Advances in Research

10(3): 1-10, 2017; Article no.AIR.32121
ISSN: 2348-0394, NLM ID: 101666096

Evaluation of Groundwater Potential Using Integrated Geophysical Data in Parts of Michael Okpara University of Agriculture, Umudike, Southern Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. Author MUI designed the study, while all the authors were actively involved in the field investigations. Author CAU wrote the protocol and wrote the first draft of the manuscript. Authors MUI and CAU managed the analyses of the study. Authors CAU, UKE and KTE managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AIR/2017/32121
Editor(s):
(1) Prof. Martin Kröger, Computational Polymer Physics, Swiss Federal Institute of Technology (ETH Zürich), Switzerland.
Reviewers:
(1) Ologun Sehinde, Nigerian Building and Road Research Institute, Nigeria.
(2) H. O. Nwankwoala, University of Port Harcourt, Nigeria.
Complete Peer review History: http://www.sciencedomain.org/review-history/19709

Original Research Article

Received 9th February 2017
Accepted 3rd April 2017
Published 27th June 2017

ABSTRACT

This study was carried out to investigate the groundwater potential in Michael Okpara University of Agriculture, Umudike area of Abia State, Nigeria. A total of nine vertical electrical soundings were acquired and the results were correlated with records available from an existing well together with previous lithologic deductions. A range of 4 to 6 geoelectric layers was delineated in this study; though the fourth and fifth geoelectric layers were predominant. Results showed that the aquifer is located within the third layers for the 4-layered zone and the fifth and sixth layers for the other layered zones. The depth to the shallowest aquifer is about 30m at VES 4 with the aquifer resistivity of 13124Ωm and transmissivity of 258.6 m^2/d. The area has huge groundwater potentials with the best prospects at VES 2 and less promising results at VES 5.

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Keywords: Groundwater potential; lithologic deductions; transmissivity; vertical electrical sounding.

1. INTRODUCTION

Water beneath the ground surface in soil pore spaces and in the fractures of rock formations is usually referred to as groundwater.

Groundwater is a natural resource with its characteristics being greatly determined by the geologic properties of the host rock.

A porous substratum that is able to hold and yield (transmit) an appreciable quantity of groundwater is called an aquifer.

Thus, groundwater acquisition is mainly dependent on the reliable empirical knowledge of the geology of the area and the depth of aquifer.

1.1 Location and Geology and Hydrology of the Study Area

The study area (Michael Okpara University of Agriculture, Umudike) lies within latitudes 5°28' and 5°29' N and longitudes 7°32' and 7°33'E, and has characteristic annual average temperature ranges of about 29°– 31°C. The area falls within the sub-equatorial belt with relative humidity values over 70%; while the wet season spans from Mid-April to October with rainfall peaks in July and September and a short break in August.

There are about 11 different geologic formations in Abia State of Nigeria but the Benin Formation of the Cenozoic Niger Delta covers almost half of the entire state.

Geologically, the study area Michael Okpara University of Agriculture, Umudike (MOUAU) is situated in the Benin Formation of the Cenozoic Niger-Delta basin of Nigeria (Fig. 1). The area is part of the oldest surface outcrop of the Cenozoic eastern Niger-Delta basin because it is situated immediately after the Bende-Ameki Formation of the Anambra basin.

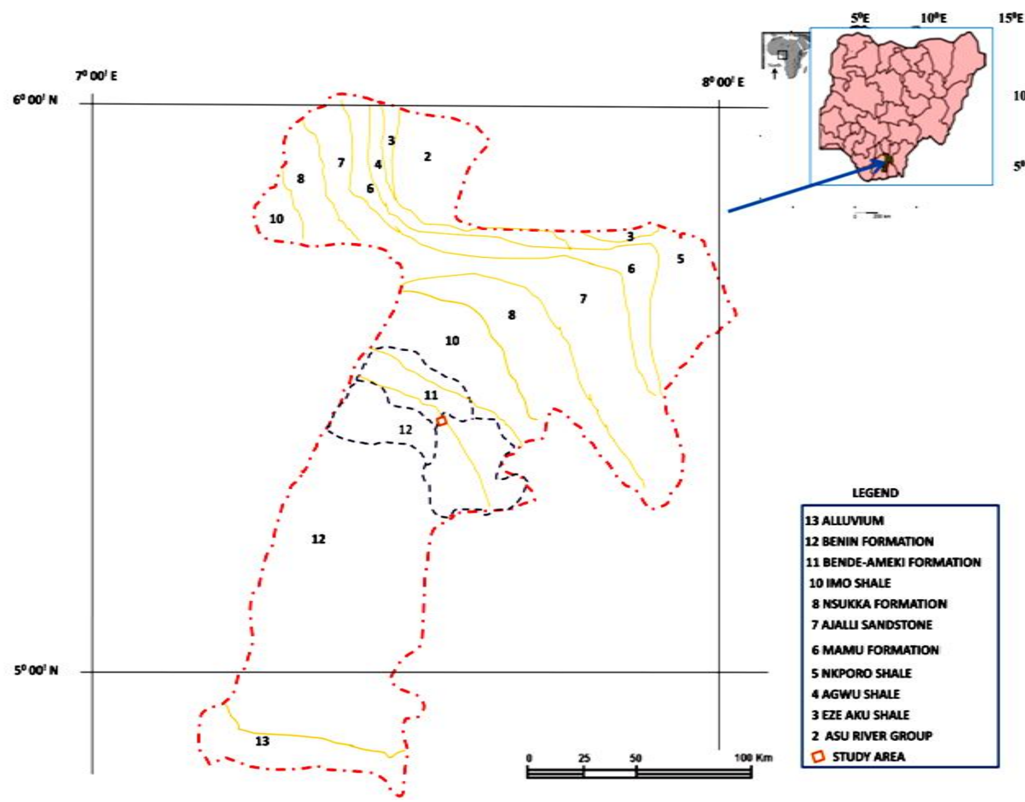

Fig. 1. Geologic map of Abia State showing the Local Government Areas and the study area (Modified after Geological Survey of Nigeria (GSN), 1985)

1.2 Significance of the Study and Choice of Method

Industrialization and urbanization, together with increase in population and rising standards of living usually add pressure on natural resources [1].

The presence of National Root Crop Research Institute (NRCRI), Umudike; the Umuahia Campus of Abia State University (ABSUPAC) and Government College Umuahia (GCU) have also added to an increase in the population of the area (Fig. 2).

The preference of groundwater to surface water by the teeming population; together with the collapse of the municipal water supply has made groundwater the main source of water supply for almost every sector in the area [2,3].

Since groundwater plays a major role in meeting the ever increasing demands for various purposes in the area; therefore, an overview of the groundwater potential of the area is essential for effective exploitation and management.

For a large scale development of groundwater, a reliable estimate of groundwater potential is essential [4]. This is usually actualized with well outlined techniques using modern scientific tools. Many approaches and methods have been used in the search for groundwater.

Geophysical surveys are most widely used because of the basic advantage of providing more accurate results than other methods.

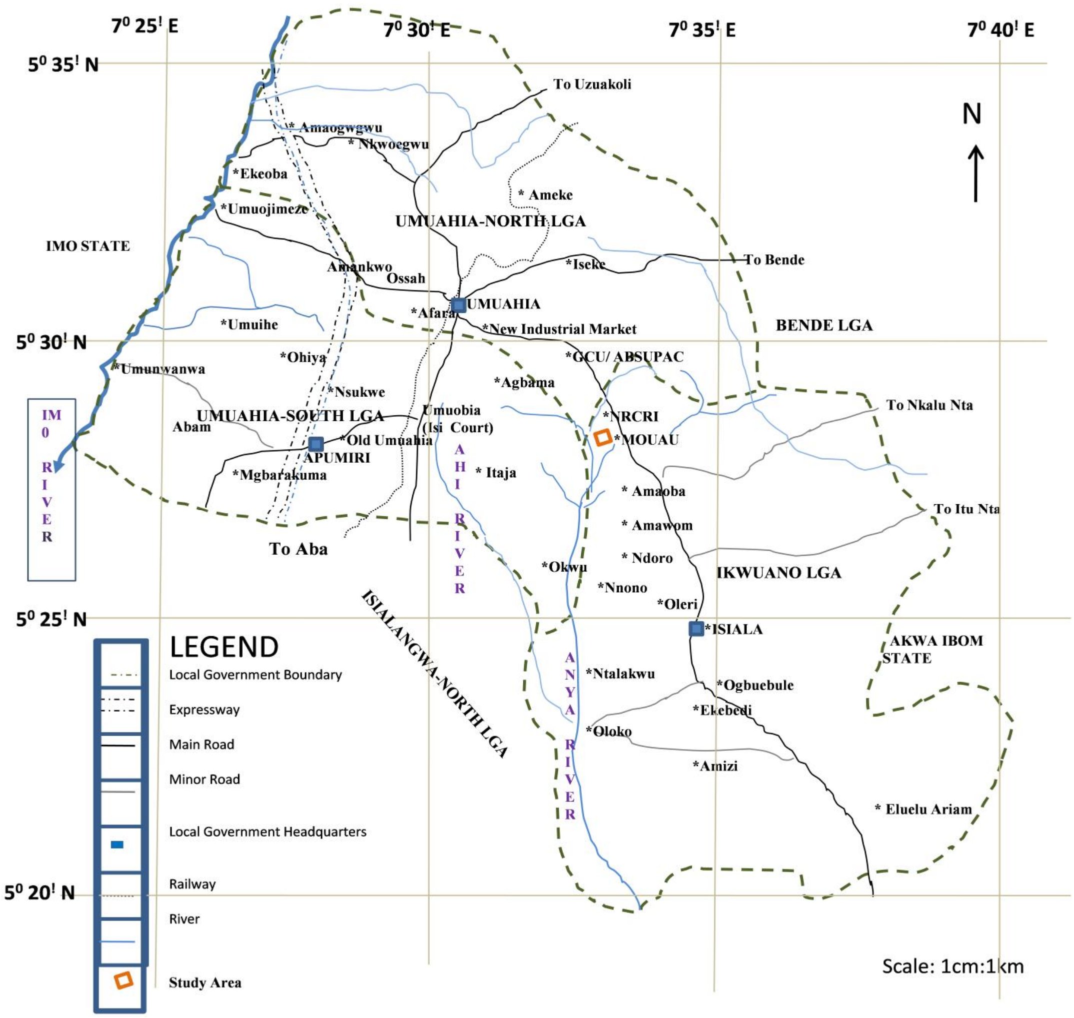

Fig. 2. Map of Ikwuano-Umuahia area showing the study area

Valuable information with respect to distribution, thickness, and depth of groundwater bearing formation can be provided by geophysical methods.

Many geophysical techniques have been used in groundwater exploration [5,6,7]; but the most widely used is the electrical resistivity method [8,9,10]. This is because less field manpower is required and the equipment is portable; hence the field operation is easy. It also has greater depth of penetration thus clarifying the subsurface structure together with the delineation of the groundwater.

For the fact that groundwater accumulates in sedimentary rocks (sands, gravels, silt, limestone etc), and also in denature crystalline basement rocks (weathered overburden, joints, fractures and faults zones). The electrical resistivity method can be best employed to estimate the thickness of overburden and also the thickness of weathered layer.

The determination of the electrical resistivity of subsurface materials (rocks, minerals etc.) can be realized using the subsurface resistivity distribution to the ground. This is at times related to the physical conditions of interest (lithology, porosity, degree of water saturation and presence or absence of voids in the rocks).

In areas where good electrical resistivity contrast exists between the water bearing formation and the underlying rocks, electrical resistivity methods are effectively used for groundwater exploration [11]. This method enables the determination of the electrical resistivity of the subsurface by sending an electric current into the ground and simultaneously measuring the electrical potential produced by the current.

The Vertical Electrical Soundings (VES) technique of electrical resistivity method gives detailed information of vertical succession of individual thicknesses, resistivities and their different conducting zones; therefore it was chosen for this study.

Well documented in standard text books are the theories of both the electrical resistivity surveying method and the Schlumberger electrode configuration.

2. MATERIALS AND METHODS

A total of nine Vertical Electrical Soundings (VES) were acquired using the Schlumberger electrode configuration with two current electrodes ‘AB/2’ widely spaced out and two potential electrodes ‘MN/2’closely spaced in between the current electrodes all along the survey line.

The current electrode spacing ‘AB/2’ was varied from 1.5 m to a maximum of 320 m; while the potential electrode spacing ‘MN/2’ was varied from 0.5 m to a maximum of 55 m.

The study area was transformed into a regular grid where nine nodal points were chosen as sounding stations at intervals of 250m. Out of the nine sounding stations, two were carried out in proximity to an existing borehole that has an available lithologic data (Fig. 3).

Garmin GPS 72 was used in determining the coordinates (longitude, latitude and elevation height above mean sea level) of each sounding point; and the ABEM Terrameter SAS 4000 was used in the data acquisition.

A 12V direct current (DC) from a battery was fed into the terrameter which was subsequently passed into the ground through the current electrodes ‘AB/2’ linked by insulated cables. The resultant potential difference (voltage) was determined using the potential electrodes ‘MN/2’.

The observed field data is read off directly from the terrameter, and it is the ratio of the voltage to the current which is a measure of resistance of the subsurface (ground resistance). This measured ground resistance in ohms is used to compute the corresponding apparent resistivity in Ohm-meters by multiplying with the geometric factor.

The value of the geometric factor is a function of electrode spacing, thus giving the required apparent resistivity results as functions of depths of individual layers:

$$\rho_a = \pi R\left(\frac{a^2-b^2}{2b}\right) \qquad (1)$$

Where

ρ_a = Apparent resistivity.
a = ‘AB/2’ = Half current electrode spacing(m).
b = MN/2 = Half potential electrode spacing (m).
R = Resistance in ohms.
$\pi\left(\frac{a^2-b^2}{2b}\right)$ = Geometric factor (K).

For each sounding point, the subsurface stratigraphy was delineated based on apparent resistivity differences. The apparent resistivity values were plotted against current electrode spacing 'AB/2' on a log-log graph paper to obtain sounding curves. Subsequently, initial estimates of the resistivities and thicknesses of the various geoelectric layers were obtained and used for computer iteration using RESIST software package.

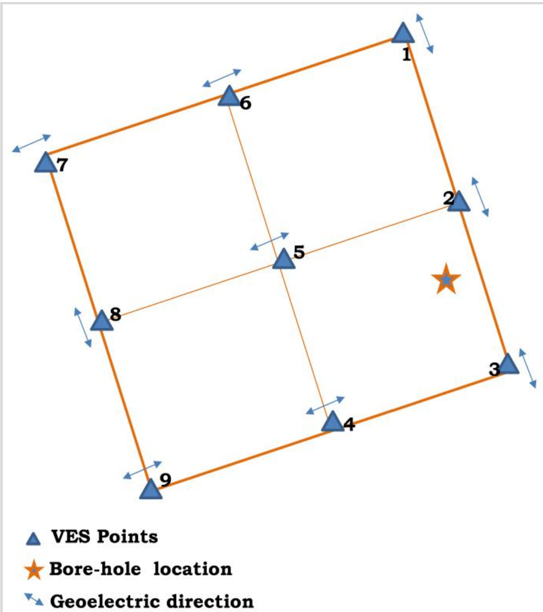

Fig. 3. Data acquisition grid of the study area

3. RESULTS AND DISCUSSION

Sounding curve acquired over a horizontally stratified medium is a function of the resistivities and thicknesses of the layers together with the electrode configuration. When the calculated apparent resistivity is plotted against the corresponding half current electrode spacing (AB/2), VES curves are derived, and the letters Q,A,K and H are used singly or in combination to indicate the variation of resistivity with depth (Fig. 4).

The resistivity type curves of the study area are indicative of good groundwater potential though based on the extent and the depth of probe of the survey, the groundwater potential of VES 4 and VES 5 are far less than those of VES 2 and VES 3. Some of the resistivity type curves are as shown (Figs. 5, 6 and 7).

A summary of the interpreted data which is within the limit of the probe is as shown in Table 1. This has revealed the existence of four to six geoelectric layers. The topsoil which is the first geoelectric layer has the resistivity varying from 13 Ωm to 4340 Ωm with thickness varying from 0.5 m to 1.4 m. The resistivity of the aquiferous zones varied from 611 Ωm at VES 2 to 99500 Ωm at VES 1. Amos-Uhegbu et al. [12] extensively worked within the study area and lithologically deduced from drill-hole and geoelectric data that sediments with resistivity < 100 Ωm are clays, 100 Ωm – 500 Ωm are silts, 500 Ωm – 1500 Ωm are fine-grained sands, 1500 Ωm – 3000 Ωm are medium-grained sands, 3000 Ωm – 5500 Ωm are coarse-grained sands, and > 5500 Ωm as sandstone [12]. This deduction has been used in the characterization of the various geoelectric layers. There is a likelihood of an existence of a possible shallow confined aquifer at VES 4 while the most reliable point recommended for sustainable groundwater potential is VES 2 (Fig. 8).

Using the hydraulic conductivity of 8.62 m/d established in the area through geostatistical approach of Amos-Uhegbu, [13], the highest aquifer transmissivity of the study area is that of VES 2 which is 810.28 m^2/d.

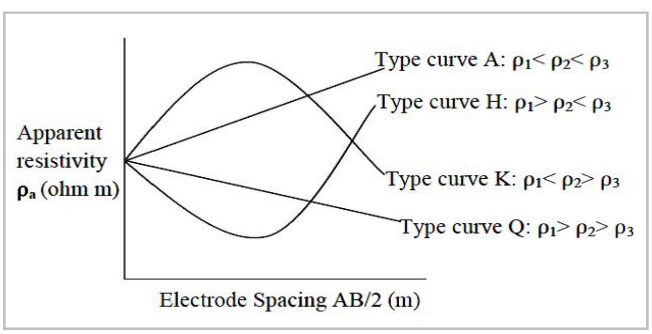

Fig. 4. Diagrammatic illustration of resistivity type curves for layered structures

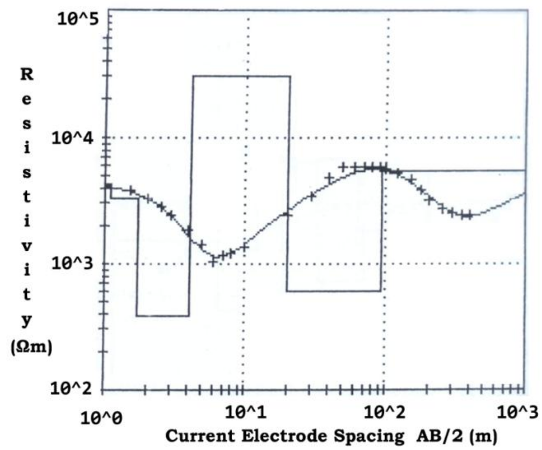

Fig. 5. Typical vertical electrical sounding curve of VES 2 (University gate)

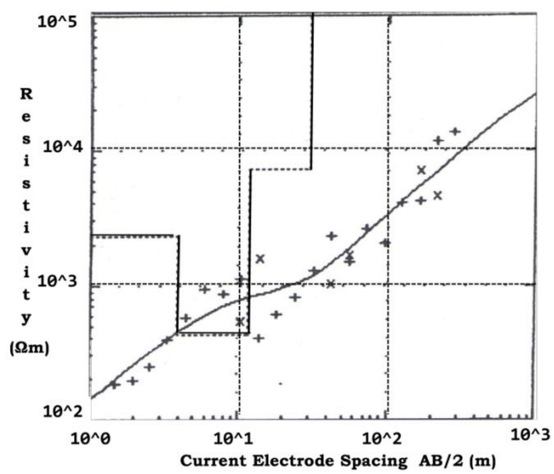

Fig. 6. Typical vertical electrical sounding curve of VES 1(School gate)

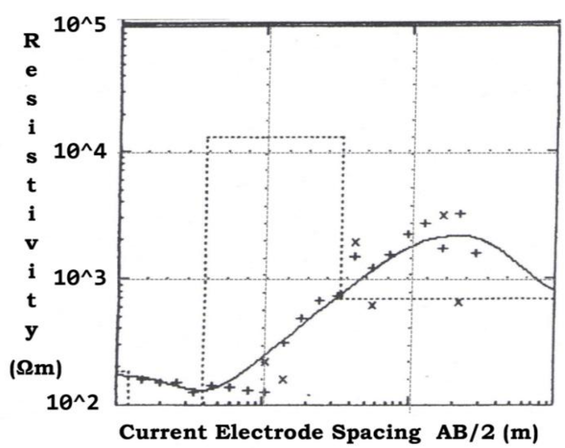

Fig. 7. Typical vertical electrical sounding curve of VES 4 (Stadium junction)

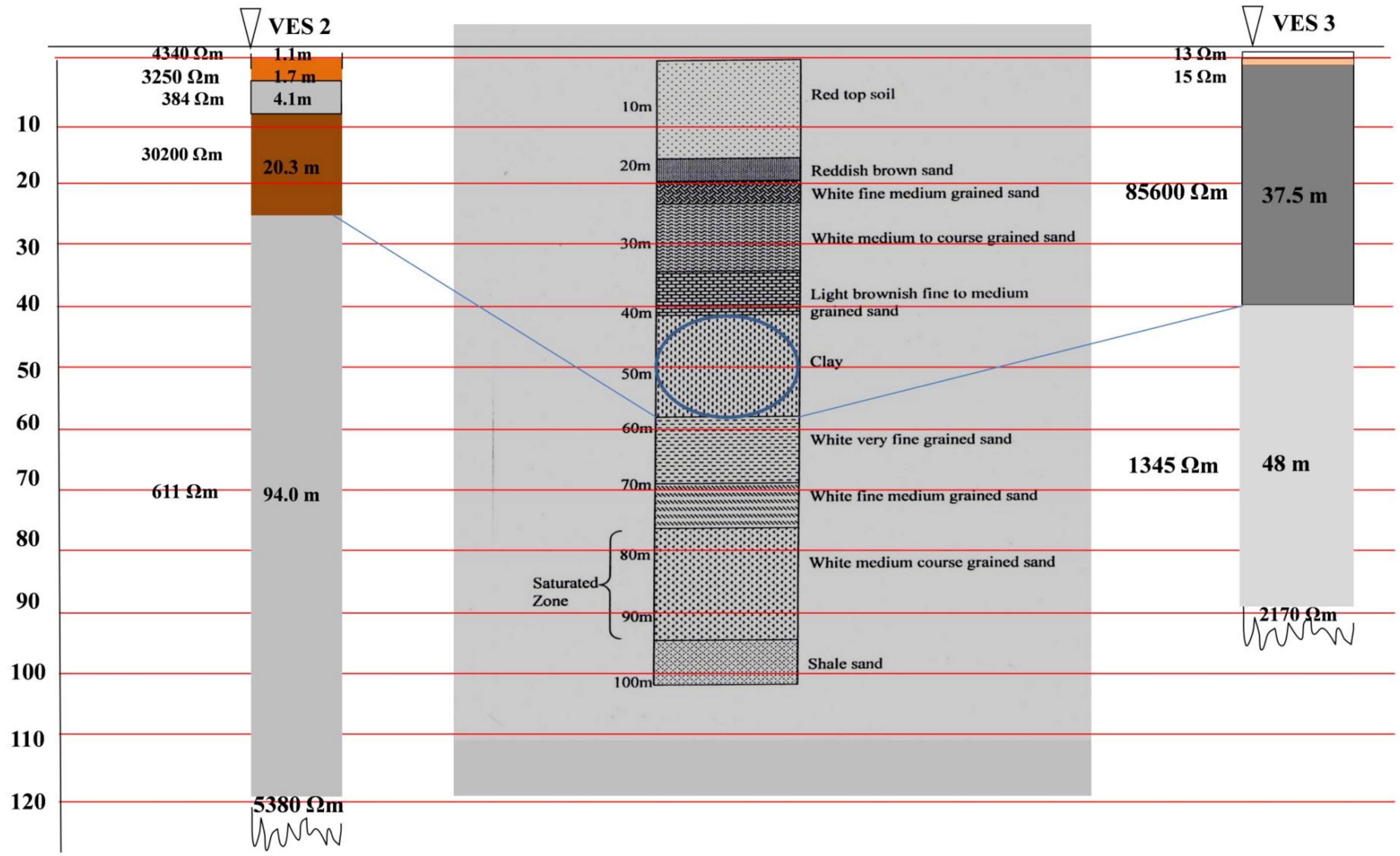

Fig. 8. A correlation of VES 2, VES 3 and a nearby borehole behind the Administrative building
(Source of borehole data [14])

Table 1. A profile of VES data and location points; with some calculated geo-electrical parameters

VES station	Location	GPS reading Elevation (m) m.s.l Latitude (°N) Longitude (°E)	Number of layers	Resistivity of layers (Ωm)	Thickness of layers (m)	Maximum depth of layers (m)	Layer conductivity σ	Fitting error (%)	Layer characteristics	Type curves
1	Opposite MOUAU School gate	**120.0 m** 5° 28. 985$^{!}$ °**N** 7° 32. 709$^{!}$ °**E**	5	ρ_1 =88 ρ_2 =2355 ρ_3 =430 ρ_4 = 7280 ρ_5 = 99500	t_1 =0.7 t_2 = 3.1 t_3 = 7.5 t_4 = 18	h_1 =0.7 h_2 = 3.8 h_3 = 11.3 h_4 = 29.3	σ_1 = 0.011364 σ_2 = 0.000425 σ_3 = 0.002326 σ_4 = 0.000137 σ_5 = 0.000010	10	L_1 =Clay L_2 =Medium-grained sands L_3 =Silts L_4 = Sandstone (Capillary fringe zone) L_5 = Sandstone (Aquiferous zone)	**KHA**
2	Opposite MOUAU University gate	**129.5 m** 5° 28. 826$^{!}$ °**N** 7° 32. 765$^{!}$ °**E**	**6**	ρ_1 =4340 ρ_2 =3250 ρ_3 =384 ρ_4 = 30200 ρ_5 = 611 ρ_6 = 5380	t_1 = 1.1 t_2 = 1.7 t_3 = 4.1 t_4 =20.3 t_5 = 94.0	h_1= 1.1 h_2 = 2.8 h_3 = 6.9 h_4 = 27.2 h_5 = 121.2	σ_1 = 0.000304 σ_2 = 0.000308 σ_3 = 0.002604 σ_4 = 0.000033 σ_5 = 0.001637 σ_6 = 0.000186	8	L_1 = Corse-grained sands L_2 = Coarse-grained sands L_3 =Silts L_4 = Sandstone (Capillary fringe zone) L_5 = Fine-grained sands (Aquiferous zone) L_6 = Coarse-grained sands (Aquiferous zone)	QHKH
3	Automobile Workshop	**136.9 m** 5° 28. 723$^{!}$ °**N** 7° 32. 782$^{!}$ °**E**	5	ρ_1 =13 ρ_2 =15 ρ_3 =85600 ρ_4 = 1345 ρ_5 = 2170	t_1 =1.1 t_2 = 2.1 t_3 = 37.5 t_4 = 48	h_1 = 1.1 h_2 = 3.2 h_3 = 40.7 h_4 = 88.7	σ_1 = 0.076923 σ_2 = 0.066667 σ_3 = 0.000012 σ_4 = 0.000743 σ_5 = 0.000461	12	L_1 =Clay L_2 =Clay L_3 =Sandstone (Capillary fringe zone) L_4 = Fine-grained sands (Aquiferous zone) L_5 = Medium-grained sands (Aquiferous zone)	AKH
4	MOUAU Stadium junction	115.5m 5° 28. 576$^{!}$ °**N** 7° 32. 507$^{!}$ ^{0}**E**	**4**	ρ_1 = 184 ρ_2 = 78 ρ_3 = 13124 ρ_4 = 280.3	t_1 = 1.2 t_2 = 2.7 t_3 = 30.0	h_1 = 1.2 h_2 = 3.9 h_3 = 33.9	σ_1 = 0.005435 σ_2 = 0.012821 σ_3 = 0.000076 σ_4 = 0.003568	10	L_1 =Silts L_2 =Clay L_3 = Sandstone (Shallow Aquiferous zone) L_4 = Silts	HK
5	Male Hostel junction	**111.6 m** 5° 28. 790$^{!}$ °**N** 7° 32. 538$^{!}$ °**E**	4	ρ_1 =84 ρ_2 =10 ρ_3 =1120.1 ρ_4 = 168.3	t_1 =1.0 t_2 = 2.5 t_3 =7.0	h_1 =1.0 h_2 = 3.5 h_3 = 10.5	σ_1 = 0.011905 σ_2 = 0.1 σ_3 = 0.000893 σ_4 = 0.005942	2.0	L_1 =Clay L_2 =Clay L_3 =Fine-grained sands L_4 = Silts	HK
6	MOUAU ICT centre	**121.4 m** 5° 28. 925$^{!}$ °**N** 7° 32. 553$^{!}$ °**E**	**6**	ρ_1 =3800 ρ_2 =65 ρ_3 =667 ρ_4 = 50 ρ_5 = 3250 ρ_6 = 61800	t_1 =0.5 t_2 = 0.7 t_3 = 2.2 t_4 = 7.0 t_5 = 12.6	h_1= 0.5 h_2 = 1.2 h_3 = 3.4 h_4 = 10.4 h_5 = 23.0	σ_1 = 0.000263 σ_2= 0.015385 σ_3 = 0.001499 σ_4 = 0.020000 σ_5 = 0.003077 σ_6 = 0.000016	20	L_1 =Coarse-grained sands L_2 =Clay L_3 =Fine-grained sands L_4 = Clay L_5 = Coarse-grained sands (Capillary fringe zone) L_6 = Sandstone (Aquiferous zone)	HKHA

VES station	Location	GPS reading Elevation (m) m.s.l Latitude (°N) Longitude (°E)	Number of layers	Resistivity of layers (Ωm)	Thickness of layers (m)	Maximum depth of layers (m)	Layer conductivity σ	Fitting error (%)	Layer characteristics	Type curves
7	COLNAS (beside COLPAS)	**102.4 m** 5° 28. 896' °**N** **7°** 32. 398' °**E**	4	ρ_1 =250 ρ_2 =1003 ρ_3 = 4650 ρ_4 = 280.3	**t_1 = 0.7** **t_2 = 17.0** **t_3 = 42.0**	**h_1 =0.7** **h_2 = 17.7** **h_3 = 59.7**	**σ_1 = 0.004000** **σ_2 = 0.000997** **σ_3 = 0.000215** **σ_4 = 0.003567**	9	**L_1 =Silts** **L_2 =Fine-grained sands** **L_3 = Coarse-grained sands (Aquiferous zone)** **L_4 = Silts**	AK
8	Works Department Junction	**113.0 m** 5° 28. 766' °**N** 7° 33. 928' °**E**	5	ρ_1 =150 ρ_2 =75 ρ_3 =151 ρ_4 = 7168 ρ_5 = 99000	**t_1 = 0.8** **t_2 = 1.5** **t_3 = 1.0** **t_4 = 6.0**	**h_1 = 0.8** **h_2 = 2.3** **h_3 = 3.3** **h_4= 9.3**	**σ_1 =0.006667** **σ_2= 0.013333** **σ_3 = 0.006623** **σ_4 = 0.000140** **σ_6 = 0.000010**		**L_1 =Silts** **L_2 =Clay** **L_3 =Silts** **L_4 = Sandstone** **L_5 = Sandstone(Saturated zone)**	HAA
9	CNREM junction	**106.7m** 5° 28. 589 °**N** **7°** 32. 388' °**E**	5	ρ_1 =84 ρ_2 =508 ρ_3 =3980 ρ_4 = 4190 ρ_5 = 5640	**t_1 =1.4** **t_2 = 1.2** **t_3 = 5.7** **t_4 = 11.6**	**h_1 = 1.4** **h_2 = 2.6** **h_3 = 8.3** **h_4 = 19.9**	**σ_1 = 0.011905** **σ_2 = 0.001969** **σ_3 = 0.000251** **σ_4 = 0.000239** **σ_5 = 0.000177**	10	**L_1 = Clay** **L_2 = Fine-grained silty-sands** **L_3 = Coarse-grained sands** **L_4 = Coarse-grained sands** **L_5= Coarse-grained sands /Sandstone (Saturated zone)**	AAA

4. CONCLUSION

It is hereby concluded that despite the shallow depth of investigation used in the assessment of the groundwater potential of the study area; the study has indicated that Michael Okpara University of Agriculture, Umudike and its environs have huge sustainable groundwater potential.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Amos-Uhegbu C. An investigation to determine the suitability of the Groundwater of Aba Metropolis for Agricultural purposes. Archives of Applied Science Research. 2012;4(5):2027-2033.
2. Igboekwe MU, Eke AB, Emeka-Chris CC, Ihekweaba G. Geophysical assessment and groundwater quality in Michael Okpara University of Agriculture, Umudike, Abia State. Pacific Journal of Science and Technology. 2013;14(2):565-575.
3. Amos-Uhegbu C, Igboekwe MU, Chukwu GU, Okengwu KO, Eke KT. Aquifer characteristics and groundwater quality assessment in Ikwuano area of Southeastern Nigeria. Journal of Scientific Research & Reports. 2014a;3(2):366-383.
4. Singh CL. Role of surface geophysical methods for groundwater exploration in hard rock areas. Proceedings of International Workshop on Rural Hydrology and Hydraulics in Fissured Basement Zones. 1984;59-68.
5. Ayolabi EA, Adeoti L, Oshinlaja NA, Adeosun IO, Idowu OI. Seismic refraction and resisitivity studies of part of Igbogbo township, South-West Nigeria. Journal Science Research and Development. 2009;11:42-61.
6. Lawrence AO, Ojo TA. The use of combined geophysical survey methods for groundwater prospecting in a typical basement complex terrain: Case study of Ado-Ekiti Southwest Nigeria, Research Journal in Engineering and Applied Sciences. 2012;1(6):362-376.
7. Gabr A, Murad A, Baker H, Bloushi K, Arman H, Mahmoud S. The use of seismic refraction and electrical techniques to investigate groundwater aquifer, Wadi Al-ain, United Arab Emirates (UAE). Conference Proceedings of the Water Resources and Wetlands. 2012;14-16.
8. Afolayan JF, Olorunfemi MO, Afolabi O. Geoelectric/electromagnetic VLF survey for groundwater in a basement terrain: a case study. Ife Journal of Science. 2004; 6(1):74-78. Eke K T. and Igboekwe M U; 2011.
9. Geoelectric Investigation of Groundwater in some villages in Ohafia Locality, Abia State, Nigeria. British Journal of Applied Science & Technology. 2011;1(4):190-203.
10. Amos-Uhegbu C, Igboekwe MU, Chukwu GU, Okengwu KO, Eke TK. Hydrogeophysical delineation and hydrogeochemical characterization of the aquifer systems in Umuahia-South Area, Southern Nigeria. British Journal of Applied Science & Technology. 2012;2(4):406-432.
11. Nejad HT. Geoelectric Investigation of the aquifer characteristics and groundwater Potential in Behbahan Azad University Farm, Khuzestan Province, Iran. Journal of Applied Sciences. 2009;9(20):3691-3698.
12. Amos-Uhegbu C, Igboekwe MU, Chukwu GU, Okengwu KO and Eke KT. Geo-electrical delineation and geochemical characteristics of aquifer systems in Kwa-Ibo River Watershed, Abia State, Nigeria. Journal of Scientific Research & Reports. 2014b;3(6):818-843.
13. Amos-Uhegbu C. A simple geostatistical approach in geoelectrical estimation of aquifer hydraulic parameters: A case study of benin hydrogeological province in Umuahia area, Southern Nigeria. Journal of Scientific Research & Reports. 2014; 3(2):306-326.
14. Ebilah S. Abia state rural water supply project, feasibility report and preliminary engineering design report. Ebillah-Salmon and Partners in association with Esokay Ltd. 1993;183.

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