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Vertical Electrical Sounding (VES) Investigation in Ibusa and Environs, Nigeria

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Abstract: *This work evaluated the groundwater potentials of Ibusa, and the environ towns using Vertical Electrical Sounding (VES). VES presents a robust, inexpensive means to alleviate the chronic water supply problem associated with these areas. VES investigations was carried out in 4 locations in 2 states in Southern Nigeria; namely, Ibusa, Asaba, Ugbolu village in Northern Delta State and Onitsha in South-western Anambra State. The VES was completed using the Schlumberger array configuration with (16) sixteen vertical electrical soundings in Ibusa; (14) fourteen vertical electrical soundings in Asaba; (13) thirteen vertical electrical soundings in Ugbolu village and (11) eleven vertical electrical soundings in Onitsha. The results from the analysis of the field data were interpreted using computer software to yield information on the nature of the geoelectric layers and the aquiferous layers in the area of study. The survey highlights the role of topography on availability of water; Ibusa is a cliff. Its topograpghy and consequent lower water table further complicates the availability of water and the supply problem. The investigations showcase the importance of these factors in any efficient construction of reliable boreholes which aims to harness the optimal potentials from prolific aquifers.*

Keywords: *Ground water development, geoelectric sections, resistivity method, VES, water.*

1. INTRODUCTION

The notion that water could be scare in a tropical country like Nigeria is considered pompous by many. The average rainfall from 1990 to 2015, according to [1] was 1,197 mm. To most, water scarcity could only be possible in the Northern Sahel Savannah (desert regions) of the country. In most villages and towns in Delta North, water is a scare commodity. This has led to the modern trade in water during dry months of the year. In the past, when the population were much smaller the scarcity of water was not so devastating, the demand for water could be controlled by communal fetching from nearby streams and rivers by the younger members of the villages for all. Now with the urban migration by the younger population most societal norms and practices have broken down. Water merchants have stepped into this role for the rich, but the fate of the old and the weak is a chilling prospectus as the role of water to life is undeniable. Another paradox, the standard of living of most of the populate visa-a-versa the great petroleum wealth of the state.

Estimates by the Joint monitoring programme for water supply and sanitation, places 73% of rural dwellers and 45% of urban dwellers as dependant on ground water in 2018 [2], a 1996 survey by the ministry of water resources observed that 63% of boreholes were functional with many out of action due to pump failure [3, 4].

Most well drilled in the area are done randomly and success rate approximately 35%. The costs of modern methods are often astronomical, beyond the reach of a great majority of the people. The uses of ancient, well-tried methods are encouraged and often the best approach for the location of water-bearing horizons. Vertical Electric Sounding (VES) is

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scientific, fast and easy to use method for subsurface investigation. It is cheap and thus a renew interest in its use in the Northern parts of Delta in the country.

Table 1: Location of study areas

Co-ordinate	IBUSA	ASABA	UGBOLU	ONITSHA
Latitude:	N 06^{0} 11.587’	N 06^{O}13.452`	N 06^{O}21.829`	N 06º 50’ N
Longitude:	E 006^{0} 37.875’	E 006^{O}44.384	E 006^{O}35.079	06º 10’” E
Altitude	96 meters	58.6 meters	60.1 meters	67 meters

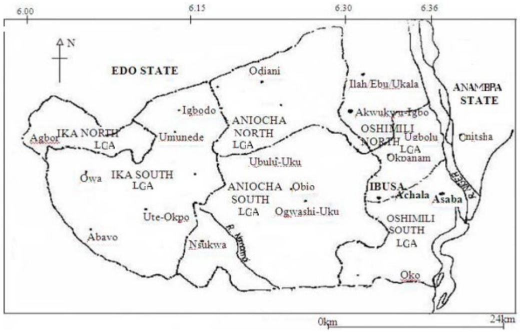

Figure 1: A map showing Asaba, Ibusa, Ugbolu in Delta State and Onitsha (Anambra state)

Adapted from [5]

This article documents the geophysical investigation carried out in 4 locations in Southern Nigeria; Asaba, Ibusa, Ugbolu, and Onitsha using Vertical Electrical Sounding (VES). The co-ordinates and altitude of the locations are shown in Table 1. These areas are well known for water shortage and insufficiency. In modern times, much relief have been obtained through the use of geological and hydrological investigation prior to the selection of sites for borehole drilling for water. Ibusa has an acute shortage of water; the difficulty in obtaining water is legendary and surpassed only by the neighbouring town of Ogwashi-Uku. For centuries, the rivers Oboshi, Atakpo, Oduche and the Asiama stream have remained major sources of water for the people of this area. Asaba, Ibusa and Ugbolu are towns and villages in Delta state, Nigeria, respectively, (Figures 1-4).

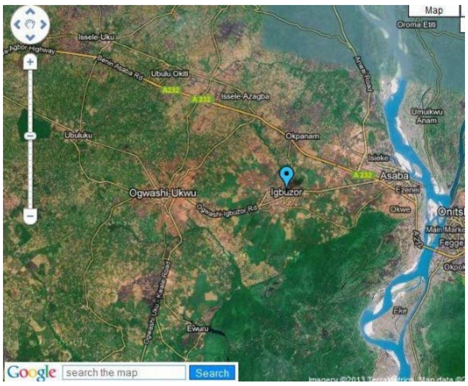

Figure 2: A map of Ibusa [6]

Ibusa is also known as Ibuzor. "Ibusa" is an anglicization of Ibuzor and both spellings are in vogue. Asaba (Figure 3) is less than 45 minutes’ drive from Ibusa; climatically and culturally there is much in common with the twin towns. Ibusa is approximately 8 km from Asaba due west. Asaba is also the capital of Delta State and is separated from the Eastern Nigeria by the River Niger. It is 25 minutes’ drive from Onitsha (Figure 4), a well-known commercial hub of West Africa. Ugbolu is a few minutes’ drive from Asaba.

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Figure 3: A map of Asaba [6]

Figure 4: A map of Onitsha [6]

Ibusa (Figure 2), Asaba (Figure 3) lies in Southern Nigeria and is characterized by 2 prominent seasons; namely the rainy season, which is wet and humid; and a hot and dry season. The rainy season (April to October) with a mean annual rainfall of approximately 2000 mm [7]) and the dry season (November to March) are characterized by high temperature with dusty atmosphere). The vegetation is tropical; lush rain forest. The study areas lies within the tropical rain forest belt of Nigeria and is drained by the great River Niger, River Anambra and River Nkisi. However the contrast in water availability is much. The VES, a well proven and tried method is offered as a means to alleviate the problem of water supply as recommended in [8]. In this article, the groundwater potentials of Ibusa, and the environ towns are evaluated using the geo-electric method of VES and documented.

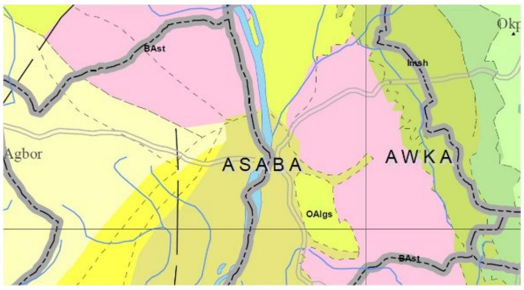

Figure 5: A geological map of Asaba community and environs [9]

Symbol:
Cps=Sand and Clay
Algs=Lignite, clay stone and shale
Bast=Clay, Clayey sands and Shale Imsh=Clay and Shale with limestone intercalation

Geologically, these towns and village fall into the sedimentary terrain of the tertiary delta. Ibusa and its environs (Ogwashi-Uku, Okpanam, and Ugbolu etc.) constitute the North fringes of Delta State, Nigeria; located in the transition zone between the Niger Delta basin underlain by the Ogwashi-Uku–Asaba formation and overlain by the Benin formation. [10]

The soil consists of friable loose highly porous sands. These sands are deeply weathered red –yellow soils and stretches from Umunede, Abavo, Agbor (North-Eastern Delta State) to some parts of the Aniocha North and South local government areas of the state (Ogwashi-Uku, Nsukwa, etc.).

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To document the subsurface complexity of this area, hydro-geophysical investigation was carried out in part of the Ibusa – Okpanam area, in Ugbolu and in Asaba. The VES investigations seek to reveal information on the lithology of the areas and are used to identify the aquifer(s) in these areas. The survey lasted for a few hours and was conducted in favourable weather conditions.

The Niger Delta and Anambra basin are of much geologic significance. Much work has been done by researchers and three major litho-stratigraphic units are recognized in the Niger Delta; these are the Akata (oldest), Agbada and the Benin (youngest) Formations; [11] showed that approximately 25-30 m thick alluvial terrace deposit underlies Asaba. It is a superficial deposit that masks the underlying Oligocene Ogwashi-Asaba Formation and is the first preferred aquifer exploited by shallow water supply boreholes.

A secondary aquifer horizon occurs at greater depths and contains iron rich water. Drilling problems encountered in accessing this secondary aquifer includes “loss of circulation problems”. There are some questions on the quality of the water and implied risk of contamination as it is believed in some quarters that River Niger could be directly recharging the aquifer in this area; [12] asserts that Asaba is underlain directly by the Benin Formation but [12] consistently places Asaba on the Ogwashi-Asaba Formation. They, however, in the same study stated that groundwater is obtained from the Benin Formation.

In a regional classification of major hydro-geological basins in Nigeria [13] and [14] alternately ascribes the Asaba (Figure 5) area first to Anambra Basin and secondly, to the Niger Delta Basin. This suggest that the Ogwashi-Asaba Formation is absent from Asaba. This is reflected by [15] in their description of lateritic iron deposits in Anambra state.

This study aims to document geological and geophysical surveys of the study areas in Delta State and the environs. This will lead to a greater understanding of aquifer locations in these areas and is of enormous important in selection of boreholes sites. Much of this information shall be derived by VES (Geoelectric mapping) and from correlation with existing Vertical Electrical Sounding (VES) data on the study area.

The importance of this cannot be over emphases as water is important for all life, as noted by the World Health Organization (WHO) in [16] and [17]. It is used for industrial, domestic and livestock production (agriculture). Water can occur as surface water (stream, pond, lake, river, sea etc.) or as subsurface water (underground water). Water supplies are however, erratic in the study areas and most people prefer to site a borehole for their personal use in their homes. Many cities, towns and communities use borehole source (groundwater) since it is a major renewable fresh water sources. Unfortunately, there is an ever increasing demand for water; hence this study is critical; because of the need for pre-drilling and detailed geological information before construction of boreholes. It is hope that with the study, that the ability of the general public to delineate a favourable hydrogeological area for producing aquifer and recommend suitable site for borehole construction would be enhanced. [18]; [19], [20] and [21], [22].

2. METHOD OF INVESTIGATION AND INSTRUMENTATION

In each survey, the Petrozenith PZ-02 Terrameter Electrical Resistivity equipment was used to conduct Vertical Electric Sounding (VES) using the Schlumberger configuration with total spread, L, of 600 meters, 240 meters, and 200 meters in Ibusa, Asaba, and Ugbolu, respectively. In Ibusa 300 meters, (L/2) were covered on the right running to Okpanam town and another 300 meters; (L/2) was covered on the left to Ibusa town (Figure 6). In Asaba, 120 m (L/2) was covered on the right running towards Asaba Community, and another 120 m (L/2) was run on the left towards Okpanam Community and in Ugbolu 100 meters, (L/2) were covered on the right running to Asaba town and another 100 meters; (L/2) was covered on the left to Ugbolu village community.The Petrozenith PZ-02 Terrameter was used to takes field measurement of resistance (R) from which apparent resistivity, Pa, was calculated using the relationship from current and potential electrodes spacing and the resistance in Ohms. All necessary precautions required in geoelectric measurement and surveys were duly considered and maintained.

3. RESULTS AND DISCUSSION

3.1 Ibusa

Field data from Ibusa (Table 2) were processed using ipi2win, a resistivity sounding interpretation software. This yielded a realistic view of the composition and layering of the subsurface. (Table 3 & 4, Figure 6). The terrain in Ibusa was observed to be predominantly of gravels, sands and clay units. It was predominantly sedimentary and of the Sombreiro Deltaic Formation. Analytical results from the ipi2win software (Table 2) revealed six sub-layers (Tables 3 & 4).

Administratively, Ibusa is divided into sub-clans. VES data from 3 of the sub-clans, Eziukwu, Ogboli and Achala by [5]. The VES survey undertaken in the Ibusa -Okpanam area by the Researchers observed and identified 6 (six) sub-surface layers. The VES interpretation suggests that the area is underlain with a substantive aquiferous formation at a depth of about 110.46 meters (362.40 ft.). This is in agreement with the earlier VES carried out by [5], In his investigation; he worked in two sub-clans of Ibusa, Ogboli and Eziukwu, and identified deep aquifers surrounded by deep-seated rocks, unlike in another neighbouring sub-clans, Achala where he observed low land zone with shallow aquifer with loose top soil to considerable depth followed by a thin layer of lateritic soil, a layer of medium to gravely sand and viable aquifer at about 30 – 40 m (Tables 3, 4 and 5 & Figures 7 and 8). In addition, Ogboli and Eziukwu sub-clans at shallow depths of 15 – 18 m consist of thick lateritic top soil to about 10 m of weathered rocks with high iron content and thick hard granite

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formation at far depth. False aquifers were observed at shallow depths of 30 – 40 m (98.43-131.23 ft.) with viable aquifer located at 80 – 110 m (262.47-360.89 ft.).

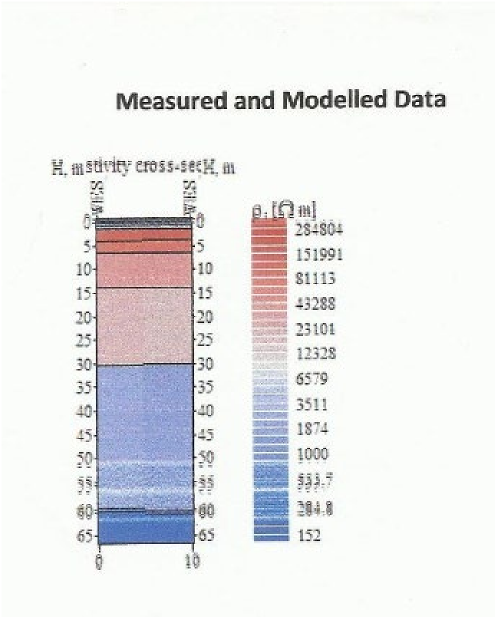

Figure 6: Measured and modelled data from Table 2

Table 2: Field data for Ibusa VES survey

S/N	AB/2	MN	K	Ro_a
1	1	1	2.36	2.45
2	2	1	11.78	2648.00
3	4	1	49.48	3969.00
4	7	1	153.15	4314.00
5	10	1	313.37	4801.00
6	14	1	614.97	5750.00
7	17	1	907.13	6368.00
8	21	1	1385.00	7590.00
9	32	1	3216.00	13925.00
10	47	2	3468.00	13907.00
11	70	2	7695.00	11081.00
12	100	4	7851.00	35644
13	150	20	3519.00	4575.00
14	200	20	6267.00	5976.00
15	250	40	4877.00	5901.00
16	300	100	2749.00	522.67

Table 3: The six sub-layers in the Ibusa section area

LAYERS	THICKNESS	DEPTH	RESISTIVITY	LITHOLOGY
1	0.5951	0.5951	282.5	Lateritic topsoil
2	0.8674	1.4625	1695	Clay stone, sandy sub-soil
3	6.848	8.3105	106624	Sandstone(dry)
4	18.91	27.2205	22557	Sandy clay formation
5	58.24	85.4605	1468	Clay stone with sands intercalation
6	UNDEFINED	UNDEFINED	112.2	Sandstone, gravelly (aquifer)

3.2 Asaba

The subsurface of Asaba consists of sand and clay units with intercalation of shale, mud stone. It is predominantly sedimentary terrain belonging to the Benin Formation (Figure 9 & 10; Table 6 & 7). In Asaba 14 (fourteen) sounding were carried out. Analyses of the results suggest 6 geoelectric layers.

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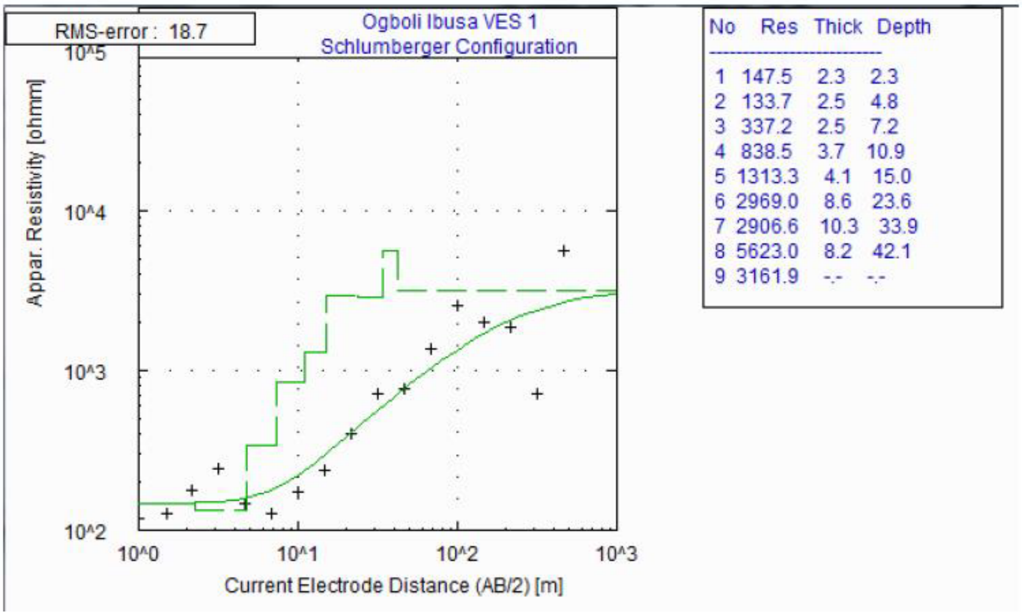

Figure 7: Ogboli-Ibusa sample plot [5]

Table 4: Results of computer interpretation of field data from Ibusa VES survey

N	ρ	H	D	Alt
1	282.5	0.5951	0.5951	0.59500
2	1695	0.8674	1.462	-1.4625
3	106624	6.848	8.31	-8.3105
4	22557	10.91	27.22	-27.225
5	1468	58.24	85.46	-85.465
6	112.2			

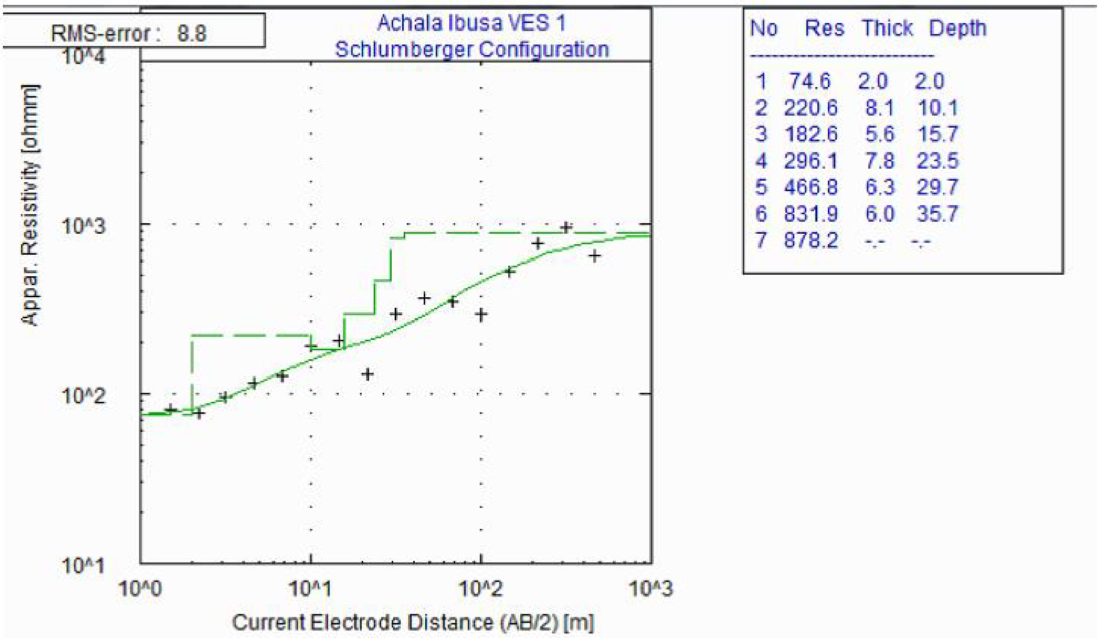

Figure 8: Achala-Ibusa Sample plot site [5]

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Table 5: Sample field data (apparent resistivity) for the sub-clans of Ibusa

MN/2	**AB/2**	**Eziukwu**	**Ogboli**	**Ogboli**	**Achala**	**Achala**
		VES 1	VES 1	VES 2	VES 1	VES 2
(m)	(m)	(Ωm)	(Ωm)	(Ωm)	(Ωm)	(Ωm)
0.2	1.00	78	118	150	75	62
	1.47	85	127	162	81	84
	2.15	97	178	130	76	108
	3.16	132	240	148	95	124
2/1.0	4.64	216	148	218	115	147
	6.81	105	128	242	128	110
1.0/3.0	10.00	168	172	294	189	128
	14.70	207	235	321	203	157
	21.50	239	398	426	130	132
	31.60	344	710	585	296	146
3.0/8.0	46.40	324	761	843	368	215
	68.10	327	1356	895	347	235
8/16	100.00	398	2563	1256	296	255
	147.00	538	1987	2272	521	219
16/30	215.00	853	1845	3532	772	405
30/50	316.00	715	3431	2188	943	278
	464.00	947	5613	1095	650	195

Table 6: Field data (resistivity data) for Asaba VES Survey

S/N	**AB/2**	**MN**	**R**	**K**	**Ro_a**
1	1	1	36.32	2.3562	85.57718
2	3	1	8.7	27.489	239.1543
3	5	1	3.94	77.754	306.3508
4	7	1	1.78	153.15	272.607
5	10	1	1.15	313.37	360.3755
6	14	1	0.76877	614.97	472.7705
7	17	1	0.59567	907.13	540.3501
8	21	1	0.4366	1385	604.691
9	32	2	0.54309	1607	872.7456
10	47	2	0.24896	3468	863.3933
11	60	10	1.13	1123	1268.99
12	80	10	0.54177	2003	1085.165
13	100	10	0.2564	3134	803.5576
14	120	20	0.45936	2246	1031.723

Table 7: The six sub-layers in the Asaba section area

Layer	**Thickness**	**Depth**	**Resistivity (Ωm**	**Lithology**
1	0.5	0.5	65.3	Sandy clay topsoil
2	0.885	1.39	270	Clayey Sand subsoil
3	2.45	3.84	415	Sandy formation
4	6.79	10.6	772	Sandstone
5	28.8	39.5	1329	Sandy formation (prospective, fresh)
6	Undefined	Undefined	1281	Sandy formation (prospective, ferrous or iron)

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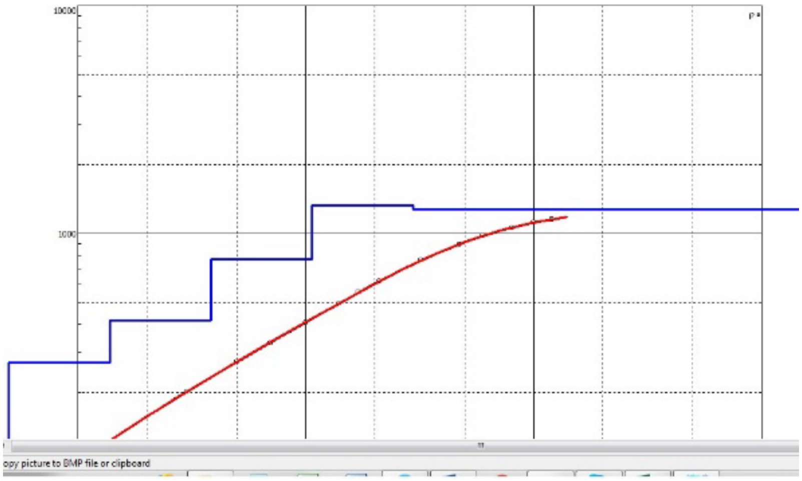

Figure 9: The layered resistivity model for Asaba.
The figure shows the six-sub layers as revealed in Table 7

The area is believed to be underlain with substantive aquiferous formation but at a depth not exceeding 39.5 meters (129.59 ft.), which is the fresh water aquifer unit devoid of iron contamination. It was proposed that to achieve best underground water development, drilling should be done to a depth exceeding 39.5 m (129.59 ft.) to allow for the water reservoirs devoid of iron contamination to be tapped. The result is similar to Tolefe 2012 [22] who used 9 (nine) sounding stations and obtained (4)Four to (5) five geoelectric layers comprising the top soil, clayey sandstone, dry sandstone, saturated sandstone, and clay. These were delineated with the latter usually occurring as the last layer. The third and fourth layers underlying dry sandstone form the aquiferous unit. This unit was found to have an average resistivity value range of 314 – 2710 Ωm and an average thickness of 25 m. It is deeply seated in some areas with an average depth of 6 – 132 meters (19.69 -433.07 ft.). Lithologic log for the borehole located near one of the sounding stations revealed that some of the geologic units were either suppressed or merged into a single geo-electric unit probably due to similarities in electrical resistivity. Based on these results, drilling should be completed to a depth of about 112.78 m (370 ft.) in Asaba. Water production at this depth, was observed to be favourable, it is advised that subsurface pump should be installed, gravel packed, and sealed against surface contamination. In Asaba, four to five (4-5) geo-electric layers comprising the top soil, clayey sandstone, dry sandstone, saturated sandstone, and clay were delineated with the latter usually occurring as the last layer. The third and fourth layers underlying dry sandstone form the aquiferous unit. This unit was found to have an average resistivity value range of 314 – 2710 Ωm and an average thickness of 25 m. It is deeply seated in some areas with an average depth of 6 – 132 m. Tolefe, 2012; [22]. It was observed that the hydraulic conductivity ranges from 0.00048 to 0.0034 m/day. The transmissivity range in this area is from 0.038 – 0.23 m2/day. From [21] the resistivity of the top soil ranges from 73 m -130 m, while the second and third layers are 120 m-230 m and 320 m-560 m, respectively.

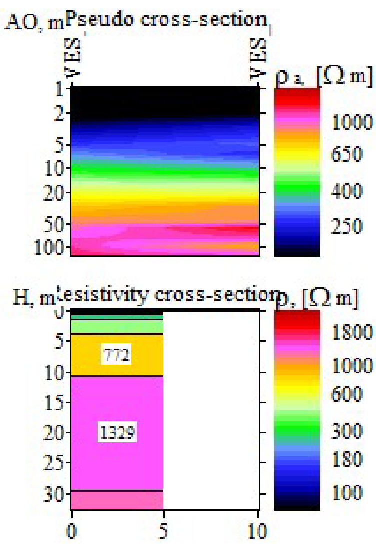

Figure 10: Measured and modelled data for Asaba

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3.3 Ugbolu

Interpretation of the data (Figure11 & 12; Table 8 & 9) suggests that the Ugbolu area is underlain with substantive aquiferous formation at a depth not below 22.5 meters (73.82 ft.), which is the main aquifer unit. It was decided that drilling should be done to a depth exceeding 22.5 m (73.82 ft.) to allow for large reservoirs within the main aquifer unit.

Table 8: Field data (resistivity data) for Ugbolu VES survey

S/N	AB/2	MN	K	Ro_a
1	1	1	2.3562	212.22
2	2	1	11.781	190.03
3	4	1	49.48	221.18
4	7	1	153.15	281.8
5	10	1	313.37	325.9
6	14	1	614.97	351.92
7	17	2	452.39	382.79
8	21	2	691.15	349.33
9	32	4	801.11	185.24
10	47	4	1732	296.43
11	60	4	2824	241.25
12	80	10	2003	222.09
13	100	10	3134	158.05

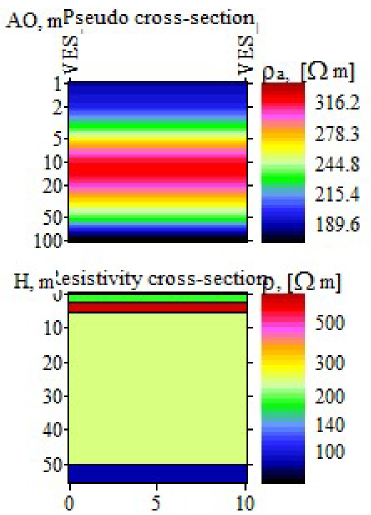

Figure11: Measured and modelled data for Ugbolu

Table 9: The sub-layers in the Ugbolu section area

Layer	Thickness	Depth	Resistivity	Lithology
1.	0.502	0.502	284	Lateritic topsoil
2.	0.883	1.39	126	Clayey subsoil
3.	21.10	22.5	356	Sandstone
4.	29.31	51.81	161	Sandstone (prospective, fresh)
5.	Undefined	Undefined	89.31	Sandstone (prospective, fresh)

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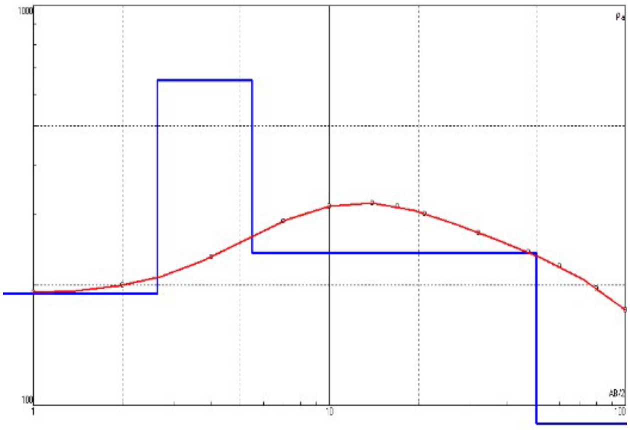

Figure 12: Layered resistivity model for Ugbolu

4. CONCLUSION

The investigation in Ibusa, showed that for adequate water development in this area, the drilling should be done to a depth not less than 110.46 metres (362.40 ft.) using geophysical methodology to locate favourable horizons. In Asaba, it was observed that the area is underlain with substantive aquiferous formation but at a depth not exceeding 39.5 meters (129.59 ft), which is the fresh water aquifer unit devoid of iron contamination. Thus for borehole construction, drilling should be done to a depth exceeding 39.5 m (129.59 ft.) to allow for the water reservoirs devoid of iron contamination to be tapped. This is not in agreement with results from Tolefe, 2012, [23] that recommended that boreholes should be drilled to an average depth of 69 m, to harness potable water within the aquifer region. The difference in value may be attributed to site location. This tends to suggest that the water table in Asaba are at different depths. Viable aquifer is within 35 m to 40 m at Asaba but above 100 m at Ibusa and Ogwashi-Uku which are just a few kilometres away [10]. The problem of portable water in Ibusa despite its nearness to Asaba and Achala (2 km away) and the River Niger is due to the topographic complexities and changes of the area; Ibusa is located on a cliff.

In conclusion, there should be adequate borehole logging of samples to enable the proper screening of the aquifer zone which is captured. The drilling of random wells lead to dry wells or at best marginally productive wells; this condition can be eliminated by a judicious application of VES and geological and geophysical studies.

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