Geophysical investigation of the Groundwater Potentials in the Imo Shale Formation of Ehime Mbano Area, Southern Nigeria

C. Amos-Uhegbu, Ph.D.[1] and D.N. Ndubueze, Ph.D.[2]

[1]Department Department of Geology, Michael Okpara University of Agriculture, Umudike, PMB 7267 Umuahia, Abia-State, Nigeria.
[2]Department of Physics (Geophysics), Michael Okpara University of Agriculture, Umudike, PMB 7267 Umuahia, Abia-State, Nigeria.

E-mail: nenyemos@yahoo.com

ABSTRACT

This study was carried out to investigate the groundwater potential in some selected villages in the Imo Shale Formation of Ehime Mbano Area, Southern Nigeria. A total of ten (10) vertical electrical soundings were conducted using the ABEM SAS 4000 Terrameter. The data obtained were subjected to interpretation by partial curve matching and then by computer iteration. A total of ten geoelectric layers were delineated in this study. Results show that the aquifer is located within the fifth layers at an average depth of about 31 m – 40 m for VES locations 1 - 4; while the resistivity of the aquifer ranged between 1240 Ωm and 1250 Ωm. Appropriate depths to which potable water can be obtained from the various locations are recommended in this study.

(Keywords: groundwater, geoelectric, Imo Shale Formation, terrameter, vertical electrical sounding, VES)

INTRODUCTION

Groundwater is usually referred to as the water beneath the ground surface in auriferous soil pore spaces, or in the fractures of rock formations in form of underground streams. Groundwater is a natural resource with its inherent characteristics being strongly determined by the geologic properties of the host rock.

A porous substratum (rock) that is able to hold and yield (transmit) an appreciable quantity of groundwater upon penetration by a borehole is called an aquifer. Thus, the search for groundwater in an area should be dependent on a reliable empirical knowledge of the local geology of the area.

Location, Physiography and Geology of the Study Area

The study area lies mainly in the Northern parts of Ehime Mbano Area of Imo State, Southern Nigeria (Figure 1), and falls within the sub-equatorial belt with average relative humidity values of about 70%; and elevation from about between 61m and 122m above sea level (Egbueri, et al., 2020).

While the wet season spans from Mid-April to the end of October with an annual average rainfall of about 230mm and temperature of the area varies from 29°C to about 33°C.

There are about five different geologic Formations in Imo State of Nigeria but the Imo Shale Formation of the Cenozoic Niger Delta is the study area (Figure 2). The main stratigraphic unit of Imo Shale Formation is Paleocene in age and runs from western to eastern Nigeria in an arcuate belt which is blue-gray in color, and in some places sandy and commonly fossiliferous.

The Formation grades into thick shelly limestone (Ewekoro Formation) in the western part of Nigeria while in the eastern part, it grades in some places into sandy to silty or shaly sandstone (Short and Stauble, 1965). The age of the Formation ranges into Early Eocene and is over-lain by Bende-Ameki Formation.

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 (Amos-Uhegbu, 2012).

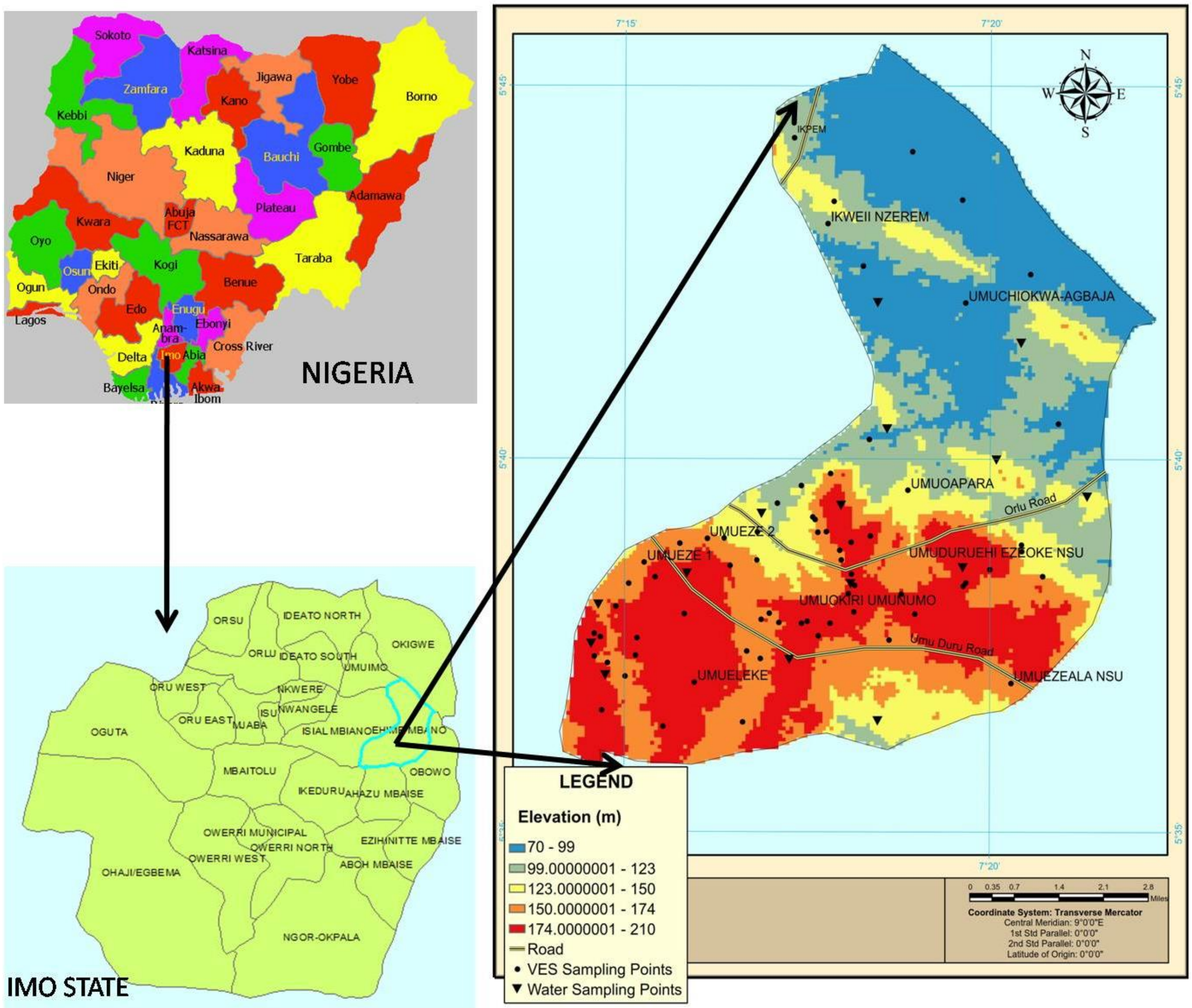


Figure 1: Physiographic Map of the Study area Ehime Mbano Area of Imo State, Nigeria.

The preference of groundwater to surface water; together with the non-availability of the municipal water supply has made groundwater the main source of water supply for almost every sector in the area (Amos-Uhegbu, 2012). The above factors have also added pressure on the groundwater of Ehime-Mbano Area.

Since it has been stated earlier that the search for groundwater in an area should be dependent on a reliable empirical knowledge of the local geology of the area; Imo Shale Formation is well known mostly for its inability to host groundwater, hence the local geology of the area (since it is Imo Shale) need be studied for groundwater potential.

Groundwater studies are usually actualized using modern scientific tools with well outlined techniques.

Geophysical surveys are most widely used because of their basic advantage of providing more accurate results than other methods. Amongst all the geophysical methods, the electrical resistivity method has been the most widely used tool for groundwater investigation. 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 (Amos-Uhegbu, et al, 2017).

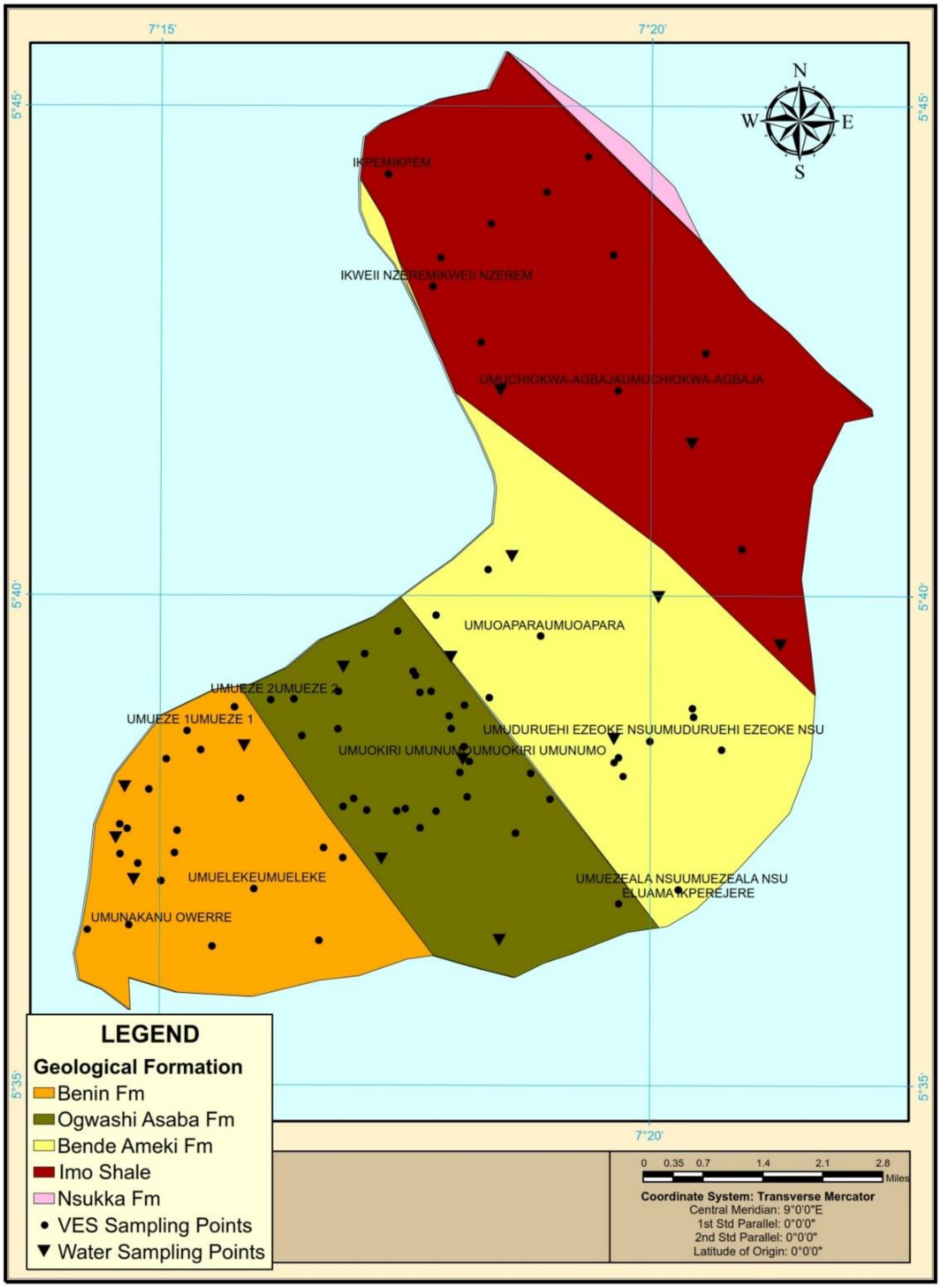


Figure 2: Geologic Map of Ehime Mbano Area of Imo State, Nigeria.

MATERIALS AND METHODS

A total of ten 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 350 m; while the potential electrode spacing 'MN/2' was varied from 0.5 m to a maximum of 55 m. 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:

$$\rho a = \pi R((L^2-l^2)/2l) \quad \textbf{(1)}$$

Where
ρa = Apparent resistivity.
L = ‘AB/2’ = Half current electrode spacing(m).
l = MN/2 = Half potential electrode spacing (m).
R = Resistance in ohms.
$\pi R((L^2-l^2)/2l)$ = 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 IPI2Win v. 2.1software package.

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 (Figure 3).

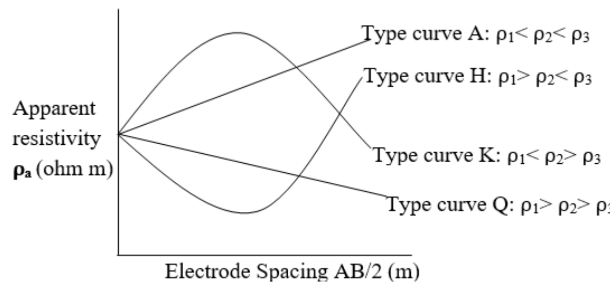


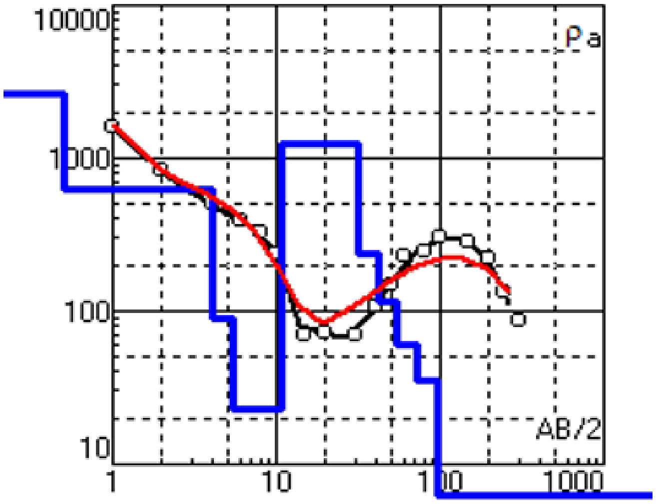
Figure 3: Schematic Diagram of Resistivity Type Curves for Layered Structures.

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 eight to ten geoelectric layers. The topsoil which is the first geoelectric layer has the resistivity varying from 86 Ωm to 2850 Ωm with thickness varying from 0.5 m to 0.6 m with 5.5 m only observed at VES 6 station.

Based on the extent (depth) of probe of the survey in the study area, the resistivity type curves, areas of groundwater potential are indicative of single auriferous units. The thickness of the 5^{th} layer of VES Stations 1 - 4 ranges from 19m to 21m and they possess favorable groundwater potential from the depth of about 31.5m. Some of the resistivity type curves are as shown (Figures 4, 5, 6 , 7, and 8).

At the vicinity of VES Station 5 after the 6^{th} layer at about 57.4 m down to about 187.4 m is a layer indicative of a huge groundwater potential with resistivity of 1300 Ωm. On the other hand, at VES 6, at about 80 m down to about 187.7 m is also a layer of resistivity of 2900 Ωm and possesses a favorable huge groundwater potential; while at VES 7 from about 10 m to 28m may likely hold shallow groundwater which may be confined because the shallow nature of the layer may probably rule out the possibility of huge groundwater potential.

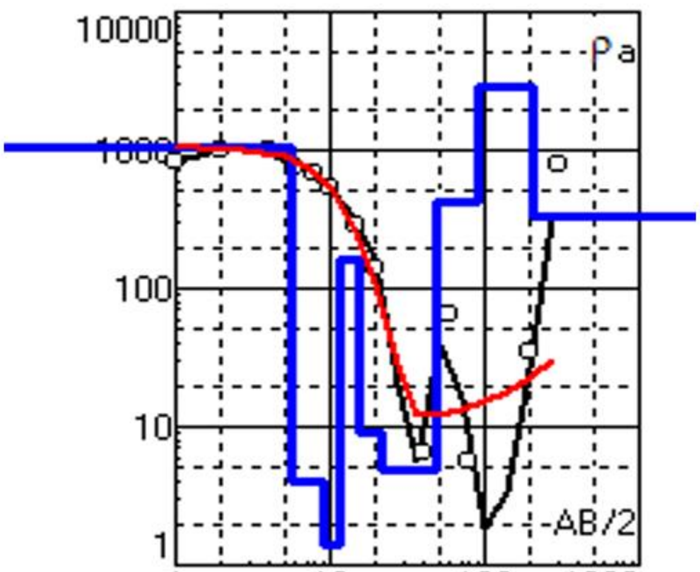
The resistivity values of VES Stations 8 -10 do not give favorable groundwater potentials more especially at stations 9 and 10.



VES 3: **Umuosu-Alike Nzerem**
5°41.500'N, 7°18.493'E, H405ft

N	ρ(Ωm)	h(m)	d(m)
1	2800	0.5	0.5
2	640	3.5	4.0
3	94	1.5	5.5
4	24	5.0	10.5
5	1250	20.0	30.5
6	225	10.5	41.0
7	118	10.5	51.5
8	65	18.0	69.5
9	35.5	21.0	90.5
10	6		

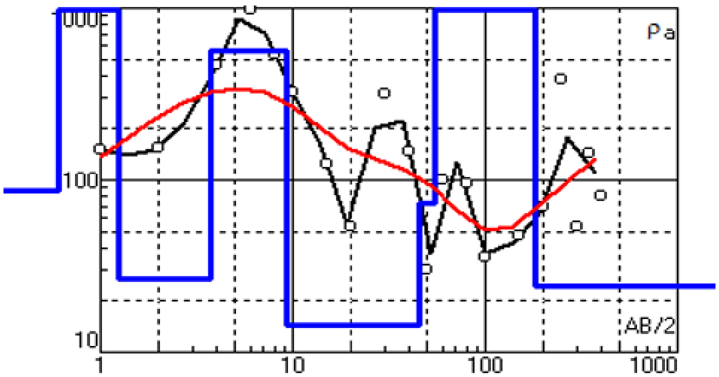
Figure 4: Typical Vertical Electrical Sounding Curve of VES 3.



VES 6: **Umuemeke Agbaja**
5°41.706'N, 7°17.085'E, H347ft

N	ρ(Ωm)	h(m)	d(m)
1	1150	5.5	5.5
2	4.0	3.5	9.0
3	1.4	3.0	12.0
4	180	4.0	16.0
5	9.2	6.0	22.0
6	4.2	25.0	47.0
7	430	35.0	82.0
8	2900	130.0	212.0
9	320		

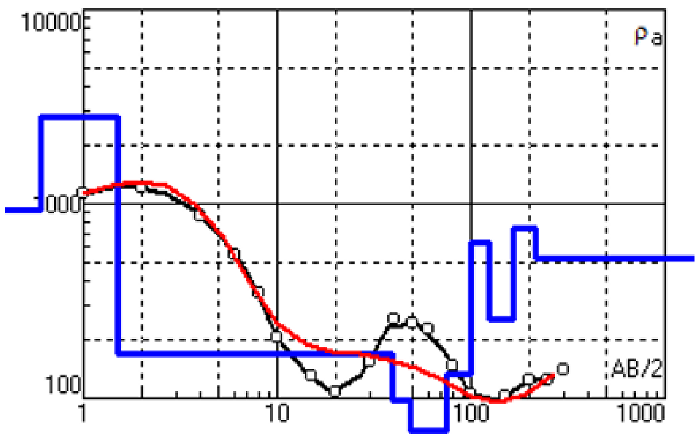
Figure 5: Typical Vertical Electrical Sounding Curve of VES 6.



VES 5: **Umuchukwu Mgbam Agbaja**
5°41.679'N, 7°14.812'E, H350ft

N	ρ(Ωm)	h(m)	d(m)
1	86	0.6	0.6
2	1150	0.6	1.2
3	27	2.6	3.8
4	580	5.6	9.4
5	15	38.0	47.4
6	75	10.0	57.4
7	1300	130.0	187.4
8	24		

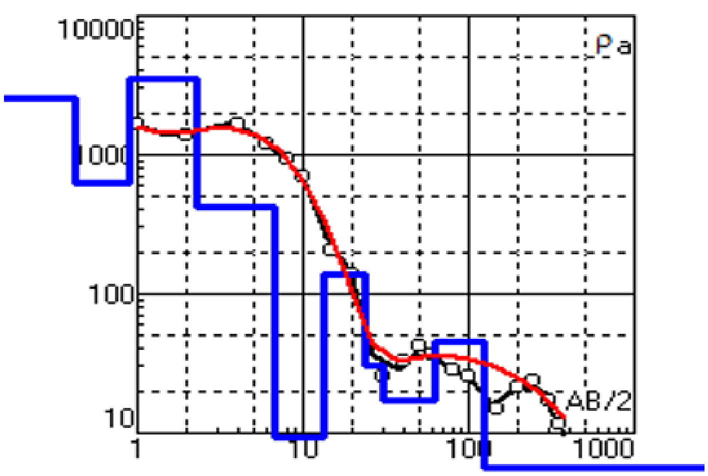
Figure 6: Typical Vertical Electrical Sounding Curve of VES 5.



VES 8: **Agbaja**
5°40.756'N, 7°15.482'E, H502ft

N	ρ(m)	h(m)	d(m)
1	930	0.6	0.6
2	2850	1.0	1.6
3	170	38.4	40.0
4	95	4.8	44.8
5	62	9.0	53.8
6	140	25.0	78.8
7	650	26.0	104.8
8	245	45.0	149.8
9	720	50.0	199.8
10	540		

Figure 7: Typical Vertical Electrical Eounding Curve of VES 8.



VES 9: **Umudike Umunuhu-Nsu**
5°39.136'N, 7°20.635'E, H205ft

N	ρ(Ωm)	h(m)	d(m)
1	2650	0.5	0.5
2	640	0.4	0.9
3	3500	1.6	2.5
4	430	4.0	6.5
5	9.5	7.0	13.5
6	140	9.0	22.5
7	31	6.0	28.5
8	18	38.0	66.5
9	45	71.0	137.5
10	4		

Figure 8: Typical Vertical Electrical Sounding Curve of VES 9.

Table 1: A Summary of the Interpreted VES Data and their Locations.

VES Station	Location	GPS reading	Resistivity of layers (Ωm)	Inferred Lithology of layers	Thickness of layers (m)	Maximum depth of layers (m)	Layer conductivity σ	Type Curves
1	**Umuna – Nzerem**	5°40.914'N, 7°19.954'E, H405ft	ρ1 =2600 ρ2 =650 ρ3 =100 ρ4 = 25 ρ5 =1250 ρ6 =240 ρ7 =110 ρ8 =60 ρ9 = 40 ρ10= 10	SandyTopsoil Silt Clay Clay Sand Clay Clay Clay Clay Clay	t1 =0.5 t2 = 3.5 t3 = 1.5 t4 = 5.0 t_5 = 21.0 t_6 = 8.5 t7 = 15.0 t8 =20.5. t9 =24.0. t10 = ?	h1 =0.5 h2 = 4.0 h3 = 5.5 h4 = 10.5 h5 = 31.5 h6 = 40.0 h7 = 55.0 h8 = 76.0 h9 =100.0 h10 = ?	σ1 =0.000385 σ2 =0.001538 σ3 =0.010000 σ4 =0.008000 σ5 =0.000800 σ6 =0.004167 σ7 =0.009090 σ8 =0.016667 σ9 =0.025000 σ10=0.100000	QQKQQQQQ
2	**Nzerem Market Road**	5°40.438'N, 7°20.755'E, H404ft	ρ1 =2400 ρ2 =600 ρ3 =95 ρ4 = 24 ρ5 =1240 ρ6 =240 ρ7 =110 ρ8 =60 ρ9 = 40 ρ10= 9	SandyTopsoil Silt Clay Clay Sand Clay Clay Clay Clay Clay	t1 =0.5 t2 = 3.5 t3 = 1.5 t4 = 5.5 t_5 = 19.0 t_6 = 8.5 t7 = 15.0 t8 =20.5. t9 =24.0. t10 = ?	h1 =0.5 h2 = 4.0 h3 = 5.5 h4 = 11.0 h5 = 30.0 h6 = 40.5 h7 = 55.5 h8 = 76.0 h9 =100.0 h10 = ?	σ1 =0.000417 σ2 =0.001667 σ3 =0.010526 σ4 =0.041667 σ5 =0.000806 σ6 =0.004167 σ7 =0.009090 σ8 =0.016667 σ9 =0.025000 σ10=0.111111	QQHKQQQQ
3	**Umuosu-Alike Nzerem**	5°41.500'N, 7°18.493'E, H405ft	ρ1 =2800 ρ2 =640 ρ3 =94 ρ4 = 24 ρ5 =1250 ρ6 =225 ρ7 =118 ρ8 =65 ρ9 = 35.5 ρ10= 6	SandyTopsoil Silt Clay Clay Sand Clay Clay Clay Clay Clay	t1 =0.5 t2 = 3.5 t3 = 1.5 t4 = 5.0 t_5 = 20.0 t_6 = 10.5 t7 = 10.5 t8 = 8.0. t9 =21.0. t10 = ?	h1 =0.5 h2 = 4.0 h3 = 5.5 h4 = 10.5 h5 = 30.5 h6 = 41.0 h7 = 51.5 h8 = 69.5 h9 =90.5 h10 = ?	σ1 =0.000357 σ2 =0.001563 σ3 =0.010638 σ4 =0.041667 σ5 =0.000800 σ6 =0.004444 σ7 =0.008475 σ8 =0.015385 σ9 =0.028169 σ10=0.166667	QQHKQQQQ
4	**Alike Nzerem**	5°40.111'N, 7°22.051'E, H406ft	ρ1 =2650 ρ2 =650 ρ3 =95 ρ4 = 23 ρ5 =1250 ρ6 =250 ρ7 =120 ρ8 =63 ρ9 = 36 ρ10= 7	SandyTopsoil Silt Clay Clay Sand Clay Clay Clay Clay Clay	t1 =0.5 t2 = 3.4 t3 = 1.4 t4 = 4.8 t_5 = 21.0 t_6 = 11.5 t7 = 15.0 t8 =25.0. t9 =40.0. t10 = ?	h1 = 0.5 h2 = 3.9 h3 = 5.3 h4 = 10.1 h5 = 31.1 h6 = 42.6 h7 = 51.5 h8 = 76.5 h9 =116.5 h10 = ?	σ1 =0.000377 σ2 =0.001538 σ3 =0.010526 σ4 =0.043478 σ5 =0.000800 σ6 =0.004000 σ7 =0.008333 σ8 =0.015873 σ9 =0.027778 σ10=0.142857	QQHKQQQQ
5	**Umuchukwu Mgbam Agbaja**	5°41.679'N, 7°14.812'E, H350ft	ρ1 =36 ρ2 =1150 ρ3 =27 ρ4 = 580 ρ5 =15 ρ6 =75 ρ7 =1300 ρ8 =24	ClayeyTopsoil Sand Clay Silt Clay Clay Sand Clay	t1 =0.6 t2 = 0.6 t3 = 2.6 t4 = 5.6 t_5 = 38.0 t_6 = 10.0 t7=130.0 t8 = ?	h1 =0.6 h2 = 1.2 h3 = 3.8 h4 = 9.4 h5 = 47.4 h6 = 57.4 h7 = 187.4 h8 = ?	σ1 =0.027779 σ2 =0.000870 σ3 =0.037037 σ4 =0.001724 σ5 =0.066667 σ6 =0.013333 σ7 =0.000769 σ8 =0.041667	KHKHQK
6	**Umuemeke Agbaja**	5°41.706'N, 7°17.085'E, H347ft	ρ1 =1150.0 ρ2 =4.0 ρ3 =1.4 ρ4 = 180.0 ρ5 =9.2 ρ6 =4.2 ρ7 =430.0 ρ8 =2900.0 ρ9 = 320	SandyTopsoil Clay Clay Clay Clay Clay Silt Sand Clay	t1 =5.5 t2 = 3.5 t3 = 3.0 t4 = 4.0 t_5 = 6.0 t_6 = 25.0 t7 = 35.0 t8=130.0 t9 = ?	h1 = 5.5 h2 = 9.0 h3 = 12.0 h4 = 16.0 h5 = 20.0 h6 = 45.0 h7 = 80.0 h8 = 210.0 h9 = ?	σ1 =0.000870 σ2 =0.250000 σ3 =0.714286 σ4 =0.005556 σ5 =0.108696 σ6 =0.238095 σ7 =0.002326 σ8 =0.000345 σ9 =0.003125	QHKQHAK

7	**Umuagim Nzerem**	5°41.275'N, 7°20.559'E, H405ft	ρ1 =2800 ρ2 =640 ρ3 =94 ρ4 = 24 ρ5 =1300 ρ6 =240 ρ7 =130 ρ8 =58 ρ9 = 37 ρ10= 5	SandyTopsoil Silt Clay Clay Sand Clay Clay Clay Clay Clay	t1 = 0.5 t2 = 3.4 t3 = 1.2 t4 = 4.8 t_5 = 19.0 t_6 = 10.0 t7 = 13.0 t8 =19.0. t9 = 4.5. t10 = ?	h1 = 0.5 h2 = 3.9 h3 = 5.1 h4 = 9.9 h5 = 28.9 h6 = 38.9 h7 = 51.9 h8 = 70.9 h9 = 75.4 h10 = ?	σ1 =0.000357 σ2 =0.001563 σ3 =0.010638 σ4 =0.041667 σ5 =0.000769 σ6 =0.004167 σ7 =0.007692 σ8 =0.017241 σ9 =0.027027 σ10=0.200000	QQHKQQQQ
8	**Agbaja**	5°40.756'N, 7°15.482'E, H502ft	ρ1 =930 ρ2 =2850 ρ3 =170 ρ4 = 95 ρ5 =62 ρ6 =140 ρ7 =650 ρ8 =245 ρ9 = 720 ρ10= 540	SiltyTopsoil Sand Clay Clay Clay Clay Silt Clay Silt Silt	t1 = 0.6 t2 = 1.0 t3 = 38.4 t4 = 4.8 t_5 = 9.0 t_6 = 25.0 t7 = 26.0 t8 =45.0. t9 = 50. t10 = ?	h1 = 0.6 h2 = 1.6 h3 = 40.0 h4 =44.8 h5 = 53.8 h6 = 78.8 h7 = 104.8 h8 = 149.8 h9 = 199.8 h10 = ?	σ1 =0.001075 σ2 =0.000351 σ3 =0.005882 σ4 =0.010526 σ5 =0.016129 σ6 =0.007143 σ7 =0.001538 σ8 =0.004082 σ9 =0.001389 σ10=0.001852	KQQHAKHK
9	**Umudike Umunuhu-Nsu**	5°39.136'N, 7°20.635'E, H205ft	ρ1 =2650 ρ2 =640 ρ3 =3500 ρ4 = 430 ρ5 =9.5 ρ6 =140 ρ7 =31 ρ8 =18 ρ9 = 45 ρ10= 4	SandyTopsoil Silt Sand Silt Clay Clay Clay Clay Clay Clay	t1 = 0.5 t2 = 0.4 t3 = 1.6 t4 = 4.0 t_5 = 7.0 t_6 = 9.0 t7 = 6.0 t8 =38.0. t9 =71.0. t10 = ?	h1 = 0.5 h2 = 0.9 h3 = 2.5 h4 =6.5 h5 = 13.5 h6 = 22.5 h7 = 28.5 h8 = 66.5 h9 = 137.5 h10 = ?	σ1 =0.000377 σ2 =0.001563 σ3 =0.000286 σ4 =0.002326 σ5 =0.105263 σ6 =0.007143 σ7 =0.032258 σ8 =0.055556 σ9 =0.022222 σ10=0.250000	HKAHKQHK
10	**Umuezeala-Uhu Road**	5°37.026'N, 7°15.571'E, H692ft	ρ1 =590 ρ2 =1250 ρ3 = 27.5 ρ4 = 7.2 ρ5 =28.5 ρ6 =29.5 ρ7 =30.5 ρ8 =32.5 ρ9 = 45 ρ10= 68.5	SiltyTopsoil Sand Clay Clay Clay Clay Clay Clay Clay Clay	t1 = 0.6 t2 = 4.0 t3 = 3.0 t4 = 14.6 t_5 = 70.4 t_6 = 29.4 t7 = 40.6 t8 =43.0. t9 =47.0. t10 = ?	h1 = 0.6 h2 = 4.6 h3 = 7.6 h4 = 22.2 h5 = 92.6 h6 = 122.0 h7 = 162.6 h8 = 205.6 h9 = 252.6 h10 = ?	σ1 =0.001695 σ2 =0.000800 σ3 =0.036364 σ4 =0.138889 σ5 =0.035088 σ6 =0.033898 σ7 =0.024631 σ8 =0.030769 σ9 =0.022222 σ10=0.014599	KQHAAAAA

CONCLUSION

The investigation of the groundwater potential of the Imo shale Formation in Ehime-Mbano Area using the electrical resistivity technique in this study has shown that groundwater in the form of confined aquifer is likely obtainable between an average depth of 31 m and 40 m within the vicinity of VES 1-4 (Nzerem 1- 4). The resistivity of the aquifer layer ranged between 1240 Ωm and 1250 Ωm. The study has also shown that groundwater can be sourced from the seventh layer in VES 5 and the eight layer in VES 6 at Agbaja 1 and 2, respectively.

Based on the depth of investigation, the possibility of obtaining sustainable groundwater at the vicinity of VES 9 and 10 is not recommended.

Finally, the study has indicated that the entire area may not have huge sustainable groundwater potential. This is because; most of the potential groundwater host rocks are single-layered not multi-layered.

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