ISSN: 2456-799X, Vol.04, No.(2) 2019, Pg.70-84

Oriental Journal of Physical Sciences

www.orientjphysicalsciences.org

Estimation of Aquifer Characteristics In Parts of Oru Lga of Imo State Nigeria Using Resistivity Data

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Abstract

This paper estimates aquifer characteristics in parts of Oru Area Imo State of Southeastern Nigeria using data from surface electrical soundings. Eighteen vertical electrical soundings were made in the study Area using a maximum current electrode separation of 1.0 km.The Abem terrameter SAS 3000 B was used in acquiring data. The Schlumberger electrode configuration was adopted in the survey. The result obtained show that the depth to water table varied from 27 m to about 205 m. Aquifer thickness varied from 24 m to about 140 m.The aquiferous zones have resistivity range of between 182Ωm to about 3934Ωm. Aquifer conductivity varied from 0.000254 Siemens at Nempi to 0.01036 Siemens at Akuma. Transverse resistance varied from 249809Ωm^2 at Nempi to 3956.5Ωm^2 at Akuma. Longitudinal conductance varied from 0.01614 mho at Nempi to 0.55656 mho at Umuoji.

Article History

Received: 20 August 2019
Accepted: 30 November 2019

Keywords:

Aquifer Characteristics;
Longitudinal Conductance;
Resistivity;
Transverse Resistance.

Introduction

Aquifer hydraulic parameters are properties that control the movement, storage and extraction of underground water.[11] Assessment of the groundwater potentials of any area cannot be complete without the estimation of these parameters. This paper estimates aquifer characteristics in parts of Oru Area Imo State of South Eastern Nigeria using data from surface electrical soundings. The superiority of the electric method over others in groundwater research is confirmed by the work of.[16],[22 and 23] reported on the ability of the resistivity method to furnish information on the subsurface geology unobtainable by other methods in the groundwater studies. For example they attested to the ability of the resistivity method to provide information on the depth of the fresh water/salt water interface. The geoelectrical method has been successfully utilized in accessing water supply potential in basement aquifers[4] and the assessment of the groundwater resource potential within the obudu basement area of Nigeria.[13,11] carried out a study for the determination of aquifer characteristics in parts of Umuahia area of Nigeria using the geoelectric method. Also[8] using the geoelectrical

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Doi: http://dx.doi.org/10.13005/OJPS04.02.07

method produced the groundwater flow modeling of kwa-Ibo river water shed in southeastern Nigeria.

Aquifer characteristics presented in this paper include aquifer depths, aquifer thicknesses, transverse resistance, longitudinal conductance and aquifer resistivity. Aquifer hydraulic parameters are estimated for any given aquifer system in order to obtain quantitative information on ground water flow. it is a standard practice to estimate aquifer hydraulic parameters using Dar-Zarrock parameters of transverse resistance and longitudinal conductance[14] High values indicates that the material is permeable, while low value indicates that the material is impermeable.[7,9,20] have successfully estimated aquifer hydraulic characteristics from Dar-zarouk parameters in many parts of Southeastern Nigeria from surface electrical resistivity sounding data.

When electrical current flows parallel to the geoelectrical boundaries, the parameter that influences current flow is the longitudinal conductance, S and when the current flows normal to the bed boundaries,the transverse resistance, T is significant.[6] Longitudinal conductance is one of the geoelectric parameters used to determine target areas of groundwater potential. Low transverse resistance values are associated with low resistivity formations (such as clayey soil). Higher Transverse resistance values are characteristic of high resistivity formations[6] Also from transverse resistance values ,it is possible to determine the direction ofground water flow in the aquifer.[6] The S and T values are also known as Dar-zarrouk parameters[12] and for a layer of thickness h and resistivity p are defined as

$$S= h/p \quad ...(1)$$

$$T =hp \quad ...(2)$$

Location and Geomorphology of the Study Area

The study area consists of some communities located within the Oru Area of Imo-State Nigeria. The increasing population in Oru which is over two hundred and twenty nine thousand according[15] and consequent increasing demand for portable water prompted the present search for favourable groundwater potential zones in the area. Besides, this paper aims at providing a quantitative information about the ground water potential in this area so as to contribute to any future water resources management program for this region. The study area lies between longitude $6^0$50 E and $7^0$00 E and latitude $5^0$50 N and $5^0$37 N as shown in the location map of the Area as in figure 1. It covers a land mass of about 315 km^2 South East Nigeria.

Geology and Hydrogeology of the Area

The Oru Area is made up of two geological formations; the Ogwashi-Asaba and the Benin formation which was formerly known as coastal plain sands.[17] Ogwashi-Asaba formation is characterized by alternation of clays and sands, grits and lignites[5,17] suggested Oligocene-Miocene age for this formation. For the Benin formation, the sands and sandstones are coarse to fine grained and commonly of granular texture. The formation consists of friable sand with intercalations of shale and clay lenses occurring occasionally at some depths.[18] The formation is partly estuarine, partly lagoon, partly deltaic and fluvid, lacustrine in origin.[17] The sands and sandstone in this formation are coarse grained, very granular, pebbly to very fine grained. They are either white in colour or yellowish brown. Hematite grains and feldspars are also obtained. The shale are grayish brown, sandy to silty and contains some plant remains and dispersed lignites.[17] The formation has an average thickness of 600 ft (196.85 m).[10]

Surface waters are not a major feature of the Oru Area. The Njaba and Obana rivers seem to be the only surface waters in the area.[1] The two formations are known to have reliable groundwater that could sustain borehole production. The high permeability of the coastal plain sands, the overlying lateritic earth and the weathered top of this formation provide the hydraulic conditions favouring aquifer formation in the study area. The copious rainfall that prevails in the area makes the aquifer prolific and continuously provides the ground water recharge. The geological map of the area is in figure 2.

Data Acquisition and Interpretation

Eighteen vertical electrical soundings were made in the study area using a maximum current electrode separation of 1.0 km. The ABEM terrameter SAS 3000 B was used in acquiring data while four metal stakes were used as electrodes. The schlumberger electrode configuration was adopted in this survey. In this array the current and potential electrode pairs have a common midpoint but the distances between adjacent electrodes differ significantly. For a schlumberger spread, the apparent resistivity computed from the measurement of voltage, ΔV and the current I is given by the equation.

$$\rho_a = \pi \left(\frac{a^2}{b} - \frac{b}{4}\right) \frac{\Delta V}{I} \qquad ...(3)$$

Theoretically, the resistivity (ρ) of a material is directly proportional to the potential difference (V) and inversely proportional to the induced current I[11]

$$\rho \propto \frac{V}{I} \qquad ...(4)$$

$$\rho = \frac{KV}{I} \qquad ...(5)$$

$$\text{Since } R = \frac{V}{I} \qquad ...(6)$$

$$\text{Hence } \rho = KR \qquad ...(7)$$

Where K is the geometric factor, R is the resistance.

The geometric factor K depends on the electrode separation. R is the resistance of the volume of ground between the potential electrodes. If V and I are measured in milli-volts and milli-amperes respectively and the distance of separations in meter,

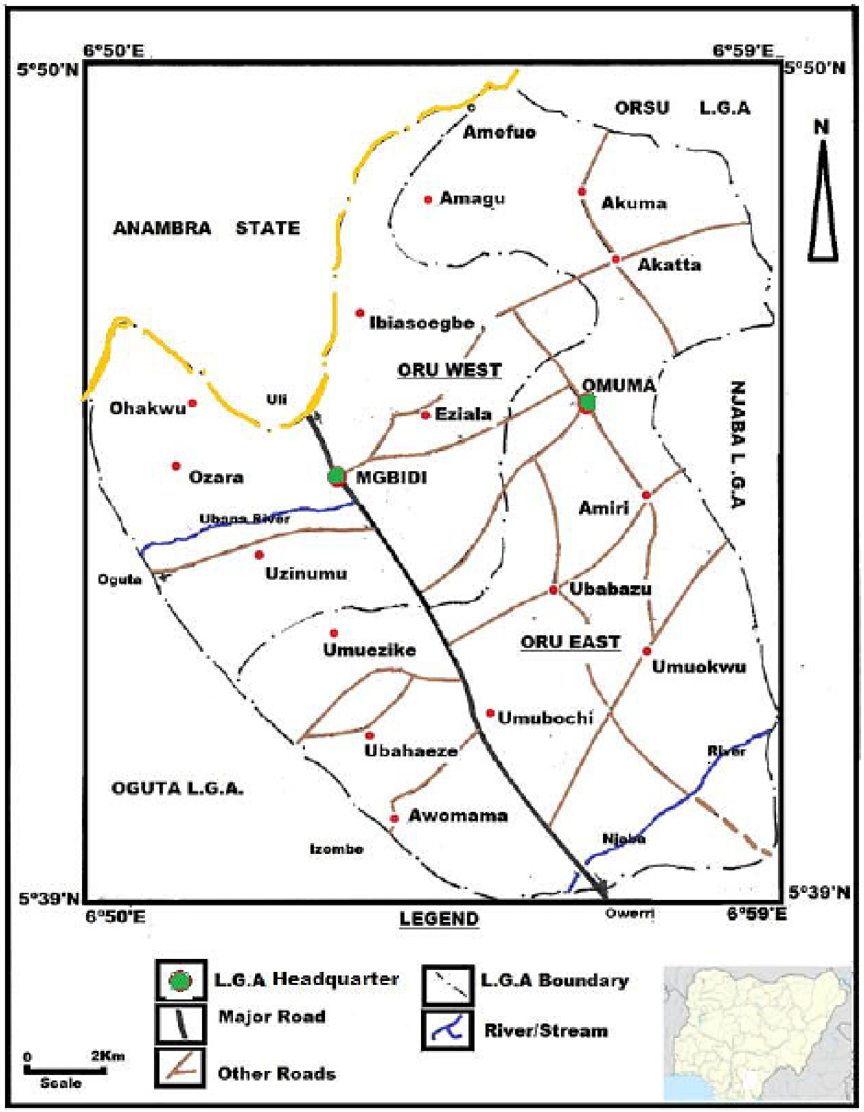

Fig.1: location map of the study area

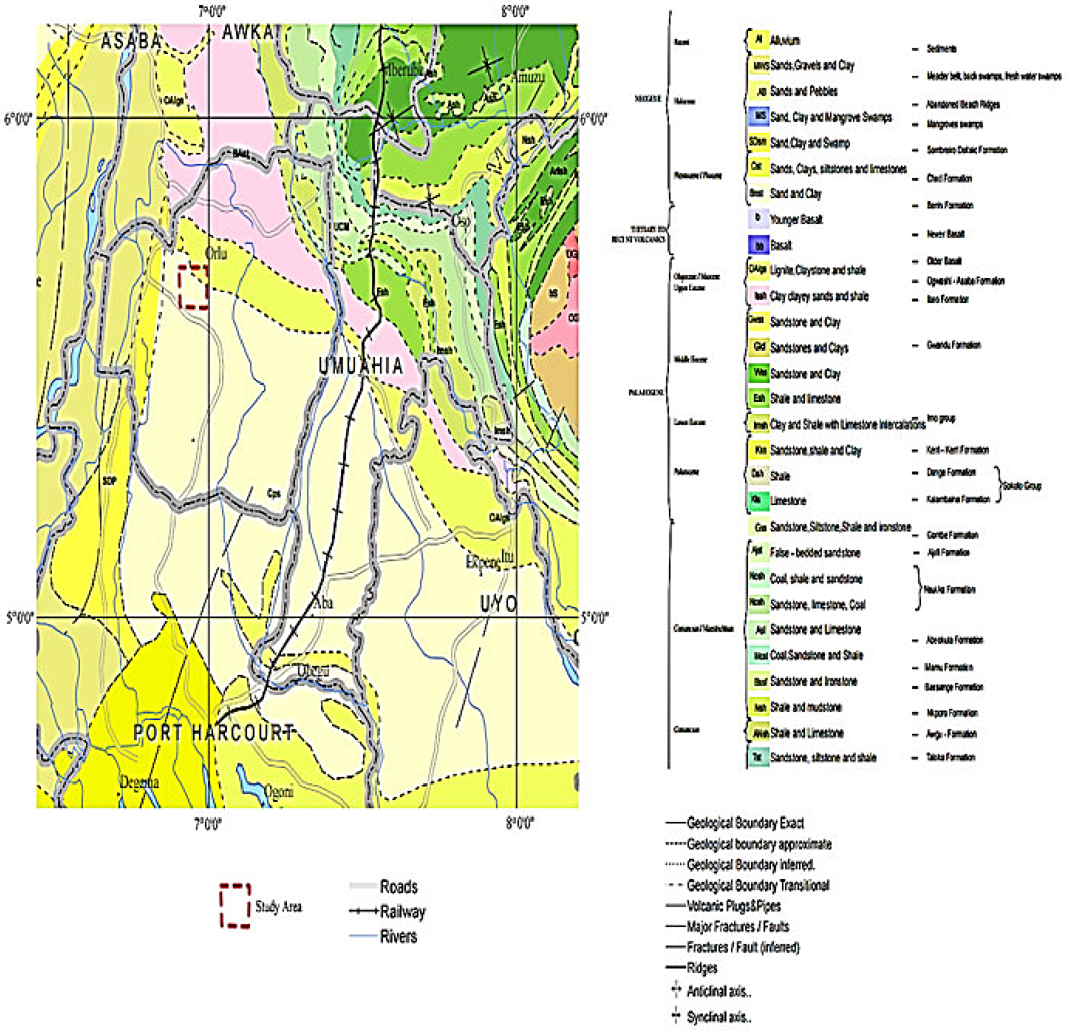

Fig: 2

then the resistivity ρ is expressed in Ohm-meter. The apparent resistivity values obtained from the field were plotted against half the current electrode spacing (AB/2) on a bi-logarithmic graph for all the VES stations. The computer modeling delineated 6-7 geoelectric layers. The computer program RESIST designed and used in the National Geophysical Research Institute (NGRI) by,[9] Hyderabad India were employed in the interpretation of the VES data. The output of the Resist software comprises a best fit curve or computer modeled curve, a set of resistivity values with corresponding layer thickness, total probe depth and the fitting error in percentage. Some of the resistivity curves obtained in the area are plotted in fig. 3, fig. 4 and fig. 5. Also the layer parameters from the resistivity soundings are shown in table 2 while table 1 displays aquifer conductivity, Transverse resistance and longitudinal conductance. The depth to water table varied from 27 m to about 205 m. Aquifer thickness varied from 24 m to about 140m and the aquiferous zones have resistivity range of between 182 ohm-m to about 3934ohm-m. The spatial variation of aquifer depth in the study area is shown in figure…6.

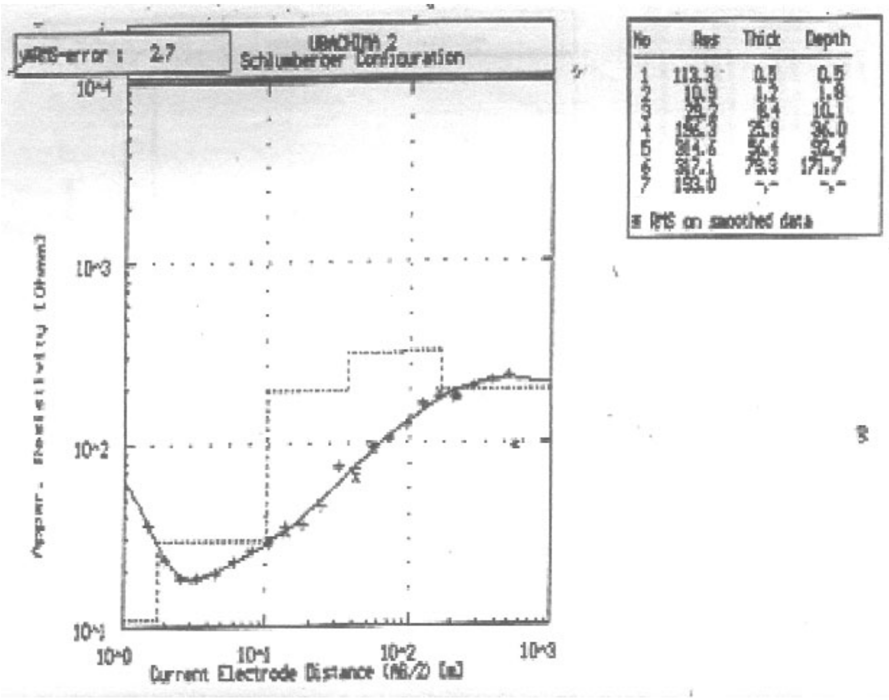

Fig. 3 : Sample of resistivity curve from the area

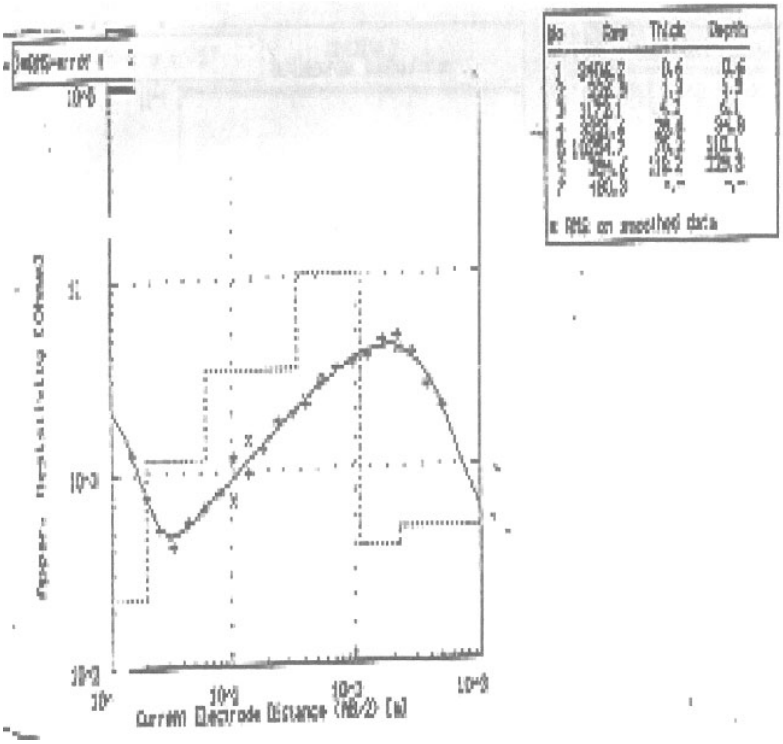

Fig. 4 : Sample of resistivity curve from the area

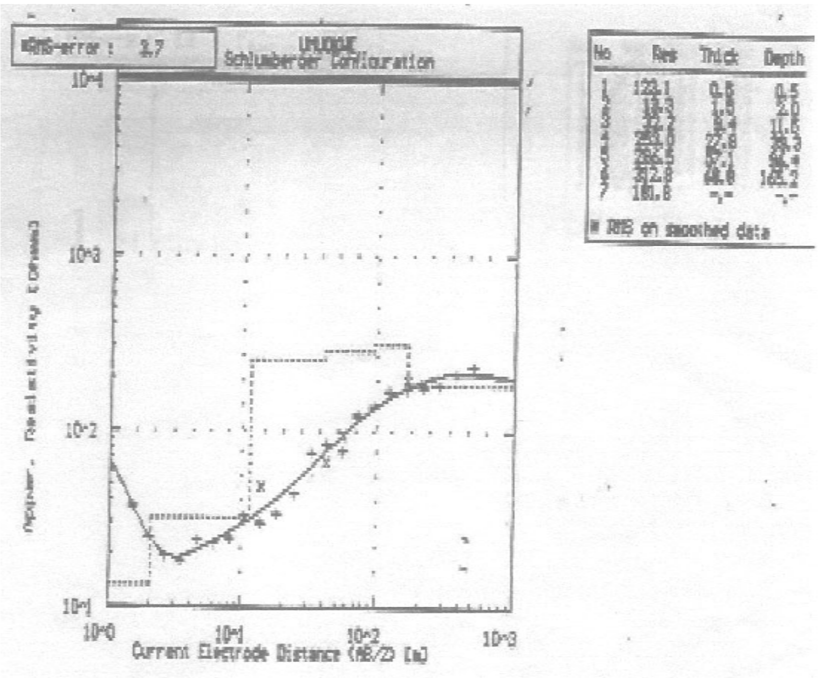

Fig 5 : Sample of resistivity curve from the area

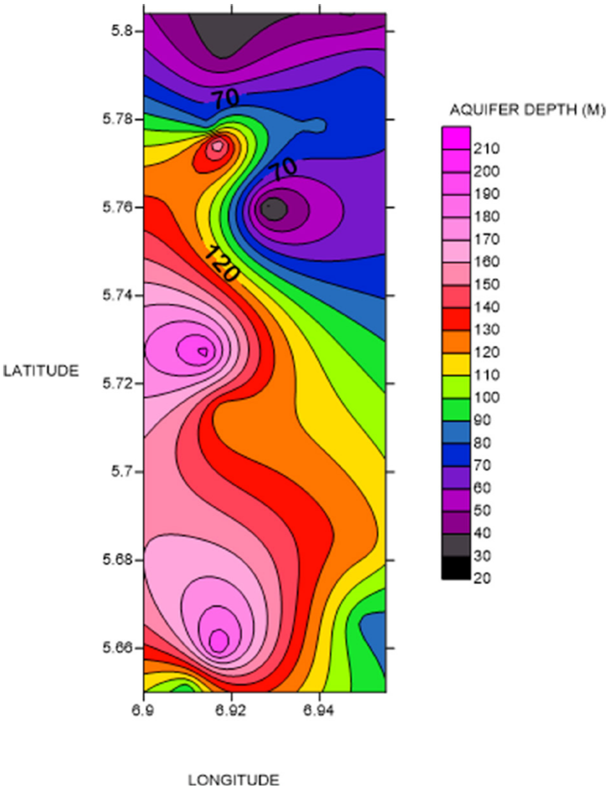

Fig. 6: Spatial Variation in aquifer depth in the area

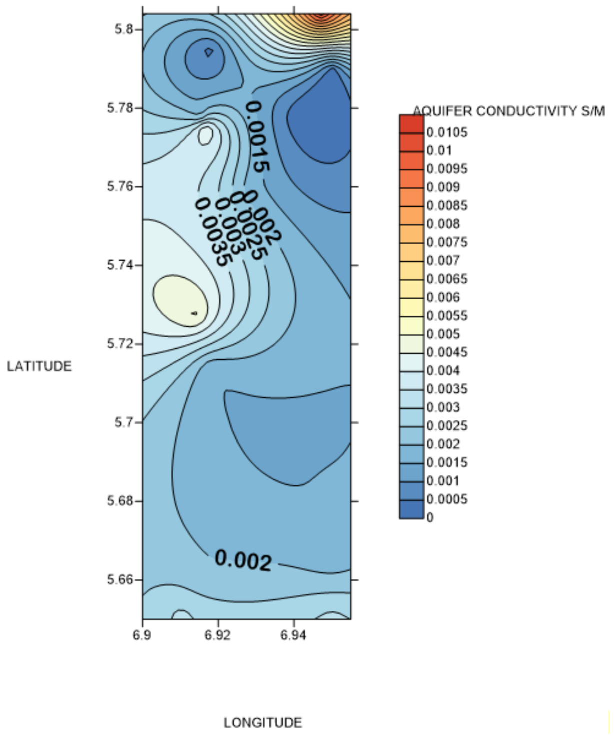

Fig. 7: Spatial variation in aquifer conductivity in the Area

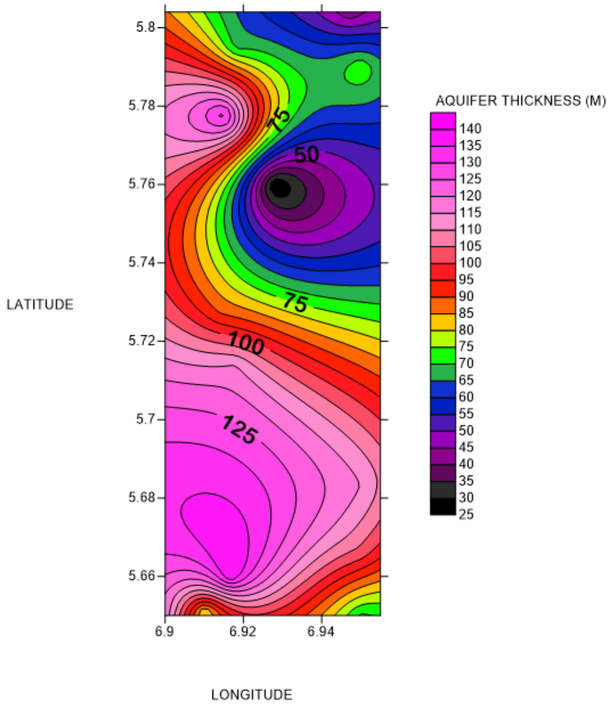

Fig. 8: Spatial variation in aquifer conductivity in the Area

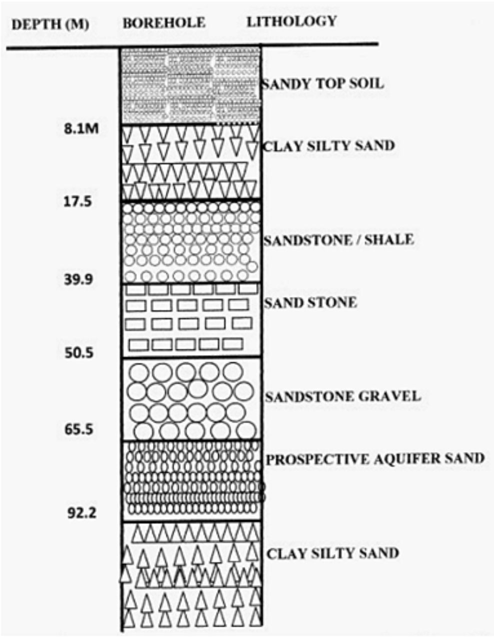

Fig. 9: Borehole lithology of the Ura –Akatta borehole in the vicinity of the study area

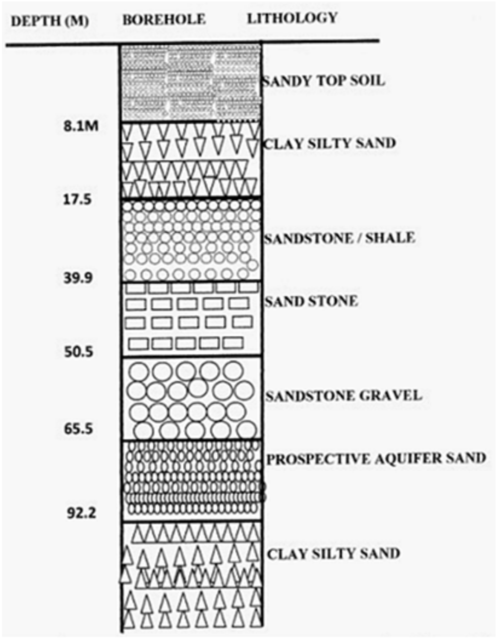

Fig. 10: Borehole lithology of the Akwada-Aji borehole in vicinity of the study area

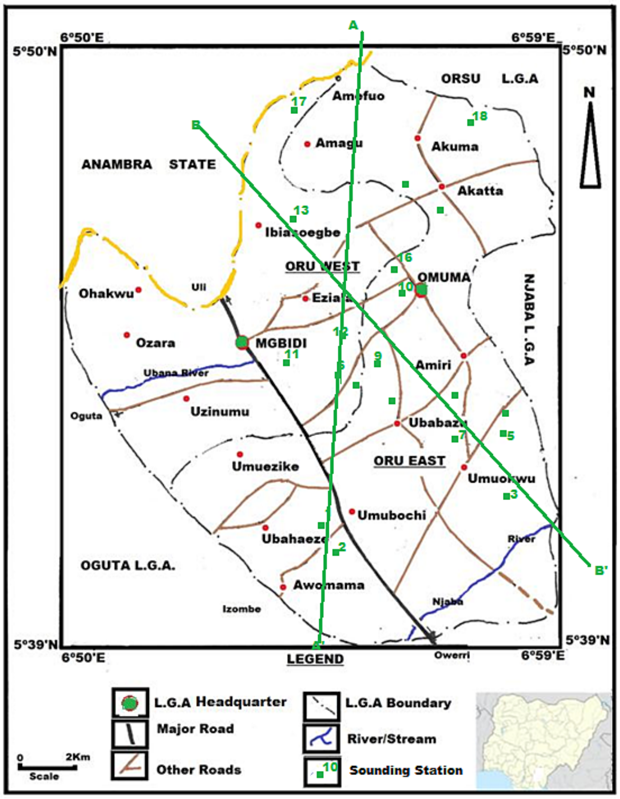

Fig. 11: Map of Study Area showing sections AA' and BB'

Map of Study Area Showing Line of Section AA[1] and BB[1]

Profile AA[1] is 13.75 km long and is located at the North Southern section of the study area and transversed the following towns Ibiasoegbe, Umuoji, Mgbidi, Otulu Oteru and Ubachima. This profile showed five distinct geo-electric units as shown in figure…12 below. The topsoil is underlain by sandy layer. Uderlying the sandy layer is a sandstone and granite layer which in turn is underlain by a fine medium and coarse grained sands which is the aquiferous layer. At the base is a conductive clay layer. The profile AA[1] geooeletric units correlates with the borehole data obtained from the area, the Ura-Akatta borehole and Akwada- Aji borehole[2] as in figure10… and figure 9….

Similarly, profile BB[1] which measures about 10km long and traverses Ibiasoegbe Ubahazu, Umuowa and Umuokwe areas trends in the (NW-SE) direction. This profile revealed four distinct geoelectric layers as with a conductive clay layer at the base .Over laying the clay base is the saturated sand unit.

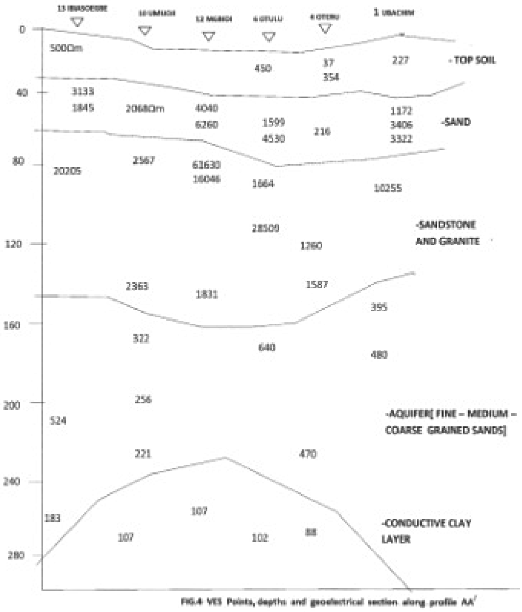

Fig. 12: Geoelectic section for profile AA'

Table 1: Aquifer Hydraulic Parameters of The Study Area Using Data from Surface Electrical Soundings[1]

VES NO	Location Resistivity (Ωm)	Apparent Depth (m)	Aquifer Thickness (m)	Aquifer Conductivity Siemens	Aquifer	T Resistance (Ωm²)	Longitudinal Conductances (mho)
1	Ubachima 1	395	110	119	0.0025	47005	0.30126
2	Ubachima x2	317	92.4	79.3	0.00315	251381	0.250157
3	Umuokwe	313	96.4	68.8	0.0031948	21534.4	0.219808
4	Oteru	470	200	140	0.00213	65800	0.2979
5	Umuowa	636	86	103	0.00157	65508	0.1619
6	Otulu 1	640	120	115	0.00156	73600	0.1796
7	Ubahazu 1	642	125	115	0.00156	73830	0.1791
8	Ubahazu 2	645	117	109	0.00155	70305	0.1689
9	Otulu 2	618	155	122	0.00162	75396	0.1974
10	Umuoji	221	164	123	0.00452	27183	0.55656
11	Mgbidi 1	196	205	90	0.00510	17640	0.4592
12	Mgbidi 2	1831	87	67	0.000546	122677	0.03659
13	Ibiaso Egbe	524	84	132	0.00191	69168	0.2519
14	Nempi	3934	81.6	63.5	0.000254	249809	0.1614
15	Akatta	3466	75	74	0.000288	256484	0.02135
16	Aji	557	27	24	0.00179	13368	0.043087
17	Ubulu	2915	36	69	0.000343	201135	0.023671
18	Akuma	96.5	39	41	0.01036	3956.5	0.42487

Table 2: Layer parameters from resistivity soundings in the Study area

Sta. No	No. of Layers	Town	Resistivity of layers	Thickness of layers	Depth from top	Aquiferous zones	Aquifer thickness	Depth to water table	Aquifer resistivity	Latitude	Longitude	Elevation above sea level	fitting error in %
1	7	UBAC	3406	0.6	0.6	6TH	119m	110Ωm	395Ωm	5°39'11.	6°54'59.	127 m	2.3
		HIMA	227	1.3	1.9	LAYER			and	4"N	6"E		
		1	1172	4.2	6.1	7TH			4-80Ωm				
			3322	28.6	34.8	LAYER							
			10253	753	110,1								
			395	119.2	229,3								
			480	-----	-----								
2	7	UBAC	113	0.5	0.5	7TH	___	172 m	193Ωm	5°39'06.	6°54'59.	123 m	2.7
		HIMA	227	1.3	1.9	LAYER				0"N	8"E		
			1172	4.2	6.1								
			3322	28.6	34.8								
			10253	753	110,1								
			395	119.2	229,3								
			480	-----	-----								
3	7	UMUO	123	0.5	0.5	7TH	___	165 m	182am	5°39'25.	6°57'48.	132 rn	3.7
		KWE	13	1.5	2.0	LAYER				5"N	9"E		
			32	9.4	11.5								
			253	27.8	39.3								
			287	57.1	96.4								
			313	68.8	165.2								
			182	----	----								
4	7	OTE	37	4.0	4.0	6TH	140 m	201 m	470Ωm	5°40'35.	6°55'08.	143 m	3.8
		RU	354	18.4	22.4	LAYER				2"N	0"E		
			216	38.5	60.9								
			1260	65.4	126.3								
			1587	74.2	200,5								
			470	140.4	340,9								
			88										
5	7	UMU	60	0.5	0.5	6TH	103 m	86 m	636nm	5°40'10.	6°57'59.	162 m	7.3

		OWA	808	12.0	12.5	LAYER				4"N	3"E		
			3792	8.3	20.8								
			18694	16.9	37.6								
			39830	48.4	86.0								
			636	102.6	188.6								
			99	----	----								
6	7	OTUL	450	0.1	0.1	6^{TH}	115 m	120m	640 am	5°42'43.	6°55'02.	113 m	5.1
		U 1	1599	23.5	23.6	LAYER				2"N	2"E		
			4530	14.3	37,9								
			16648	30.1	68.1								
			28509	51.9	120.0								
			640	114.7	234.7								
			102	----	----								
7	7	UBAH	353	0.1	0.1	6^{TH}	115 m	125m	642Ωm	5°41'42.	6°57'41.	122 m	3.5
		AZU 1	1705	22.5	22.6	LAYER				7"N	5"E		
			4511	16.8	39.4								
			14702	32.5	71.9								
			27531	53.3	125.2								
			642	114.5	239.7								
8	7	UBAH	684	0.1	0.1	6^{TH}	109 m	117m	645Ωm	5°41'16.	6°57'45.	141 m	2.5
		AZU 2	1385	16.6	16.7	LAYER				2"N	5"E		
			3928	17.2	33.9								
			13409	29.9	63.7								
			28373	53.4	117.2								
			645	109.1	226.3								
			107	----	----								
9	7		109	0.3	0.3	6^{TH}	122 m	155m	618Ω	5o42'6.	6°55'06.	l35 m	3.7
			1694	37.2	37.4	LAYER				2" N	9"E		
			3924	30.1	67.5								
			10940	43	110								
			15864	44.2	154.6								
			618	121.8	276.4								
			101	----	----								
10	7	UMU	2068	0.6	0.6	4^{TH}	3 m	127m	322Ωm	5°45'32.	6°55'11.	139 m	2.
		OJI	2567	71.2	71.8	LAYER	42 m		256Ωm	8"N	5"E		

			2363	5S.2	127.0	5^{TH}	44 m		221Ωm				
			322	37.0	164.0	LAYER							
			256	42.0	206.0	6^{TH}							
			221	44.0	250,0	LAYER							
			107	----	----								
11	6	MGB	757.2	0.4	0.4	6^{TH}	----	205 m	196Ωm	5°43'10.	6°54'06	155 m	38
		IDI 1	4570	13.7	14.1	LAYER				N	1"E		
			13349	25.1	39.2								
			3490	76.5	115.7								
			3371	89.1	204.9								
			196	----	----								
12	6	MGB	4040	0.7	0.7	5^{TH}	67.2 m	87 rn	183Ωm	5°43'40,	6°54'37.	148 m	5.
		IDI 2	6260	21.8	22.5	LAYER				2"N	6"E		
			61630	29.4	52.0								
			16046	34.5	86.5								
			1831	67.2	153.7								
			107										
13	7	IBIAS	500	0.4	0.04	5^{TH}	L32 m	84 m	5240m	5°46'35.	6°54'37.	119 m	4.5
		OEGB	3133	5.0	5.4	LAYER			183Ωm	8"N	6"E		
		E	1843	22.6	28.1	6^{TH}							
			20205	56.3	84.4	LAYER							
			524	131.5	215.9								
			183	----	----								
14	7	NEM	282	0.7	0.7	7^{TH}				5°46'38.	6°56'2.6"	135 m	3.7
		PI	583	7,4	8.2	LAYER							
			823	11.6	19.7								
			8509	25.4	45.1								
			12812	36.5	81.6								
			3934	63.5	145.1								
			302										
15	7	AKA	138	0.9	0.9	7^{TH}	----			5°47'21.	6°57'14.	156 m	63
		TTA	431	6.3	7.2	LAYER							
			923	9.4	16.6								
			6032	15.6	32.2								
			25483	42.5	74,7								

			3466	74.4	149.1								
16	7	AJI	904	0.7	0.7	5TH	24 m	27 m	557Ωm	5°45'42.	6°55'15.	122 rn	5.9
			1110	6.0	6.7	LAYER				8"N	6"N		
			4-525	8.6	15.4								
			1116	11.9	27.3								
			557	23.9	51.2								
			7994	42.5	93.6								
			100,000	----	----								
17			683	0.5	0.5	5TH	59 m	96 m	2915Ωm	5°47'41.	6°54'59.	148 m	6.8
			10876	1.6	2.1	LAYER				1"N	7"E		
			1782	31.8	33.9								
			12807	61.9	35.8								
			2915	68.9	164.7								
			6889	115.2	279.9								
			10322	----	----								
18	7	AKU	1129	0.5	0.5	4TH	41 m	39 m	965Ωm	5°48'11	6° 56 '48.	127 m	6.7
		MA	580	1.3	1.8	LAYER				.9"N	5"E		
			2678	37.4	39.2								
			965	41.2	890.4								
			7539	76.8	157.2								
			3696	52.5	209.7								
			29967	----	----								

Conclusion

In this research work, some aquifer characteristics of parts of Oru LGA have been estimated using electrical resistivity data. The result obtained show that the depth to water table varied from 27 m to about 205 m. Aquifer thickness varied from 24 m to about 140 m and the aquiferous zones have resistivity range of between 182Ωm to about 3934Ωm aquifer conductivity varied from 0-000254 Siemens at Nempi to 0.01036 Siemens at Akuma,transverse resistance varied from 249809Ωm^2 at Nempi to 3956.5Ωm^2 at Akuma longitudinal conductance varied from 0.01614mhos at Nempi to 0.55656mhos at Umuoji.

Acknowledgement

I humbly acknowledge the contributions of the following persons in the production of this work. The officers of Imo State National Population Commission for releasing the 2006 Oru population data. I am also grateful to Imo State Ministry of water resources for the bore hole data within the area. Finally, I thank the typist of this work in person of Victoria Chukwu for a good work done.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

Conflict of Interest

The authors do not have any conflict of interest.

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