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Geoelectric Investigation of Water Table Variation with Surface Elevation for Mapping Drill Depths for Groundwater Exploitation in Owerri Metropolis, Imo State, Nigeria.

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ABSTRACT

A total of 20 Vertical Electrical Soundings (VES) were carried out in different locations in Owerri Metropolis, Imo state of Nigeria in order to investigate water table variation with surface elevation for assessment of groundwater potential. Field data were acquired using the OHMEGA-500 resistivity meter and accessories. The Schlumberger electrode configuration with maximum electrode spread of 700m was adopted. At each VES point, coordinates and elevations were measured using the Global Positioning System (GPS). The field data were interpreted using the Advanced Geosciences Incorporation (AGI) 1D software and the Schlumberger automatic analysis version. The results revealed that the area is underlain by multi geoelectric layers with about 6 to 9 lithological units identified. The aquiferous layer is composed mainly of fine sand and sandstone units with low resistivity values recorded in Owerri West Area. The resistivity values ranged from 0.6Ωm to 1100.8Ωm. The depth to the water table varied across the area with surface elevation and ranged from 16.80m to 85.6m. Similarly, the aquifer thickness ranged from 13.23m to 111.56m. Areas of high aquifer thickness such as Awaka, Amakohia, and New Owerri have high groundwater potential and are good for siting water boreholes with high yield expectations. The study revealed that areas of topographic highs like Owerri North with elevation equal or greater than 200ft generally have high value for depth to water table and require higher drill depth for productive water wells while areas of topographic lows in Owerri Municipal and Owerri West have shallow water table and require lower drill depth. This has implication on cost effectiveness in groundwater exploitation in the study area.

INTRODUCTION

There are two main sources of water in the study area. These are surface water drawn from Nworie and Otamiri Rivers and groundwater. Owing to urbanization, there has been rapid increase in commercial and industrial activities that result in pollution of the surface waters. Other human activities such as poor waste management, agricultural practices and the presence of mechanic villages at Orji and Nekede have compounded the pollution problem of not only surface waters but also serve as sources of contamination of shallow water wells. (Nwosu Leonard and Nwosu Brpght., 2016; Nwachukwu et al., 2013)

The relative advantages of groundwater over surface water in terms of quality and cost of development are quite obvious (Nwosu et al., 2013; Nwosu and Nwankwo, 2016). However, many residents in the study area ignore the advantages of using potable groundwater and rely on surface water which they consider to be cheap and readily available (Obianwu et al., 2011). Worse still, some of the residents rely on groundwater drawn from private commercial shallow wells that are vulnerable to contamination. It has been noted that most of these private commercial water wells are contracted to drillers who ignore the need for pre-drilling geophysical survey. Casing of water wells is done once the drillers penetrate shallow aquifer. Most times, they assume that the depth to water in one area also applies to other areas without considering variation in surface elevation. This could lead to extraction of groundwater from contaminated subsurface hydrogeological units or from units that suffer drawdown during dry season.

The aim of this study is to delineate using vertical electrical sounding data, the water table variation with surface elevation for mapping drill depths for groundwater exploitation Owerri metropolis, Imo state. This will enable the delineation of sites for productive borehole and enhance proper planning and cost of both private and public water development projects in the study area. The results of this study will also provide safer source of potable groundwater to the inhabitants for both domestic and commercial uses.

A good number of literature materials show that Vertical Electrical Sounding (VES) has proved to be effective in solving groundwater problems. These include Onuoha and Mbazi (1988); Mbonu et al. (1991), Ekine and Osobonye (1996) and Eze and Ugwu (2010). Also, Nwosu et al. (2013) employed VES method using Schlumberger electrode array to evaluate groundwater potential of Okigwe district of Imo State, Nigeria. In their research, they were able to discover that the Southern part of the district recorded the highest values of

groundwater yield and is, therefore, the most prolific in terms of groundwater exploitation and thus the most promising in siting productive boreholes. Umeh et al. (2014) also employed the resistivity survey method in the exploration of groundwater in Lokpaukwu, Abia State in Southeastern Nigeria and delineated areas of high potential for groundwater.

LOCATION AND GEOLOGICAL SETTING OF THE STUDY AREA

The study area is Owerri Metropolis which forms the capital territory of Imo State, Nigeria. It is made up of three Local Government Areas namely Owerri Municipal Council, Owerri West and Owerri North (Fig. 1a and 1b). It lies between latitudes $5^0$24'N and $5^0$33'N and longitudes $6^0$58'E and $7^0$06'E. Figure 2 is the geological map of Imo River Basin where the study area is located. The area is underlain by the Benin Formation. This formation which is Miocene to Recent in age consists of Coastal Plain Sands with minor clay beds. The mean depth to the water table in this formation is about 24m (Nwachukwu et al., 2010). The Benin Formation is overlain by alluvium deposits and underlain by Ogwashi-Asaba Formation which consists of lignite, sandstone, clay and shale. The Benin Formation provides good conditions for groundwater storage because of its high permeability and porosity. The area is drained mainly by River Nworie and River Otamiri and their tributary streams. Like most towns in Nigeria, Owerri metropolis experiences two distinct climate seasons namely dry season (October to March) and wet season (April to September). A period of cold dry dusty winds known as "Harmattan" occurs from December to February annually. Owerri has a mean temperature range between 24^0C and 34^0C with a relative humidity of 70% in dry months and 90% in wet months.

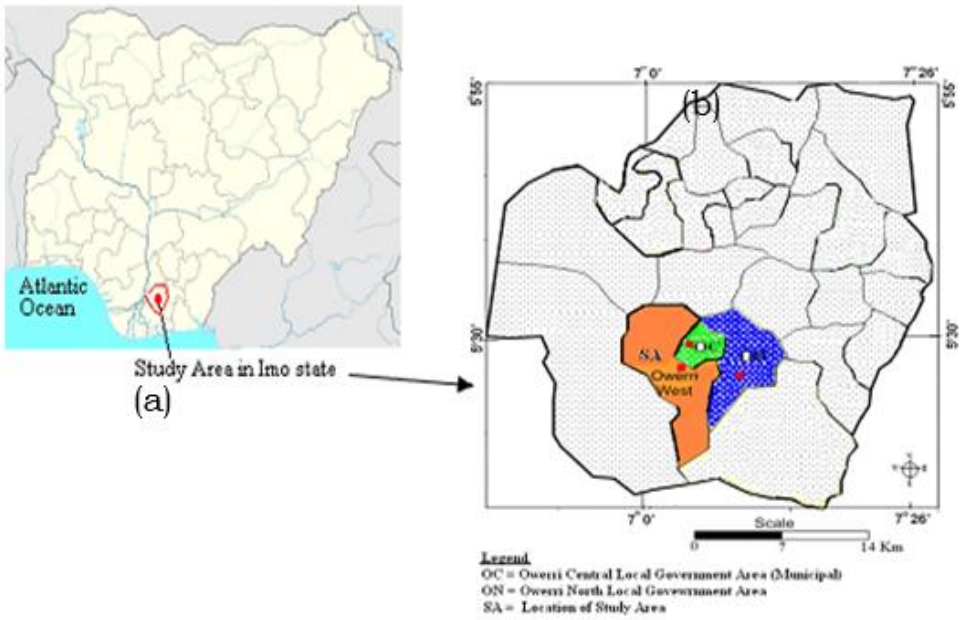

Fig. 1a: Map of Nigeria showing Imo state; (b): Map of Imo state showing Owerri (after Nwachukwu et al., 2010).

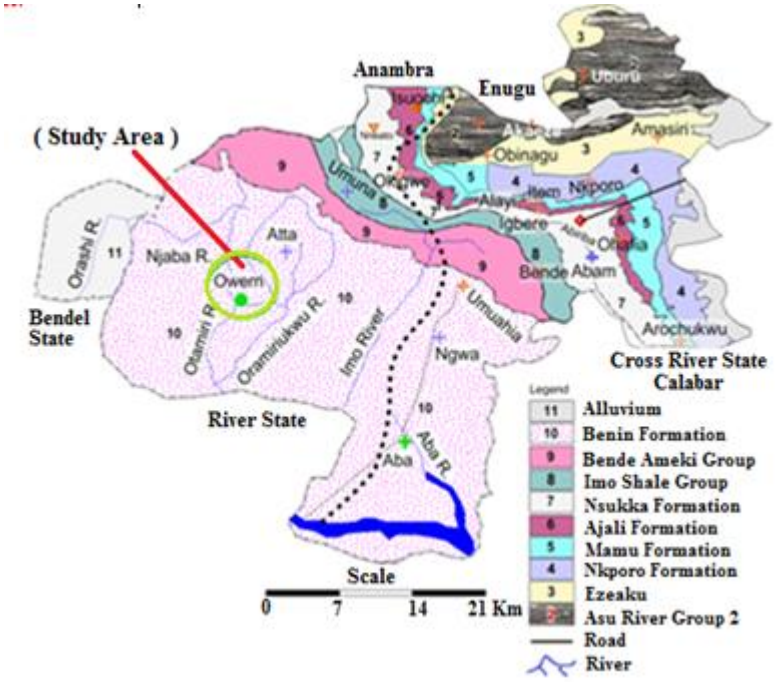

Fig. 2: Geologic Map of Imo River Basin, showing the study area (after Nwachukwu, 2010 as cited in Nwosu Leonard and Nwosu Bright., 2017))

METHODOLOGY

A total of 20 Vertical Electrical Soundings (VES) were carried out in the study area and at least five sited in each of the local government areas that make up Owerri metropolis (Fig. 1).

The field procedure involved the use of Schlumberger electrode configuration with maximum electrode spread of 700m. The OHMEGA–500 resistivity meter and accessories were used to conduct the survey with necessary precautions adopted. Details of field procedure and suitability of VES method in groundwater prospecting abound in many literature materials such as Dobrin and Savit (1988) and Telford et al. (1990).

The current electrodes were expanded systematically from the station point keeping the potential electrode spacing constant until it became necessary to increase it when the recorded signal diminished. With this procedure called electric drilling, the properties of the subsurface were explored. After initial manual computation, the field data were subjected to computer interpretation using the Advanced Geosciences Incorporation (AGI) ID Software and the Schlumberger automatic analysis version. The result is a display of 12 geoelectric layers which were constrained to between seven to nine layers depending on the significant value of resistivities and thicknesses. At each station point, elevation and coordinates were measured using the Global Positioning System (GPS). The lithologic units were inferred by correlation with standard resistivity table and available borehole information. Table of approximate ranges of resistivity's of rocks and soil has been published by Vingoe (1972) and Ekine (2010).

RESULTS

Typical modeled results of the VES data interpretation are shown in Fig. 3a, 3b and 3c while Tables 1, 2 and 3 show the analytical results presented by the software. Table 4 shows the summary of the field data and parameters determined for the aquiferous layer in each VES location. The variation of resistivity of the aquiferous layers is displayed in Fig 4 showing resistivity contour map. Figure 5 shows the surface elevation map of the study area while Figure 6 is the water table contour map showing the variation of depth to water table in the study area.

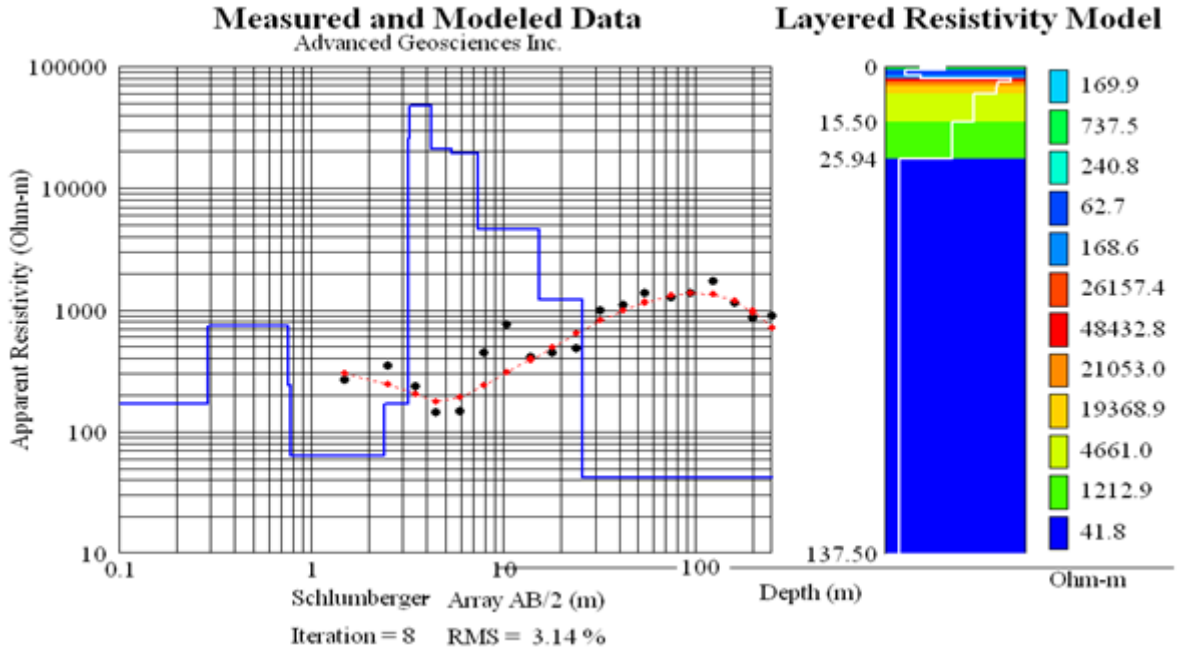

Fig. 3a: Model result for VES located at Eziobodo Owerri West

Table 1: Analytical result presented by the AGI 1D Software and the Schlumberger automatic analysis package revealed 12 geoelectric layers constrained to 8 layers as follows:

LAYER	DEPTH (m)	RESISTIVITY	LITHOLOGY	COLOR
1	0.7	240	Topsoil	Light Blue
2	2.4	63	Sand	Blue
3	3.3	26157	Sandstone	Red
4	5.2	21053	Sand/Gravel bed	Off Red
5	7.3	19368	Sandstone	Yellow
6	15.4	4660	Siltstone	Orange
7	25.9	1212	Mixed sand	Green
	>135	41.8	Sand (Lower Prospective)	Blue

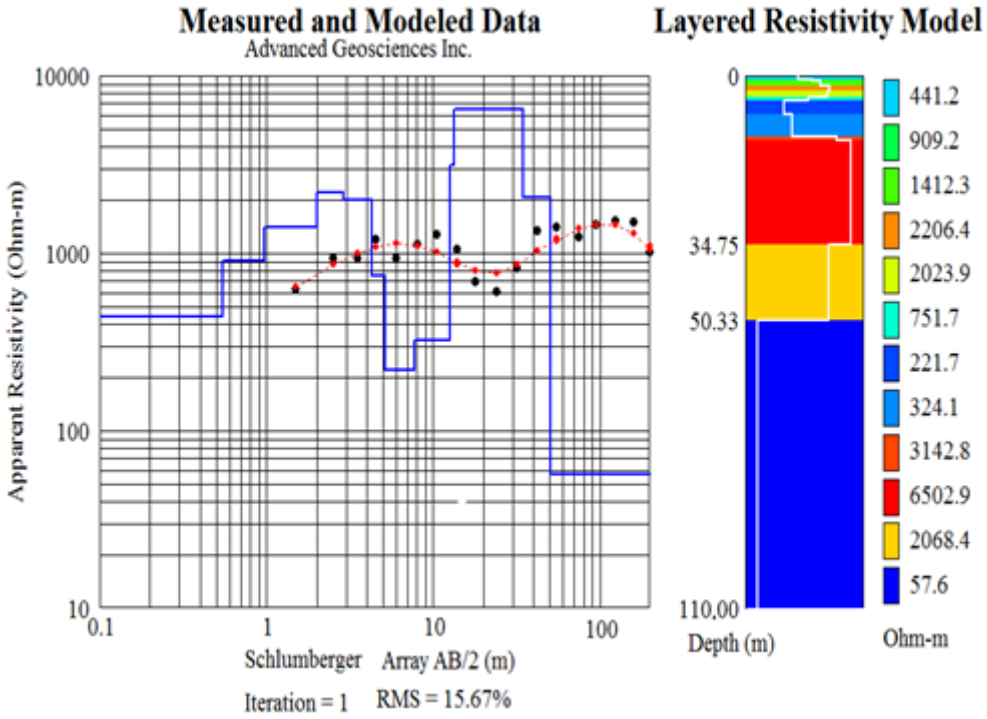

Fig. 3b: Model result for VES located at Awaka Owerri North

Table 2: Analytical result presented by the AGI 1D Software and the Schlumberger automatic analysis package revealed nine geo-electric sub-layers as follows:

LAYER S/No.	DEPTH (m)	RESISTIVITY (Ohm-m)	LITHOLOGY	COLOR
1	0.5	441	Topsoil	Mixed Blue
2	2.0	1412	Siltstone	Green
3	5.1	751	Sand	Light Blue
4	7.7	221	Sand	Blue
5	12.5	324	Sand	Mixed blue
6	13.3	3142	Sand/Gravel	Red
7	34.7	6502	Sandstone	Red
8	50.3	2068	Siltstone	Yellow
9	110	57.6	Sand (Prospective Unit)	Blue

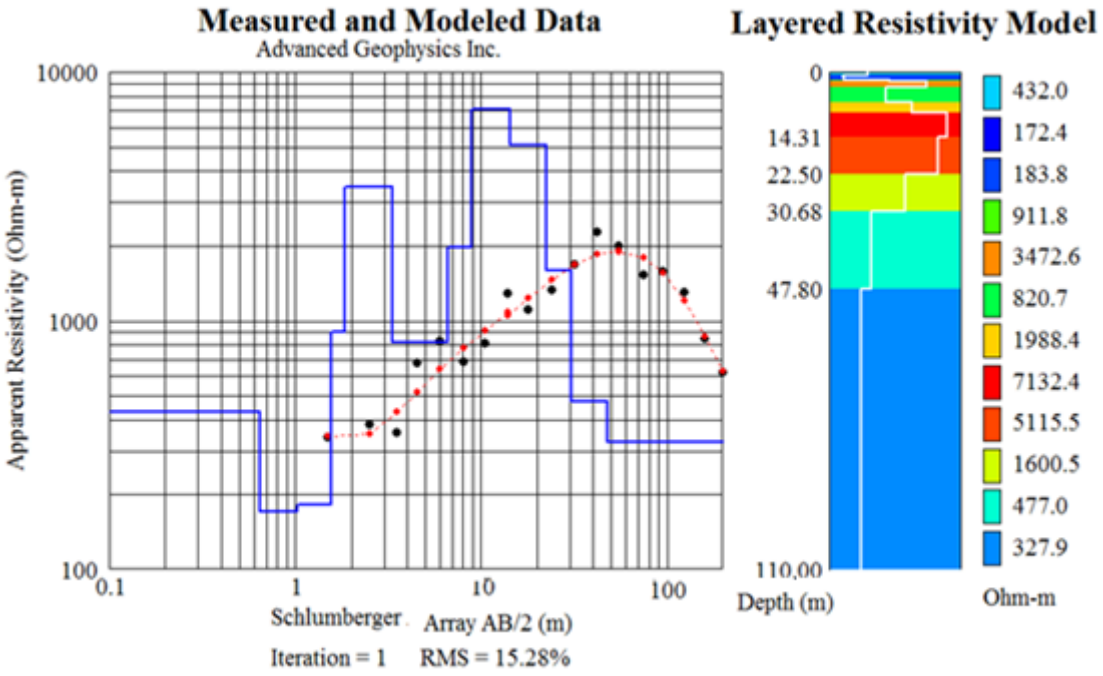

Fig. 3c: Model result for VES located at Umuguma Owerri West

Table 3: Analytical result presented by the AGI 1D Software and the Schlumberger automatic analysis package revealed nine geo-electric sub-layers.

LAYER	DEPTH (m)	RESISTIVITY (Ohm-m)	LITHOLOGY	COLOR
1	1.8	911	Topsoil	Green
2	3.3	3472	Sandstone	Brown
3	6.5	820	Sandy-clay	Green
4	8.8	1988	Siltstone	Yellow
5	14	7132	Sand/Gravel	Red
6	22.4	5115	Sandstone	Red
7	30.6	1600	Siltstone	Orange
8	47.8	476	Sand (Upper Prospective)	Light Blue
9	>110	328	Sand (Lower Prospective)	Blue

Table 4: Summary of the relevant field data and aquifer parameters

S/No	Location	Elevation (ft)	Coordinate E (Degree)	Coordinate N (Degree)	Depth to Water Table (m)	Aquifer Resistivity (Ωm)
1	Awaka	450	07°05.185/	05°28.584/	57.6	35.5
2	Foundation Rd. Aladima (IMSU)	126	07°02.916/	05°29.545/	16.8	201.1
3	Orji	413	07°08.239/	05°07.987/	43.0	186.5
4	Toronto Junction	418	07°05.101/	05°29.527/	43.0	68.5
5	New Owerri	140	07°00.839/	05°.29.344/	26.0	41.8
6	Amakohia	258	07°02.214/	05°23.006	39.0	630.81
7	Ugwu Orji Owerri	460	06°51.907/	06°07.749/	64.5	209.8
8	Naze	225	07°03.769/	05°27.071/	50.0	57.6
9	Nekede (Aforama Mkt)	213	07°.01.067/	05°26.750/	30.0	327.9
10	Oforola	120	06°54797/	05°24.899/	17.0	186.5
11	Umuguma	245	06°58.189/	05°27.793/	47.8	10.7
12	Obinze Junction	202	06°57.855/	05°24.032/	48.6	1100.8
13	National Library	103	07°00.726/	05°28.315/	23.0	803.0
14	Eziobodo Owerri West	86	06°59.943/	05°22.605/	26.2	5.4
15	Nekede Police Primary School	243	07°00.724/	05°24.895/	60.5	204.5
16	Nworie River Bank	165	07°01.348/	05°29.338/	23.8	0.5
17	Industrial Court Owerri	221	07°01.758/	05°29.356/	85.6	0.7
18	Avu Junction (PH – Rd)	175	06°58.756/	05°26.040/	64.0	209.0
19	INEC Commissioners Quarters	286	07°00.918/	05°28.649/	40.1	0.6
20	Ihiagwa (FUTO Building)	227	06°59.618/	05°23.092/	56.2	26.1

DISCUSSION OF RESULT

The elevation map of the study area (Fig. 4), shows that areas in Owerri North are at higher elevation than others with Awaka having highest value of 450ft (1350m) above sea level. Figure 5 is the aquifer resistivity contour map of the study area.

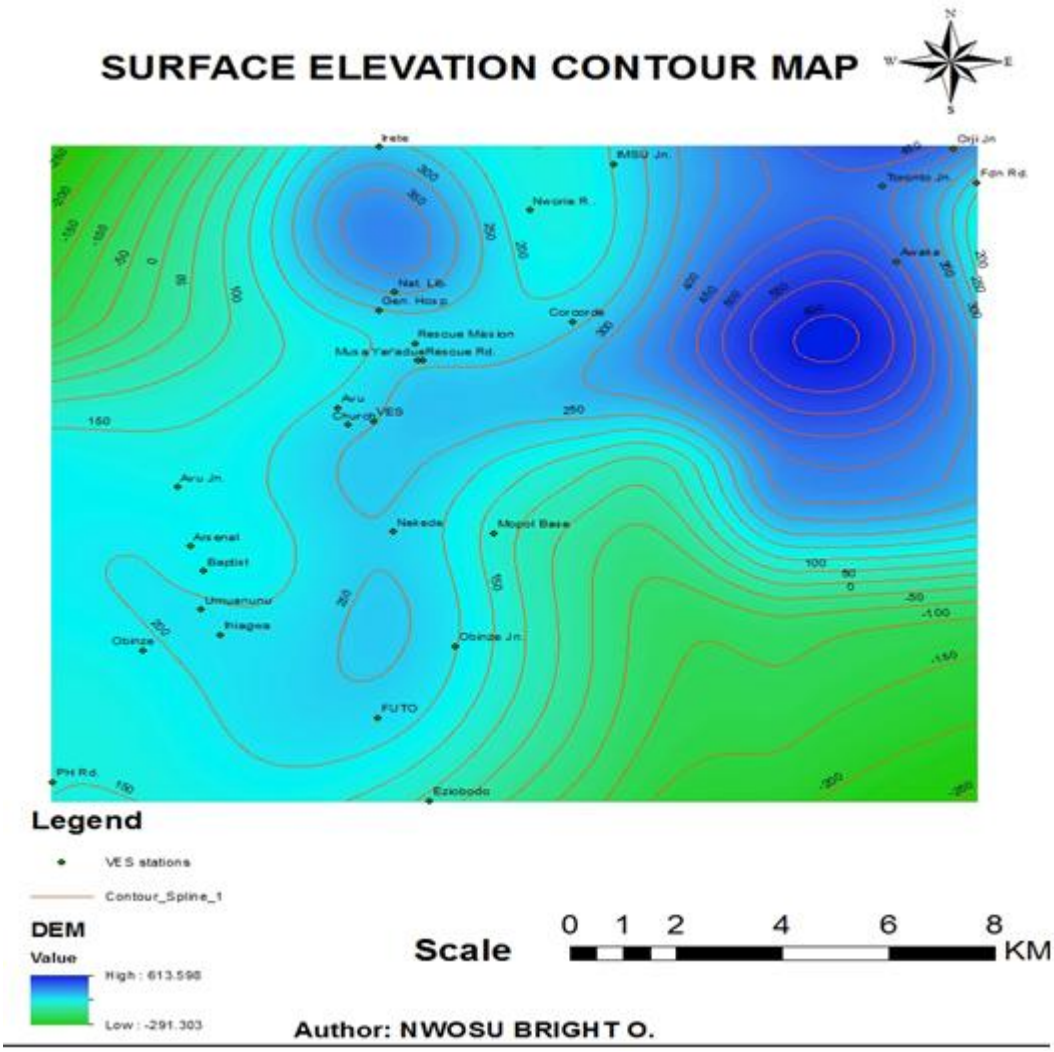

Fig 4: Surface elevation contour map of the study area

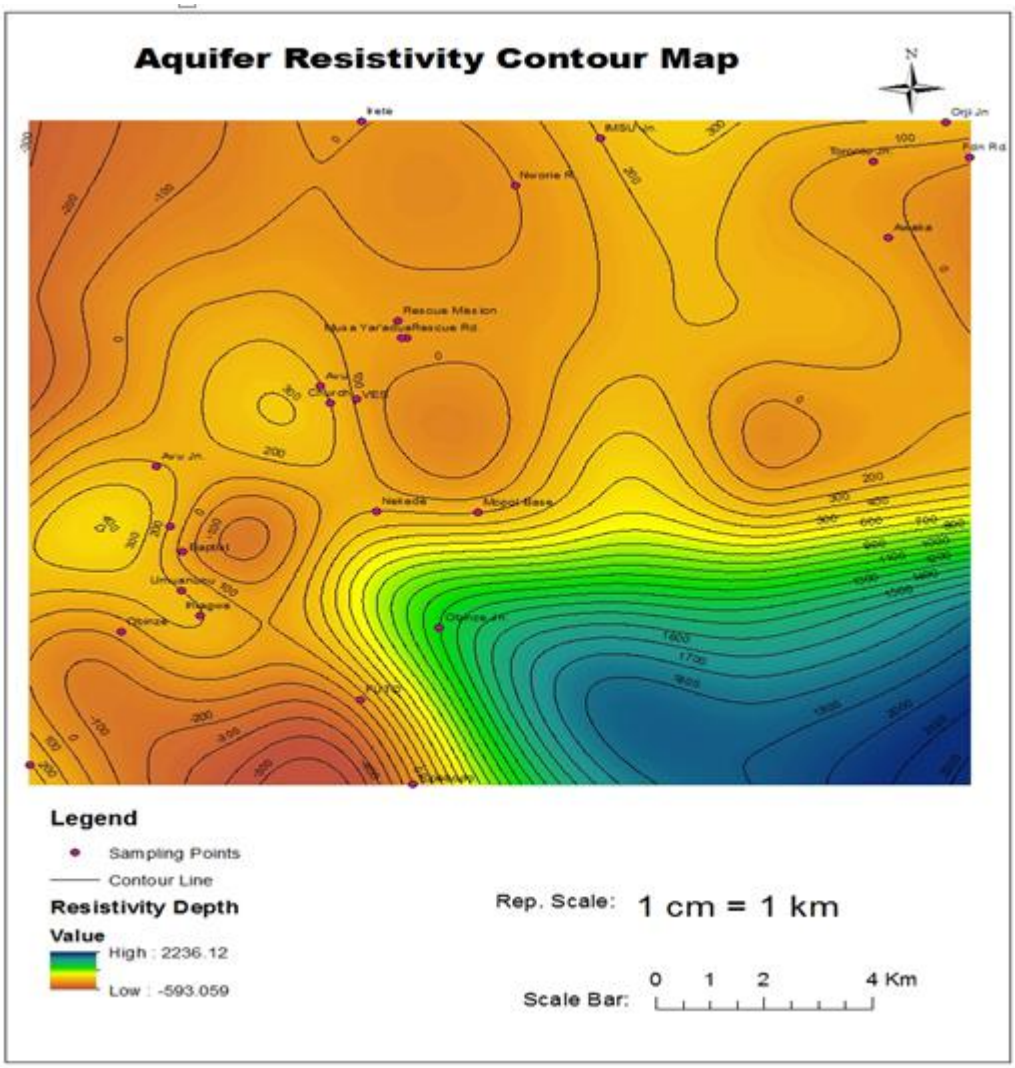

Fig. 5 Aquifer resistivity contour map

Low resistivity values were recorded in areas around Federal University of Technology Owerri (FUTO), Ihiagwa, Nekede and Eziobodo all in Owerri West area with resistivity values of 200 Ωm or below. Higher values of aquifer resistivity were observed in areas around Obinze with value of 1100Ωm and Amakohia. The resistivity values are characteristic of Coastal Plain Sands aquifer.

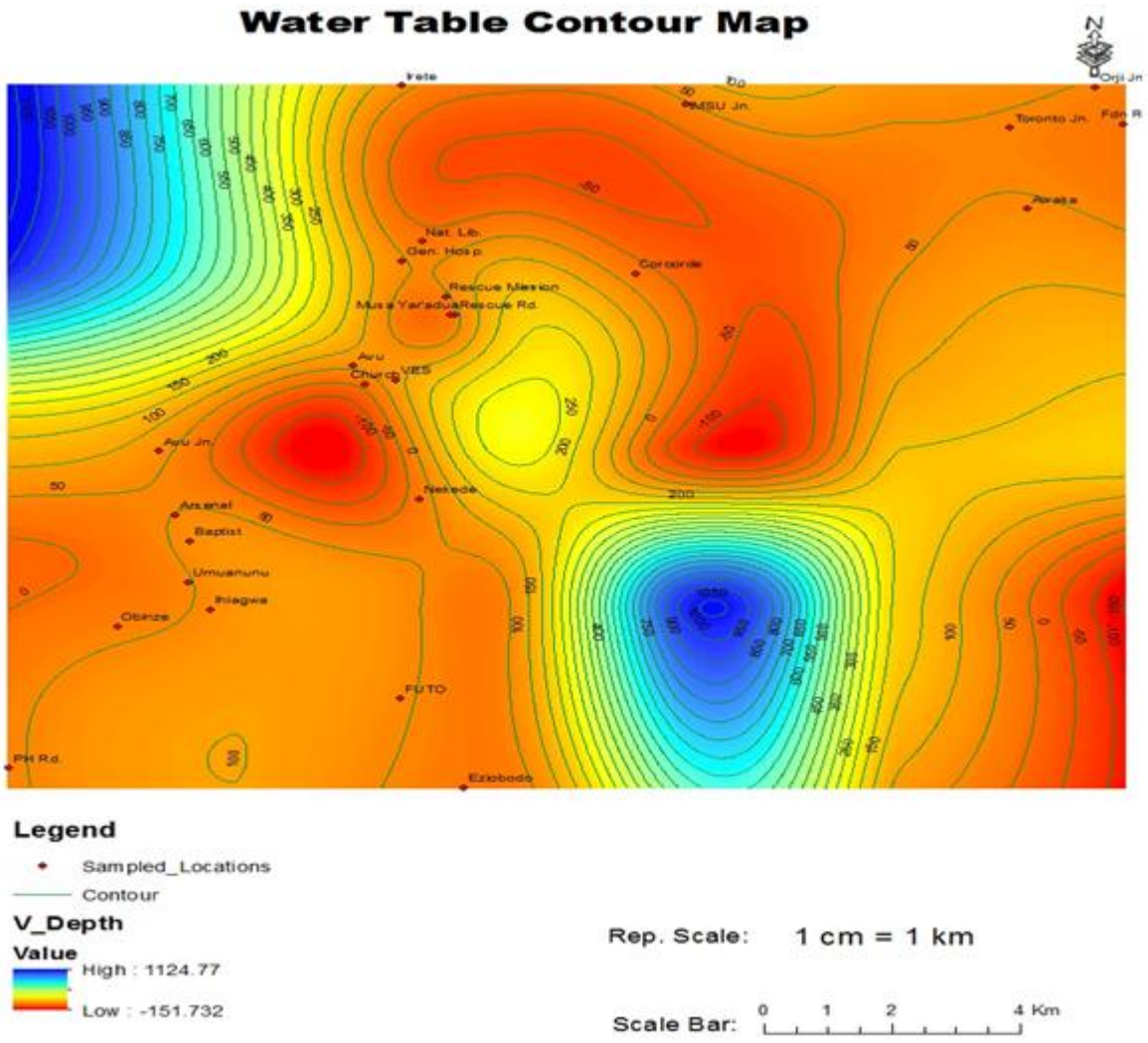

Fig 6: Water table contour map

Figure 6 is the water table contour map of the study area. The water table values are characteristic of the Benin Formation. Topographic low areas include Eziobodo in Owerri West Local Government area with surface elevation of 86ft where the water table is at a depth of 22.2m, Foundation Road Aladinma near Imo State University in Owerri Municipal Council located in a valley of Lake Nwaebere with surface elevation of 126ft. The depth to water table in this location is 16.8m. Other areas include Oforola with surface elevation of 120ft which is located in Owerri West and has water table at a depth of 17m. Water table is shallow in this locality as hand pump water wells popularly called "Man Power" can be seen at some locations in the area. In the valley of Nworie Riverbank, relatively higher elevation of 165ft was recorded with water table at a depth of 23.8m.

On the other hand, in topographic high locations in the study area (Table 4) relatively higher values of depth to water table were recorded. These places include Awaka in Owerri North at

elevation of 450ft and water table value of 57.6m, Orji and Toronto Junction in the same Local Government Area having the same depth to water table values of 43m. The highest value of depth to water table of 85.6m was recorded at Industrial Court Owerri. These results agree with the works of Nwachukwu et al. (2012) in a study on sustainable water supply development in parts of the present study area in which they observed that the area has near surface aquifer with average depth of 50m (164ft). The study also recorded water table value of 16 to 21 table value of 16 to 21m in parts of Owerri West including Ihiagwa and Nekede. Generally, it can be concluded from the results that depth to water table varies with surface elevation. Water table is shallow in topographic low locations and deep for topographic high places. Deep wells are therefore prescribed in topographic high locations for sustainable groundwater development. Recommended drill depth for standard water well development in areas of low surface elevation (less than 150ft) especially in Owerri Municipal Council and Owerri West areas is 55m to 60m. Relatively high surface elevation areas such as Nekede, Avu, Orji and Awaka, the drill depth of 100m or more is recommended. Thus the cost of drilling standard water well should be relatively higher in Owerri North than other areas in the study area.

The results of the present study confirm earlier study of Nwachukwu et al. (2013) on groundwater development in Imo River Basin Nigeria using Geographic Information System (GIS). They observed that average water table in Owerri West and corresponding aquifer resistivity values are 90m and 850Ωm; that of Owerri Urban are 100m and 980Ωm while the average values for Owerri North are 160m and 911 Ωm respectively.

CONCLUSION

Vertical Electrical Sounding (VES) data has been used to delineate the water table in the study area. The results of this study show that water table varies with surface elevation. Generally, shallow water table was delineated in topographic low areas requiring low drill depth for groundwater exploitation while in areas of topographic high deeper water table was delineated requiring high drill depth value for standard water well development. The result of this study which is reliable has implication in cost effectiveness in groundwater project planning within the study area. The slight deviation from linearity could be due to the complexity of the depositional environment and/or constraints during field operations.

ACKNOWLEDGMENT

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