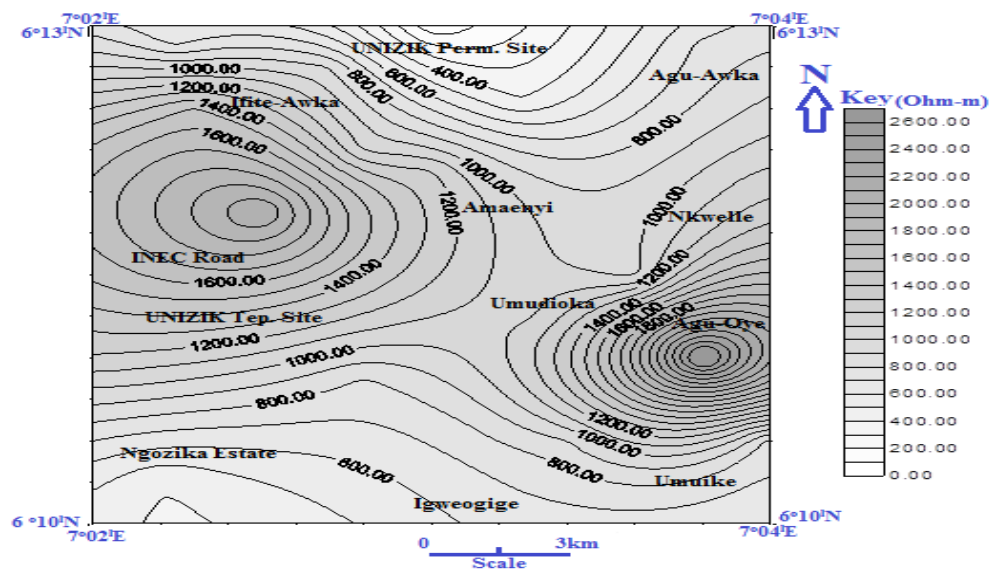


Figure 9: Aquifer resistivity map within the study (Contour Interval~100 Ω-m).

3.2.5 Geological implication

Because of the fact that the study area is underlain by two differential geological formations pave way for the variation of depth to aquifer within the study area. Actually those regions which high thickness of Imo Shale yields far depth to far which invariably will lead to high cost of citing a borehole in these areas such as Ifite-Awka, Government House and UNIZIK areas which will be in neighbourwood of 5 to 10 million naira. This is because that the Imo Shale is a very compacted shale and drilling through it is very difficult which may last as far as 5 to 8 weeks based on drilling rig available. However drilling those area region where Nanka Sands outcropped is very easy to be penetrated the all sort of drilling rig because of the loose nature of the Nanka Sands (Onwemesi and Egboka, 2006; Okoro *et al.*, 2010, Anakwba *et al.*, 2014). So the cost of drilling in the southern region is very low to compare with the cost of

drilling in the far northern parts of this study area.

In addition, the results revealed the presence of four to eight geo-electric layers in the area (Table 1). The geo-electric curve types encountered in the study area depict dominate of HK-type and H-type with 35% and 30% respectively which signify good aquiferous region and conforms with Anizoba *et al.* (2015). The study area is characterized by a thick and prolific aquiferous zone, tapped by many productive boreholes and wells. This is due to the composition of the aquifer zone, consisted of unconsolidated medium to coarse grained sands and gravel. The thickness and depth of these underground saturated sand layers varied from site to site. Actually Awka and its environs have fertile land and with good potential of groundwater, good planning and management, it should be possible to practice modern agriculture here with a view to producing food that will go a long way to feeding the inhabitants of the Territory.

4.0 CONCLUSION

Vertical electrical survey was conducted in twenty locations in Awka of Anambra State, Nigeria. The investigation was done to discover the groundwater potential in the area. The geo-electric investigation of the area revealed four to eight geo-electric layers in

which the water saturated layers have suitable thickness for huge accumulation and reserves of the groundwater resources. The depths to the water saturated sandstones (aquifer) were met in this study area from 30.83m at Kenneth Dike memorial Secondary School Awka to

225.03m at UNIZIK Science Village Awka. The aquifers are capable of yielding enough water that would serve their immediate

4.1 RECOMMENDATIONS

Based on the results of the geophysical investigation carried out at the above area, the following are being recommended:

- Recommended depths for sustainable boreholes are 30.83 to 225.03 meters.
- Hydro-chemical study should be carried out in the area to determine the water quality for both domestic and industrial uses.

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environs. Thus the groundwater flow direction is southwest-northeast (SW-NE) within the study area.

- If the cost of drilling a deep borehole is high for some individuals, then it is advisable for a hand dug well which must be completed.
- The borehole could be located in any convenient place within the surveyed area.

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